ACT/MERC Test Plan for Evaluations of the Jotun Hull Skating Solution A Proactive Biofouling In-Water Cleaning Solution

August 4, 2020

Director:

Mario Tamburri, ACT/MERC/UMCES

University of Maryland Center for Environmental Science Chesapeake Biological Laboratory
146 Williams Street
Solomons, MD 20688

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Approved for Release:

Mario Tamburri
Digitally signed by Mario Tamburri
Date: 2020.08.05 06:52:59 -04'00'

Dr. Mario Tamburri
Principal Investigator and Director
Alliance for Coastal Technologies/Maritime Environmental Resource Center
University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory
146 Williams Street, Solomons, MD 20688
Phone: 410-326-7440 / Email: tamburri@umces.edu

Accepted by:

oftedga
Digitally signed by oftedga
DN: cn=oftedga
Date: 2020.09.02 09:14:34 +02'00'

Geir Axel Oftedahl
Business Development Director - Marine
Jotun A/S
Mobile: +47 90 18 04 64
geir.axel.oftedahl@jotun.no
www.jotun.com

Record of Revisions

Revision Number	Description of Changes

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List of Abbreviations and Acronyms

ACT	Alliance for Coastal Technologies
ADQ	Audit of Data Quality
CBL	Chesapeake Biological Laboratory
CRMS	New Zealand Craft Management Risk Standard for vessel biofouling
CSLC	California State Lands Commission
Cu	Copper
CTT	Core Testing Team
DI	Deionized Water
DM	Data Manager
DOC	Dissolved Organic Carbon
FR	Fouling Rating
HSS	Hull Skating Solution
ISO	International Organization for Standardization
KW	Kruskal-Wallis
LPSA	Laser Particle Size Analysis
MARAD	U.S. DOT Maritime Administration
MERC	Maritime Environmental Resource Center
MP	Microplastics
MPA	Maryland Port Administration
NASL	Nutrient Analytical Services Laboratory
NRL	Naval Research Laboratory
PERMANOVA	Permutational Multivariate Analysis of Variance
POC	Particulate Organic Carbon
PSD	Particle Size and Distribution
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QAQC	Quality Assurance/Quality Control
QC	Quality Control
QMP	Quality Management Plan
QMS	Quality Management System
SERC	Smithsonian Environmental Research Center
SM	Standard Methods
SOP	Standard Operating Procedure
TAC	Technical Advisory Committee
TSA	Technical System Audit
TSS	Total Suspended Solids
UMCES	University of Maryland Center for Environmental Science
USEPA	United States Environmental Protection Agency
Zn	Zinc

1. Background and Objectives

The Alliance for Coastal Technologies (ACT) and Maritime Environmental Resource Center (MERC), in collaboration with the US Naval Research Laboratory (NRL), Smithsonian Environmental Research Center (SERC), and California State Lands Commission (CSLC), comprise a Core Testing Team (CTT) that will provide an **independent evaluation of a proactive ship in-water cleaning system designed to prevent macrofouling** growth on vessel surfaces as part of an ongoing biofouling management program. Support for this Evaluation is provided by the U.S. Maritime Administration (MARAD), Maryland Port Administration (MPA), and CSLC.

Participation by Jotun in this testing effort is voluntary and free of charge. *Results will be made available to the public in the form of a final report*. While the data and report produced from this Evaluation may be used by Jotun to apply for approvals for use of their in-water cleaning system, it is important to note that **ACT and MERC do not certify systems or technologies and does not guarantee that a system or technology will always, or under circumstances other than those used in testing, operate at the levels verified.**

2. Description of the Jotun Hull Skating Solution

2.1. General Description

The Jotun Hull Skating Solution (HSS) has been developed for ships in challenging operations to ensure underwater hull areas (excluding niche areas) can remain clean. The solution combines a high-performance hull coating, real-time fouling alerts based on a fusion of operational and environmental data and inspection, and proactive cleaning with an underwater cleaning vehicle. This vehicle is to be permanently stored on board but operated from a control center (located either shipboard or remote) as well as performance and service level guarantees.

The HSS has been developed by Jotun in collaboration with a number of industry, technology, and shipping partners including Kongsberg Maritime, Semcon, DNV GL, Telenor, and Wallenius Wilhelmsen Ocean. The hull coating is a high-performance, biocide-containing hull coating optimized for ships in challenging operations and for proactive cleaning with the underwater cleaning vehicle.

The fouling alerts are configured to ensure any fouling is identified and removed at an early stage (FR10 to 20) – before it significantly affects vessel performance and before it represents a significant biosecurity risk.

The Hull Skater is a magnetic crawler with 4 high definition cameras for navigation and inspection and a 900 mm wide brush, purpose designed for proactive cleaning of the specific high-performance coating without causing damage or erosion. It is normally operated at a speed of around 0.5m/s. Inspection and proactive cleaning of all hull areas will normally take around 2 to 8 hours depending on vessel size and fouling condition.

The underwater cleaning vehicle is kept onboard the vessel and launched via a launch and recovery ramp on the vessel deck. An umbilical connects the vehicle with an onboard communications interface from which a secure network allows operation from a control center onshore.

Reactive cleaning, here defined as removal of fouling beyond the clean hull threshold for short stay vessel as per the New Zealand Craft Management Risk Standard (CRMS) for vessel biofouling (MPI 2014), is out of scope for the Jotun HSS and will be addressed by other appropriate hull cleaning methods (e.g., with collection). A need for reactive cleaning on underwater hull areas (excluding niche areas) would represent a failure to perform under the service level guarantee.

2.2. Jotun Hull Skating Solution Operations and Logistical Requirements

This Evaluation will document, to the extent possible, operational and logistical requirements of the Jotun system needed to complete proactive in-water cleaning of vessels as specified by Jotun. While it is understood that these requirements can vary greatly based on location, vessel, level of fouling, type and age of coatings, etc., this information will be included in the final report to help convey what was used to produce the measured Jotun system performance and to provide end users with some background information on logistical and operational requirements.

The following considerations will be documented in detail by Jotun and the vessel operator and will be submitted to the Director prior to initiating the Evaluation (as per Morrisey *et al.,* 2015). This information will also be included in the final report, which will be publicly available.

1. Description and specification of the cleaning process, cleaning system, and if applicable, the collection and filtration system tested:
   - **a.** Mechanism of action to clean biofouling;
   - **b.** Equipment design;
   - **c.** Method of operation; and
   - **d.** Workforce requirements.
2. Description of system applications:
   - **a.** Areas of hull and other immersed structures that the system may be used on;
   - **b.** Type of hull system may be used on (steel, aluminum, composite);
   - **c.** Type of hull coating(s) the system is intended to be used on; and
   - **d.** Level and types of biofouling (e.g., biofilms, soft or small macrofouling, etc.) that the system is intended to remove. The level of biofouling used to define the operation of the equipment shall be based on the US Navy FR (Naval Ships' Technical Manual 2006) and biofouling percentage cover (Floerl *et al.,* 2005).
3. Standard operating procedure (SOP) or guidelines for the system, which must detail:
   - **a.** The mode of operation of the system, including how it will be applied;
   - **b.** The physical environment suitable for use of the system (e.g., alongside berth, enclosed in floating dock, open water, whether the entire fouled area of the hull must be submerged);
   - **c.** Other safety considerations (e.g., pressure, electricity, high-tension operations);
   - **d.** Contingency plans to manage biosecurity risks following system failure;
   - **e.** The sea state and weather conditions under which the system is intended to be used (e.g., limits on current speed, wave height, water temperature, water clarity to ensure efficacy, operator safety); and
   - **f.** The total time, including set-up and demobilization, it takes to clean a vessel.

3. Experimental Design

3.1. Summary

This Evaluation of the Jotun HSS will specifically assess following performance parameters listed below, based on Jotun's specifications and performance claims, on *one Primary Test Vessel* (described in Section 3.2.5):

1. Prevention of macrofouling growth through time, with some qualitative assessments of biofilm removal (Section 3.2).
2. Impacts to local water quality as a result of in-water cleaning activities (Section 3.3).
3. Impacts to coating as a result of in-water cleaning activities (Section 3.4).
4. Jotun's ability to rate sub-sections of hull as "clean" or "fouled" as per clean hull threshold for short stay vessels in the CRMS (MPI 2014) (Section 3.5).
5. Other performance parameters that may be considered (Section 9).

This Evaluation may include the assessment of the following sub-suite of performance variables on *two Secondary Test Vessels* (Section 3.2.5):

1. Prevention of macrofouling growth through time.
2. Impacts to local water quality as a result of in-water cleaning activities.

Finally, the Evaluation may also include the assessment of a sub-suite of performance variables on a number of additional test vessels over a longer period of time as a part of Jotun's broader Piloting Program (Section 9).

These efforts follow the ACT (www.act-us.info) and MERC (www.maritime-enviro.org) approaches for independent testing.

3.2. Proactive In-Water Cleaning Prevention of Macrofouling

Assessments of the Jotun Hull Skater performance will be based in part on the system's ability to prevent macrofouling in a designated treated (cleaned) test area on the vessel. It is Jotun's and the shipping line's responsibility to carry out cleaning operations in a manner and at a frequency that they have predicted to be sufficient to prevent macrofouling growth (which will be documented and included in the final report).

This Evaluation will use a dive survey team and only consider external submerged surfaces of the ship's hull. It will not consider niche areas or the cleaning or removal of biofouling from internal surfaces such as sea chests, seawater intakes, and internal piping. The efficacy of proactive in-water cleaning using diver surveys, will be determined by both quantitative assessments and systematic qualitative descriptions and images. Surveys will include the following:

1. Quantification of <u>macrofouling</u> and <u>biofilms</u> in the predesignated control and treated test areas over time, using the benchmark of visible (≥ 0.5 cm) intact macrofouling (Morrisey *et al.,* 2015).
2. Qualitative visual assessments of biofilms in the area to be cleaned (predesignated treated area preferred) immediately prior to and immediately after a cleaning event.

3. Documentation of the type, age, and condition of the coatings present on the test surfaces. This may include scratching, flakes or polish-through areas.

Details regarding the dive survey techniques can be found in the *ACT-MERC/SOP/IWC/DS 1.0 – Dive Surveys.*

Additionally, all Jotun pertinent fouling assessment videos during the entire testing period (as part of their normal anti-fouling systems operations) will be provided to ACT/MERC for additional independent assessments of vessel fouling through time.

