Ballast Water Treatment Systems: Type Approval, Certification, Comparison and Retrofitting Ship

Rajesh Madusudanan

Master Thesis

presented in partial fulfillment
of the requirements for the double degree:
"Advanced Master in Naval Architecture" conferred by University of Liege
"Master of Sciences in Applied Mechanics, specialization in Hydrodynamics, Energetics and Propulsion" conferred by Ecole Centrale de Nantes

developed at West Pomeranian University of Technology, Szczecin
in the framework of the

"EMSHIP"
Erasmus Mundus Master Course
in "Integrated Advanced Ship Design"

EMJMD 159652 – Grant Agreement 2015-1687

Supervisor: Prof. Zbigniew Sekulski, West Pomeranian University of Technology, Szczecin

Reviewer: Prof. André Hage, University of Liege

Szczecin, February 2018

This page is intentionally left blank.

DECLARATION OF AUTHORSHIP

I declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

Where I have consulted the published work of others, this is always clearly attributed.

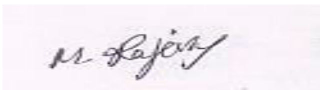
Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.

I have acknowledged all main sources of help.

Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma.

I cede copyright of the thesis in favour of the West Pomeranian University of Technology, Szczecin.

Date: 12/01/2018 Signature: 

This page is intentionally left blank.

ABSTRACT

International Maritime Organization (IMO) has developed a legislation called 'International Convention for the Control and Management of Ships Ballast Water and Sediments' to regulate the discharge of ballast water and reduce the risk of introducing non-native species from ships ballast water. To reduce this risk, there are various treatment methods available in the market. These treatment systems must be approved by the administration in accordance with IMO guidelines. The main objective and scope of this work is to review and compare IMO and USCG requirements in terms of type approval, inspection and certification requirements, to describe and compare different treatment methods and to discuss about selection of appropriate technology based on various factors such as safety, environment, practicability, cost and biological effectiveness in terms of effective removal or inactivation of harmful aquatic organisms and pathogens in ballast water. In this thesis work, some of the alternate and innovative ballast water management systems have been discussed as well. In addition to that, a case study about retrofitting ship has been conducted. This work has been developed in association with Westcon Design Poland, to serve as a reference covering various aspects of ballast water management and it can provide different perspective to all stakeholders such as classification societies particularly to Overseas Marine Certification Services (OMCS Class), ship owners, design offices, shipyards, treatment system manufacturers and others who are involved in the implementation of the convention. Based on data collected from various sources associated with this subject, comparison and analysis at different stages of this work, conclusions and recommendations have been obtained to serve the purpose for which this work has been carried out.

Keywords: Ballast Water Management, Invasive Aquatic Species, IMO, USCG, Type Approval, Classification Societies, Ship Owners, Inspection, Retrofitting

This page is intentionally left blank.

TABLE OF CONTENTS

List of Figures

List of Tables

This page is intentionally left blank.

Abbreviations

AS Active Substances
AMS Alternate Management System
BW Ballast Water
BWE Ballast Water Exchange
BWM Ballast Water Management
BWMC Ballast Water Management Convention
BWMP Ballast Water Management Plan
BWMS Ballast Water Management System
BWTS Ballast Water Treatment System
BWRB Ballast Water Record Book
CAPEX Capital Expenditure
CMFDA 5-ChloroMethylFluorescein Di-Acetate
COTP Captain-Of-The-Port
DBP Disinfection By-Products
EPA Environmental Protection Agency
ETV Environmental Technology Verification
FDA Fluorescein Di-Acetate
GEF Global Environment Facility
GESAMP-BWWG Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection-Ballast Water Working Group
GIA Global Industry Alliance
HAOP Harmful Aquatic Organisms and Pathogens
IACS International Association of Classification Societies
IAS Invasive Aquatic Species
ICS International Chamber of Shipping
IL Independent Laboratory
IMO International Maritime Organization
IOC Intergovernmental Oceanographic Commission
IOPPC International Oil Pollution Prevention Certificate
LOC Limited Operating Conditions
LOI Letter of Intent
MEPC Marine Environment Protection Committee (of IMO)
MPN Most Probable Number
MSC Marine Safety Center
OPEX Operational Expenditure
SDL System Design Limitations
TRO Total Residual Oxidant
UN United Nations
UNCLOS United Nations Convention on the Law of the Sea
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
USCG United States Coast Guard
VGP Vessel General Permit
WMU World Maritime University

This page is intentionally left blank.

1. INTRODUCTION

1.1. Background

Steel hulled vessels were introduced in the late 19th century, since then ballast water discharge has increased considerably around the world. Due to high volume of ballast water and decrease in the voyage period has increased the transfer of aquatic species from one region to other. Ballast water contains a variety of organisms including bacteria and viruses and the adult and larval stages of many marine organisms. While most of these organisms will not survive until ballast water is discharged, some may survive and thrive in their new environment. The establishment of these non-native species, can have a serious ecological, economic and public health impact on the receiving environment. Marine biologists and environment activists are really concerned about the impact of non-native species and the consequences of their invasion into the local marine environment.

Introduction of such non-native species has badly affected many areas around the world. Statistics indicate that the rate of bio-invasions is continuing to increase at an alarming rate as shown in figure 1. There are 7000 species are transferred in every hour of everyday. Even though the volumes of seaborne trade continue to increase, the problem may not yet have reached its peak. However, the Ballast Water Management Convention, adopted in 2004 by International Maritime Organization (IMO) [1], aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships ballast water and sediments. A number of guidelines have been developed to facilitate the implementation of the Convention.

Addressing invasive species is listed as a target under the UN Sustainable Development Goal 15 [25], which calls on States, by 2020, to introduce measures to prevent the introduction and significantly reduce the impact of invasive aquatic species on land and water ecosystems and control or eradicate those species. A simple pictorial representation of ballasting and deballasting process is shown in figure 2. During internship period, the author has studied international regulations and researched various treatment systems available in the market to select an appropriate system for ship owners to retrofit their ship.

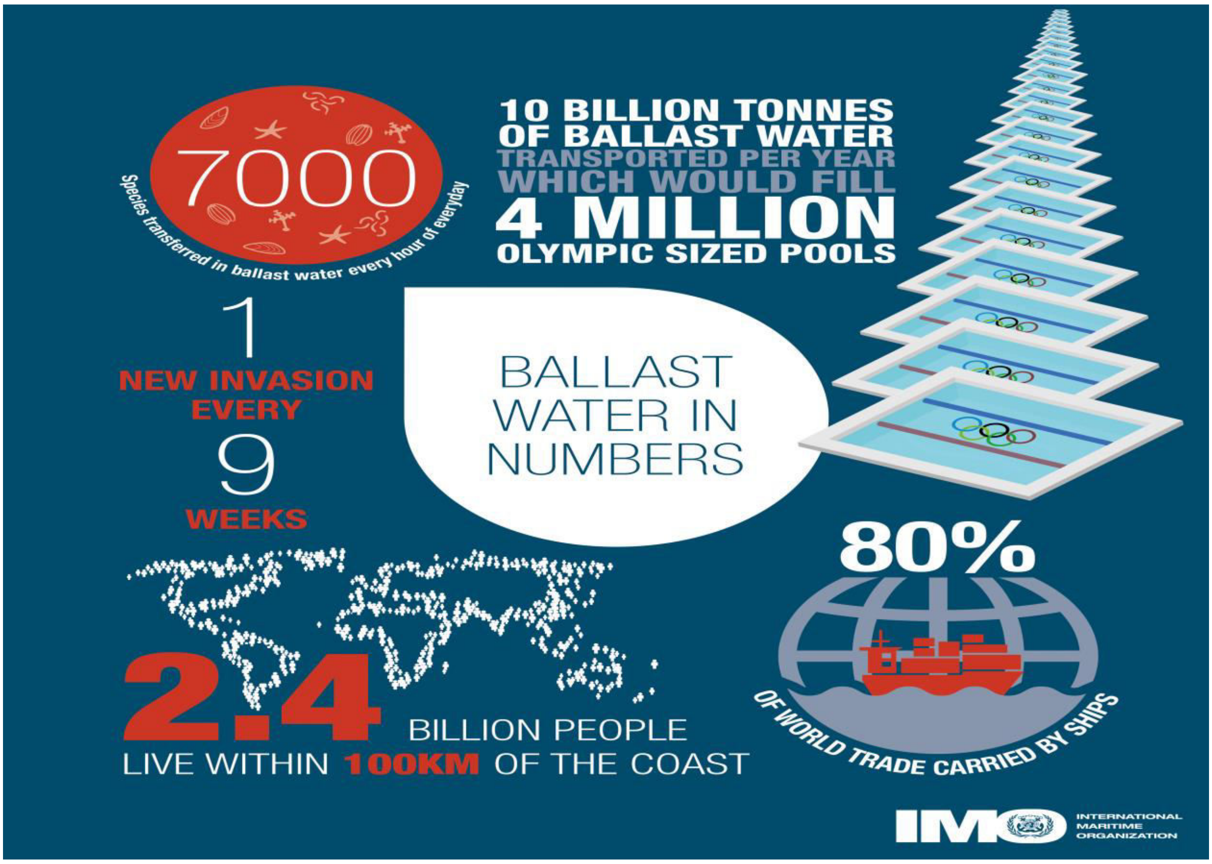


Figure 1: Ballast water statistics [26]

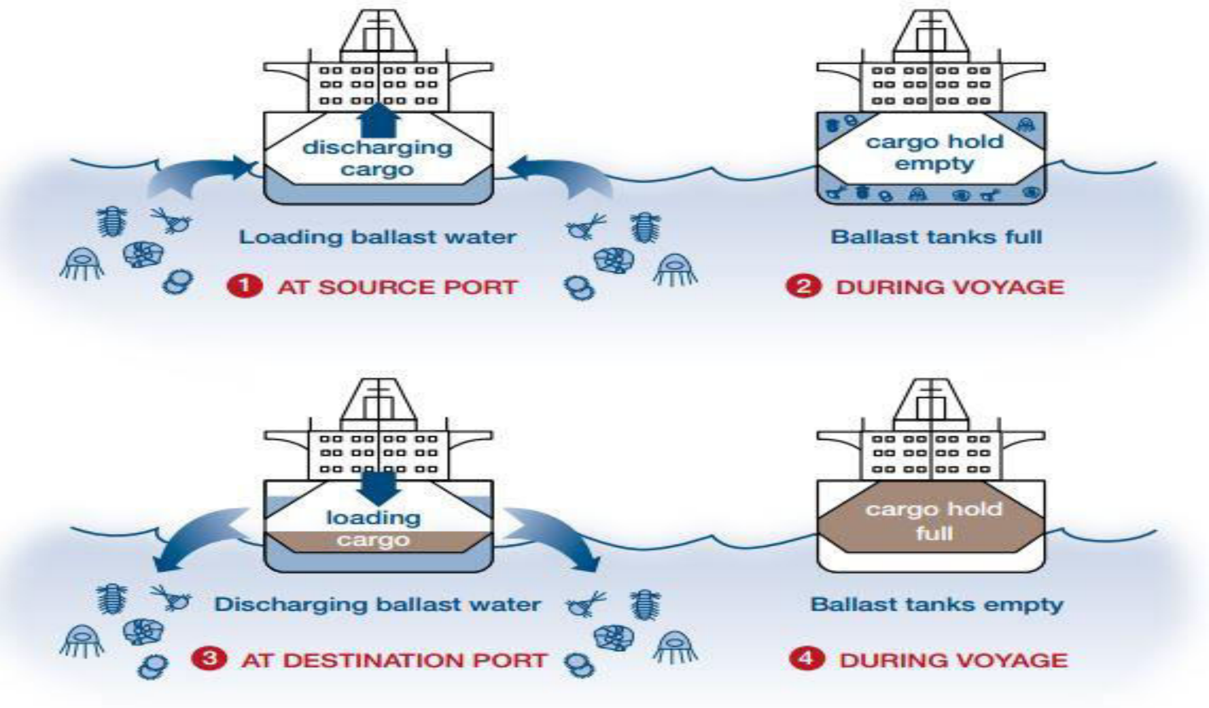


Figure 2: Ballasting and deballasting process [26]

1.2. Invasive Aquatic Species (IAS)

Ballast water serves as a vector for the transfer of species from one part of the world to another. Where this new area is outside of its natural geographic range, the species which has been transferred is commonly known as an invasive aquaic species (alternative terms are alien species, non-native or non-indigenous) [27]. If the environmental conditions in this new geographic area are suitable, the invasive aquatic species may then not only survive, but may establish and spread, in many cases it has the potential to cause, harm to the local environment, economy or human health. Such species are generally called invasive aquatic species, but other terms used for invasive species include Introduced Marine Pests (IMPs) (Australia and New Zealand), Aquatic Nuisance Species (ANS) (United States), Harmful Aquatic Organisms and Pathogens (HAOP) (IMO Ballast Water Management Convention).

