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DEVELOPMENT OF GUIDELINES AND OTHER DOCUMENTS FOR UNIFORM IMPLEMENTATION OF THE 2004 BWM CONVENTION

Scaling of ballast water management systems

Submitted by Germany and Norway

SUMMARY

Executive summary:	This document provides draft guidance on the scaling of ballast water management systems
Strategic direction:	7.1
High-level action:	7.1.2
Planned output:	7.1.2.3
Action to be taken:	Paragraph 3
Related documents:	MEPC 58/23; MEPC 57/21 and BLG 14/5/3

Introduction

1 In addition to the guidance contained in the Guidelines for approval of ballast water management systems (G8), BLG 14, having considered a proposal by Norway (BLG 14/5/3), agreed on the need to develop a guidance document on the scaling of ballast water management systems employing UV disinfection and filtration. BLG 14 also invited Members and observers to provide technical submissions to facilitate the development of such document.

2 Using document BLG 14/5/3 as a starting point, the co-sponsors have prepared a revised draft of the guidance document on the scaling of ballast water management systems, as set out in the annex.

Action requested of the Sub-Committee

3 The Sub-Committee is invited to consider the draft guidance contained in the annex and decide as appropriate.

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ANNEX

GUIDANCE ON SCALING OF BALLAST WATER MANAGEMENT SYSTEMS

1 References in the Guidelines for approval of ballast water management systems (Guidelines (G8))

1.1 The Guidelines (G8) contain the following definitions:

.1 **Shipboard Testing** is a full-scale test of a complete Ballast Water Management System (BWMS) carried out on board a ship according to part 2 of the annex to Guidelines (G8), to confirm that the system meets the standards set by regulation D-2 of the Ballast Water Management Convention (BWM Convention). Refer to paragraph 3.9 in Guidelines (G8).

.2 **Treatment Rated Capacity (TRC)** is the maximum continuous capacity expressed in cubic metres per hour for which the BWMS is type approved. It states the amount of ballast water that can be treated per unit time by the BWMS to meet the standard in regulation D-2 of the Convention. Refer to paragraph 3.10 in Guidelines (G8).

.3 **Land-based Testing** is a test of the BWMS carried out in a laboratory, equipment factory or pilot plant including a moored test barge or test ship, according to parts 2 and 3 of the annex to Guidelines (G8), to confirm that the BWMS meets the standards set by regulation D-2 of the Convention**.**

1.2 In addition to the definitions given in Guidelines (G8), the following terms are defined:

.1 **Base unit** is the functional part of a BWMS that has been tested in accordance with the requirements for land-based testing.

.2 **Scaled unit** is the functional part of a BWMS that is based on the base unit but has been modified to accommodate a higher or lower TRC.

.3 **MADC**: Maximum allowable discharge concentrations as recommended by the GESAMP-BWWG*.*

1.3 Success criteria for shipboard testing of a BWMS are given in part 2 of the annex to Guidelines (G8), paragraph 2.2.2. In evaluating the performance of BWMS installation(s) on a ship or ships, the following information and results should be supplied to the satisfaction of the Administration (only parts of paragraph 2.2.2 are quoted below):

.1 "Documentation that the BWMS is of a capacity within the range of the treatment rated capacity for which it is intended." (Refer to paragraph 2.2.2.2 in part 2 of the annex to Guidelines (G8).); and

.2 "The amount of ballast water tested in the test cycle on board should be consistent with the normal ballast operations of the ship and the BWMS should be operated at the treatment rated capacity for which it is intended to be approved." (Refer to paragraph 2.2.2.3 in part 2 of the annex to Guidelines (G8).).

1.4 In-line treatment equipment may be downsized for land-based testing, but only when the following criteria are taken into account:

.1 equipment with a TRC equal to or smaller than 200 m^3/h should not be downscaled;

.2 equipment with a TRC larger than 200 m^3/h but smaller than 1,000 m^3/h may be downscaled to a maximum of 1:5 scale, but should not be smaller than 200 m^3/h; and

.3 equipment with a TRC equal to, or larger than, 1,000 m^3/h may be downscaled to a maximum of 1:100 scale, but should not be smaller than 200 m^3/h.

(Refer to paragraph 2.3.13 in part 2 of the annex to Guidelines (G8).)

1.5 The manufacturer of the equipment should demonstrate by using mathematical modelling and/or calculations that any downscaling will not affect the required functioning and effectiveness on board a ship of the type and size for which the equipment will be certified. (Refer to paragraph 2.3.14 in part 2 of the annex to Guidelines (G8).)