3.2.1. Fouling Levels

The Jotun Hull Skater is designed and intended for use only on biofilms or slime layers that grow on a specific biocidal coating type, and with the anti-fouling system initiated as soon as a vessel leaves drydock. Therefore, testing will only be conducted on vessel surfaces with the first or lowest level of biofouling (≤ FR20, and accommodations described in the New Zealand regulations), as defined by the US Navy Fouling Rating (FR). However, the performance of the proactive in-water cleaning system over time (in the control and treated test locations) will be assessed and reported using the full FR scale and percentage cover categories defined in Floerl *et al*. (2005).

Biofouling type categories (Naval Ships' Technical Manual 2006):

- Slime (FR 20 or less);
- Moderate (soft) biofouling (FR 30);
- Moderate (hard) biofouling (FR 40–80); and
- Heavy (hard) biofouling (FR 90 or greater).

Percentage cover categories (Floerl *et al*., 2005):

- Absent (0%);
- Light (1–5% of the available surface);
- Considerable (6–15%);
- Extensive (16–40%); and
- Very heavy (41–100%).

3.2.2. Delineating the Control and Treated Test Areas

In coordination with Jotun and the M/V *Talisman* (IMO 9191319) the testing team will clearly define two test locations on the test vessel:

1. The first location will be designated as "*treated*", where periodic proactive use of the Hull Skater will be used to prevent macrofouling in the predesignated operations and frequencies decided on by Jotun and test vessel(s) [TBD].
2. A second location on the vessel will be designated as the "*control*" and will be *left untouched* (i.e., not cleaned in any way) once testing commences and throughout the entire testing period. Control site observations may be extended past the initial testing period if macrofouling fails to exceed FR 20 during the that time frame. Both Jotun and the ship will be consulted in advance.

The two testing locations (control and treated) will be designated using above-surface markings on the vessel, hull weld seams, and/or other markers as appropriate. The control and treated test areas will preferably be located on the same side of the vessel. Regardless, the two test areas should be similar in size, shape, contour, coating type and age, etc. The test areas should not include the area of the vessel's bow that is potentially scoured free of biofouling by wave action, nor located in areas where the Hull Skater cannot clean (such as niche areas). The treated (cleaned) test area will ideally consist of a length of the ship at least 20-30 m long and incorporate all of the surface from the waterline to the flat bottom (or keel) and the flat bottom areas to the midline of the ship (or all surface and coating types to be cleaned by the HullSkater). Ideally, the control test area will be the same size and dimension as the treated test area. However, accommodations to the size (minimum of 15 m in length) and location of the control can be made based on vessel operational requirements (to be confirmed with test vessels).

3.2.3. Dive Survey Biofouling Assessments

For the *Primary Test Vessel*, dive surveys to quantify biofouling will take place a minimum of three times in the treated and control test area. The surveys will be spread out as evenly as possible over the course of the testing period of 9-12 months (approximately beginning, middle and end). Control site observations may be extended if macrofouling fails to exceed FR 20 in the control area within the initial testing time frame. For the *Secondary Test Vessels*, only one dive survey will be conducted of control and treated locations at least 6 months after the Jotun proactive in-water cleaning process has been initiated. The designated control and treated areas and all appropriate surface types within those areas will be surveyed according to *ACT-MERC/SOP/IWC/DS 1.0 – Dive Surveys* (see Section 3.2.7). The biofouling assessment dive surveys will occur in Long Beach, CA.

3.2.4. Diving Safety

This diving is not identified as commercial diving, but as scientific observations as part of research diving. Activities consist of photographing gridded plots in pre-designated areas and taking notes. All divers are approved as scientific divers by American Academy of Underwater Sciences (AAUS) institutions and will follow the AAUS diving safety standards (*AAUS Standards for Scientific Diving Manual, December 2018*). On-site safety measures will include pre-dive meetings with Jotun and relevant ship crew, lock-out/tag-outs, plus live communication before, during and after diving. Specific safety requirements are covered during safety briefings on working days. Diving safety procedures specific to this test can also be found in the *ACT-MERC/SOP/IWC/DS 1.0 – Dive Surveys*.

All parties have liability coverage from their own institutions – in this case, the University of Maryland and the Smithsonian Institution.

3.2.5. Test Vessel Descriptions

Below are selected details for each test vessel participating in this Evaluation.
Details are provided by Jotun:

Primary Test Vessel

- Company and vessel name: *M/V Talisman* (IMO 9191319) owned and operated by Wallenius Wilhelmsen Lines;
- General vessel type and size/dimensions (length, draft, etc.): 38,300 dwt vehicle carrier, 240.6 m long (overall), 32.3 m breadth (extreme), and 11.7 m draught;

- Vessel age and last drydocking: Delivered from Daewoo Heavy Industries, South Korea in 2000, last docked in China April 2018, and is scheduled to dock again in Singapore or China in July 2020;
- Average and maximum speeds during typical voyage: average speed is ~ 17.3 knots; maximum speed: is 21 knots;
- Coating details: SeaQuantum Skate to be applied in next dry docking;
- Routes, ports, lay-up periods, and timing of selected test ports (Baltimore and Long Beach): Updated schedule https://vop.2wglobal.com/schvop/ctrl/searchSchedule;
- Estimated time ship is in the ports of Baltimore and Long Beach: Booked slot is typically around 12 hours, vessel usually spends between 6 and 10 hours in port depending on cargo to be loaded and discharged; and
- Estimated daylight hours that MERC/ACT will have access to the vessel for dive surveys and water quality testing: Vessel will typically arrive in port early morning (4 to 5 am) so most of the time in port will be spent during daylight. Expect MERC/ACT will have access to vessel hull from 1 to 2 hours after arrival until 1 to 2 hours before departure (4 to 8 hours in total).

Secondary Test Vessel(s): Planned secondary test vessel(s) selections are delayed due to the COVID-19 situation. Currently working to secure alternative vessel(s).

- Company and vessel name;
- General vessel type and size/dimensions (length, draft, etc.);
- Vessel age and last dry-docking;
- Coating details;
- Routes, ports, timing of selected test ports (TBD/Baltimore and Long Beach);
- Estimated time the ship is berthed in the ports of Baltimore and Long Beach; and
- Estimated daylight hours that MERC/ACT will have access to the vessel for dive surveys and water quality testing.

3.2.6. Vessel Surfaces to be Surveyed

Within the two delineated test sites (one control and one treated), the dive team will conduct biofouling assessment surveys on 2 to 4 basic hull surface types (to include at a minimum one curved or angled surface and one flat surface). Possible surface types to be surveyed are:

- Flat vertical sides;
- Vertical curved surfaces, such as the turn of the bilge where the hull transitions from vertical to flat bottom;
- Flat bottom (horizontal downward facing surfaces); and
- Angled hull surfaces where the orientation of the surface changes abruptly (edges), such as the chine, keel and skegs.

Niche areas, such as rudders, propellers, shafts, anodes, and gratings, and any other areas that Jotun would not normally clean, will not be surveyed.

3.2.7. Biofouling Dive Survey Sampling Methods

Biofouling dive surveys are designed to quantify *both* macrofouling (organisms or colonies larger than 5 mm or visible by eye) and biofilms (i.e., slime layers) in the designated control and treated sites. Vessel hull surveys are aided by the use of a quadrat which delineates a 1 m^2 plot. The quadrat is vertically divided into 4 bands by using 5 equally spaced straps. Each strap is demarked to create a 50-point count (see Section 3.2.9). Four (4) images can be photographed within each band. Each image is 18 x 24 cm in size and are called sub-plots. A total of 16 sub-plots can be imaged for each 1m^2 plot (Figure 1).

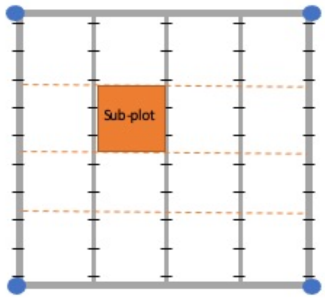


Figure 1. The quadrat used for each 1 m^2 plot contains 4 survey bands. A total of 16 sub-plots can be imaged and/or 50 point counts defined.

Surveying of vessel surfaces will consist of video and/or digital still imaging and/or visual observations stratified by the surface types described in 3.2.6 and depicted in Figure 2. Within each surface type, divers will examine the surface of at least six 1 m^2 plots, which corresponds to the type of sample and minimum number of replicates recommended per surface type in Morrisey et al. (2015). If the vendor cleans the angled surfaces (edges), linear transects along edges will be photographed immediately adjacent to the edge (not 1 m^2 around the edge, but a single camera field of view centered upon the edge). If visibility permits, 16 still images (18 x 24 cm quadrat) will be taken within each 1 m^2 plot. These images will be reviewed upon returning to the home institution, and organisms or biofilm growing immediately adjacent to the points will be determined. Moreover, estimates of fouling rating and percent cover will be made from composite photographs of each plot band (Figure 1). If visibility is poor, the full area of sample plots will be visually inspected using point counts (Section 3.2.9). Any video collected by the individual technologies will be provided to the testing team as well. These control and treated sample plots will be used for the pre-cleaning and post-cleaning dive surveys. An example of a dive survey scheme for the Jotun HSS, including the defined surface types within a single treated (cleaned) or control area is defined in Table 1.

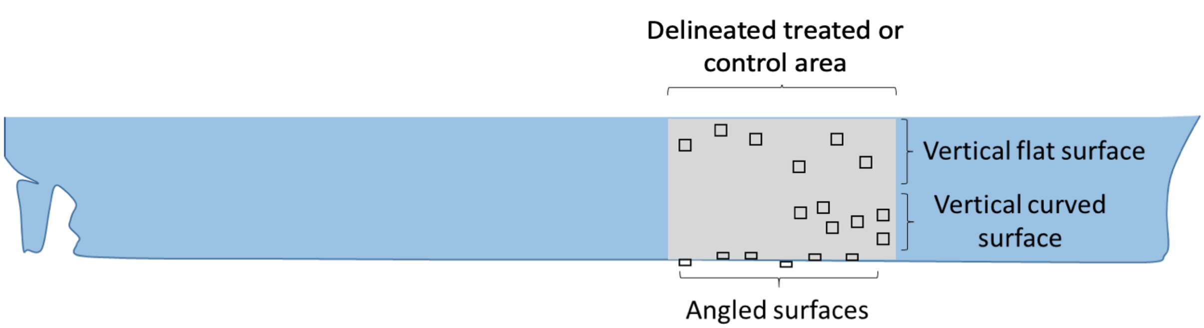


Figure 2. Pictorial representation (not to scale) of a delineated treated or control area (grey), surface types within the cleaning area (named), and six replicate plots within each surface stratum (black boxes). The bottom area, not visible in this figure, will also be sampled in six replicate plots.