Invasive aquatic species are now generally recognized as one of the greatest threats to biodiversity globally. They also have serious economic, environmental and health impacts and, as a result, place major constraints on development. In marine and coastal environments, invasive species have been identified as one of the four greatest threats to the world's oceans along with:

- marine pollution from land-based sources
- over-exploitation of living marine resources
- physical alteration/destruction of marine habitats

It is important to note that shipping and ballast water is one of the many possible vectors for the transfer of invasive species. Also, vectors and pathways often overlap. Following table 1 list some examples which are termed as 'ten most wanted', though there are hundreds of other serious invasions which have been recorded around the world. This table contains the origin of those ten most wanted species, region where they are normally introduced and the economical, ecological and health impacts they have on local environment. In most of the case, they have severe impact on local fishing community and eco system, in other cases they have human health impact which can cause massive out break of epidemics such as cholera etc. They also have large scale effect on tourism activities as well. Another important fact to note that these species are also transferred through ship's underwater hull and structures.

Table 1: Aquatic bio-invasions causing major impact [27]

Name	Native to	Introduced to	Impact
Cholera *Vibrio cholerae* (various strains)	Various strains with broad ranges	South America, Gulf of Mexico and other areas	Cholera epidemics
Cladoceran Water Flea *Cercopagis pengoi*	Black and Caspian Seas	Baltic Sea	Dominate the zooplankton community and clog fishing nets and trawls
Chinese mitten crab *Eiocheir sinensis*	Northern Asia	Western Europe, Baltic Sea and west coast North America	Causing erosion and siltation, Interferes with fishing activities
Toxic algae (red/brown/ green tides) various species	Various species with broad ranges	New areas in ships' ballast water	Formation of harmful algae blooms, Massive kills of marine life, release of toxins and/or mucus, can foul beaches and impact on tourism and recreation
Round goby *Neogobius melanostomus*	Black, Asov and Caspian Seas	Baltic Sea and North America	Competes with native fishes
North American comb jelly *Mnemiopsis leidyi*	Eastern seaboard of the Americas	Black, Azov and Caspian Seas	Depletes zooplankton stocks; altering food web and ecosystem function
North Pacific seastar *Asterias amurensis*	Northern Pacific	Southern Australia	Reproduces in large numbers, reaching 'plague' proportions rapidly
Zebra mussel *Dreissena polymorpha*	Eastern Europe (Black Sea)	western and northern Europe, eastern half of North America	Fouls all available hard surfaces, Displaces native aquatic life
Asian kelp *Undaria pinnatifida*	Northern Asia	Southern Australia, New Zealand, West Coast of US, Europe and Argentina	Displaces native algae and marine life
European green crab *Carcinus maenus*	European Atlantic coast	Southern Australia, South Africa, US and Japan	Displaces native crabs, Alters inter-tidal rocky shore ecosystem

1.3. Objective and Scope

The main objective of this work is to study about IMO and USCG regulations for the ballast water management, highlight the salient features of these regulations, discuss about the type approval procedures and compare them. Then, to provide a brief description about various ballast water treatment technologies and comparison between most widely used treatment methods, to discuss about alternate options for ballast water management, innovative solutions for ballast water treatment, to discuss about important factors such as ship, crew, environment, economy, biological effectiveness and practicability for the selection and installation of appropriate treatment system. Also, case study has been conducted with regard to retrofitting ship. From discussions on the overview of regulations, treatment technologies and retrofitting process, this project aims to provide comparison and analysis at each section of this work and conclusions are expected to be drawn from that work. Also, author would like to provide recommendations to various stakeholders associated with the implementation of this convention based on the knowledge and experience gained during this project.

The scope of this work is limited to presently available data from the associated industry. Existing ships will be required to install onboard an approved ballast water treatment system by the first IOPP renewal survey after the 8th of September 2017, whilst new ships (constructed after the entry into force date) will have to be compliant on delivery. So, this work is very appropriate at this point of time to choose a suitable technology available in the market which can be installed on board ships well before the deadline.

1.4. Literature Review

There are several publications and papers which discuss about the ballast water management, efficacy of different ballast water treatment technologies and problems associated with them. Some of the following publications were useful to understand the subject clearly and relevant for this project.

S. Gollasch [2] described the history of ballast water management, activities of various governments around the world with respect to ballast water and solutions for the removal of barriers to the effective implementation of ballast water control and management measures in developing countries. He explains various treatment options, costs of treatment for each type and followed by recommendations. Also, he has emphasized that ship designers and ship builders must have awareness related to ballast water issues and their treatment system installation onboard new ships as compared to old fashioned ships.

T.P. Mackey *et al.* [3] described the BWT system which doesn't use any chemical or other active substances. It also explains about the development and test programs leading to final approval as per IMO and USCG requirements.

J. Kazumi [4] discussed ballast water treatment technologies and their application for vessels entering Great Lakes via Saint Lawrence seaway. It also deals with factors affecting the implementation of ballast water treatment technologies for ships passing through this seaway.

E.Solaki *et al.* [5] summarizes the available technologies applied for ballast water treatment. Even though, this paper discusses about port-based and ship-based technologies, special emphasis was given to onboard treatment methods, which can be categorized as physical separation, mechanical or chemical methods. The efficiency of the methods, as well as the capacity of application and the target microorganisms were compiled and are presented in this review.

R. Balajt *et al.* [6] reviews some of the representative systems to treat ballast water. It explains further that an effective method for species reduction has been to employ chemicals. In terms of capital cost, foot print and power requirements, chemical solutions fare better than the physical disinfection methods. However, it is feared that chemicals might cause greater harm to the environment. Physical disinfection methods have lesser issues than the usage of chemicals. Considering the long-term harm of chemicals, a filtration system in combination with heat treatment is suggested.

J. Janutėnienė *et al.* [7] compares the technical parameters of different types of ballast water treatment equipment. Advantages and disadvantages of treatments methods are discussed and best solution to dry cargo ships has been proposed.

1.5. Important Definitions

The following important definitions are from IMO’s International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWMC) [1] adopted in 2004.

Active Substance means a substance or organism, including a virus or a fungus, that has a general or specific action on or against Harmful Aquatic Organisms and Pathogens.

Administration means the Government of the State under whose authority the ship is operating. With respect to a ship entitled to fly a flag of any State, the Administration is the Government of that State. With respect to floating platforms engaged in exploration and exploitation of the sea-bed and subsoil thereof adjacent to the coast over which the coastal State exercises sovereign rights for the purposes of exploration and exploitation of its natural resources, including Floating Storage Units (FSUs) and Floating Production Storage and Offloading Units (FPSOs), the Administration is the Government of the coastal State concerned.

Ballast Water means water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship.

Ballast Water Management means mechanical, physical, chemical, and biological processes, either singularly or in combination, to remove, render harmless, or avoid the uptake or discharge of Harmful Aquatic Organisms and Pathogens within Ballast Water and Sediments.

Ballast Water Management System (BWMS) means any system which processes ballast water such that it meets or exceeds the ballast water discharge performance standard in Regulation D-2 of the Convention. The BWMS includes ballast water treatment equipment, all associated control equipment, monitoring equipment and sampling facilities.

Convention means the International Convention for the Control and Management of Ships Ballast Water and Sediments.

Harmful Aquatic Organisms and Pathogens means aquatic organisms or pathogens which, if introduced into the sea including estuaries, or into fresh water courses, may create hazards to the environment, human health, property or resources, impair biological diversity or interfere with other legitimate uses of such areas.

Sediments means matter settled out of Ballast Water within a ship.

System Design Limitations of a BWMS means the water quality and operational parameters, determined in addition to the required type approval testing parameters, that are important to its operation, and, for each such parameter, a low and/or a high value for which the BWMS is designed to achieve the performance standard of regulation D-2. The System Design Limitations should be specific to the processes being employed by the BWMS and should not be limited to parameters otherwise assessed as part of the type approval process. The System Design Limitations should be identified by the manufacturer and validated under the supervision of the Administration in accordance with these Guidelines.

Treatment Rated Capacity (TRC) means 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. The TRC is measured at the inlet of the BWMS.

Type Approval refers to the IMO approval and certification regime of BWMS made by an IMO Member State in accordance with the Convention Guidelines G8, G9 and G10. An approved BWMS is to have a valid Type Approval Certificate in the proper form and signed by that Member State.

Viable organisms mean organisms that have the ability to successfully generate new individuals in order to reproduce the species.

2. IMO REGULATIONS FOR BALLAST WATER MANAGEMENT

2.1. Overview

To combat the problem of invasive species from ballast water, the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004. On 8 September 2016, the convention was finally ratified and it has entered into force on 8th September 2017 one year after ratification. So far the convention has been ratified by more than 60 countries, representing more than 70% of world merchant shipping tonnage. From the date of entry into force, ships will be required to manage their ballast water to avoid the transfer of potentially invasive species. All ships will be required to have a ballast water management plan and keep a ballast water record book.

Vessels constructed (keel laid) before 8 September 2017 must install a ballast water treatment system by first IOPP renewal survey after this date and vessels constructed (keel laid) at or after 8 September 2017 will have to install a system upon delivery. The Convention is divided into Articles and an Annex which includes technical standards and requirements in the Regulations for the control and management of ships ballast water and sediments.

Annex is further divided into five sections from A to E, in which section D provides the standards for ballast water exchange and performance standards for ballast water treatment systems and then appendix contains the ballast water management certificate and ballast water record book samples. An overview of the convention is shown in table 2.

Table 2: Overview of BWMC [1]

Secton A: General provisions	It contains defnitions (A-1), general applicability criteria (A-2), exceptions to the Convention (A-3), granting of exemptions to the Convention (A-4) and equivalent compliance for pleasure craft (A-5).

Secton B: Management and control requirements for ships	The contents of the Ballast Water Management Plan are specified (B-1), together with the requirement of having a Ballast Water Record Book on board (B-2). The procedure to follow regarding ballast water management depending on the construction date and the ballast water capacity of the ship is also detailed under this section (B-3), establishing specific provisions for ballast water exchange (BWE) (B-4) and sediment management (B-5). It ends up with requirements on the issue for the officers and crew (B-6).
Secton C: Special requirements in certain areas	The procedure to apply additional measures to those established in Secton B of the Conventon (C-1) and to define areas where ballast water is not to be uptaken are detailed (C-2), including the communication procedure to follow on this measures (C-3).
Secton D: Standards for ballast water management	Standards for ballast water exchange (D-1) and management (D-2) are specifed. The procedure a ballast water treatment system has to fulfill to be approved for its installation on board is also detailed (D-3). Finally, special attention is given to the use of prototypes of promising ballast water treatment technology (D-4) and the update of the standards by IMO (D-5).
Secton E: Survey and certfcation requirements for ballast water management	Information on the requirements for inital, renewal, intermediate, annual and additional surveys (E-1) and certifcation requirements (from E-2 to E-5) is provided. Ballast water management certficate and ballast water record book forms are contained in Appendix.

2.2. Key Requirements

Following are the key requirements of IMO's BWMC [1] adopted in 2004.

- have an approved ballast water management plan onboard
- manage their ballast water on every voyage according to the plan, and with due regard to the safety of the vessel, e.g. by exchanging ballast mid-ocean, treating it onboard before discharge or discharging it to a reception facility/barge

- assign a competent officer to manage ballast water and to train the officers and crew so that they can carry out their respective duties
- maintain a ballast water record book which must be up to date at all times and
- for a vessel of 400 GT and above, it is mandatory to have onboard an international ballast water management certificate

2.3. Ballast Water Management Plan

BWMC Regulation B-1 [1] requires that each ship should have on board and implement a Ballast Water Management plan. This plan has to be approved by the Administration taking into account guidelines developed by the organization. The Ballast Water Management plan shall be specific to each ship and it must include the following particulars.

