Standard Operating Procedure

Procedure to generate representative Samples of Ballast Water from Ballast Water Pipe Systems on board Ships

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Content

1 BACKGROUND

In 2004 the International Maritime Organization (IMO) of the United Nations set up the '*International Convention for the Control and Management of Ships' Ballast Water and Sediments*'. According to article 18 of this convention the regulations and requirements therein come into force 12 months after 30 states ratified the convention representing 35% gross tonnage of the world's merchant shipping.

In view of the fact that organism transported with ballast water of ships and released into the sea including estuaries and into fresh water courses may cause severe and irreversible ecological damages, impair biological diversity and create hazards to human health, property or resources, this convention regulates that all ships to which this convention applies shall treat the ballast water by adequate on-board technologies to achieve a quality, which is defined by limit values for the density of organisms in the treated ballast water to be re-discharged to the sea, estuaries or fresh water courses.

The annex to the convention, Section D, '*Standards for Ballast Water Management*', Regulation D-2 '*Ballast Water Performance Standard*' defines these limit values for the density of organisms in ballast water to be re-discharged to the sea, estuaries or freshwater courses as :

Organism / Organism Group	Limit Value
Plankton Organisms >50µm	<10 viable organisms per m^3
Plankton Organisms >10µm<50µm	<10 viable organisms per ml
Bacteria	
Escherichia coli	<250 cfu per 100ml
Intestinal Enterococci	<100 cfu per 100ml
Vibrio cholerae (O1 and O139)	<1 cfu per 100ml
(cfu : colony forming unit)	

To control the compliance of this regulation adequate technologies and methods to generate ballast water samples on board ships and to execute the analysis of the ballast water have to be defined.

In 2011 the *Federal German Hydrographic and Maritime Agency (BSH)*, Hamburg, Germany, launched the project '*Effective New Technologies for the Assessment of Compliance with the Ballast Water Management Convention*', which aimed at the development of technologies and methods to rapidly sample and assess the ballast water quality on board ships.

Within the frame of this project a new, innovative sampling system as well as several analytical methods have been developed which allow for the rapid assessment of the ballast water on board ships.

The project was managed, conducted and executed by *SGS S.A., Environmental Services, Geneva, Switzerland and SGS Institut Fresenius GmbH, Taunusstein, Germany* in cooperation with international scientific institutions and companies.

On board technologies and methods to sample ballast water and assess its quality should, above all, generate reliable data within a minimal time, since these compliance tests can, at present, only be executed during unload and load procedures while the ships stay in the harbor.

The sampling of ballast water on board ships has to follow defined regulations set up by the convention.

The sampling port installed in the ballast water pipe system on board ships has to be designed as a "L"-shaped isokinetic sampling pipe centrically inserted into the main ballast water pipe with the opening facing upstream the volume flow. The ballast water sampling ports have to located as close to the discharging ballast water outboard valves as possible and the ballast water sampling ports have to be installed for each discharging ballast water outboard valve and each ballast water tank.

2 INTRODUCTION

2.1 GENERAL

Within the frame of the BSH project mentioned above (cf. para 1) a new, innovative ballast water sampling system for a mobile use on board ships was developed.

The technical characteristics of this new sampling system were guided by a set of major criteria, thought to be indispensible for the adequate, representative sampling of ballast water on board ships:

- The use of an isokinetic sampling pipe as defined by the regulations
- The performance of adequate filtration to ensure that viable target organisms are not impacted by the filtration process
- The option to vary the sample volume within a wide range
- A minimal waste water volume
- Easy and rapid sampling procedures
- The option to use the sampling system for all pipe systems on all ships

A system, which fulfills all of these criteria has to be split into three major technical parts: (i) the sampling system, (ii) the universal, isokinetic sampling port and (iii) the back flush port.

To be able to install the sampling system for representative sampling of ballast water on to the ballast water pipe systems on board ships, the main ballast water pipe system has to be equipped with flanges to which the sampling port and back flush port fit. For more information cf. para 2.3, 2.4 .