Table 1. Example of a dive survey fouling quantification scheme for one of the control or treated test area surveys (in this example, 4 total surface types) for biofouling.

Surface Type	Number of Plots	Number of Images Within One Plot	Total Photos
Vertical flat	6	16	96
Horizontal flat	6	16	96
Vertical curved	6	16	96
Angled Surfaces	6	5	30

3.2.8. Assessment of Proactive Cleaning on Biofilms

A new method is being attempted to qualitatively estimate the efficacy of biofilm removal during the periodic proactive in-water cleaning. The resulting photographs will be reviewed by trained observers and each plot band will be assigned a fouling rating (FR) based on the US Navy FR scale (Naval Ships' Technical Manual 2006) and an estimate of percent cover based on Floerl *et al.* (2005).

Type and level (FR) of biofilm

- Bare/absent (FR 0);
- Light slime (FR 10);
- Full slime (FR 20); and
- Moderate (soft) biofouling (FR 30) (i.e., algae growth).

The biofilm cleaning assessment will occur in conjunction with at least one Jotun HSS in-water cleaning event and consists of two surveys:

- One pre-cleaning survey will occur within 1-2 hours before in-water cleaning begins; and
- One post-cleaning survey will occur within 1-2 hours after in-water cleaning ends.

These two surveys will be conducted on the vertical flat surfaces of the ship's hull on the area of the test vessel being cleaned that day. A survey within the predesignated treated test area is preferred, but not required.

Randomly placed 1 m^2 quadrats (locations determined in the water by individual divers) will be used to document the biofilm in the designated area, with at least 12 replicates sampled before and 12 replicates sampled after cleaning activities. After the quadrat is attached to the hull of the ship, a diver will remove the biofilm from 2 of the 4 quadrat bands (Figure 3).

Any biofilm will be removed using one clean sponge per quadrat. This will enable observers to visually compare biofilm on the hull to a set standard (bare hull) in a photo comparison. The single-use sponge will be photographed to document any collected biofilms. The dive team will then document the growth within each plot by taking at least one randomly placed photo of a small 18 x 24 cm sub section. For a direct comparison, a single photo image will capture both wiped and un-wiped spaces side-by-side. Once the plot has been photographed, the quadrat will be removed from the hull and placed at another location (selected at random) within the designated area on the vertical surface of the hull and the survey repeated. An example of a biofilm survey scheme for the Jotun HSS cleaning process is defined in Table 2.

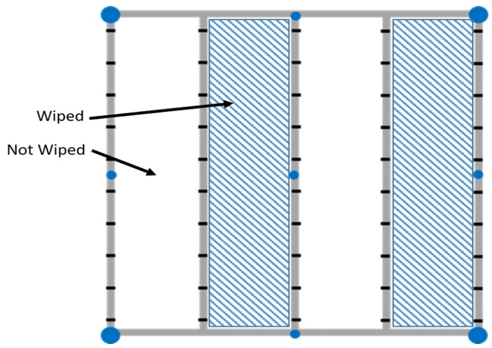


Figure 3. Quadrats are used to determine biofilm cover by using percent cover visual estimates and fouling ratings within the four bands. The two quadrats bands identified in blue will be sponge-wiped of biofilm. Side-by-side photos will compare wiped versus not wiped sections.

Table 2. Example of a dive survey biofilm quantification scheme.

Surface Type	Number of Plots	Number of Images Within Plots	Total Photos
Vertical flat	12 Pre-cleaning	≥ 1	≥ 12
Vertical flat	12 Post-cleaning	≥ 1	≥ 12

3.2.9. Dive Survey Sampling Methods During Low Visibility

In low visibility conditions when still images are unreliable for photo-quadrat surveys, an *in-situ* method will be used. For each hull area sampled, 1 m^2 quadrats will be placed in the test areas in at least 6 locations per surface type. The quadrats will be used to determine biofouling cover by first, using a point count method of the 50 evenly spaced points delineated on the bands of the 1 m^2 area; and second, using percent cover visual estimates within each of the four bands (Figure 4). Biofouling will be identified to FR rating 0-20 for biofilm, plus accommodations for the New Zealand regulations, (Section 3.2.1) with higher FR ratings for macrofouling. Divers will use data sheets and dive slates to record data in the field. After a quadrat is positioned, one diver uses an underwater light to illuminate the sampling area while the other records data on the data sheet. These visual estimates of percent coverage and type of fouling organisms will be based on both the US Navy FR scale to define the type of biofouling (Naval Ships' Technical Manual 2006) and Floerl *et al.* (2005) to define percentage cover.

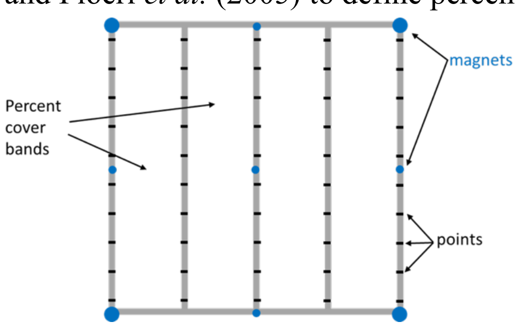


Figure 4. Quadrats are used to determine biofouling cover when low visibility prevents photos of subplots.

Qualitative biological samples may be collected at the end of the sampling period to provide better determinations of dominant biofouling taxa that are present on the hull of the ship. Differences in biofouling percent cover obtained from point counts will be tested among areas sampled using non-parametric Kruskal-Wallis (KW) tests, and in biofouling composition using the PERMANOVA test. During surveying, divers also record whether the following coating conditions were visible within the quadrat: scratches, brush marks, paint flakes, pitted, bare metal/polish through, dock block, or no blemishes.

3.2.10. Biofouling Quantification Survey Reporting

Reporting for this Jotun system Evaluation will include the following:
General requirements:

1. A description and specification of the equipment tested; a description of the standard operating procedure (SOP) for the system.
2. A description of how the test was undertaken, including:
   a. The location, type of vessel inspected, hull material, surface (e.g., coating/unpainted), and environmental conditions during the test; and
   b. A description of the procedures followed during set-up, testing of the system, and demobilization.

For each dive survey for biofouling:

1. Type, level (FR), and cover (%) of biofouling present in each test area.
2. Presence, type, and condition of anti-fouling coating.
3. The video and/or still image(s) on which these assessments were made are to be provided with the report.
4. A description of any variations or deviations in application of the surveys relative to the SOP and test requirements.
5. A discussion of the system efficacy.

To be included when appropriate:

1. The amount and type of residual biofouling for each of the test plots analyzed:
   a. Type of biofouling;
   b. Number of biofouling patches and size of each patch;
   c. Location of the test area on the hull;
   d. Relevant image identifier (file name); and
   e. A description of the condition of any residual biofouling and on the surface on which it settled.

3.2.11. Assessment of Proactive Cleaning on Biofilms Reporting

Reporting for this Jotun system Evaluation will include the following:
General requirements:

1. A description and specification of the equipment tested; a description of the standard operating procedure (SOP) for the system.
2. A description of how the test was undertaken, including:
   a. The location, type of vessel used, hull material, surface (e.g., coating/unpainted) and environmental conditions during the test; and
   b. A description of the procedures followed during set-up, testing of the system and demobilization.

For each dive survey for biofilm assessment:

1. Type, level (FR), and cover (%) of biofilm present in each test area.
2. Presence, type, and condition of the anti-fouling coating.

3. The video and/or still image(s) on which these assessments were made are to be provided with the report.
4. A description of any variations or deviations in application of the surveys relative to the SOP and test requirements.
5. A discussion of the system efficacy.

To be included when appropriate:

1. The amount and type of residual biofilm for each of the test plots analyzed:
   a. Location of the test area on the hull;
   b. Relevant image identifier (file name); and
   c. A general description of the condition of any residual biofilm.

3.3. Water Quality Impacts

Quantification of water quality impacts will include the following measures and will take place during a minimum of three observed in-water cleaning operations on the Primary Test Vessel and once on the Secondary Test Vessels:

1. Water quality sampling (Section 3.3.2).
2. Characterization of general background environmental conditions (Section 3.3.3).
3. Documentation by video of the Jotun HSS system during operations (Section 3.3.4).

3.3.1. Safety During Testing

Testing team personnel will follow standard laboratory and field work safety procedures and will wear protective clothing and equipment when appropriate. All parties have liability coverage from their own institutions – in this case, the University of Maryland Center for Environmental Science, the Smithsonian Institution, and the U.S. Naval Research Laboratory.

All testing operations will cease if there are any concerns regarding human health and safety and/or any significant environmental impacts during testing operations. Decisions to terminate testing will be made in consultation with and the operators of the Jotun HSS and the on-site testing team Program Coordinator, with a final decision made by the Director of ACT and MERC in consultation with the QA Manager.

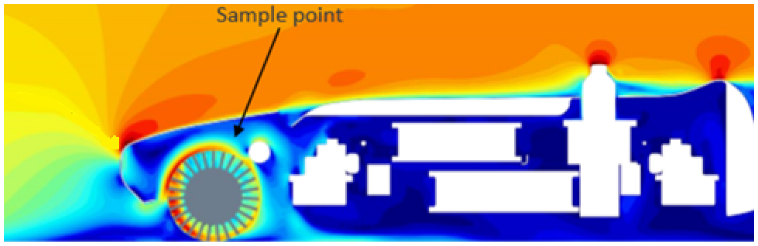
3.3.2. Water Quality Sampling and Analyses

3.3.2.1. Station locations

Continuous, time-integrated water samples will be collected at two stations (U and B1) during three in-water cleaning events, of at least 30 minutes. Background/ambient water quality conditions will be measured at Station B2 before and after the three in-water cleaning events (Table 3). All samples will be collected according to *ACT-MERC/SOP/IWC/SC 1.0 – In-Water Cleaning Sample Collection.* Station details follow:

- *Station U. Sampling intake located on the cleaning unit*. One sampling hose will be attached to the HSS vehicle to sample the exhaust water from the HullSkater (Figures 5A and B). The exact intake site (and method of mounting the hose) will be determined by ACT/MERC and Jotun based on Jotun's computational fluid dynamics assessment of the location of the highest concentrations of material removed from vessel during proactive in-water cleaning. Water will be drawn to sample carboys using a pump. The sample collection station will be located on a small boat positioned near the cleaning unit's point of entry into the water. A Jotun representative will be on board the small boat to assist with cable handling.