- Detailed safety procedures for the ship and the crew associated with Ballast Water Management
- Detailed description of the actions to be taken to implement the Ballast Water Management requirements and supplemental Ballast Water Management practices
- Detailed procedures for the disposal of Sediments at sea and ashore
- Procedures for coordinating shipboard Ballast Water Management that involves discharge to the sea with the authorities of the State into whose waters such discharge will take place
- Designated officer on board in charge of ensuring that the plan is properly implemented
- Reporting requirements for ships
- It has to be written in the working language of the ship. If the language used is not English, French or Spanish, a translation into one of these languages shall be included.

2.4. Ballast Water Record Book

BWMC Regulation B-2 [1] requires each ship should have onboard an electronic record system or record book. It must be kept onboard upto two years after the last entry and then in the shore based office for minimum three years. Enties related to operation of ballast water must be made in this record book without delay and it must be readily available for inspection at all times. Entries in the Ballast Water record book should be made on each of the following occasions:

- When Ballast Water is taken on board
- Whenever Ballast Water is circulated or treated for Ballast Water Management purposes
- When Ballast Water is discharged into the sea
- When Ballast Water is discharged to a reception facility
- Accidental or other exceptional uptake or discharges of Ballast Water

Specific details related to each operation such as date, time and location, signature of the officer in charge of operation and volume of ballast water etc. are recorded in this book. The volume of ballast water onboard should be estimated in cubic metres. The ballast water record book contains many references to estimated volume of Ballast Water. It is recognized that the accuracy of estimating volumes of ballast is left to interpretation.

2.5. Implementation Schedule

In accordance with the implementation schedule defined in Regulation B-3 of the BWM Convention [1], as per the amendments agreed by IMO MEPC 71 (has been circulated by the IMO on 8 September 2017 and will be adopted at MEPC 72) the following table 3 has been created to provide the outline of the schedule clearly.

For new ships, convention enters into force on or after 8th September 2017 where as existing ships have to follow the regulations as prescribed in the new draft amendments. These new draft amendents have been developed to give sufficient time for ship owners to implement the BWMC onboard their ships.

Table 3: BWMC Implementation Schedule [28]

Ship Category	**Required BWM standard**
1. A ship constructed* on or after entry into force on 8 September 2017	The ship must conduct Ballast Water Management that at least meets the standard described in Regulation D-2 (treatment) from the date of delivery of the ship.

2. A ship constructed* prior to 8 September 2017 which has completed an IOPP renewal survey on or after 8 September 2014 but prior to 8 September 2017	(i) The ship must conduct Ballast Water Management that at least meets the standard described in Regulation D-2 (treatment) from the date of the 1st IOPP renewal survey after 8 September 2017. (ii) From 8 September 2017 until the date of the 1st IOPP renewal survey following EIF of the BWM Convention the ship must either conduct Ballast Water Exchange (BWE) and comply with Regulation D-1 or alternatively comply with Regulation D-2.
3. A ship constructed* prior to 8 September 2017 which has NOT completed an IOPP renewal survey on or after 8 September 2014 but prior to 8 September 2017 and which has its 1st IOPP renewal survey following entry into force due in the period 8 September 2017 to 7 September 2019.	(i) The ship must conduct Ballast Water Management that at least meets the standard described in Regulation D-2 (treatment) from the date of the 2nd IOPP renewal survey after 8 September 2017. (ii) From 8 September 2017 until the date of the 2nd IOPP renewal survey following entry into force of the BWM Convention the ship must either conduct Ballast Water Exchange (BWE) and comply with Regulation D-1 or alternatively comply with Regulation D-2.
4. A ship constructed* prior to 8 September 2017 for which an IOPP renewal survey is not required.	(i) The ship must conduct Ballast Water Management that at least meets the standard described in Regulation D-2 from the date decided by the Administration, but not later than 8 September 2024. (ii) From 8 September 2017 until the 8 September 2024 the ship must either conduct Ballast Water Exchange (BWE) and comply with Regulation D-1 or alternatively comply with Regulation D-2.

Note: Constructed* In accordance with the BWMC [1] "Constructed" in respect of a ship means a stage of construction where: (a) The keel is laid or (b) Construction identifiable with the specific ship begins or (c) Assembly of the ship has commenced comprising at least 50 tonnes or 1 percent of the estimated mass of all structural material, whichever is less or (d) The ship undergoes a major conversion.

2.6. Application

Referring to Article 3 of the BWMC [1], this Convention shall apply to:

- ships entitled to fly the flag of a Party

- ships not entitled to fly the flag of a Party but which operate under the authority of a Party

This convention shall not apply to:

- ships not designed or constructed to carry ballast water
- ships of a party which only operate in waters under the jurisdiction of that party
- ships of a party which only operate in waters under the jurisdiction of another Party
- ships which only operate in waters under the jurisdiction of one party and on the high seas
- any warship, naval auxiliary or other ship owned or operated by a state and used, for the time being, only on government non-commercial service
- permanent ballast water in sealed tanks on ships, that is not subject to discharge

Ships which are flying with flag of a countries which are not party to the convention, they shall apply the requirements of this convention as may be necessary to ensure that no more favourable treatment is given to such ships.

2.7. Exceptions

There are some exceptions for ships from complying with BWMC during certain operations and in emergency situations. Refering to regulations A-3 of BWMC [1], BWMC regulations shall not apply during the following situations.

- the uptake or discharge of ballast water and sediments necessary for the purpose of ensuring the safety of a ship in emergency situations or saving life at sea
- the accidental discharge or ingress of ballast water and sediments resulting from damage to a ship or its equipment subject to certain conditions detailed in the convention
- the uptake and discharge of ballast water and sediments when being used for the purpose of avoiding or minimizing pollution incidents from the ship
- the uptake and subsequent discharge on the high seas of the same ballast water and sediments

- the discharge of ballast water and sediments from a ship at the same location where the whole of that ballast water and those sediments originated subject to certain conditions detailed in the convention

2.8. Exemptions

There are some possibilities for ships to get an exemption from complying with reference to regulations A-3 of BWMC [1]. These exemptions are given by administration only when they are:

- granted to a ship or ships on a voyage or voyages between specified ports or locations or to a ship which operates exclusively between specified ports or locations
- effective for a period of no more than five years subject to intermediate review
- granted to ships that do not mix ballast water or sediments other than between the ports or locations specified and
- granted based on the guidelines on risk assessment developed by the organization

Exemptions granted are not effective until after communication to the organization and circulation of relevant information to the members which are parties to the BWMC.

Exemptions granted under this regulation should not impair or damage the environment, human health, property or resources of adjacent or other States. If any state that the party determines may be adversely affected should be consulted, with a view to resolve any identified concerns.

Exemptions granted under this regulation, should be recorded in the ballast water record book.

2.9. Regulations D1 & D2

Standards for ballast water management are provided in the regulations D1 & D2 of the ballast water management convention as shown in table 4 & 5. The difference is that D-1 relates to ballast water exchange, while D-2 specifies the maximum amount of viable organisms allowed to be discharged, including specified indicator microbes harmful to human health.

Table 4: D1 Ballast Water Exchange Standard [1] & [8]

Reference	Description
Reg. D-1	Atleast 95% of volumetric exchange or if using the pumping through methods, three times the volume of each tank
Reg. B-4	The Ballast Water exchange shall be conducted at least 200 nautical miles from the nearest land and in water at least 200 metres in depth
Guidelines	Ballast Water Exchange (G6) Designation of areas for ballast water exchange (G14) Ballast water exchange in the antarctic area (MEPC.163(56)) Ballast water exchange design and construction standards(G11)

Table 5: D2 Ballast Water Performance Standard [1] & [8]

Reference	Description	
Reg.D-2	Organism Category	Regulation
	Viable Organism (Plankton) $\geq 50\mu m$	< 10 cells per m3
	Viable Organism (Plankton) 10-50μm	< 10 cells per ml
	Toxicognic Vibrio Cholera (O1 & O139)	< 1 cfu per 100 ml or < 1 cfu per 1g zooplankton samples
	Escherichia Coli	< 250 cfu per 100 ml
	Intestinal Enterococci	< 100 cfu per 100 ml
Guidelines	Approval of Ballast Water Management Systems (G8)	
	Approval of Ballast Water Management Systems that make use of active substances (G9)	
	Approval and oversight of prototype ballast water treatment technology programmes (G10)	
Note: cfu-colony forming unit		

2.10. Latest Update

The MEPC 71 held in July, 2017 has agreed for a practical and pragmatic implementation schedule for ships to comply with the IMO BWMC, which aims to control the transfer of potentially invasive species in ships ballast water. Draft amendments to the treaty approved by the MEPC clarify when ships must comply with the requirement to meet the D-2 standard. The draft amendments are circulated after the entry into force of the BWM Convention on 8 September 2017, with a view to adoption at the next MEPC session (MEPC 72 in April 2018). IMO has released an infographic shown in figure 3. The approved amendments [28] are:

(a) Ships constructed on or after 8 September 2017, shall conduct ballast water management that at least meets the D-2 standard from the date they are put into service.

(b) Ships constructed before 8 September 2017, the date for compliance with the D-2 standard is linked with the renewal survey of the ship associated with the International Oil Pollution Prevention Certificate under MARPOL Annex I. For existing ships this would be the first or second five-year renewal survey after 8 September 2017:

- By the first renewal survey: this applies if the first renewal survey of the ship takes place on or after 8 September 2019 or a renewal survey has been completed on or after 8 September 2014 but prior to 8 September 2017.

- By the second renewal survey: this applies if the first renewal survey after 8 September 2017 takes place before 8 September 2019. In this case, compliance must be by the second renewal survey (provided that the previous renewal survey has not been completed in the period between 8 September 2014 and 8 September 2017).

American Bureau of Shipping (ABS) has summarized the provisions of the draft amendments to regulation B-3 of the convention approved at MEPC 71 for ships constructed before 8 September 2017 as shown in figure 4. An existing ship to which the IOPP renewal survey under MARPOL Annex I does not apply shall meet the D-2 standard from the date decided by the administration, but not later than 8 September 2024. The MEPC adopted a resolution which resolves that Parties to the BWM Convention should implement the schedule for compliance outlined in the draft amendments, ahead of their adoption and entry into force.