2.2 THE SAMPLING SYSTEM

Guided by the selection criteria listed above the new ballast water sampling system follows the principle of a closed bypass-back flush system as presented in figure 1.

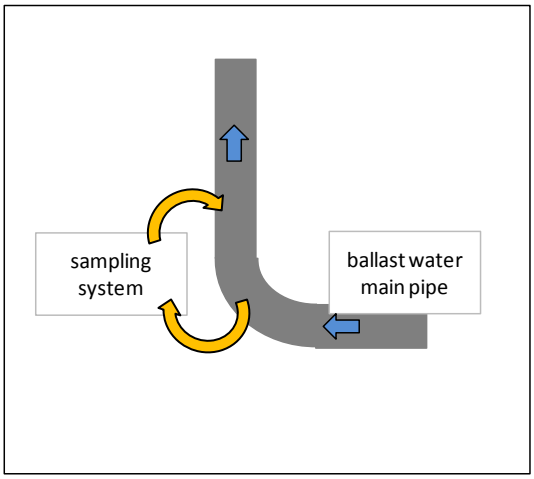

Figure 1 : Closed bypass back flush system

Via an isokinetic pipe (not shown in figure 1) the ballast water is directed to the sampling system and back flushed to the main ballast water pipe.

The system itself may comprise filter units, meters for volume flow, pressure gauges, valve, etc., as presented in figure 2.

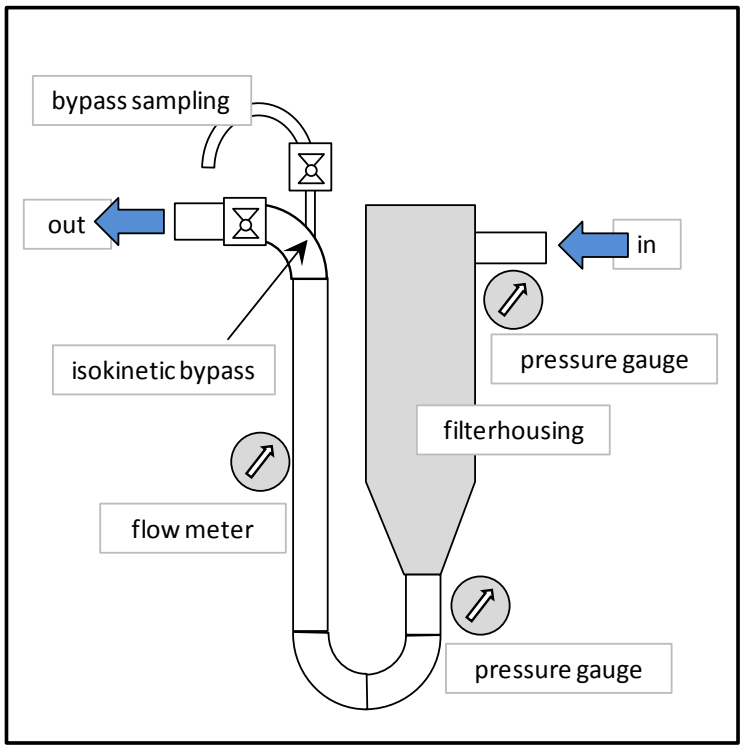

Figure 2 : Closed bypass-back flush system fully equipped with technical sub-parts necessary to adequately sample ballast water

The ballast water deviated by the isokinetic sampling pipe installed in the main ballast water pipe system of the ship enters into the large filter housing of the system. This filter housing is equipped with a filter basket to safely filter the target plankton organisms >50µm. Behind the filter housing the ballast water passes a straight section with an inductive volume flow meter. Behind the volume flow meter an isokinetic bypass sampling port allows for the sampling of ballast water for the determination of the organism densities of plankton >10µm<50µm and bacteria. Behind the bypass sampling port the ballast water leaves the system and is back flushed to the main ballast water pipe system.

Two pressures gauges allow for the monitoring of the differential pressure in the filter housing possibly generated by the blocking of the filter material itself.

Several valves installed in the system allow for the de-aeration of the system and the partial shut-down of the system, too. All valves installed are stainless steel ball valves.