A



B

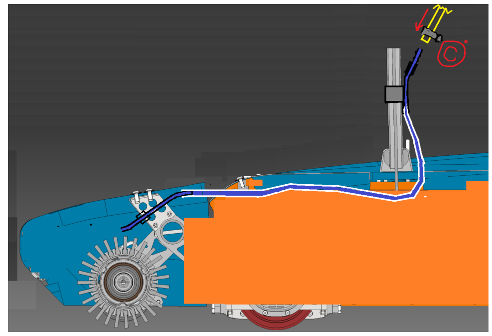


Figure 5. Hull Skating Solution, (A) computational flow dynamics during operations and (B) sample collection location and design for Station U

Sample at Station U will be collected at two different times (U1 and U2) during each test cleaning event. U1 samples will be collected as a water quality control, where the HHS is traveling across the hull but with cleaning brushed elevated above the surface and not rotating for at least 30 minutes. After the continuous time-integrated U1 sample is collected, the HHS will be stopped (sit in place on the hull) and the pump and hose sample system will be flushed ambient water for an additional 30 minutes, prior to collecting the U2 sample. The U2 sample will then be collected (into a separate carboy) over at least a 30 minute cleaning period (HHS brush lowered and rotating in normal biofilm removal mode).

- Station B1. *Background sample > 50 m away from test area.* A pump and hose system will be deployed at least 50 m away from a predesignated area to be cleaned. (The exact sample station location is TBD, but will be located beside the test vessel). The pump intake will be positioned at approximately mid-depth between water line and bilge keel (for the M/V *Talisman* tests, the sampling depth will be about 6 m) and adhered directly to the hull with magnets.

Sample collection is similar at Stations U1, U2 and B1. The sample flow rate will be set to draw a minimum of 40 L of sample water continuously over the entire test period (at least 30 minutes). Using a manifold equipped with flowmeters and valves, approximately 20L will be diverted into each of 2 sample carboys. After the initial sample collection exact carboy volumes will be measured. Then, one 20 L carboy sample will be uniformly mixed prior to collecting subsamples for triplicate analyses of total suspended solids (TSS), particulate organic carbon (POC), dissolved organic carbon (DOC), and biocides (e.g., copper (Cu), zinc (Zn)). Particle size distribution (PSD) will be sampled in triplicate for Station U, with a single sample at Station B1. The second 20 L carboy (glass) will be mixed, then subsampled for microplastics (MP) analysis. Subsample volume requirements, containers, and sample processing will follow SOPs.

- *Station B2. Pre- and post- in-water cleaning background samples.* Background ambient water quality will be characterized by discrete sampling at a predetermined location before and after the in-water cleaning event (Figure 6 and Table 3). This background station will be located near the test vessel berth and may be accessed either by small boat or by the pier. Samples for TSS and biocides will be collected using a Van Dorn-style water sampler. Along with the background data from station B1, information collected at station B2 will be used to determine if samples collected at station U (on the cleaning unit) contain concentrations of TSS and biocides that are significantly higher than the range found in ambient waters in the vicinity of the ship during Jotun system in-water cleaning operations.

A target of eight (8) discrete samples are planned, plus, observations of the current environmental conditions (Section 3.3.3) will be recorded at Station B2. For the M/V *Talisman* tests, the sampling depth will be about 6 m.

1. Three samples collected at three different times (at least two hours apart) one day before in-water cleaning begins on the predesignated area.
2. One sample collected approximately two hours before in-water cleaning begins on the predesignated area.
3. One sample collected approximately two hours after in-water cleaning ends on the predesignated area.
4. Three samples collected at three different times (at least two hours apart) one day after in-water cleaning ends on the predesignated area.

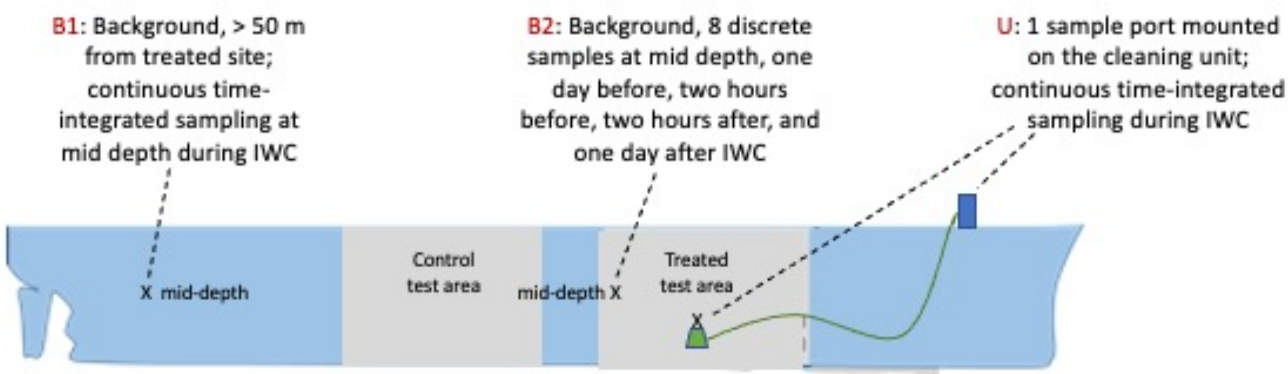


Figure 6. Diagrammatic example (not to scale) of the locations of the three water quality sampling sites: U, B1, and B2. This sampling scheme represents 10-11 samples total, with each analysis conducted in triplicate to quantify analytical variance.

Table 3. Water Quality Collection Sampling Summary. Please note that this is a target list of samples but not all analyses maybe conducted for all samples collected.

Station ID	Location	When Sampled (8x total)	Type of Sample	Sample Depth	Analyses	Sampling Method
U	Attached to cleaning unit	1x, during cleaning	Time-integrated	Varies over cleaning period	TSS, POC, DOC, PSD, Cu, Zn, MP	Pump
B1	> 50 m from treated test site, but beside the vessel	1x, during cleaning	Time-integrated	~6 m	TSS, POS, DOC, PSD, Cu, Zn, MP	Pump
B2	Pier or small boat near ship's berth	3x/day prior to test	Discrete	~6 m	TSS, Cu, Zn	Van Dorn Sampler
		2x/day of test				
		3x/day after test				
QA/QC field replicate	Pier or small boat near ship's berth	1x at B2	Discrete	~6 m	TSS, Cu, Zn	Van Dorn Sampler
QA/QC field blank	On-site DI carboy	1x during sampling	Discrete	NA	TSS, POC, DOC, PSD, Cu, Zn, MP	Direct from DI carboy

3.3.2.2. Sample storage and transfer

All subsamples will be placed in cleaned bottles of the appropriate analysis type and size (examples: 8-9 L for TSS/DOC/POC, 250-500 mL for biocides, 125 mL for PSD, 20 L for MP), All sample bottles will be labeled with unique identification numbers prior to sampling. All samples will be stored at the appropriate temperature for the analysis and delivered to the analytical laboratories within the appropriate time frame for each analysis (see SOPs for details).

3.3.2.3. Sample processing and analysis

Samples for TSS, POC, DOC, PSD, biocides, and microplastics will be analyzed at laboratories approved by the MERC/ACT Quality Assurance Manager. Table 4 lists the sample type, analytical method, and limit of detection for each analysis.

TSS, POC, and DOC samples will be processed and analyzed following the procedures outlined in *MERC/SOP/WQA 2.4 – Water Quality Analysis* and the SOPs used by the Nutrient Analytical Services Laboratory (NASL) located at the Chesapeake Biological Laboratory, UMCES). Biocide samples will be processed following the procedures outlined in *ACT-MERC/SOP/SPMA*

1.0 – Sample Processing for Metals Analysis. The metals sample collection method is modified from EPA 1669. The biocide samples will be analyzed using EPA 200.8 and/or EPA 6020A (Heyes SOP Trace Metals By ICP-MS). The trace metal sample extraction method is EPA 3051A. Particle size and distribution samples will be analyzed by the static automated analysis method (ISO-13322-1) by Particle Technology Labs, located in Downers Grove, IL. Microplastic samples will be processed and analyzed following the procedures outlined in *MERC/SOP/MP 1.0 – Microplastics*. Analyses will be conducted by the Department of Environmental Science and Technology, Aquatic Toxicology Laboratory, University of Maryland, College Park, MD.

Table 4. Sample type, analytical methods, limits of detection.

Sample Type	Analytical Method	Method Detection Limit	QA'd Reporting Limit
TSS	NASLDoc-030, SM208 E, EPA 160.2	2.4 mg TSS/L (2019)	2.4 mg TSS/L (2019)
POC	NASLDoc-033, EPA 440.0	0.0633 mg C/l (2019)	0.0633 mg C/l (2019)
DOC	NASLDoc-014, SM5310B	0.16 mg/L DOC (2019)	0.50 mg/L DOC (2019)
PSD	ISO-13322-1	>10 – 1000 µm (2020)	>10 – 1000 µm (2020)
Particulate/Dissolved Copper (Cu)	EPA 200.8/EPA 6020A	0.1 µg L^{-1} (2018)	0.5 µg L^{-1} (2018)
Particulate/Dissolved Zinc (Zn)	EPA 200.8/EPA 6020A	Diss. 0.5 µg L^{-1} Part. 0.1 µg L^{-1} (2018)	Diss. 1.0 µg L^{-1} Part. 1.0 µg L^{-1} (2018)
Microplastics (MP)	Masura et al. (2015)	TBD	TBD

3.3.3. General Environmental Characterization

At station B2, in conjunction with all water sample collections, the following background environmental characteristics will be observed or measured and recorded: temperature, salinity, and dissolved oxygen concentrations; water clarity; wind speed and direction; tide; air temperature; and weather. Temperature, salinity and dissolved oxygen concentrations will be measured using a YSI multiparameter instrument. Water clarity will be measured using a Secchi disc. Wind speed and direction will be measured using a hand-held anemometer. Tide data will be recorded from the NOAA/international tide tables and visually observed. Air temperature will be measured using a thermometer. Weather observations such as precipitation and cloud cover will be visually observed and recorded.