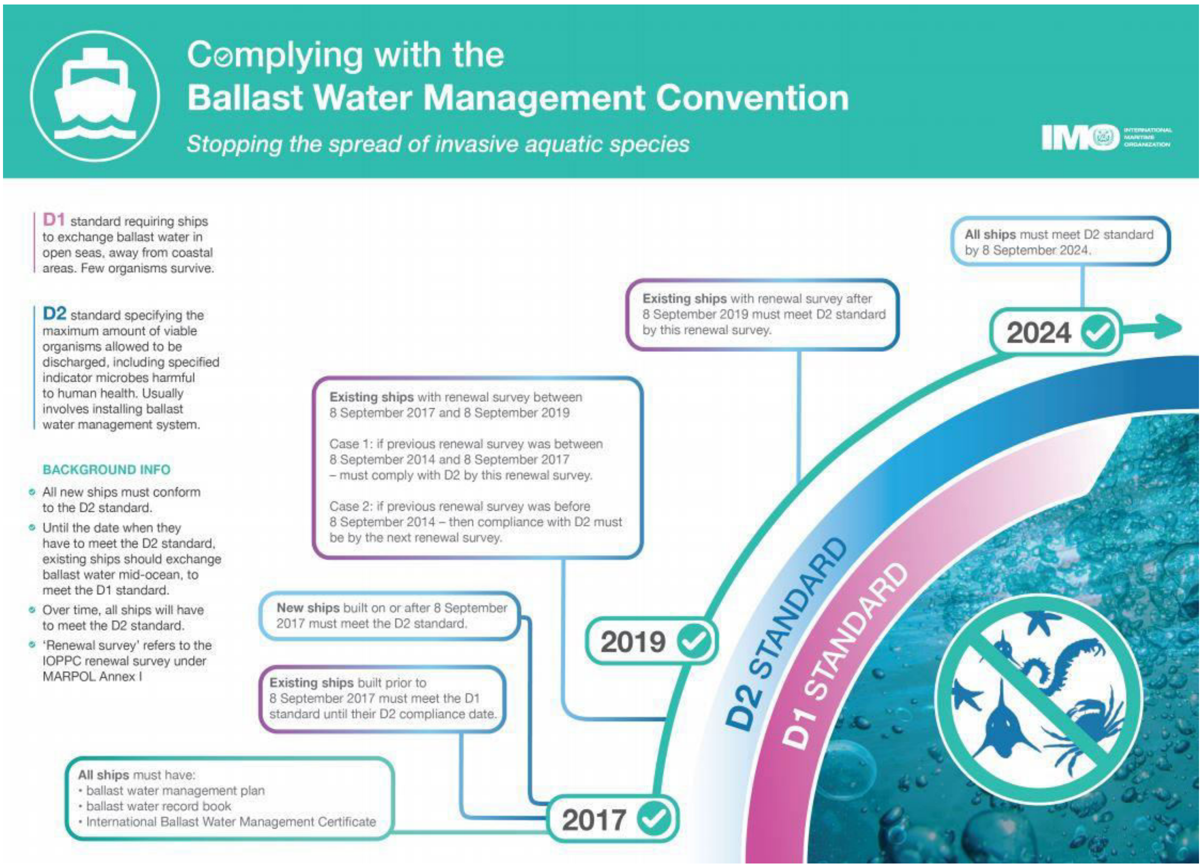


Figure 3: IMO Infographic [29]

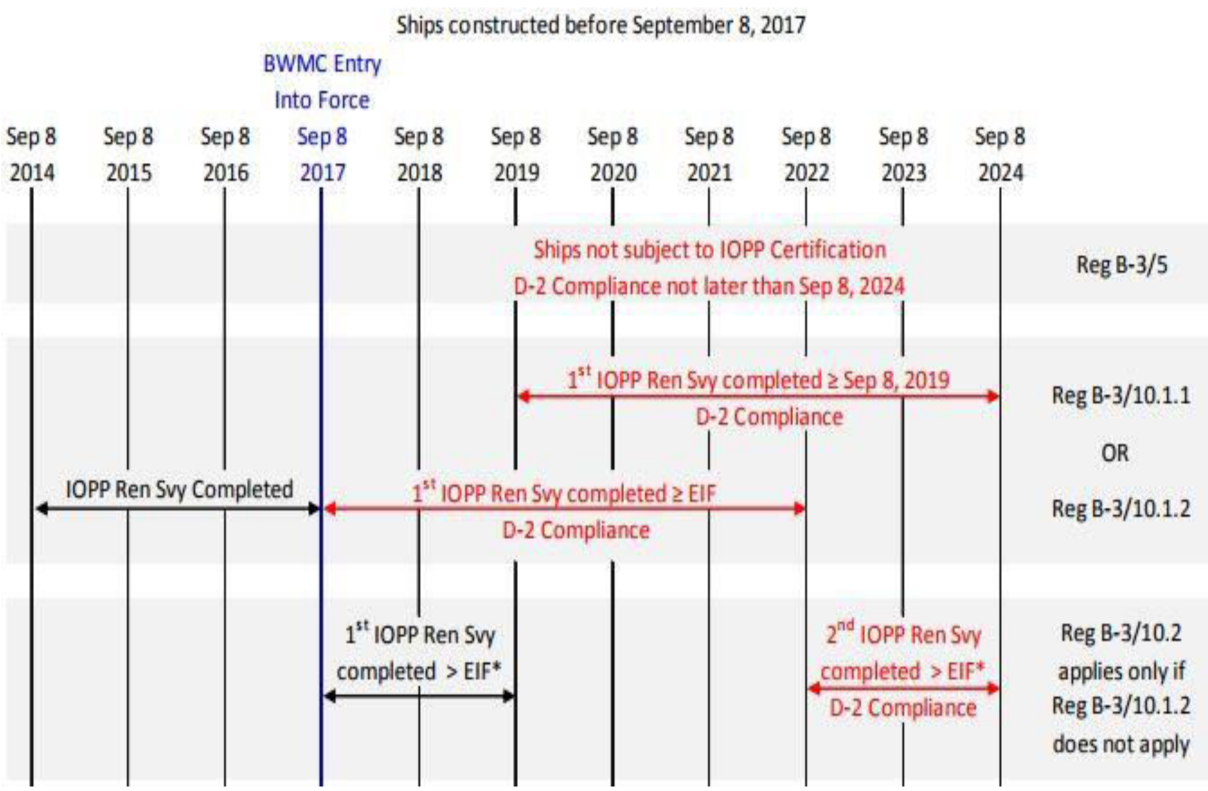


Figure 4: Provisions of the draft amendments approved by MEPC 71 [30]

In addition to that MEPC 71 has approved and adopted the following with respect to implementation of the BWMC.

- adopted the 2017 Guidelines for ballast water exchange (G6)
- adopted the 2017 Guidelines for risk assessment under regulation A-4 of the BWM Convention (G7)
- adopted an MEPC resolution on "The experience-building phase associated with the BWMC". This envisages a three-stage approach: data gathering, data analysis & Convention review. Based on the experience and feedback gained, as well as the analysis of the data gathered, draft amendments to the Convention could be put forward for consideration at MEPC 79 (in 2022)
- approved the Code for approval of ballast water management systems, and approved draft amendments to the BWMC to make the Code mandatory, for adoption at the next session
- approved amendments to section E (Survey and certification) of the BWMC also for adoption at MEPC 72
- approved a manual on "Ballast Water Management: How to do it"
- approved Guidance on contingency measures under the BWM Convention
- approved a circular on Application of the BWMC to ships operating in sea areas where ballast water exchange in accordance with regulations B-4.1 and D-1 is not possible
- granted final approval to one and basic approval to two ballast water management systems that makes use of active substances. (The current list of approved ballast water management systems can be found at Appendix C)

2.11. Technical Guidelines

A number of technical guidelines have been developed and adopted since Marine Environment Protection Committee (MEPC) 53 to support the uniform implementation of the BWM Convention. The available Guidelines as mentioned in table 6, which are contained in various MEPC Resolutions.

Table 6: List of Guidelines for the uniform implementation of the BWMC [1] & [8]

Guidelines	Title	IMO Resolution
G1	Guidelines for sediment recepton facilites	MEPC.152(55)
G2	Guidelines for ballast water sampling	MEPC.173(58)
G3	Guidelines for ballast water management equivalent compliance	MEPC.123(53)
G4	Guidelines for ballast water management and development of ballast water management plans	MEPC.127(53)
G5	Guidelines for ballast water reception facilites	MEPC.153(55)
G6	Guidelines for ballast water exchange	MEPC.124(53)
G7	Guidelines for risk assessment under regulation A4 of the ballast water management convention	MEPC.162(56)
G8	Guidelines for approval of ballast water management systems	MEPC.174(58)
G8	2016 Guidelines for approval of ballast water management systems	MEPC.279(70)
G9	Procedure for approval of ballast water management systems that make use of Actve Substances	MEPC.169(57)
G10	Guidelines for approval and oversight of prototype ballast water treatment technology programmes	MEPC.140(54)
G11	Guidelines for ballast water exchange design and construction standards	MEPC.149(55)
G12	Guidelines on design and constructon to facilitate sediment control on ships	MEPC.209(63)
G13	Guidelines for additonal measures regarding ballast water management including emergency situatons	MEPC. 161(56)
G14	Guidelines on designaton of areas for ballast water exchange	MEPC. 151(55)
	Guidelines for Ballast Water Exchange in the Antarctic Treaty Area	MEPC. 163(56)
	Guidelines for Port State Control under the BWM Convention	MEPC. 252(67)

2.12. Revised Guidelines for approval of BWMS (G8)

The goal of these guidelines is to ensure uniform and proper application of the standards contained in the BWMC. The G8 Guidelines [8] are aimed primarily at administrations or their designated bodies, in order to assess whether ballast water management systems meet the standard as set out in regulation D-2. This document can be used as guidance for manufacturers and shipowners during evaluation procedure for the equipment to be used for ballast water management systems. The guidelines address various aspects of the approval process, including the detailed requirements of land-based and ship-board testing of systems, and the approval and certification procedures.

The main purpose of the revision is to improve robustness and confidence that type approved systems will meet the D-2 standard. Revised G8 Guidelines has been adopted and available now for any manufacturer to recertify before 2020 even though it will become mandatory from this year. In the revised G8 which has set higher standard for approval which is close to USCG regulations. This revision require more details and transparency about testing which reaffirms the definition of viability.

Administrations are recommended to apply the revised G8 as soon as possible, but no later than 28th October 2018. BWMS installed on board ships on or after 28th October 2020 should be approved in accordance with the revised Guidelines (G8). Also, MEPC 71 [28] has considered draft ‘Code for approval of BWMS’ or ‘BWM Code’ which makes it very clear about the strong involvement of IMO to implement the convention.

2.13. Procedure for approval of BWMS that make use of AS (G9)

The G9 Guidelines [9] describe the approval process for systems that make use of ‘active substances’. Active substances and preparations may be added to the ballast water or be generated onboard ships within the BWM system. These substances must comply with the BWM Convention. BWM systems that make use of active substances (or preparations containing one or more active substances) need to be approved by IMO, based on a procedure developed by the Organization. The objective of this procedure is to determine the acceptability of the active substances in ballast water management systems concerning ship safety, human health and the aquatic environment. The procedure is thus provided as a safeguard for the sustainable use of active substance, and is not intended for the evaluation of the efficacy of the active substances. The proposal for approval of an active substance must include:

- data on effects on aquatic plants, invertebrates, fish and other biota, including sensitive and representative organisms
- data on mammalian toxicity
- data on environmental fate and effect under aerobic and anaerobic conditions

- physical and chemical properties of the active substance and preparations and the treated ballast water
- analytical methods at environmentally relevant concentrations

Section 8 of the G9 [9] sets out the methodology to be followed for the approval of such systems and requests IMO to establish a Technical Group to review the proposals submitted by members and report to IMO on its findings. Based on the report of the Group, the Marine Environment Protection Committee decides on the approval of a proposal submitted by a Member of IMO.

2.14. Type Approval

Ballast Water Management systems must be approved by the Administration in accordance with IMO Guidelines (Regulation D-3 Approval requirements for Ballast Water Management systems [1]). These include systems which make use of chemicals or biocides; make use of organisms or biological mechanisms; or which alter the chemical or physical characteristics of the ballast water.

BWMS must be certified through specific IMO processes and testing guidelines designed to ensure that the technologies are reliable to meet IMO standards, do not have adverse environmental impacts and are safe and suitable for shipboard use. Individual type approval certifications are granted by a flag administration, often in consultation with a recognized classification society and based on results of testing conducted under the G8. G8 includes both land-based testing and shipboard testing of efficacy but only provides very general guidance on assessing the ability of BWMS to safely and reliably meet the D-2 discharge standards. These stages of the approval are likely to take between six weeks and six months for the land-based testing and six months for the shipboard testing.

The Approval Process: A company offering a treatment process must have the process approved by a flag administration. In general, the manufacturer will use the country in which it is based to achieve this approval. Although, this is not a specific requirement and some companies may choose to use the flag state where the testing facility is based or the Flag State of a partner company. In general the flag state will probably choose to use a recognised organization such as a classification society to verify and quality assure the tests and resulting data.

The testing procedure is outlined in the G8 guidelines and it is represented in the figure 5. The approval consists of both land based testing of a production model to confirm that the D2 discharge standards are met and ship board testing to confirm that the system works in service. As mentioned earlier, these stages of the approval are likely to take between six weeks and six months for the land based testing and six months for the ship board testing.

Further requirements apply if the process uses an ‘active substance’ (AS). For processes employing an AS, basic approval from the GESAMP-BWWG, is required before shipboard testing proceeds. This is to safeguard the environment by ensuring that the use of the AS poses no harm to the environment. It also prevents companies investing heavily in developing systems which use an active substance that is subsequently found to be harmful to the environment and is not approved. The GESAMP BWWG assessment is based largely on data provided by the vendor in accordance with the G9 Guidelines [9].