The functional principle of the sampling system finally lead to the construction of the '*Prototype 01*' presented in figure 3 (cf. following page).

The system is placed in a stainless steel frame, with a rather small footprint of 40x50cm and a height of 80cm and with weight of approximately 12 kg.

It can easily be transported on board ships and can be installed even under the very narrow spatial conditions of the technical decks on ships.

The pipe size of the system is 2 inch, the bypass sampling port is half inch wide and the large filter housing has a diameter of approximately 12 cm.

The filter screen inserted into the filter housing collects the target plankton organisms >50µm by means of stainless steel screen, which has been perforated by laser to a round shaped pore size of exactly 50µm.

The filter basket equipped with valve at its lower end for easy retrieval of filtered plankton organisms is presented in figure 4 (cf. following page).

Figure 3 : Ballast water sampling system Prototype 01

Figure 4 : Filter screen 50µm of the ballast water sampling system '*Prototype 01'*

Within the frame of the above mentioned BSH project the ballast water sampling system has successfully passed several hydraulic test series under various pressure and volume flow conditions and has successfully been applied for ballast water sampling.

2.3 THE UNIVERSAL, ISOKINETIC SAMPLING PORT

The isokinetic principle describes the deviation of bypass flow at the same speed as encountered in the main pipe. Figures 5 and 6 presents the isokinetic sampling port as required by the IMO.

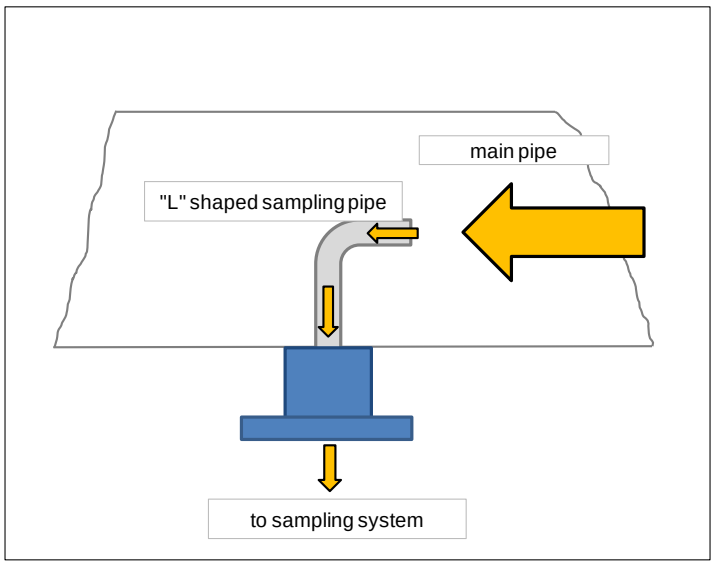

Figure 5 : “L” shaped isokinetic sampling port (schematic)

Figure 6 : “L” shaped isokinetic sampling port disconnected from main ballast water pipe

In view of the various ballast water pipe systems installed on board ships in terms of pipe diameter and pump capacity, the volume flow in the pipe system ranges from less than 1,0 m/s up to larger than 10,0 m/s. Therefore it is essential to dimension the isokinetic pipe inserted into the main ballast water pipe system to a diameter which secures an adequate flow velocity within the sampling system ensuring that the viable target organisms in the ballast water are not impacted or even killed during the process of sampling.

It is a common and well know fact, that the very sensitive marine micro-plankton organism cannot withstand a flow velocity at the filter material which exceeds the critical limit of 0, 5 to 0,65 m/s.

Within the frame of the BSH research and development project mentioned above test series were executed to assess the hydrodynamic impacts on marine micro-plankton with increasing flow velocities directly at the filter material. The range of the critical flow velocity of 0,5 to 0,65 m/s has been confirmed.