3.3.4. Video Documentation of the Cleaning Unit

3.3.4.1. Cameras mounted on cleaning unit

Video recording from the four existing video cameras as part of Jotun system cleaning unit (3 facing forward and 1 facing aft) will be used to document any material removed from the ship's surfaces that is released into the immediate environment. This video documentation will be limited to macroscopic objects and debris plumes. Microscopic particles will not be visible at the magnification and resolution of the video cameras, which may also be limited by water visibility. This video documentation will be collected by the Jotun system for all Test Vessels, during their individual testing periods, and relevant video (e.g., surveys test and control locations, cleaning of test areas) will be made available to MERC/ACT when conditions permit for an efficient transfer of the data. Video from the cameras will be reviewed by members of the testing team. Reviewers will independently document releases of visible material, ranking the magnitude of releases on a qualitative scale. This Evaluation of this proactive in-water cleaning will be based upon the average of these ratings and the variation among reviewers will be recorded.

3.3.4.2. Observations of proactive in-water cleaning operations

Once during the proactive in-water cleaning of the *Primary Test Vessel*, video and/or still photos will be taken from a safe distance away from the cleaning system to document the presence or absence of a debris field around the Jotun system during cleaning. If possible, video analysis of optical density of debris plumes will be conducted but a minimum, images will be included in the final report.

3.4. Coating Impacts Resulting from In-Water Cleaning Activities

To examine the impacts to a vessel's coating as a result of in-water cleaning activities, Jotun will train the ACT/MERC dive team to take samples of the ship's coating before and after a specified cleaning. A tailor-made test rig, fastened to the hull with magnets enables semi-automated removal of paint samples of the coating system. Three samples from before the in-water cleaning and three samples collected after the in-water cleaning mission are to be collected. The samples are to be molded into epoxy using suitable molding forms and liquid epoxy. The liquid epoxy is preferably heated briefly to enable efficient air release prior to the molding operation as entrapped air make correct assessments more challenging. The crosscut of each paint flake is polished before examination by microscopy to determine the thickness of the leached layer, easily detectable by the color difference when the soluble pigments and biocides has been depleted in this layer. The samples collected before and after in-water cleaning is compared to determine if significant (> 5-10 μm) reduction of the leached layer has resulted from the in-water cleaning operation.

3.5. Jotun Estimates of "Cleaned" and "Fouled" Surfaces

To test the Jotun's ability to rate sub-sections of hull as "clean" or "fouled" as per clean hull threshold for short stay vessels in the CRMS (MPI 2014), the results from the pre-cleaning biofilm assessment dive survey outlined under section 3.2.8 will be compared with a rating done by the Jotun based on an inspection of the hull conducted immediately prior to the dive survey.

4. Evaluation Schedule

Note that the schedule below is provisional. Actual dates for each milestone may vary.

- *Primary Test Vessel* Biofouling survey 1 - August 2020;
    - Water quality impact sampling during cleaning event 1- September, 2020;
    - Biofouling survey 2 - [TBD];
    - Water quality impact sampling during cleaning event 2 - [TBD];
    - Biofouling survey 3 - [TBD];
    - Water quality impact sampling during cleaning event 3 - [TBD];

- *Secondary Test Vessel* A Biofouling survey - [TBD];
  - Water quality impact sampling during cleaning event - [TBD];
- *Secondary Test Vessel* B Biofouling survey - [TBD];
  - Water quality impact sampling during cleaning event - [TBD];
- *All test vessels*
  - Data validation and analyses - [TBD];
  - Draft evaluation report for review- [TBD]; and
  - Final evaluation report released- [TBD].

5. Data Processing, Storage and Presentation

Field custody documentation will consist of both field logbooks and chain-of-custody forms. Data are recorded in standardized formats, e.g., data collection forms, laboratory and field logbooks, laboratory record books, spreadsheets, computer records, and output from instruments (both electronic and hardcopy).

The data logs and records (full or partially completed) are submitted for review daily to the Program Coordinator or the on-site Data Manager (DM). The originator and reviewer both sign and date the log sheet. If possible, the originator copies the documents, which are turned in to either the Program Coordinator or onsite DM. The original and (if possible) hard copies are filed in binders specific to the test and kept offsite. The originator also scans the documents to a thumb drive and/or takes a picture and sends to the DM. All relevant survey videos and images are submitted to the Director and DM at the end of the test. The DM uploads the data logs, records, and other files to the secure online information system, using a unique name. Name must include test name, cycle number, sample date, and parameter tested.

Chain-of-custody procedures are strictly followed for all samples transported from the sampling site so the possession of a sample from the time of its collection until the time of its analysis is traceable and documentable. Chain-of-custody forms are started at the sample point and checked daily by DM. The chain-of-custody form will contain for each sample: unique identification number, sample date and time, station ID, sample type, sample preservative (if any), and analyses required.

The original chain-of-custody form will remain with the samples at all times. Each form is signed by the person relinquishing samples once that person has verified that the chain-of-custody form is accurate. Copies are made prior to shipment for separate field documentation and retained by the individual relinquishing the sample. Upon arrival at the analytical laboratory, chain-of-custody forms are signed by the person receiving the samples (if different from the sample collector) once that person has verified that all samples identified on the chain-of-custody forms are present. Laboratory sample custody is performed in accordance with the laboratory's Quality Assurance Manual and SOPs and will be consistent with the guidelines set forth in this Test Plan.

6. Quality Management

All technical activities conducted by ACT and MERC comply with their respective Quality Management System (QMS), which includes the policies, objectives, procedures, authority, and accountability needed to ensure quality in their work processes, products, and services. The QMS provides the framework for quality assurance (QA) functions, which cover planning, implementation, and review of data collection activities and the use of data in decision-making, and quality control (QC). The QMS also ensures that all data collection and processing activities are carried out in a consistent manner to produce data of known and documented quality that can be used with a high degree of certainty by the intended user to support specific decisions or actions regarding technology performance. Both ACT's and MERC's QMS meets the requirements of ISO/IEC 17025:2017(E), *General requirements for the competence of testing and calibration laboratories*; the National Environmental Laboratory Accreditation Conference (NELAC) Institute (TNI) Standard FSMO-V1, *General requirements for field sampling and measurement organizations*; which is modeled after ISO/IEC 17025, the American National Standards Institute (ANSI)/American Society for Quality (ASQ) E4-2004 *Quality Systems for Environmental Data and Technology Programs*; and U.S. Environmental Protection Agency, quality standards for environmental data collection, production, and use. In addition, the NRL's QMS is compliant with these standards, and SERC is a MERC collaborator.

Preventive actions will be taken throughout the tests to anticipate and resolve any problems before the quality of performance is compromised. QA/QC procedures for this Evaluation will follow the requirements described in this Test Plan, any participant-specified requirements, and the general principles and specific QA/QC from technical documents. Technical staff has the responsibility to identify problems that could affect data quality or the ability to use the data. Any problems that are identified will be reported to the Program Coordinator and/or Director, who will work with the Quality Assurance (QA) Manager and the Technical Advisory Committee (TAC) to resolve any issues. Action will be taken to control the problem, identify a solution to the problem, and minimize losses and correct data, where possible.

Additional information on the sections below can be found in the *MERC/SOP/QS/TSA 1.1 – Technical Systems Audit, MERC/SOP/QS/CA 1.1 – Corrective Actions, MERC/SOP/QS/IA 1.1 – Internal Audits, MERC/QS/QMP 5.0 – Quality Management Plan,* and *MERC/QS/QAPP 4.0 – Quality Assurance Project Plan, ACT/SOP/QS.QCFL.01 - Quality Control for Field Samples and Laboratory Analyses.*

6.1. Quality Control for Sample Collection and Analyses

QC refers to the operational activities that confirm that the QA methods are functional and that the data collected is accurate, precise, and properly recorded. QC samples are used to identify, measure, and control sources of errors that may be introduced in sampling, analysis, or data evaluation used to estimate measurement uncertainty. QC begins with sample collection in the field and ends with the reporting of data.

All components of the sampling equipment are flushed and rinsed before and after all testing events. Cleaning is verified through the use of blank samples. See *ACT-MERC/WI/IWC/PPTEC 1.0 – Pre- and Post-Testing Equipment Cleaning* for more detail. The system components and cleaning requirements are:

- **Sample pumps**: Pre-testing - flushed with ambient water for > 1 hour immediately prior to testing. Post-testing - flushed with potable then DI;
- **Sample tubing**: Pre-testing - New tubing acquired for each test. Flushed with ambient water for >1 hour immediately prior to testing;
- **Sample flow control manifolds**: Flushed with ambient water for 1 hour immediately prior to testing. Post-testing - flushed with potable then DI;
- **Metals sample collection bottles**: Pre-testing - prepared bottles obtained from analytical laboratory, sample rinsed x 3;
- **PSD sample collection bottles**: Pre-testing - DI rinsed x 3, sample rinsed x 3. Bottles are not reused;
- **TSS, POC, and DOC sample collection jugs**: Pre-testing - sample rinsed 3x. Post testing - Potable rinsed x 3, then DI rinsed x 3; and
- **MP sample collection carboys**: Pre-testing – DI rinsed x 3, sample rinsed x 3. Post Testing – TBD.

Field QC includes daily field logs and sample handling and chain-of-custody procedures. The types of field QC samples that may be collected in the field for TSS, POC, DOC, Cu, Zn, and PSD include:

- **Background samples**: Define ambient conditions and evaluate potential error associated with sampling design, sampling methodology, and analytical procedures;
- **Field replicates**: Collected simultaneously, to assess error associated with sample heterogeneity, sampling methodology, and analytical procedures; and
- **Field blanks**: A blank solution that is subjected to all aspects of sample collection including field-processing, preservation, transportation, and laboratory handling. A field blank is primarily used to evaluate contamination error associated with field operations, sample handling and transport, and laboratory handling.

Laboratory analysis of the samples for TSS, DOC, POC, Cu, Zn, and PSD will be conducted by certified laboratories utilizing approved EPA and/or Standard Methods (Table 4). Laboratory analysis of the samples for microplastics will following the methods in Masura et al. (2015). QC requirements for this method include laboratory duplicates and matrix spikes. QC requirements for metals require calibration blanks, laboratory reagent blank, laboratory fortified sample matrix, laboratory fortified blank, and laboratory duplicates.