Basic Approval is the first step in the approval process when using an active substance. It is an ‘in principle’ approval of the environmental impact of an active substance. After the basic approval for active substances, treatment systems can be tested both on land and onboard ship according to G8 guidelines.

Final Approval by the GESAMP BWWG will take place when all testing is completed. Once final approval is granted by GESAMP, the flag administration will issue a type approval certificate in accordance with the G8 guidelines [8]. If the process uses no active substances the flag administration will issue a type approval certificate without the need for approval from the GESAMP BWWG. The approval scheme for active substances is shown in figure 6. During final approval process, additional data set is required by organization to confirm the residual toxicity of discharged ballast water with the evaluation under basic approval process. After the approval of environmental impact, type approval certificate will be issued and the organization publishes the list of approvals in their website.

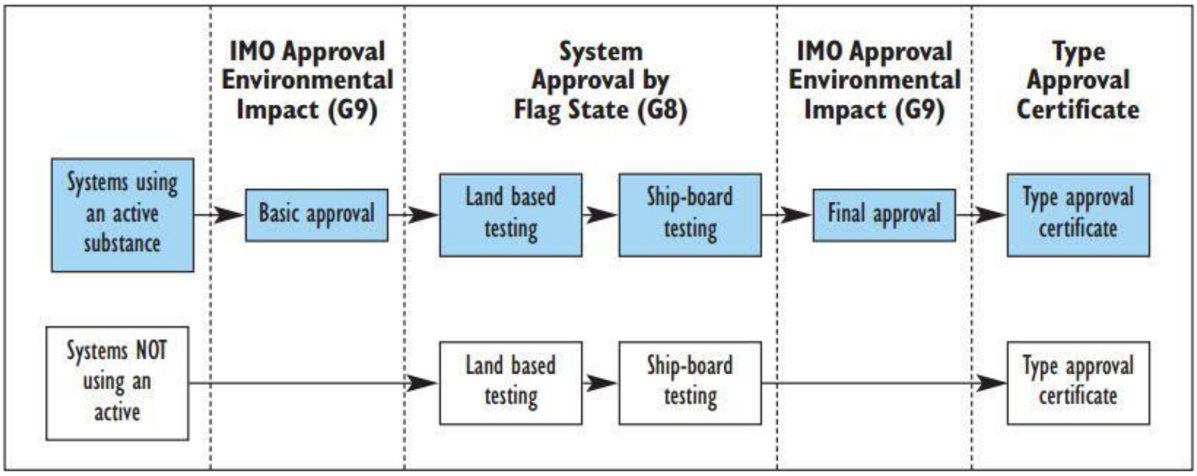


Figure 5: IMO Procedure for Type Approval [10]

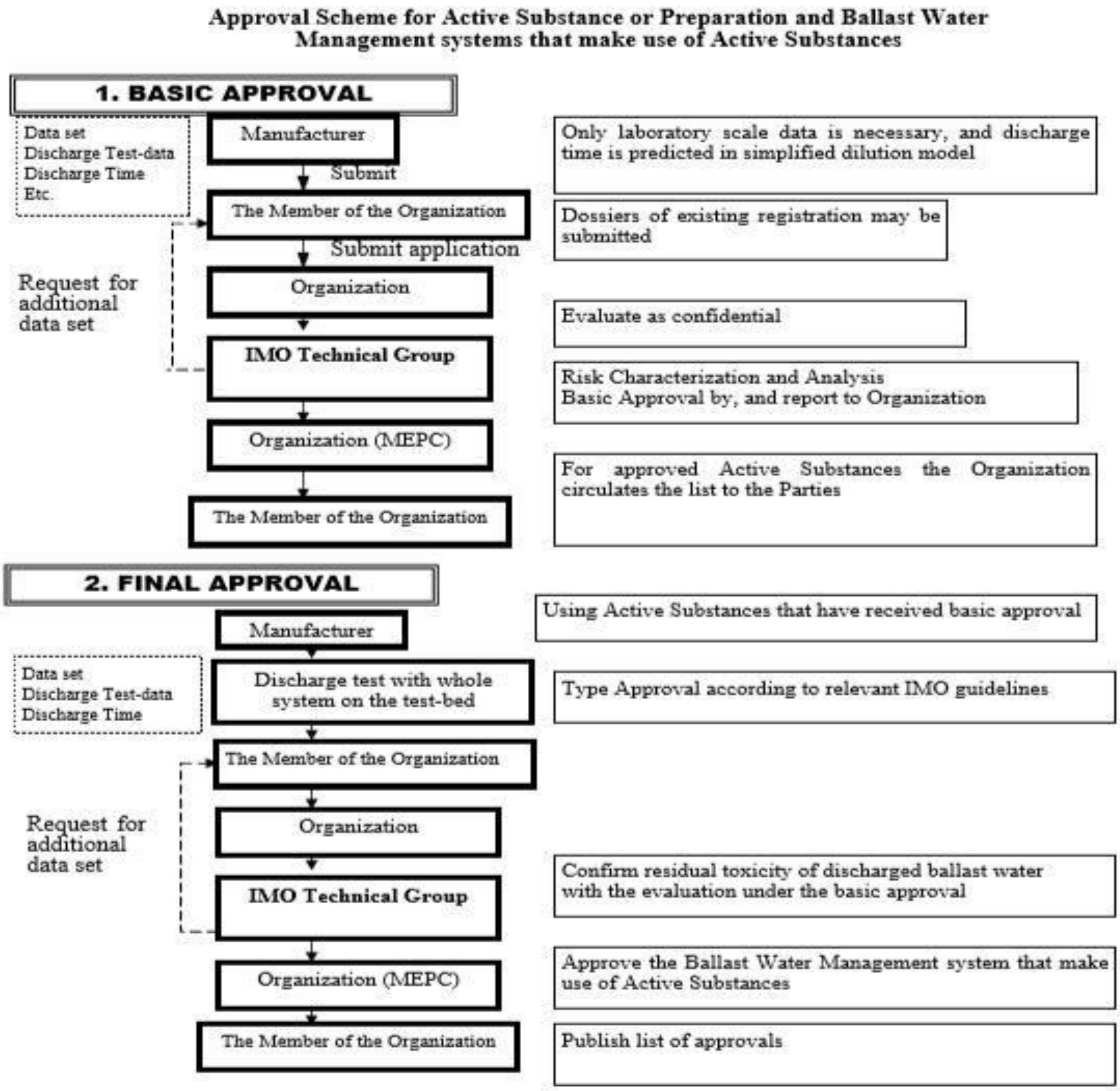


Figure 6: Approval Scheme for Active Substances [9]

2.15. Certification

The requirements for the type approval certificate are laid down in the G8 Guidelines Part 7 [8] and it states that the type approval certificate should:

- identify the type and model of the BWMS to which it applies and identify equipment assembly drawings, duly dated

- identify pertinent drawings bearing model specification numbers or equivalent identification details

- include a reference to the full performance test protocol on which it is based

- identify if it was issued by an Administration based on a Type Approval Certificate previously issued by another Administration. Such a certificate should identify the Administration that supervised conduction of the tests on the BWMS and a copy of the original test results should be attached to the Type Approval Certificate of BWMS

- identify all conditions and limitations for the installation of BWMS on board the ship;

- include the System Design Limitations, which should be listed under the heading "This equipment has been designed for operation in the following conditions"

- include any restrictions imposed by the Administration due to the minimum holding time or in accordance with paragraph 6.4 in the annex to G8 Guidelines, such restrictions should include any applicable environmental conditions (e.g. UV transmittance, etc.) and/or system operational parameters (e.g. min/max pressure, pressure differentials, min/max Total Residual Oxidants (TRO) if applicable, etc.)

- an appendix containing test results of each land-based and shipboard test run. Such test results should include at least the numerical salinity, temperature, flow rates, and where appropriate UV transmittance. In addition, these test results should include all other relevant variables. The Type Approval Certificate should list any identified system design limitation parameters

The sample type approval certificates are attached in the Appendix C, D & E. Appendix C shows the type approval certificate which is based on G8 guidelines and Appendix D shows the type approval certificate sample fomat which is based on revised G8 guidelines. USCG approval certificate for one of the treatment system is shown in Appendix E.

2.16. GESAMP-BWWG

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) – "Ballast Water Working Group on Active Substances", GESAMP – BWWG or WG 34, was established in November 2005 [31] to review any proposals submitted to IMO in preparation for the BWM Convention for approval of Ballast Water Management systems that make use of 'Active Substances'. WG 34 reports to IMO on whether such proposals present unreasonable risk to the environment, human health, property or resources in accordance with the G9. WG 34 does not evaluate the operation or design of the systems, or their effectiveness, only their potential for environmental and human health risks as an advisory group to IMO.

2.17. Globallast Partnerships

The GEF-UNDP-IMO GloBallast Partnerships Programme is assisting developing countries to reduce the transfer of harmful aquatic organisms and pathogens in ships' ballast water and implement the IMO Ballast Water Management (BWM) Convention [32]. This project has been implemented by United Nations Development Project (UNDP) and executed by International Maritime Organization (IMO), under the Global Environmental Facility (GEF). This project started during October 2007 initially for five year period and later on extended for another five years until June 2017. Globallast in associaiton with Global Industry Alliance (GIA) has established a network of organizations called GloBal TestNet which is involved in testing for the type approval and certification of ballast water treatment systems.

2.18. OMCS Class

This thesis work has been carried out in association with OMCS Class [33]. It's a leading classification society based in Panama. They have been appointed by Panama Maritime Administration as recognized organization and recognized security organization to provide maritime industry with a diversified team of qualified professionals dealing with maritime safety aspects. So far, they have been authorized by 13 flag states to perform survey and issue certificates. They have offices in South America, Africa, Europe, China and Middle East.

3. USCG REGULATIONS FOR BALLAST WATER MANAGEMENT

3.1. Key Requirements

Besides the IMO convention, ships sailing in United States of America (USA or US) waters are required to employ a type approved BWMS which is compliant with United States Coast Guard (USCG) regulations. At the entry into force of the BWMC, the US is not a signatory to the convention and has a separate national legislation on ballast water. The US Coast Guard (USCG) regulations [11] are coupled to the scheduled drydocking date, but the discharge standards are similar to IMO requirements. The USCG regulation is in force on BWE and when a ship's compliance is due a BWMS must be installed or an other accepted method applied.

Before vessel's compliance date

- Perform Ballast Water Exchange beyond 200 nautical miles at more than 200 m depth or beyond 50 nautical miles, if the first criteria is not possible

After vessel's compliance date

- Install and use USCG approved BWMS
- Self-monitoring and records as required

Other accepted methods

- Obtain an extension from USCG allowing continued use of BWE
- Use an IMO type approved BWMS accepted by the USCG as an Alternate Management System (AMS) (valid for 5 years)
- Use of ballast water obtained exclusively from a U.S. public water system
- Discharge of ballast water to a reception facility
- No discharge in US waters according to BWMP

3.2. Compliance Schedule

Following table 7 shows the compliance schedule for vessels calling US ports. Compliance date depends on whether the vessel is new or existing based on the date of construction and ballast water capacity.

Table 7: Compliance Schedule for USCG Requirements [11]

	Vessel's ballast water capacity	Date constructed	Vessel's compliance date
New vessels	All	On or after December 1, 2013	On delivery
Existing vessels	Less than 1500 m^3	Before December 1, 2013	First scheduled drydocking after January 1, 2016
	1500-5000 m^3	Before December 1, 2013	First scheduled drydocking after January 1, 2014
	Greater than 5000 m^3	Before December 1, 2013	First scheduled drydocking after January 1, 2016

3.3. Exemptions

As per USCG regulations [11], the following vessels are exempt from ballast water management requirements, reporting requirements, and recordkeeping requirements:

- Crude oil tankers engaged in coastal trade and
- Vessels which operate exclusively within one 'Captain of the Port' (COTP) zone.