1.6 In-tank treatment equipment should be tested on a scale that allows verification of full-scale effectiveness. The suitability of the test set-up should be evaluated by the manufacturer and approved by the Administration. (Refer to paragraph 2.3.15 in part 2 of the annex to Guidelines (G8).)

1.7 Larger scaling may be applied and lower flow rates used than provided for in paragraph 1.4 above, if the manufacturer can provide evidence from full-scale shipboard testing and according to paragraph 1.5 that scaling and modification of flow rates will not adversely affect the ability of the results to predict full-scale compliance with the standard.

2 Scaling of BWMS

2.1 A system configuration which includes the base unit, for example 250 m^3/h, should be tested according to the requirements of part 2 of the annex to Guidelines (G8) for land-based tests.

2.2 To increase or decrease the flow capacity of the system, two approaches may be utilized:

.1 systems using multiple base units mounted in parallel; and

.2 systems using scaled units.

Multiple base units mounted in parallel

2.3 Multiples, "N", of the base unit of for instance 250 m^3/h, could be used in parallel to increase the total flow capacity of the system. A 1,000 m^3/h system may employ four of the 250 m^3/h previous validated base units to attain this flow rate requirement. There should be no limitation on the parallel multiples allowed given that the base unit has been extensively performance tested.

2.4 Systems consisting of multiple base units, for example 1,000 m^3/h mounted according to paragraph 2.3, should be tested according to the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests. Shipboard tests of such system configurations should be considered equivalent to shipboard tests of one base unit (250 m^3/h unit in this example).

2.5 The operational criteria such as flow rate, pressure drop, velocity, Total Residual Oxidants (TRO) dosage, etc., for the base unit (250 m^3/h unit in this example) during land-based tests should be the same for each unit in the multiple system configurations (each of the 4 x 250 m^3/h units in this example) during the shipboard tests.

2.6 This arrangement complies with the Guidance note contained in BWM.2/Circ.8, dated 27 October 2006.

2.7 The Type Approval Certificate should refer to the type and model of the system configuration only (250 m^3/h unit in this example). It should specify the maximum amount of "N".

Systems using scaled units

2.8 Alternatively to the use of parallel mounted base units, it is possible to use a system with scaled units, which may be more effective, both in cost and performance in treating the required higher or lower flows than the base unit.

2.9 The scaling of the base unit should meet the following requirements:

.1 the scaling should follow mathematical modelling and/or calculations demonstrating that the scaled system employs equivalent parameters affecting the system performance as the unit tested according to the requirements for land-based tests; and

.2 an equipment review and certification of the scaled system should be undertaken by the Administration. When required by the Administration, environmental tests specified in part 3 of the annex to Guidelines (G8) should be undertaken on all configurations falling within the scope of the Type Approval given.

2.10 The assumptions made for the scaling of the base unit have to be verified for each scaled unit (i.e. discrete models, e.g., 250 m^3/h, 500 m^3/h, 1,000 m^3/h) by testing to the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests (hereafter referred to as shipboard tests).

2.11 This arrangement complies with the requirements of part 2 of the annex to Guidelines (G8) paragraphs 2.3.13 to 2.3.16.

2.12 The same consideration should be given for scaled systems (i.e. discrete models, e.g., 250 m^3/h, 500 m^3/h, 1,000 m^3/h) that are tested according to the requirements for land-based tests.

2.13 In the case where all discrete models are tested according to the requirements for land-based tests, the most vulnerable model should be tested (e.g., largest filter) according to the requirements for shipboard tests, to demonstrate the ability of the model to operate in normal ships' conditions.

2.14 Combinations of base units and scaled units which have been verified in their performance according to paragraphs 2.8 to 2.13 should be regarded as multiple units mounted in parallel.

2.15 Failing to meet the requirements of paragraphs 2.8 to 2.13, each scaled system should be tested according to the requirements for land-based tests and shipboard tests.

Scaled systems that employ parameters affecting the system performance should be equivalent to the unit tested according to the requirements for land-based tests

2.16 The type approval documentation should identify the parameters that affect system performance. These parameters should be used in the mathematical model for scaling.

2.17 The mathematical modelling and/or calculations should identify the parameters that are important to be measured during the shipboard tests to verify that modelling and/or calculations of the scaling have predicted values for those parameters that are consistent with the measured real-life values. Parameters chosen should cover both efficacy of the unit as well as environmental impacts.