Field QC procedures for the video documentation includes the use of multiple cameras and multiple photo-quadrats. The subjective nature of the analysis of the video data requires that QC must focus on the quality of the video footage and potential variability between analysts. Using multiple analysts to review the same footage will minimize error from analyst bias.

6.2. Quality Assurance Technical and Data Quality Assessments

Assessments include technical audits and data quality assessments. Fundamental principles of the assessment process include:

- Assessments are performed by the QA Manager, who is independent of direct responsibility for performance of the Evaluation;
- Each assessment is fully documented;
- Each assessment must be responded to by the appropriate level of the project team;

Quality assessment reports require a written response by the person performing the inspected activity, and acknowledgment of the assessment by the Director; and

- If needed, corrective action must be documented and approved on the original assessment report, with detailed narrative in response to the assessor's finding. Initials and date are required for each corrective action response. Acknowledgment of the response will be provided by the Director.

Technical Audits – Technical audits are systematic and objective examinations of the system performance test implementation to determine (1) whether data collection activities and related results comply with the Test Plan, (2) the tests are implemented effectively, and (3) the tests are suitable to achieve data quality goals. Audits for the Proactive In-Water Cleaning Technologies for Ships Evaluation will include Technical System Audits (TSAs) and Audits of Data Quality (ADQ).

A TSA is a thorough, systematic, and qualitative evaluation of the sampling and measurement systems associated with an in-water cleaning performance test. The objective of the TSA is to assess and document the conformance of on-site testing procedures with the requirements of the Test Plan, published reference methods, and associated SOPs. The TSA assesses test facilities, equipment maintenance and calibration procedures, reporting requirements, sample collection, analytical activities, and QC procedures. Both laboratory and field TSAs are performed. The QA Manager will conduct a TSA of the laboratory component and at least one field test during the verification. The TSA is performed following the EPA document *Guidance on Technical Audits and Related Assessments for Environmental Data Operations*, EPA QA/G-7, January; 2000. A TSA checklist based on the Test Plan is prepared by the QA Manager prior to the TSA and reviewed by the Program Coordinator. At the close of the TSA, an immediate informal debriefing will be conducted. Non-conformances are addressed through corrective action. The QA Manager will document the results of TSAs and any corrective actions in a formal audit report.

An ADQ is a quantitative evaluation of the system performance test data. The objective of the ADQ is to determine if the test data were collected according to the requirements of the Test Plan and associated SOPs and whether the data were accumulated, transferred, reduced, calculated, summarized, and reported correctly. The ADQ assesses data accuracy, completeness, quality, and traceability. The QA Manager conducts the ADQ after data have been 100 % verified by the Program Coordinator. The ADQ entails tracing data through their processing steps and duplicating intermediate calculations. A representative set of the data (10 %) is traced in detail from raw data and instrument readouts, to data transcription or transference, to data manipulation, to data reduction, to data calculations and summaries, and to final reported data. The focus is on identifying a clear, logical connection between the steps. Particular attention is paid to the use of QC data in evaluating and reporting the data set. Problems that could affect data quality are immediately communicated to the Program Coordinator. The results of the ADQ are documented in a formal audit report with conclusions about the quality of the data from the verification and their fitness for their intended use.

Data Quality Assessment (DQA) – Technology testing data are reviewed to ensure that only sound data that are of known and documented quality, and that meet technology testing quality objectives are used in making decisions about technology performance. DQA is conducted in two phases. The first phase consists of reviewing and determining the validity of the analytical data: data verification and validation. The second phase consists of interpreting the data to determine its applicability for its intended use: usability assessment.

Data verification is the process of evaluating the completeness, correctness, and consistency of the test data sets against the requirements specified in the Test Plan. Data verification is conducted by the QA Manager. The process includes verifying that:

- The raw data records are complete, understandable, well-labeled, and traceable;
- All data identified in the Test Plan has been collected;
- Instrument calibration and QC criteria were achieved; and
- Data calculations are accurate.

Corrective action procedures are implemented if data verification identifies any non-compliance issues.

Data validation evaluates data quality in terms of accomplishment of measurement quality objectives, such as precision, bias, representativeness, completeness, comparability, and sensitivity. Data validation:

- Establishes that required sampling methods were used and that any deviations were noted;
- Ensures that the sampling procedures and field measurements met performance criteria and that any deviations were noted;
- Establishes that required analytical methods were used and that any deviations were noted; and
- Verifies that QC measures were obtained, and criteria were achieved; and that any deviations were noted.

Data validation is performed by the QA Manager. Any limitations on the data and recommendations for limitations on data usability are documented.

Data usability assessments determine the adequacy of the verified and validated data as related to the data quality objectives defined in the Test Plan. All types of data and associated information (e.g., sampling design, sampling technique, analytical methodologies) are evaluated to determine if the data appear to be appropriate and sufficient to support decisions on technology performance. A data usability assessment has an analytical and a field component. An analytical data usability assessment is used to evaluate whether analytical data points are scientifically valid and of a sufficient level of precision, accuracy, and sensitivity. The field data usability assessment evaluates whether the sampling procedure (e.g., sampling method, sample preservation and hold times) ensures that the sample that is collected for analysis is representative.

Corrective Action - Corrective action is implemented in response to any situation that compromises the quality of testing or data generated during the Evaluation. The need for corrective action can be identified by any project personnel and implemented with the prior approval of the Program Coordinator, in consultation with the QA Manager. The Program

Coordinator is responsible for determining appropriate corrective action to address an issue. Any findings that have a direct impact on the conduct of the system performance test will be corrected immediately following notification of the finding. Implementation of corrective actions must be verified by the QA Manager to ensure that corrective actions are adequate and have been completed. This will be done in real-time if corrective actions can be immediately performed. All corrective actions are documented. Any impact that an adverse finding had on the quality of the test data is addressed in the test report.

Audit Reporting – The QA Manager is responsible for all audit reports. These written reports focus on whether the field and laboratory activities and related analytical results:

- Comply with the Test Plan and related SOPs;
- Are implemented effectively; and
- Are suitable to achieve data quality goals.

A TSA report usually consists of:

- An introduction describing the date, location, purpose, and scope of the audit;
- A detailed account of the findings and their basis;
- Conclusions, including a discussion of any findings requiring corrective action; and
- Recommendations (if requested) for resolving problems that affect quality.

TSA findings are audit results that can generally be divided into three categories:

- Noteworthy practices or conditions;
- Observations, which are neither positive nor negative; and
- Nonconformances, which are deviations from standards and documented practices (e.g., Test Plan, SOPs, reference methods).

Nonconformances can be divided into two subcategories:

- Deficiencies, which adversely impact the quality of results; and
- Weaknesses, which do not necessarily (but could) result in unacceptable data.

The TSA report will be prepared within approximately 30 days of completion of the audit.

The DQA report documents the results of a QA review of data. The report addresses three data quality factors:

- Sample representativeness;
- Data accuracy; and
- Usability of the data for decision-making.

The DQA report generally includes:

- A summary description of the data review process;
- A summary of the data verification and data validation results that highlights significant findings and a discussion of their impact on data usability;
- A discussion of the statistical tests for sample representativeness and data accuracy; and
- A recommendation or decision on the usability of the data set for the project's decision-making.

If corrective action is required due to nonconformances identified in either the TSA or DQA, a corrective action report will be prepared. The report includes:

- Identification of nonconformity;
- Description of extent of the nonconformity with respect to achievement of the project's objectives;
- Findings and conclusions;
- Determination of cause to prevent reoccurrence;
- Corrective action taken and implemented; and
- Follow-up by the Quality Manager to document the effectiveness of solutions.

7. Roles and Responsibilities

The **Evaluation Participants**: Jotun **and the shipping lines, where appropriate,** will:

- Identify the primary points of contact for Jotun, the test ship, and the relevant port to communicate with the Director and/or Program Coordinator;
- Work with the ship owner(s) and Director to identify a suitable testing platform (ship) and testing locations;
- Meet with the Director and/or Program Coordinator on site prior to the start of testing to discuss and clarify all vendor, ship, diving, and testing logistics;
- Prior to testing, provide to the Director all relevant documentation, including:
    - Competed initial vendor information survey;
    - Signed Test Plan and other relevant contracts;
    - Cut sheets (including mechanical configurations, operational parameters and options), Operations Manual, and/or Guidelines (Appendix A);
    - Relevant SOPs and safety procedures;
    - All relevant certifications, approvals, and permits, including cleaning permits; and
    - Any relevant past studies.
- Communicate with the Director and Program Coordinator concerning all pre-testing and testing logistics;
- Work with the Director, Program Coordinator, and Lead Diver to identify control and treated test locations;
- Agree to a provisional evaluation schedule to include dive surveys and identification of a specific cleaning event date for water quality sampling and quantification of cleaning debris;
- Perform in-water cleaning on the designated test ship, with the exception of the control location(s), at the predetermined (agreed to) frequency, based on vessel and coating type and age, operational constraints, routes, and ports of call, etc.);
- Document, verify, and report on all in-water cleaning activities (dates, times, locations, biofouling assessments, waste production and disposal, etc.) during the entire test period to the Director in a timely manner; and
- Work on site with the test team to ensure all activities take place safely and successfully.

The **Director (**ACT/MERC) will:

- Ensure that all QMS and client requirements are communicated, understood, and followed by all;
- Serve as the primary point of contact for Jotun and the ship;
- Send Test Plan to Jotun for discussion and signature;
- Determine the testing schedule in consultation with the vendor, ship, test participants;
- Confirm all requested documentation from the vendor and or shipping company are received prior to testing including: proof of permitting, cut sheets (including mechanical configurations, plus, operational parameters), SOPs, etc.;
- Work with all entities to identify payment for all aspects of the testing;
- Serve as the primary point of contact for TAC;
- Serve as the initial primary point of contact for testing participants; and
- Ensure that confidentiality of proprietary participant technology and information is maintained.

The **Program Coordinator** will:

- In coordination with the Director, send the pre-testing logistics survey to vendor/ship contacts, and continue this communication before and during testing;
- Communicate with the testing team to include conference calls, on-site meetings, emails, contact information spreadsheet, etc.;
- Work with Director, primary test team members, and QA personnel to develop a Test Plan for the Jotun HSS system;
- Assist the Director during all stages of testing;
- Ensure that all quality procedures specified in the Test Plan are followed before, during, and after testing;
- Serve as primary point of contact for ship, vendor, and test team during testing;
- Respond to any issues/corrective actions that may arise during testing including communication with the on-site test team, the Director, and the QA Manager; and
- Ensure that the testing team complies with all health and safety protocols while on the test site (including ship, vendor, and test team protocols).