The following vessels are exempt only from ballast water management requirements:

- Seagoing vessels that operate in more than one COTP Zone, do not operate outside of the Exclusive Economic Zone (EEZ), and are less than or equal to 1,600 gross register tons or less than or equal to 3,000 gross tons (International Convention on Tonnage Measurement of Ships, 1969).
- Non-seagoing vessels
- Vessels that take on and discharge ballast water exclusively in one COTP zone.

To get an exemption, application for exemption has to be submitted by eligible vessel operators for the evalution by USCG.

3.4. Extensions

If the options given by the USCG are not practicably available despite all efforts, vessel owners can request an extension from the USCG to the implementation schedule. The availability of an Alternate Management System (AMS) does not prohibit a vessel owner from receiving an extension. The USCG regulations provide the process for requesting these extensions and when it can be documented.

There weren't USCG type approved systems available few years ago, so the USCG has provided guidance on how to apply for an extension which would allow ships to operate in US waters without treating ballast water for up to five years after the compliance date. But, at present there are six USCG approved systems already in the market.

In order to avoid penalising ships which are fitted with a treatment system approved by another flag administration, the USCG has introduced an Alternate Management System (AMS). Some important aspects of AMS are given below:

- AMS are ballast water treatment systems which have been accepted for use in US waters by the USCG
- AMS is a temporary solution until the USCG type approved systems are available
- AMS approval does not necessarily mean that the system will achieve the USCG type approval
- A ship with an AMS installed can only use this system for a period of five years, After this date they should either get the USCG approval letter for their treatment system or replace the system with USCG approved one.

3.5. Approval Procedures

Approval procedures are different in the case of USCG as compared to IMO requirements. Administrations are the approval authority issuing type approval certificate in the case of IMO system. In the federal register of US [11], the approval procedures for ballast water treatment systems are explained. They are described as follows.

(a) Letter of Intent (LOI): Not less than 30 days before initiating any testing of a ballast water management system (BWMS), the results of which are intended for use in an application for type approval, the manufacturer must submit a Letter of Intent (LOI) providing as much of the following information as possible to the Commanding Officer, U.S. Coast Guard Marine Safety Center (MSC).

- Manufacturer's name, address, and point of contact, with telephone number or email address.
- Name and location of independent laboratory and associated test facilities and subcontractors, plus expected dates and locations for actual testing.
- Model name, model number, and type of BWMS.
- Expected date of submission of full application package to the Coast Guard.
- Name, type of vessel, and expected geographic locations for shipboard testing.

(b) Independent Laboratory (IL): The manufacturer must ensure evaluation, inspection, and testing of the BWMS is conducted by an independent laboratory, accepted by the Coast Guard. Testing may begin 30 days after submission of the LOI unless otherwise directed by the Coast Guard.

- If an evaluation, inspection, or test required by this section is not practicable or applicable, a manufacturer may submit a written request to the Commanding Officer, USCG (MSC) for approval of alternatives as equivalent to the requirements in this section. The request must include the manufacturer's justification for any proposed changes and contain full descriptions of any proposed alternative tests
- The Coast Guard will notify the manufacturer of its determination, any limitations imposed by the BWMS on testing procedures and all approved deviations from any evaluation, inspection, or testing required by this subpart must be duly noted in the Experimental Design section of the Test Plan

(c) Submission of Application: The manufacturer must submit an application for approval.

(d) Evaluation of Application: Upon receipt of an application completed, the MSC will evaluate the application and either approve, disapprove, or return it to the manufacturer for further revision.

(e) Environmental Evaluation: In addition to tests and evaluations required by this subpart, the Coast Guard will independently conduct environmental analyses of each system in accordance with the National Environmental Policy Act, the Endangered Species Act, and/or other environmental statutes. The Coast Guard advises applicants that applications containing novel processes or active substances may encounter significantly longer reviews during these environmental evaluations.

(f) Eligibility for Approval: A BWMS is eligible for approval if

- It meets the design and construction requirements
- It is evaluated, inspected, and tested under land-based and shipboard conditions and thereby demonstrates that it consistently meets the ballast water discharge standard
- All applicable components of the BWMS meet the component testing requirements
- The BWMS meets the requirements, if the BWMS uses an active substance or preparation and
- The ballast water discharge, preparation, active substance or relevant chemical are not found to be persistent, bioaccumulative, or toxic when discharged

(g) Issue of Approval Certificate: After evaluation of an application, the Coast Guard will advise the applicant whether the BWMS is approved. If the BWMS is approved, a certification number will be issued and an approval certificate sent to the applicant. The approval certificate will list conditions of approval applicable to the BWMS. There is a sample approval certificate in the Appendix E.

3.6. Indepenent Laboratories and Sub-Laboratories

USCG approval proedure involves land based, ship board and environmental testing which are conducted in an independent laboratories and sub-laboratories authorised by USCG [34]. Following table 8 shows the list of those authorised laboratories. Recently, one of the sub-laboratories called MERC has withdrawn from BWMS certification testing services. However, they will complete the testing for which they are currently contracted, but they have suspended all future testing of BWMSs.

Independent laboratory means an organization that meets the requirements in United States Code of Federal Regulations (CFR), 46 CFR 159.010–3. In addition to commercial testing laboratories, which may include not-for profit organizations, the Commandant of USCG may also accept classification societies and agencies of governments (including State and Federal agencies of the United States) that are involved in the evaluation, inspection, and testing of BWMS.

Independent Laboratories are responsible to conduct readiness evaluation and determine the acceptability of the BWMS for testing upon request from manufacturer. The Independent Laboratory must prepare a written test plan for each approval test to be completed. Prior land-based and ship-board testing, they must ensure that the BWMS supplied by the manufacturer has been set up in accordance with Operation, Maintenance and Safety Manual (OMSM). Also, they must request manufacturer to sign a written statement to state that the BWMS has been properly assembled and installed at the test facility or onboard the test vessel. The Independent Laboratory or it's Sub-laboratories must conduct all approval testing and evaluations in accordance with the test requirements under USCG regulations and forward the complete test report to the commanding officer of the USCG. After the receipt of the test report, the commanding officer will review the report and decide about the issue of approval.

Table 8: List of USCG approved laboratories [34]

Laboratory	Country	Sub-laboratories
NSF International	USA	MERC, GSI, Retlif, ABS, Curtis Strauss
DNV GL	Norway	DHI-Denmark/Singapore, Golden Bear, NIVA, Applica, DELTA, Phoenix TestLab, Retlif, TUVSUD, SGS Gihe, Labtest
Korean Register of Shipping	Korea	KOMERI, KTL, SGS Giheung Lab, Dt&C.
Control Union Certifcations	The Netherlands	IMARES, NIOZ, GoConsult, Dr Matej David Consult, TNO, ABS, GSI
Lloyd's Register EMEA	UK	DHI Denmark, DELTA, DHI Singapore, TUV SUD PSB Singapore, Phoenix Testlab, SGS Korea, NIVA

3.7. Approval Status

USCG has so far approved six treatment systems and other two treatment systems approval is under review based on the approval status from USCG website [35]. Following table 9 shows the list of approved treatment systems which has been updated by USCG on 7th November 2017.

Table 9: USCG approval status list [35]

Approved						
Date Received	Manufacturer (Country)	Model	Independ ent Lab	System Type	Approved Range	Certificate Issued*
20-Sep-16	Optimarin (Norway)	OBS/ OBS Ex	DNV GL	Filtration + UV	167-3000 m^3/h	2-Dec-16
21-Sep-16	Alfa Laval (Sweden)	Pure Ballast 3	DNV GL	Filtration + UV	150-3000 m^3/h	23-Dec-16
23-Sep-16	TeamTec OceanSaver AS (Norway)	OceanSav er MK II	DNV GL	Filtration + Electro dialysis	200-7200 m^3/h	18-Oct-17
24-Jan-17	Sunrui (China)	BalClor	DNV GL	Filtration + Electrolysis	170-8500 m^3/h	7-Jun-17
31-Mar-17	Ecochlor, Inc. (USA)	Ecochlor BWTS	DNV GL	Filtration + Chemical Injection	500-16200 m^3/h	10-Aug-17
2-May-17	Erma First (Greece)	Erma First FIT	Lloyds Register	Filtration + Electrolysis	100-3740 m^3/h	18-Oct-17
Under Review						
Date Received	Manufacturer (Country)	Model	Independ ent Lab	System Type	Approved Range	Certificate Issued
28-Sep-17	Samsung Heavy Industries Co., Ltd (Republic of Korea)	Purimar BWMS	Korean Register	Filtration + Electrolysis	250-10000 m^3/h	Pending
31-Oct-2017	Techcross Inc.	Electro-Cleen System	Korean Register	Electrolysis	150-12000 m^3/h	Pending

This page is intentionally left blank.

4. COMPARISON BETWEEN IMO AND USCG REGULATIONS

4.1. Federal Requirements

US is not a signatory to IMO's BWMC, vessels calling US ports have to fulfill additional requirements prescribed by national and state regulations. While comparing IMO and USCG requirements, it is important to note that US requirements pay particular attention to bio-fouling and sediments as well. They also differ in type approval procedures listed in table 10. In addition to IMO requirements, following are the additional requirements of USCG for which vessel must be ready for inspection at all times by authorities in US waters.

- Maintain a BWMP covering US requirement, but there is no special requirement to get approval for this section of BWMP
- USCG approval certificate or AMS acceptance for BWMS, in addition to IMO type approval
- To submit a port-specific reporting form at least 24 hours before calling at an US port
- Plans for management of biofouling and sediment must be available, e.g. in the BWMP, and records of ballast, sediment and fouling management must be kept
- Records for shipboard officers and crew training
- Operation and maintenance, alarm and training records for BWMS

Table 10: Comparison between IMO & USCG Type Approval [14]

	IMO Type Approval	USCG Approval
Approval by	Flag (or Class onbehalf of flag)	USCG
Operator for testing	Manufacturer	IL
Laboratory for testing	Any competent lab	Approved ILs only
Observation of testing	Self-observed by lab	Observed by IL
Reporting of results	Manufacturer/Lab	Reported to USCG by IL
Testing methods required	G8/G9 Guidelines	ETV Protocol only

Most Probable Number (MPN) Method: MPN method is used for the evaluation of biological efficacy of UV-based treatments systems during their approval process. Most of the systems tested against IMO G8 Guidelines had used the MPN method. But, United States

Environmental Technology Verification (ETV) protocol accepts vital staining method only. This method uses a combination of two fluorescein-based stains (FDA and CMFDA) to evaluate the status of organisms. The USCG has declined [36] the use of the MPN method for evaluating the biological efficacy of UV-based treatment technologies for ballast water. The reason behind the USCG decision is that the wording in the regulation is live/dead and that the MPN method does not evaluate the performance of a BWMS to that discharge standard. The MPN method evaluates the ability of an organism to reproduce and hence its ability to colonize a new environment. So, USCG argues that MPN method does not provide a result equivalent to that of the vital staining method.

Even though, classification societies such as DNV-GL has expressed opinion [15] about MPN method which shows that the MPN method is the most relevant method and is a reliable way of evaluating the performance of UV technologies. MPN method has been validated to a greater extent than most of the methods described in the Environmental Technology Verification (ETV) protocol and UV technologies are commonly accepted in other water treatment industries.

4.2. Environmental Protection Agency (EPA) Requirements

Vessel General Permit (VGP): VGP issued by the US Environment Protection Agency (EPA) under the National Pollution Discharge Elimination System (NPDES) to regulate discharges incidental to the normal operation of vessels trading in US waters [37]. EPA first issued the Vessel General Permit (VGP) in 2008, subsequently reissued it on 19th December 2013 and it is valid until 18th December, 2018. Ballast water is one of the discharge categories that comes under VGP.

Following are the additional requirements which are found in the VGP for periodical sampling of the ballast water discharge:

- Records of annual calibration of sensors
- Sampling of biological indicators
- Sampling of residual biocides

The records of the periodical sampling must be retained onboard for 3 years. Also, EPA requires an annual report containing analytical results and reports, analytical methods used, reports of ballasting operations and list of personnel involved.

4.3. Compliance Requirements

IMO monitors the ballast water compliance through the administrations around the world by means of standard survey and certification procedures. Port state control inspection also verifies the compliance of vessels calling their ports. In the case of US, Federal requirements and EPA's VGP requirements are monitored by USCG. In the case of USCG requirements, non-compliance lead to penalties which are clearly stated in the CFR. USCG doesn't require special approval of Ballast Water Management Plan (BWMP), but they can review the plan during port state control examination or vessel inspection.