2.18 Values to be measured during shipboard tests should be identified by mathematical modelling and/or calculations taking into consideration actual measurements from land-based testing. Where the measured real-life values during shipboard tests of the parameters that the mathematical modelling and/or calculations have identified as important do not correspond with the predicted values of those parameters by the mathematical modelling and/or calculations, then the following re-iteration process is required to be carried out:

.1 the mathematical modelling and/or calculations are to be adjusted taking into account the new measured real-life values during shipboard tests;

.2 the scaled model is re-adjusted for a revision of the mathematical modelling and/or calculations; and

.3 the revised scaled model should be tested according to the requirements for shipboard tests.

2.19 In principle, each and every scaled system should be tested according to the requirements for shipboard tests.

2.20 The number of scaled systems to be tested according to the requirements for shipboard tests could be reduced given the following:

.1 the mathematical modelling and/or calculations should identify the minimum number of scaled systems, within a given range of scaled systems, which need to be tested according to the requirements for shipboard tests;

.2 the minimum number of scaled systems to be tested according to the requirements for shipboard tests should give sufficient evidence to the Administration to validate the mathematical modelling and/or calculations as accurate enough to build scaled systems without the need for further shipboard tests;

.3 the given range of scaled systems as given in paragraph 2.20.1 above, for which the mathematical modelling and/or calculations are valid, should be identified by the manufacturer and submitted to the Administration; and

.4 the range of scaled systems to be tested according to the requirements for shipboard tests should include the systems with the minimum and the maximum flow rates.

Mathematical modelling and/or calculations

2.21 The manufacturer should submit to the Administration explanations and calculations of the physical and/or chemical processes that occur when the BWMS is operating.

2.22 The manufacturer should submit to the Administration Computational Fluid Dynamics (CFD) to demonstrate the proper scaling of each and every configuration to be included in the Type Approval.

2.23 Modelling should address the efficacy and environmental impact of the system. In particular it should demonstrate that the PEC/PNEC ratios of the Active Substances and/or by-products are not adversely affected, i.e. are equivalent to the base unit.

2.24 CFD models may also be used by the manufacturer to scale system pipe diameters or other components that affect the inflow or outflow of the BWMS so as to correlate the scaled design to the performance tested validated configuration.

2.25 The CFD model itself needs to be validated by relating the units to other validated tests (not necessarily ballast water tests). This would demonstrate the functionality of the CFD model.

2.26 The accuracy of the model should be determined and this factor can be added as an error factor in any units scaled but not tested. In addition, any existing approved unit could easily retrospectively be validated by using the CFD method, hence, other units could be added to the product range of approved systems.

Basic and Final Approval according to the Procedure for approval of ballast water management systems that make use of Active Substances (Procedure (G9))

2.27 When scaling systems that received Basic and Final Approval from MEPC according to Procedure (G9), the manufacturer and the Administration have to ensure that the conditions to which Basic and Final Approval were granted are still met for the scaled system or systems.

2.28 When preparing documentation for the scaling of the base unit, the manufacturer should take the aspects put forward in appendix 2 to this document into consideration.

Issuance of Type Approval for systems using scaled units

2.29 If the documentation of the manufacturer clearly shows that the scaled unit can with confidence be expected to perform equivalent to the base unit, the Administration can issue a Type Approval certificate for systems using the scaled unit before testing, according to paragraph 2.10, is completed. This type approval certificate should be valid for no longer than [five] years. Relevant measurements and testing should then be undertaken on the first installed system using the scaled unit.

2.30 If the Administration issues a Type Approval using paragraph 2.11, it should retain the option to withdraw the Type Approval immediately if the test results, according to paragraph 2.10, do not confirm the assumption that the scaled unit will perform equivalent to the tested unit. The manufacturer should be instructed that failure to verify the results of modelling will result in the withdrawal of the Type Approval for the system using the scaled unit affected.

2.31 The Type Approval Certificate issued by the Administration should include each and every scaled system if the scaling is done according to these procedures.

Application to existing Type Approvals involving scaled units

2.32 Administrations are encouraged to apply this guidance document to systems having received Type Approval involving scaled units prior to the approval of the guidance document to the greatest extent possible.

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APPENDIX 1

SCALING OF BALLAST WATER MANAGEMENT SYSTEMS EMPLOYING UV DISINFECTION AND FILTRATION

1 Scaling of filtration systems

1.1 For filtration system scaling, extrapolation should be used for the key design parameters. The efficiency of small-scale systems should be similar in quality to systems in large scale.

1.2 When scaling the filtration system one of the following two methods should be taken into consideration with regard to filter units:

.1 worst-case scenario testing; and

.2 use of manufacturer's statement.