The **QA Manager** will:

- Review the Test Plan to ensure compliance with the QMP;
- Review and approve participating analytical laboratories;
- Conduct technical audit and data quality assessments;
- Assist the Program Coordinator and the Director if a stop work order should be issued, if audits or other on-site issues indicate that data quality is being compromised, or if proper health and safety practices are not followed;
- Review implementation of any necessary corrective actions; and
- Prepare audit reports.

Field Testing Team will:

- Assist in developing the Test Plan;
- Under the direction of the Director, Program Coordinator, or other designated person, perform all field work, including dive surveys, sample collections, and analyses as detailed in the Test Plan (to include approved Test Plan deviations);

- Assist with other duties, such as pre-testing site visits, as requested by the Director/Program Coordinator;
- Assist with onsite QA/QC protocols outlined in the Test Plan;
- Conduct their work in conformance with the requirements of the QMS;
- Abide by all on-site health and safety requirements; and
- Provide image and sample analyses, data management and analysis, and results on time (determined by the evaluation schedule).

8. References

American National Standards Institute and American Society for Quality (ANSI/ASQ), 2004. Quality Systems for Environmental Data Collection and Environmental Technology Programs: Requirements with Guidance for Use. E4-2004. Milwaukee, WI.

Floerl O, Inglis GJ and Hayden BJ, 2005. A risk-based predictive tool to prevent accidental introductions of non- indigenous marine species. Environmental Management 35:765-778.

International Organization for Standardization (ISO). 2017. ISO/IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories

Maritime Environmental Resource Center (MERC). 2019. Internal Audits Standard Operating Procedure. 1.1.

Maritime Environmental Resource Center (MERC). 2019. Corrective Action Standard Operating Procedure. 1.1.

Maritime Environmental Resource Center (MERC). 2019. Quality Management Plan.

Maritime Environmental Resource Center (MERC). 2019. Technical Systems Audit Standard Operating Procedure. 1.1.

Masura, J., Baker, J., Foster, G., and Arthur, C. 2015. Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. NOAA Technical Memorandum, NOS-OR&R-48.

Ministry for Primary Industries, New Zealand [MPI] (2014). Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand. CRMS- BIOFOUL. Wellington: Ministry for Primary Industries.

Morrisey D, Inglis G, Tait L, Woods C, Lewis J, and Georgiades E, 2015. Procedures for evaluating in-water systems to remove or treat biofouling. Ministry for Primary Industries, New Zealand, ISBN No:978-1-77665.

Naval Ships' Technical Manual. 2006. Chapter 081 – waterborne underwater hull cleaning of Navy ships. Publication # S9086-CQ-STM-010/CH-081 Revision 5, Washington, DC: Naval Sea Systems Command.

Standards for Scientific Diving Manual, American Academy of Underwater Sciences, December 2018 (corrections March 2019). https://www.aaus.org/AAUS/About/Diving_Standards/AAUS/Diving_Standards.aspx?hkey=25acfc9a-aea5-4e7f-86c6-9c514c1e764c

United States Environmental Protection Agency (EPA). 2000a. Guidance on Technical Audits and Related Assessments for Environmental Data Operations. Reissue Notice May 2006. EPA QA/G-7: EPA/600/R-99/080. Office of Environmental Information. Washington, D.C.

9. Annex

Additional related efforts planned in conjunction with the formal ACT/MERC Evaluation, described above.

9.1. Pilot Program

(provided by Jotun)

In preparation for a global launch of the Hull Skating Solution (HSS), Jotun is preparing a Piloting program where the full HSS program will be rolled out on up to 50 carefully selected ships in a step-by-step fashion (not taking on additional ships until ships already equipped are under control). The program is planned to start March 2020. The ships will be followed for a full dry-docking interval (typically 3 to 5 years).

The ships' trade and operating profiles shall be representative for ships in challenging operations and include the most important sub-vessel types (Crude Oil Tankers, Bulkers, Container Carriers, Gas Carriers, Cruise and Navy Ships).

For Jotun, one area of focus will be working with early customers on improving all aspects of the HSS. This includes building technical margins and scaling the delivery and support organization as needed to serve a growing install base on ships in world-wide trades.

Another area of focus will be to build awareness of and knowledge about proactive cleaning amongst relevant stakeholders, including stakeholders with jurisdiction in ports and at anchorages (e.g., ports as well as national and local environmental authorities).

Jotun will therefore establish a Stakeholder Forum and invite interested stakeholders to join the forum as members. Members will receive regular updates on progress and results. Members will also be invited to propose areas of interest to be included in the regular reporting. In addition, Jotun is interested in collaborating with stakeholders on investigating additional research questions of relevance to proactive cleaning.

One such collaboration opportunity is to use minor reference areas, not undergoing cleaning, to be inspected as often as possible to follow the growth of the various fouling organisms. Combining this information with oceanographic data available for the vessels in their specific trade, it may be possible to map how different parameters affect the growth rate of fouling organisms. This is an area of common interest between the Jotun and ACT/MERC. Depending on the resource demand and the information made available during the regular inspections, the feasibility of this work will be further discussed and possible actions agreed upon.

9.2. Fuel Efficiency Assessment

Jotun work with ACT/MERC and test vessel operators to conduct a 2-year fuel efficiency assessment for test vessel(s) employing the proactive in-water cleaning system based on ISO 19030-2.

Appendix A: Jotun Guideline for Proactive Cleaning of Ships' Underwater Hull Areas while in Port and at Anchorage

Guideline for Proactive Cleaning of Hull Areas in Port & at Anchorage

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Executive Summary

The intent of this guideline is to provide input to ports and other jurisdictions facing requests for proactive in-water cleaning of ships' underwater hull areas while in port or at anchorage. It addresses key points to consider, such as requirements and how delivery on these requirements is to be documented.

Table of contents

Contact for further information: Geir Axel Oftedahl
Jotun A/S, Hystadveien 167, 3209 Sandefjord, Norway
geir.axel.oftedahl@jotun.no

1. Introduction

1.1. Purpose

The intent of this guideline is to provide input to ports and other jurisdictions facing requests for proactive in-water cleaning of ships' underwater hull areas while in port or at anchorage. It is intended to support the accelerated implementation of (ecologically and economically sound) proactive in-water cleaning procedures in port and at anchorage.

1.2. Background

Biofouling on the hull of a ship is an important vector for the spread of aquatic invasive species. Biofouling also increases ship hull resistance and decreases propeller efficiency; both leading to higher fuel consumption and associated emissions to air (CO_2, SOx, NOx, etc.). The increase in fuel consumption (or saving potential) may be significant. It is estimated that approximately10 % of the fuel consumed by the world's fleet could be saved by better management of hull and propeller surfaces, *IMO (2011a)*.

Measures to combat biofouling, collectively termed 'antifouling measures', are, therefore, an environmental and economic necessity for shipping. The most commonly used approach is based on antifouling coatings. These coatings contain one or more biocides, embedded in a slowly dissolving or eroding matrix. Another common antifouling approach is fouling release coatings. These have surface properties that make fouling adhesion difficult. Fouling release coatings typically require higher speeds to be self-cleaning.

When the biofouling pressure exceeds the antifouling or fouling release capabilities in the coating used, biofouling will begin to settle on the hull. Biofouling progresses in several stages:

- Stage 1 (USN FR 0 to 10): Settlement of individual bacteria (within minutes)
- Stage 2 (USN FR 20): Biofilm / slime (within 1 day)
- Stage 3 (USN FR 30): Algae and single-cell organisms (within 1 week)
- Stage 4 (USN FR 40 and up): Macro-fouling (tubeworms, barnacles, etc.) (within 2-3 weeks)

USN FR refers to the US Navy Fouling Rating scale (US Navy, 2006) also included as Annex 1.

Cleaning of the first two stages can be done using minimal force and is often referred to as soft cleaning. Cleaning of the last two stages of fouling will require more force.

An inherent risk when cleaning antifouling and fouling release coatings with too much force, is that the coatings are eroded or damaged. This may result in excessive amounts of biocides or coatings particles being released into the local environment. It will typically also result in a deterioration in antifouling or foul release capabilities and therefore an increased risk of the biofouling problem reemerging.

It is generally held that biofouling in the two first stages is of no concern in terms of aquatic invasive species. An inherent risk when cleaning biofouling at stage is that the cleaning may result in the release of aquatic invasive species into the local environment, however.

Proactive cleaning means to remove the biofouling during the first two stages and before it has progressed to stage 3. If done correctly, biofouling can therefore be removed without causing erosion of or damage to the coating and without risk of transfer of aquatic invasive species.

Proactive cleaning in port or at anchorage may be done using divers or remotely operated vehicles (ROVs). Divers and operators of ROVs are both exposed to health and safety risk and may represent a risk to other marine traffic. There may also be privacy and security concerns related to cameras and other sensors used.

Key concerns of ports and jurisdictions related to in-water cleaning are:

- Release of aquatic invasive species
- Release of biocides and other paint components
- Health, safety and (other) environmental concerns
- Privacy & security

These concerns of ports and other jurisdictions must be addressed appropriately by any proactive cleaning procedure before a port or other jurisdiction can grant permission for such a procedure to be used.

1.3. Who should read this guideline?

Ports and other jurisdictions who may want to grant permission to undertake proactive cleaning in a port or at an anchorage, ship operators or service providers who may want to apply for such permission (hereinafter the "Applicant"), as well as other representatives from ports, jurisdictions, ship operators, service providers, other regulatory authorities and associations of the above.

2. Requirements for proactive cleaning of ships' underwater hull areas

The key concerns of ports and other jurisdictions translate into corresponding requirements for any proactive cleaning procedure. In the following subchapters, such requirements are listed. It is also suggested how these requirements can be addressed and how acceptable fulfillment of requirements might be proven.

2.1. Basic documentation

Any procedure must be documented with an account of its working principle and operational requirements, including:

- Equipment to be used with specific manufacturers/models
- On what parts of the ship's underwater hull area the equipment can be used and what areas are excluded (e.g. specific hull features, extreme curvature, etc.)
- Other requirements or limitations (e.g. wind, waves, temperature, daylight, etc.)