Compliance Calculator: One of the retrofit engineering specialists 'Clean Ship Solutions' has come up with a compliance calculator, a simple tool to find out vessel's compliance date as per IMO and USCG Regulations. It will be very useful especially for ship owners with large fleet of vessels to find out compliance date for each vessel and create a data base as reference. This tool can be accessed at 'Clean Ship Solutions' website [38]. After feeding some of the vessel particulars into the system, it displays the IMO D-2 and USCG compliance date for the vessel. Following vessel particulars are required to utilize this tool.

- Vessel name
- Ballast capacity
- Date of Built
- IOPP Applicable, Yes or No
- Last IOPP Renewal Survey date
- Next IOPP Renewal Survey date
- Has the vessel previously completed an IOPP survey?
- IOPP Renewal Cycle (years)
- Last Scheduled Drydocking date
- Next Scheduled Drydocking date

This page is intentionally left blank.

5. BALLAST WATER TREATMENT TECHNOLOGIES

5.1. Classification

Ballast Water Management technologies could be defined as procedures, activities and mechanisms which are able to reduce or eliminate all or part of risks associated with discharge of non-indigenous species in ships ballast water. BWM methodologies are classified based on technology, biology, capacity, costing, size, regions, regulations and many other parameters. A large number of treatment technologies are approved by administrations around the world as listed in the Appendix F. But, most of the times classification is based on technology used for treating ballast water. The main groups such as Mechanical, Physical and Chemical are very common as mentioned below.

- Mechanical treatment methods such as filtration and separation
- Physical treatment methods such as sterilization by ozone, ultra-violet light, electric currents and heat treatment
- Chemical treatment methods such adding biocides to ballast water to kill organisms
- Various combinations of the above

Figure 7, which represents the broader classification of ballast water management systems, Figure 8, shows the classification of ballast water treatment methods based on technologies used for the system. Table 11, shows the brief description about each treatment method.

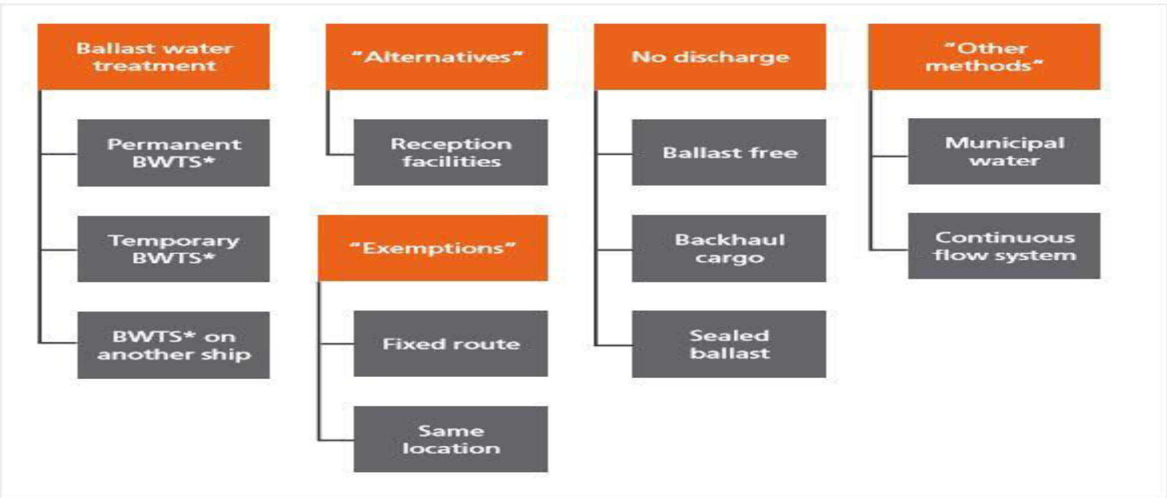


Figure 7: Classification of BWMS [16] *Ballast Water Treatment Systems

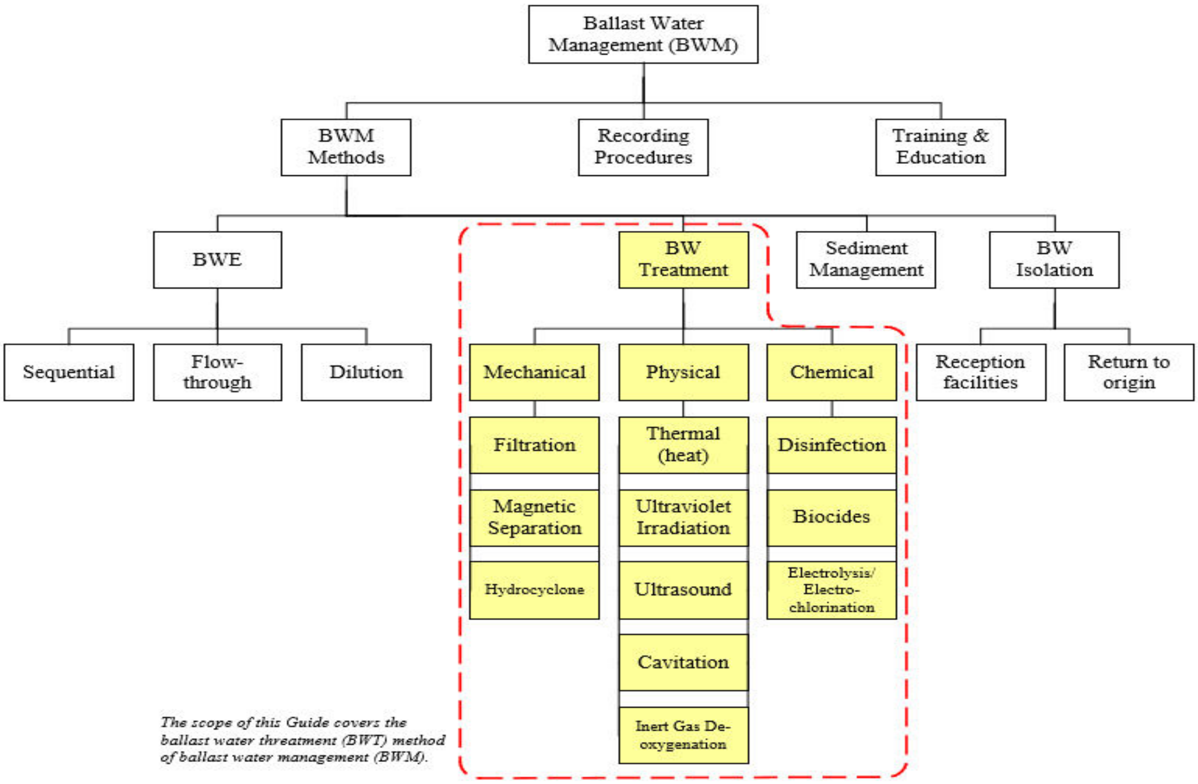


Figure 8: Classification of BWTS [17]

Table 11: Brief description of treatment Methods [8] & [9]

Method	Description	
Mechanical	Filtration	It aims to remove the sediments and particles from the ballast water during the intake, using discs or screen filters
	Cyclonic Separation	It provides enhanced sedimentation by injecting the water at high velocity to impart a rotational motion which creates a centrifugal force, increasing the velocity of particles relative to the water, allowing them to be separated and removed
	Flocculation	It consists in the injecton of a substance (flocculent) to aggregate particles, which are subsequently removed by filtration or magnetic separation
Physical disinfection	UV irradiation	UV light radiations generate photochemical reactions that atack and break down the cell membranes, killing or sterilizing organisms

	UV irradiation + TiO_2	UV light also activates the surface of the titanium catalytc semiconductor, disinfectng ballast water using both photochemical and photocatalytic reactions
	Ultrasound treatment	The effect of ultrasound, generated by a transducer (which converts mechanical or electrical energy into high frequency vibratons) is based on physical and chemical changes in the destruction of organisms and the rupture of cell membranes, resulting from cavitation
	Cavitation	It kills organisms by the high pressure, shear forces, and shock waves generated by the collapse of vapour bubbles induced into the ballast water
	Deoxygenation	It kills organisms by creating severe hypoxia (through lowered pressure via venture or vacuum, or lowered partial pressure via gas sparging with inert gas)
Chemical Disinfection	Different biocides or chemical are used for ballast water treatment including: • Chlorination • Electrochlorination • Ozonation • Chloride dioxide • Peracetic acid • Hydrogen peroxide • Menadione/Vitamin K	

5.2. Comparison between UV and Electro-Chlorination

A comparison has been done between treatment systems using UV and Electro-Chlorination. These two are the most widely used treatment methods used onboard ships and obviously it's the reason for choosing them for comparison. Based on one of the treatment system manufacturer [39] and discussions with experts, various factors are taken into consideration for comparison such as technology, suitability, capital expenditure and operational expenditure, operation and maintenance, safety, hazards associated etc. The comparison is listed in table 12. Both treatment methods have their own advantages and disadvantages, however the compatibility for the vessel has to be considered during the selection process.

Table 12: Comparison between UV & Electro-Chlorination [39]

Parameters	UV	Electrochlorination
Technology	Electrical	Chemical
No. of sensors	Less	More
Hazards	Related to Electrical	Related to Chemical
By-products	No	Yes
Neutralization	Not required for discharge	Required for discharge
Capital Expenditure	Lower	Higher
Suitability	Low volume of ballast water	High volume of ballast waters
Salinity	Works in all salinity	For fresh water, additional salinity required
Power Consumption	Disinfection 0.045-0.063 kW per m^3	Disinfection 0.014-0.042 kW per m^3, Fresh and Cold water treatment ~2-4x Higher
Chemical costs	CIP (Clean-in-place) or Physical Wiper Cleaning	Neutralization chemicals, Supplement for fresh water treatment
Cleaning costs	Automatic Lamp Cleaning, Filter Backwash	Hydrochloric Acid Cleaning of Electrode Scaling, Filter Backwash
Replacement costs	Medium-pressure Lamp Replacement (~3 Yrs)	Electrode Replacement (~5 Year Life)
Planned Maintenance	Inspection, Lamp Replacement	Inspection, Electrode Replacement
Unplanned Maintenance	Manual Filter & Lamp Cleaning	Premature Tank Coating & Seal Failure, Manual Filter Cleaning
Calibration costs	UVI Sensor Calibration	Total Residual Oxidants (TRO), pH, Temperature, Turbidity, Sensor Calibration
Compliance costs	Discharge Sampling Only	Discharge Sampling + Additional TRO & Disinfection By-product Sampling
Training costs	New Operator Training	New Operator Training, Chemical Handling & Safety
Safety costs	No Additional Safety Provisions Required	Hydrogen Gas Management System

5.3. Analysis of Important Limitations

5.3.1. Ultra Violet Transmittance (UVT)

UVT is the ratio of light entering the water to that exiting the water. To explain this further, water with high UVT (e.g., 90%) is relatively clear which allows more UV light to reach the organisms that are going to be treated. As water quality decreases, the UVT is reduced (e.g., 50%) which in turn reduces the amount of UV light that is able to penetrate and provide treatment as shown in figure 9 and table 13. For UV systems, UVT is the most important parameter impacting the effectiveness of the system. In the case of electro chlorination systems, the salinity,temperature and organic content of the water will have great impact on the efficacy of system.

Based on data collected from the manufacturer [40] as shown in table 14, waters around the world have different UV-T values. If the treatment system has design limitation well above the UV-T value of water to be treated, it may not perform to fulfill the discharge standards. For example, a treatment system having design limitation for UV-T as 80%, if it has to treat water from the Shanghai port in China (UV-T: 49%), treatment process can not provide the expected discharge standards. It is important for ship owners to find out if there is any design limitation for the treatment system which they are planning to purchase and if so, they should try to purchase a system with a very low UV-T limitation to operate in waters with low UV-T.