Worst-case scenario testing

1.3 For ballast water filtration systems testing to validate the system should include a worst-case scenario with respect to water quality. There are several water quality parameters that need to be tested such as turbidity, total suspended solids, particle counts and biological loading while monitoring and recording the differential pressure throughout the filtration cycle. Each of these parameters has to be tested at the pre- and post-filtration sample locations to determine overall filtration performance throughout the filtration cycle. A filtration cycle begins with a clean filtration system and continues until the differential pressure measured across the filtration system reaches the terminal head loss point as determined by the system manufacturer.

1.4 This filtration testing is to be done in conjunction with the UV system testing protocol to ensure total system compliance.

Use of manufacturer's statement

1.5 Statements from different filter manufacturers confirm that the efficiency of large-scale filters and small-scale filters, given that they are of same type and model, is maintained. This is due to the modular construction of some of the filtration units available in the market. Such statements from manufacturers of filters, when accompanied by documentation proving the modular construction of the filter, may be accepted as an alternative to testing; when the same type and model of a filter with modular construction is scaled.

1.6 Accepting statements from manufacturers as proof of efficiency should only be used for scaling purposes. It should not be permitted for component substitution. Different filter manufacturers rate their filters differently and report their efficiencies on different scales. The filter not only provides particle removal but also provides water conditioning for the UV system. For example, two filter manufacturers claim 85% removal at 50µm. This is acceptable at that particle size but the efficiency at 40µm or 60µm is not identified. Filters have efficiency curves, not straight lines; the shape of those curves greatly influences the final efficacy of the entire system.

1.7 Considerations could be given to installing the filtration system in series, where a staged approach to filtration is applied. Multi-stage filtration should only be considered as long as one of the filtration stages has the identical media and flow rate per surface area of media as the filtration unit originally tested.

2 Scaling UV systems

2.1 One system configuration, for example, 250 m^3/h, should be tested according to the requirements for land-based tests.

2.2 Downscaling the equipment for land-based tests as accepted by Guidelines (G8), annex, part 2, paragraphs 2.3.13 to 2.3.16, should be done according to the recommendations given below.

2.3 To increase the flow capacity of the system, two approaches may be utilized:

.1 multiple UV units mounted in parallel; and

.2 scaled-up systems.

Multiple UV units mounted in parallel

2.4 Multiples,"N", of the tested UV system unit, for example, 250 m^3/h, could be used in parallel to increase the total flow capacity of the system. For example, a 1,000 m^3/h system may employ "N" or four of the 250 m^3/h previous validated system units to attain this flow rate requirement. There should be no limitation on the parallel multiples allowed given that the unit has been extensively performance tested.

2.5 This arrangement complies with the Guidance note contained in BWM.2/Circ.8, dated 27 October 2006.

Multiple UV units mounted in series

2.6 The same consideration should not be given to UV systems mounted in series. Reactors are designed with specific flow velocities, and increasing these internal velocities will not produce a linear dose delivery as the hydraulic behaviour of the reactor changes as velocity changes.

Scaled-up systems

2.7 If a parallel arrangement of UV system units is not appropriate, a further possible option is to achieve a higher flow system by up-scaling that may be more cost efficient in treating the required higher flows. The scaling of the validated unit should meet the following conditions:

.1 each scaled-up system should be tested according to the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests;

.2 the number of scaled-up systems to be tested with the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests could be reduced given the following:

- the mathematical modelling and/or calculations should identify the minimum number of scaled-up systems, within a given range of scaled-up systems, which need to be tested with the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests;

- the minimum number of scaled-up systems to be tested with the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests should provide enough information for the Administration to validate that the mathematical modelling and/or calculations are accurate enough to accept scaled-up systems without the need to be tested with the requirements of part 2 of the annex to Guidelines (G8) for shipboard tests; and

- the given range of scaled-up systems as given in paragraph 2.20.1 of the main document, for which the mathematical modelling and/or calculations are valid for, should be identified by the Manufacturer and submitted to the Administration;

.3 the scaled-up UV system should have the same lamp spacing and hydraulic configuration of the unit tested according to Guidelines (G8). The scaled-up UV system should also have lamps in substantially the same relative orientations as those of the validated unit;

.4 the scaled-up UV system employs parameters that affect UV system performance should be equivalent to the unit tested according to Guidelines (G8);

.5 Computational Fluid Dynamics and Light Intensity modelling should show that the scaled-up system is at least as effective as the tested system (i.e. delivers the same UV dose to each organism); and

.6 where required by the Administration, environmental tests listed in Guidelines (G8), annex, part 3 are to be undertaken on all configurations falling within the scope of the Type Approval to be given.

Scaled-up UV system has the same lamp spacing and hydraulic configuration of the unit tested

2.8 The scaled-up UV system should have the same lamp spacing as the unit tested. The lamp orientations (hydraulic layout) should be substantially similar to that of the validated system. If the orientations are equivalent, and the reactor hydraulic performance is different from the validated performance, then it has to be retested according to Guidelines (G8). In this case, the Administration should undertake an evaluation if Procedure (G9) approval is required for the new system.