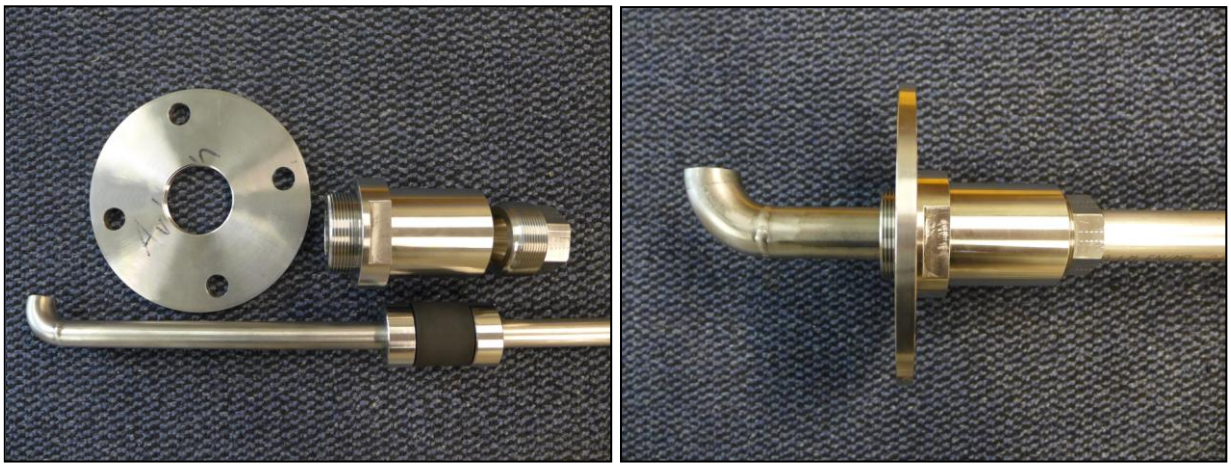

Figure 7 : Universal sampling port, different parts (left) and assembled (right)

Figure 8 : Flanges of different size for application with the universal sampling port

Since the flow velocity within the sampling system is triggered by the flow velocity in the main ballast water pipe system and by the diameter of the inserted, isokinetic sampling pipe, too, a universal sampling port was developed, designed and constructed, which allows for the use of isokinetic sampling pipes with different diameter. With this universal sampling port the sampling system presented in para 2.1 can be fixed to most if not all ballast water pipe systems ensuring the adequate flow velocity during the sampling and filter procedures.

The concept of this universal sampling port allows for its use with a large variety of flange sizes, since the cartridge, which holds the isokinetic sampling pipe may be screwed to flanges of all sizes.

The universal sampling port is connected to the sampling system by a simple 1 inch tube.

At present the universal sampling port provides these “L”-shaped isokinetic sampling pipes : ¼ inch, ½ inch and 1 inch diameter.

2.4 THE BACK FLUSH PORT

The back flush port re-directs the ballast water back to the main ballast water pipe system. The port comprises a simple ball valve.

Figure 9 : Back flush port

The back flush port is connected to the sampling system by a simple, pressure resistant tube.

2.5 ADDITIONAL INFORMATION

The entire sampling system encompassing the universal sampling port, the back flush port and the sampling system itself has been validated by an external, independent institution specialized in marine ecology, and ballast water analysis.

Reference is made to various documents and other sources listed in para 8.

Figure 10 : The sampling system connected to a ballast water pipe system with : universal sampling port (flange on the right, green tube, the sampling system '*Prototype 01*' and the back flush port (flange on the left, white tube)

3 EQUIPMENT

- Sampling system '*Prototype 01'*
- Universal sampling port
- Back flush port
- Small tube
- Large tube
- Basic tools for assembly of the sampling system

4 SUPPLIES

- Different beakers, 100ml, 200 ml, 500 ml
- Squeeze bottle with artificial seawater
- Stopwatch

5 PROCEDURE

The procedure for the sampling of ballast water with the presented sampling system from ballast water pipe systems on board ships is split into five different parts.