2.2. No release of aquatic invasive species

While the procedure needs to facilitate the effective inspection and proactive cleaning of a hull, its execution shall not lead to the release of aquatic invasive species. For proactive cleaning this is achieved by restricting cleaning to areas of the hull with biofouling at stage 1 or 2. As long as proactive cleaning is only done on areas that are already clean by this standard, there will be no significant risk that the cleaning results in a release of aquatic invasive species.

In order to ensure proactive cleaning will only be done on areas that are already clean, the Applicant must document that procedures are in place to:

- Identify areas with biofouling at stage 3 and above as per what is considered "unacceptable" fouling in Guideline for Diving Service Providers published by New Zealand's Ministry of Primary Industries (*MPI*, 2018) and included as Annex 2.
- Avoid these areas during the proactive cleaning

The Applicant must also document that the procedures in place are adequate. This can be documented by inclusion of a risk assessment by a competent third party.

In order for a port or other jurisdiction to be able to verify that proactive cleaning has only done on areas that are already clean, the Applicant must agree to:

- Capture, store and make available to the port or other jurisdiction video of the full proactive cleaning operation, where video must be of sufficient quality to allow determining if the areas proactively cleaned were already clean or not.
- If in dispute, refer final decision to a competent third party agreed upon upfront and cover half the cost of such verification. The Applicant may nominate a competent third party, and vouch for a maximum cost of verification, as a part of the application.

Areas that are found to be fouled with biofouling in Stage 3 or beyond should be recorded. Such areas may undergo conventional/reactive cleaning in a port where such conventional/reactive cleaning services are allowed.

2.3. No unacceptable release of biocides and other chemicals

The cleaning should remove fouling effectively but must not be abrasive to the paint. The Applicant must therefore document that:

- The cleaning equipment to be used can be operated on the same type of paint system in a similar condition (including age and remaining dry film thickness) and on the same type of fouling without significant risk of erosion or damage to the paint.
- In biocide-containing paints, there should be no visible sign of the cleaning resulting in erosion to the intact antifouling paint beneath the leached layer.

This can be documented by inclusion of a risk assessment by a competent third party.

2.4. Respecting other stakeholders

2.4.1. Non-interference with normal port operations

It should not be possible to use the cleaning equipment to collect photographic or other information about other ships in ports. Also, the use of the cleaning equipment must not interfere with normal port operations. It therefore needs to be documented that:

- sensors (including cameras) are not able to reach near-by ships
- the use of the cleaning equipment will not interfere with normal port operations

This can be documented by inclusion of a risk assessment by a competent third party.

2.4.2. Respecting health & safety requirements

Health and safety aspects may be addressed in various forms, usually using a combination of design of equipment, training and instructions. The details will depend on the procedure chosen.

The Applicant must document that

- The procedure does not pose any unusual risks for human health or the environment during the complete phase of operation including launching, operation, retrieval and stowage of equipment.

This can be documented by inclusion of a risk assessment by a competent third party certifying that the procedure yields acceptable safety level.

3. Training & instructions for proper operation

It should be ensured that operators of cleaning equipment meet defined competence requirements which are accepted by the industry and concerned authorities. Suitable training should address the competence criteria, covering all work processes and all roles involved in cleaning operations.

It should be demonstrated that

- Training and/or instructions for operators are in place
- The success of training is assessed, and a record is kept (electronic format suffices)

This can be documented by inclusion of a risk assessment by a competent third party certifying that the training yields an acceptable safety level.

4. Documentation

The Applicant must document compliance with these guidelines. If not included as a part of the original documentation, the port or jurisdiction may require that a competent third party issue a statement of compliance.

Documentation requested from a potential supplier by the port or jurisdiction may be submitted via a portal (e.g. Vessel Check Portal), email or in paper version. A submission via a portal is recommended as the facilitates the review by all stakeholders.

In general, all quality management measures in place should be documented and stated when applying for in-principle permission to clean with a given procedure or technology in port or at anchorage.

5. References

CSC (2011), *A transparent and reliable hull and propeller performance standard,* Submission by Clean Shipping Coalition to MEPC.63-4-8, Int. Maritime Org., London, https://jotunimages.azureedge.net/images/images/mepc-63-4-8_tcm214-10265.pdf

IMO (2011), *2011 Guidelines for the Control And Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species,* Resolution MEPC.207(62), Int. Maritime Org., London, http://www.imo.org/en/OurWork/Environment/Biofouling/Documents/RESOLUTION%20MEPC.207[62].pdf

MPI (2018), *GUIDELINES FOR DIVING SERVICE PROVIDERS inspecting vessels arriving to New Zealand*, Ministry for Primary Industries, Wellington/New Zealand, https://www.mpi.govt.nz/dmsdocument/27852-guidelines-for-diving-service-providers-inspecting-vessels-arriving-to-new-zealand

US Navy (2006), *Naval Ships' Technical Manual Chapter 081 - Waterborne Underwater Hull Cleaning of Navy Ships*, US Navy, https://www.hnsa.org/wp-content/uploads/2014/07/ch081.pdf

Annex 1: US Navy Fouling Rating Scale (*US Navy*, 2006).

S9086-CQ-STM-010

Table 081-1-1 FOULING RATINGS (FR) IN ORDER OF INCREASING SEVERITY

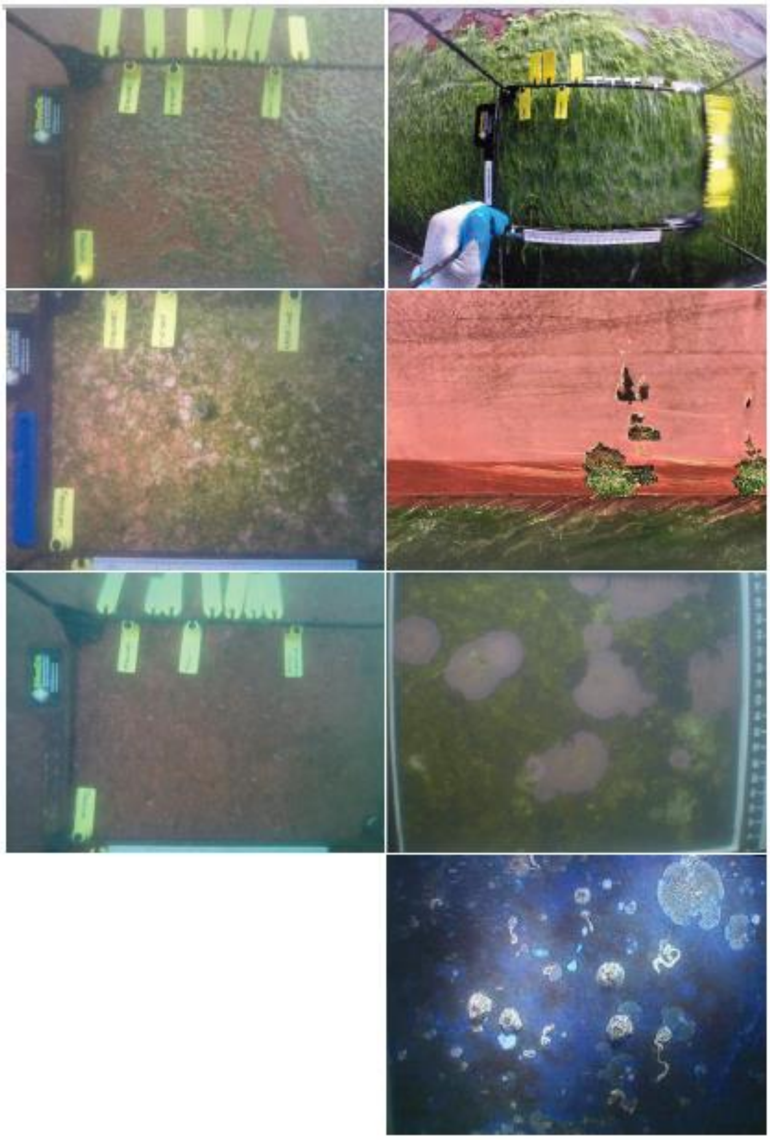
Type	Fouling Rating (FR)	Description
Soft	0	A clean, foul-free surface; red and/or black AF paint or a bare metal surface.
Soft	10	Light shades of red and green (incipient slime). Bare metal and painted surfaces are visible beneath the fouling.
Soft	20	Slime as dark green patches with yellow or brown colored areas (advanced slime). Bare metal and painted surfaces may by obscured by the fouling.
Soft	30	Grass as filaments up to 3 inches (76 mm) in length, projections up to 1/4 inch (6.4 mm) in height; or a flat network of filaments, green, yellow, or brown in color; or soft non calcareous fouling such as sea cucumbers, sea grapes, or sea squirts projecting up to 1/4 inch (6.4 mm) in height. The fouling can not be easily wiped off by hand.
Hard	40	Calcareous fouling in the form of tubeworms less than ¼ inch in diameter or height.
Hard	50	Calcareous fouling in the form of barnacles less than ¼ inch in diameter or height.
Hard	60	Combination of tubeworms and barnacles, less than ¼ inch (6.4 mm) in diameter or height.
Hard	70	Combination of tubeworms and barnacles, greater than ¼ inch in diameter or height.
Hard	80	Tubeworms closely packed together and growing upright away from surface. Barnacles growing one on top of another, ¼ inch or less in height. Calcareous shells appear clean or white in color.
Hard	90	Dense growth of tubeworms with barnacles, ¼ inch or greater in height; Calcareous shells brown in color (oysters and mussels); or with slime or grass overlay.
Composite	100	All forms of fouling present, Soft and Hard, particularly soft sedentary animals without calcareous covering (tunicates) growing over various forms of hard growth.

Annex 2: What is considered "unacceptable" fouling in Guideline for Diving Service Providers published by New Zealand's Ministry of Primary Industries (MPI, 2018)

Waterline and flat hull surfaces

The waterline and flat surfaces of the hull should have no more than a slime layer and incidental (1% cover) of macrofouling. Filamentous slime is unacceptable, as are encrusting organisms such as bryozoans. Damage to the antifouling coating should be repaired, as a vessel with a damaged antifouling system is not following best practices for biofouling management. Scattered fouling presents a lower biosecurity risk than clumped fouling. Therefore, clumped biofouling and/or fouling of >1 organism type or species exceeds the thresholds and should be cleaned prior to the vessel's departure for New Zealand.

Acceptable ☑ | Unacceptable ☒



Ministry for Primary Industries GUIDELINES FOR DIVING SERVICE PROVIDERS March 2018 5