Scaled-up UV system employs parameters that affect UV system performance should be equivalent to the unit tested

2.9 The scaled-up UV system should use the same type of lamp (i.e. medium pressure or low pressure), and the parameters that affect system performance, for example, lamp power density (mW/cm), arc length (cm), sleeve diameter (cm), flow rate (m^3/hr), should be equivalent to the unit tested.

2.10 At present there are two main lamp types: medium pressure and low pressure. Medium pressure lamps produce a polychromatic output. They emit wavelengths of energy over the entire spectrum of the germicidal curve 240 nm to 280 nm. Low pressure lamps are monochromatic. They produce a single wavelength of energy in the germicidal range, 254 nm. When used appropriately, both lamp types can perform adequate disinfection. However, they are not interchangeable.

Computational Fluid Dynamics and Light Intensity modelling

2.11 The manufacturer should submit to the Administration Computational Fluid Dynamics (CFD) and Light Intensity modelling to demonstrate the proper scaling of all the configurations to be included in the Type Approval.

2.12 Such models may also be used by the manufacturer to scale system pipe diameters or other components that affect the inflow or outflow of the Ballast Water Management System so as to correlate the scaled-up design to the performance tested validated configuration.

2.13 The CFD model itself needs to be demonstrably proven by relating the units to other validated tests (not necessarily ballast water tests). This would then demonstrate that the CFD model is functional.

2.14 The accuracy in the model could be determined and this factor can be added as an error factor in any units scaled but not tested. In addition any existing approved units could be easily retrospectively validated by the CFD method, and other units could be added to the product range of existing approved systems.

2.15 The dose distribution a UV reactor delivers can be estimated using mathematical models based on CFD and the Light Intensity Distribution (LID). CFD is used to predict the trajectories of organisms as they travel through the UV reactor. LID is used to predict the intensity at each point within the UV reactor. UV dose to each organism is calculated by integrating the UV intensity over the organisms' trajectory through the reactor.

2.16 It is possible to measure dose delivery using a technique termed biodosimetry. With biodosimetry, the log inactivation of a surrogate organism is measured through the UV reactor.

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APPENDIX 2

CONSIDERATIONS FOR THE DOCUMENTATION FOR SCALING OF BALLAST WATER MANAGEMENT SYSTEMS USING ACTIVE SUBSTANCES

1 The list of items to be taken into consideration is not exhaustive but should serve as guidance to Administrations. It is understood that Administrations can at any time demand additional information and/or tests from applicants.

2 When preparing documentation for the scaling of the base unit, the manufacturer should take into consideration the aspects as follows:

- .1 the manufacturer has to specify the technical changes made due to the scaling of the system, in particular, he has to identify the parts of the system that affect its method of work and were scaled-up or down;

- .2 the manufacturer has to specify for each change:

    - .1 the technical changes in comparison to the base unit; and

    - .2 the reasons for the technical change, including all relevant calculations and modelling;

- .3 the scaling of filters is to be done in accordance with appendix 1, paragraphs 1.1 to 1.6;

- .4 the manufacturer has to demonstrate that a concentration of Active Substance equivalent to the concentration of the tested system is reached by the scaled system. The manufacturer chooses appropriate modelling and/or calculations. For in-line treatment, a sufficient mixing of Active Substance and ballast water before disposal in the tank has to be documented;

- .5 the manufacturer has to demonstrate that the maximum allowable discharge concentration (MADC) of Active Substances and Relevant Substances of the system using scaled units is not exceeded. If the system uses automatic regulation of Active Substances, the manufacturer should provide a plausible explanation of its functioning;

- .6 the manufacturer has to demonstrate that the scaled system meets the requirements of the environmental tests (Guidelines (G8), annex, part 3);

- .7 the manufacturer has to demonstrate that a neutralization unit (if used) is sufficient to achieve the same level of neutralization as the tested system. In particular the manufacturer needs to demonstrate sufficient generating/dosing capacity and sufficient mixing of neutralizing agent and ballast water is achieved before discharge. Modelling and/or model calculations are possible methods;

.8 the manufacturer needs to demonstrate that human exposure risk and risk to the ship is not increased by scaling. In particular, that all necessary vents and overflow pipes are sufficiently dimensioned to ensure safety of ship and crew; and

.9 the manufacturer should submit a shipboard test protocol for the scaled systems to the Administration for approval taking into account paragraphs 2.10 and 2.16 to 2.21 of the main document.

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