PART 1 : selection of the adequate isokinetic sampling pipe diameter to be used for the targeted ballast water pipe system

(1) Get the relevant hydraulic parameters of the targeted ballast water pipe system : (i) diameter of the main ballast water pipe in mm and (ii) volume flow in the main ballast water pipe system as m^3/hour

(2) Calculate the resulting flow velocity directly at the filter screen in the filter housing of the sampling system '*Prototype 01*' using these equations :

v_{main} (m/s):	low velocity in the main ballast water pipe
d_{main} (mm) :	diameter of the main ballast water pipe
Q_{main} (m³/h):	volume flow in the main ballast water pipe
v_{iso} (m/s) :	flow velocity in the isokinetic sampling pipe
d_{iso} (mm) :	diameter of the isokinetic sampling pipe
Q_{iso} (m³/h) :	volume flow in the isokinetic sampling pipe
v_{filter} (m/s) :	flow velocity directly at the filter screen
A_{screen} (m²) :	open area of the filter screen 50µm

$$v_{main} = (Q_{main}/3600)/((d_{main}/2)^2 \times 3{,}14159)/10^6) \quad (1)$$

$$v_{main} = v_{iso} \quad (2)$$

d_{iso} = ¼ inch (6,35mm), ½ inch (12,7mm) or 1 inch (25,4mm) (3)

$$Q_{iso} = ((d_{iso}/2)^2 \times 3{,}14159/10^6) \times v_{iso} \quad (4)$$

$$A_{filter} = 0{,}004656 \quad (5)$$

$$v_{filter} = Q_{iso}/A_{screen} \quad (6)$$

(3) Select the adequate isokinetic pipe, which generates a flow velocity directly at the filter screen of <0,65m/s.

PART 2 : Connection of the sampling system '*Prototype 01*' to the main ballast water pipe system

(1) Equip the universal sampling port with the isokinetic sampling pipe selected in Part 1
(2) Close the valve of the universal sampling port
(3) Make sure the main ballast water pipe system is empty
(4) Open the corresponding flanges in the main ballast water pipe system
(5) Install the universal sampling port at the corresponding flange in the main ballast water pipe system
(6) Open all valves of the sampling system '*Prototype 01*'
(7) Connect sampling system '*Prototype 01*' and the universal sampling port with the tube
(8) Install the back flush port at the corresponding flange in the main ballast water pipe system
(9) Close the valve of the back flush port
(10) Connect the sampling system '*Prototype 01*' and the back flush port with the tube
(11) Close all valves of the sampling system '*Prototype 01*'
(12) Activate the volume flow in the main ballast water pipe system (= start deballasting procedures)

PART 3 : Sampling of ballast water

(1) Open the valve of the universal sampling port
(2) Open the valve at the outlet of the sampling system '*Prototype 01*'

(3) Open the valve at the back flush port: ballast water is running through the sampling system '*Prototype 01*'

(4) Open the valve at the lid of the filter housing for de-aereation of the system

(5) Close the lid valve when water flushes out

(6) Let the sampling system flush for 10 minutes

(7) Close the valve at the universal sampling port

(8) Open the valve at the lid of the filter housing for depressurizing of the system

(9) Remove the lid of the filter housing

(10) Insert the filter screen, make sure the bottom valve of the filter screen is closed

(11) Close the filter housing

(12) Close the lid valve

(13) Open the valve at the universal sampling port: ballast water is running through the sampling system '*Prototype 01*'

(14) Immediately record the value in the display of the volume flow meter

(15) Calculate the volume of ballast water sampled by this equation :

Q_{system} (m^3/h) : Volume flow in the sampling system '*Prototype 01*'

V_{min} (m^3) : Volume of ballast water sampled per minute

$$V_{min} = Q_{system}/60$$

(16) Control desired sample volume for the detection of target plankton organisms >50µm

(17) As soon as desired sample volume is achieved, close the valve at the universal sampling port

(18) Close the valve at the outlet of the sampling system '*Prototype 01*'

(19) Close the valve at the back flush port

(20) Gently open the lid valve of the filter housing

(21) Open the filter housing

(22) Remove the filter screen

(23) Gently rinse the inner surface of the filter screen with artificial seawater top-down

(24) Hold the bottom valve of the filter screen into a beaker

(25) Open the bottom valve

(26) Gently rinse the inner surface of the filter screen into the beaker: the containing organisms represent the total amount of target plankton organisms >50µm in the desired sample volume and the volume rinsed from within the filter screen can enter follow up steps of further analysis by (i) optical counts of viable organisms >50µm or (ii) chemical analysis procedures

(27) Close the bottom valve of the filter screen

(28) Replace the filter screen into the filter housing

(29) Close the filter housing

(30) Close the lid valve

(31) Open the valve of the universal sampling port

(32) Open the valve at the outlet of the sampling system '*Prototype 01*'

(33) Open the valve at the back flush port: ballast water is running through the sampling system '*Prototype 01*'

(34) Gently open the lid valve of the filter housing for de-aereation of the system

(35) Close lid valve when water is flushing out

(36) Prepare beaker for the desired sample volume for the detection of target plankton organisms >10µm<50µm

(37) Gently and fully open the valve at the bypass sampling port of the sampling system '*Prototype 01*'

(38) Let water flush out for a few seconds

(39) Take the ballast water sample of the desired volume

(40) Close the bypass valve

(41) Close the valve at the back flush port

(42) Close the valve at the outlet of the sampling system '*Prototype 01*'

(43) Close the valve at the universal sampling port

(44) Gently open the lid valve of the filter housing for depressurization of the system

(45) Filter the sample volume taken under step (39) through a nylon mesh of 7µm

(46) Gently flush the filter residue with artificial seawater into a small beaker: the containing organisms represent the total amount of target plankton organisms >10µm<50µm in the sample volume taken from the bypass of the sampling system '*Prototype 01*'; the volume in the small beaker can enter follow up steps of further analysis by (i) optical examination of viable organisms >10µm<50µm, (ii) measurements of chlorophyll activity or (iii) chemical analysis procedures

(47) The filtrate generated by step (45) represents a filtered ballast water sample of the volume taken at the bypass valve for further analysis regarding the concentration of bacteria.

(48) Repeat step (6) to (47) for additional ballast water samples

PART 4 : Dismounting of the sampling system

(1) Make sure the de-ballast procedures have stopped and the main ballast water pipe is empty

(2) Open all valves

(3) Dismantle the universal sampling port

(4) Disconnect universal sampling port from the sampling system '*Prototype 01*'

(5) Disconnect the back flush port from the sampling system '*Prototype 01*'

(6) Remove the lid from the filter housing

(7) Tilt the sampling system '*Prototype 01*' over and let the system run empty

(8) Replace the lid of the filter housing

(9) Dismantle back flush port

(10) Close both corresponding flanges in the main Ballast water pipe system

PART 5 : Storage of the sampling system (in landbased laboratory)

(1) Sufficiently rinse all parts of the sampling system with freshwater

(2) Place ports and connecting tubes into adequate disinfectant solutions for at least one day

(3) Fill the sampling system '*Prototype 01*' with adequate disinfectant solutions for at least one day

(4) Place filter screen into adequate disinfectant solutions for at least one day

(5) Let all parts of the sampling system sufficiently dry out after disinfection

6 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

1. Procedures outlined in this SOP should be followed to the letter. Any deviation should be documented.
2. Conduct all quality assurance and quality control procedures according to relevant QA/QC standards of the executing institution or company.

7 DATA STORAGE AND ARCHIVING

1. Storage and archivation of data should be executed following relevant guidelines and SOPs of the executing institution or company.

8 REFERENCES AND RELATED DOCUMENTS

SOP '*Procedure for the Analysis of Ballast Water to determine the Concentration of Bacteria using the Adenosin-Triphosphate Method*

SOP '*Procedure for the Analysis of Ballast Water to determine the Concentration of Plankton Organisms >50µm using the Adenosin-Triphosphate Method*

SOP '*Procedure for the Analysis of Ballast Water to determine the Concentration of Plankton Organisms >10µm<50µm using the Adenosin-Triphosphate Method*

SOP '*Procedure to produce artificial seawater from prefabricated salt mixtures*'

'The Sampling of Ballast Water on board ships with the Sampling System Prototype 01', Validation Report

'*Effective New Technologies for the Assessment of Compliance with the Ballast Water Management Convention*', project reports

Websites :

International Maritime Organization – IMO : www.imo.org

9 APPENDIX

CONTACT

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