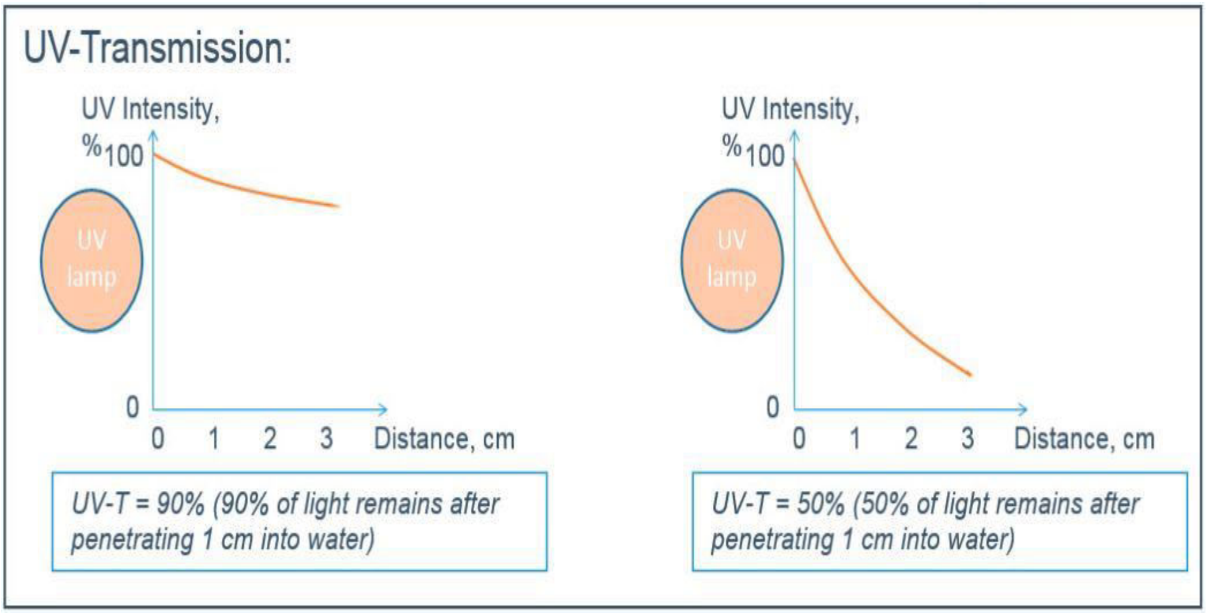


Figure 9: Comparison between two different UVT [40]

Table 13: Comparison of UV Intensity [40]

Distance from UV lamp (cm)	UV-T=90% UV Intensity (%)	UV-T=50% UV Intensity (%)
0	100	100
1	90	50
2	81	25
3	72.9	12.5

Table 14: UVT in different ports [40]

Port	UV-T, %
Shanghai, China	49
Vera Cruz, Mexico	94
Houston, USA	74
New Orleans,USA	54
Hong Kong, China	80
Antwerp, Belgium	66
Lisbon, Portugal	53

5.3.2. Disinfection by-products (DBP)

For vessels using treatment systems based on chemical disinfection, there are more chances of disinfection by-products (DBPs) formation which are thought to have impact on health. New research in this field [18] observed the extent of disinfection by-products (DBP) formation during chemical treatment of ballast water. Chlorine, ozone, peracetic acid (PAA) and chlorine dioxide are widely used in ballast water management systems. They were used to examine and assess DBP formation in different ballast water types such as seawater, brackish water, freshwater. This study include trihalomethanes (THMs), bromate, and haloacetic acids (HAAs). Approximately 50% of the formation of DBPs occurred within 24 hours of the usual 5 days ballast water treatment holding time.

The research show several factors that influence DBP formation in saline waters: salinity, dissolved organic matter (DOM) type/concentration, oxidant type/dose and temperature. Particularly salinity seems to influence the bromide concentration and brominated DBPs dominated in high bromide-containing waters.

Temperature shows diverse and limited influence on DBP formation. But, many treatment system manufacturers using chemical method, are trying to prove their product doesn’t deliver any harmful by-products. Ship owners opting to purchase chemical based treatment systems have to convince themselves about this issue by having discussions with treatment system manufacturer before selecting and installing the system. However, many treatment system manufacturers using active substances argue that their system doesn’t pose any threat to the health and environment.

5.3.3. Deoxygenation and Corrosion Effect

Deoxygenation is a process of reducing the pressure in the space above the water by means of vacuum along with inert gas injection. In this process oxygen is removed from the water, which ultimately asphyxiates the micro-organisms. The elevated level of CO_2 reduces the pH level of the water, which is fatal to aerobic organisms. Deoxygenation will kill organisms with great efficacy in most water conditions, but the main disadvantage is that it requires a hold time of four to five days to allow for full deoxygenation to occur. In the absence of oxygen, bacteria will thrive in the system and these organisms are highly corrosive.

N.E.I Treatment System [41] has come up with Venturi Oxygen Stripping (VOS) System which uses deoxygenation and cavitation to ensure compliance with IMO's ballast water discharge standards. This system induces a low-oxygen environment within the ballast tanks which eliminates harmful aquatic organisms, without the use of active substances. It assists in protecting the ship's ballast tank coatings against degradation and corrosion of steel surfaces.

As per this manufacturer, the VOS System removes 95 percent of the dissolved oxygen in less than 10 seconds from ballast water by mixing very low-oxygen inert gas with natural water as it is drawn into the ship as ballast. In a process similar to evaporation, the inert gas strips the water of its dissolved oxygen:

- Stripping Gas Generator (SGG) provides low-oxygen inert gas to the Venturi Injectors which are shown in figure 10.
- Ballast water passes through the Venturi Injectors, where it is mixed with the inert gas from the SGG which is shown in figure 11.
- A cavitation process with the inert gas creates a micro-fine bubble emulsion in the water & the dissolved oxygen diffuses from a liquid phase to a gas phase.

During discharge below the water line, the ballast water once again passes through the Venturi Injectors, where air is re-introduced back into the water before release into the environment. As water exits the ballast tanks, the tanks are filled with inert gas in order to maintain a low-oxygen condition, which has two key benefits:

- When deoxygenated water is once again drawn into the ballast tanks, it will not reoxygenate.
- Coating life is extended and steel corrosion reduced by up to 84 percent.

As the vessel life increases, the coating condition of ships using VOS method falls gradually but the vessel is expected to maintain good rating by class survey throughout the life period of the vessel as shown in figure 12. It is compared with the vessels not using VOS which has premature coating failure and requires steel renewal, sandblasting and re-coat of the same. Using two different steel samples, manufacturer displays the effect of corrosion with and without using VOS as shown in figure 13 & 14.

Figure 10: VOS Venturi Injectors [41]

Figure 11: VOS Stripping Gas Generator [41]

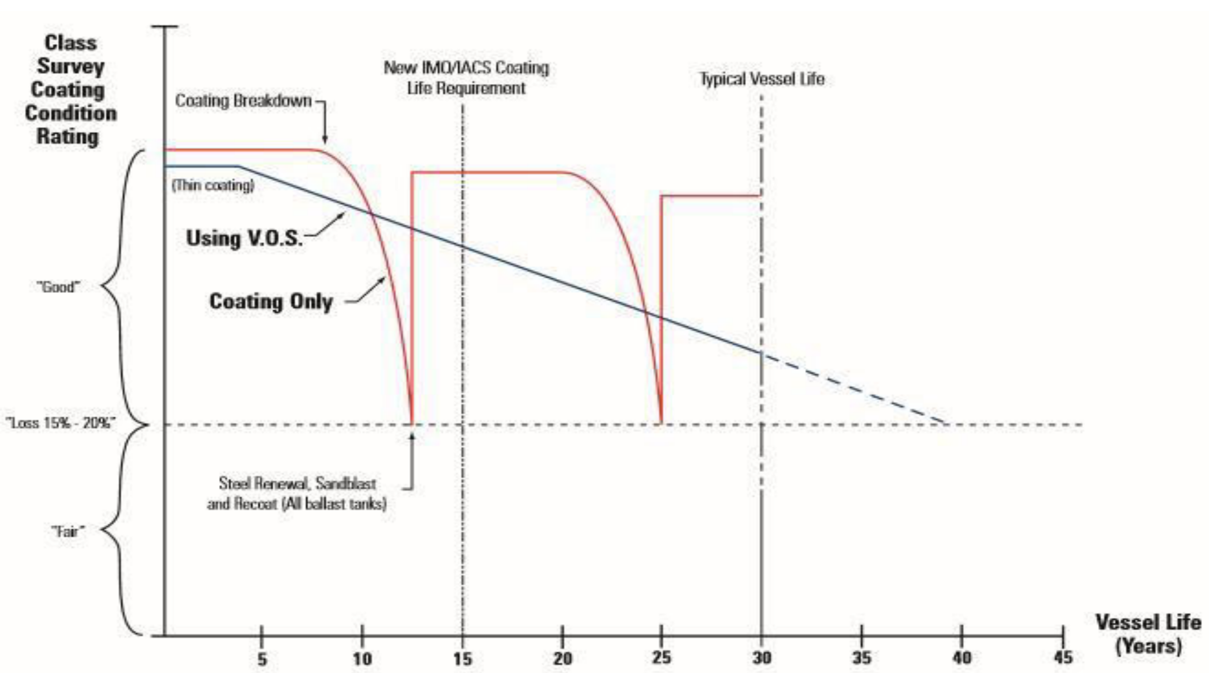


Figure 12: Coating condition rating Vs Vessel life [41]

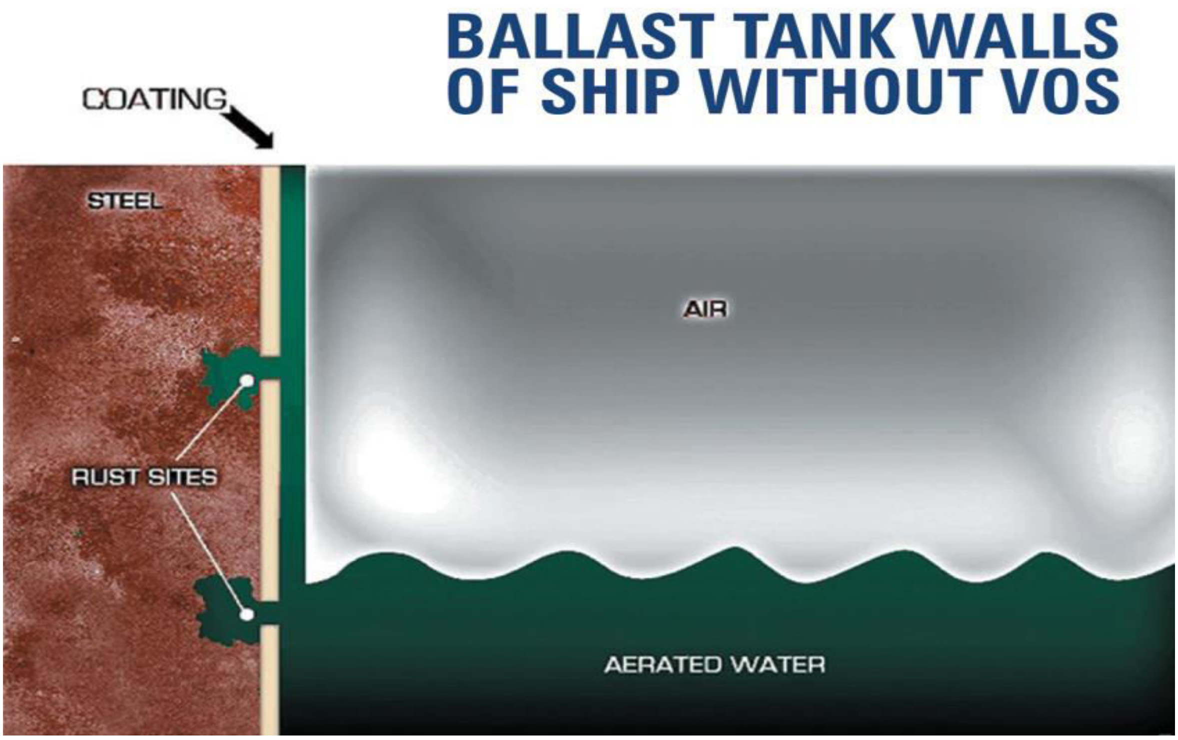


Figure 13: Ballast tank wall condition without VOS [41]

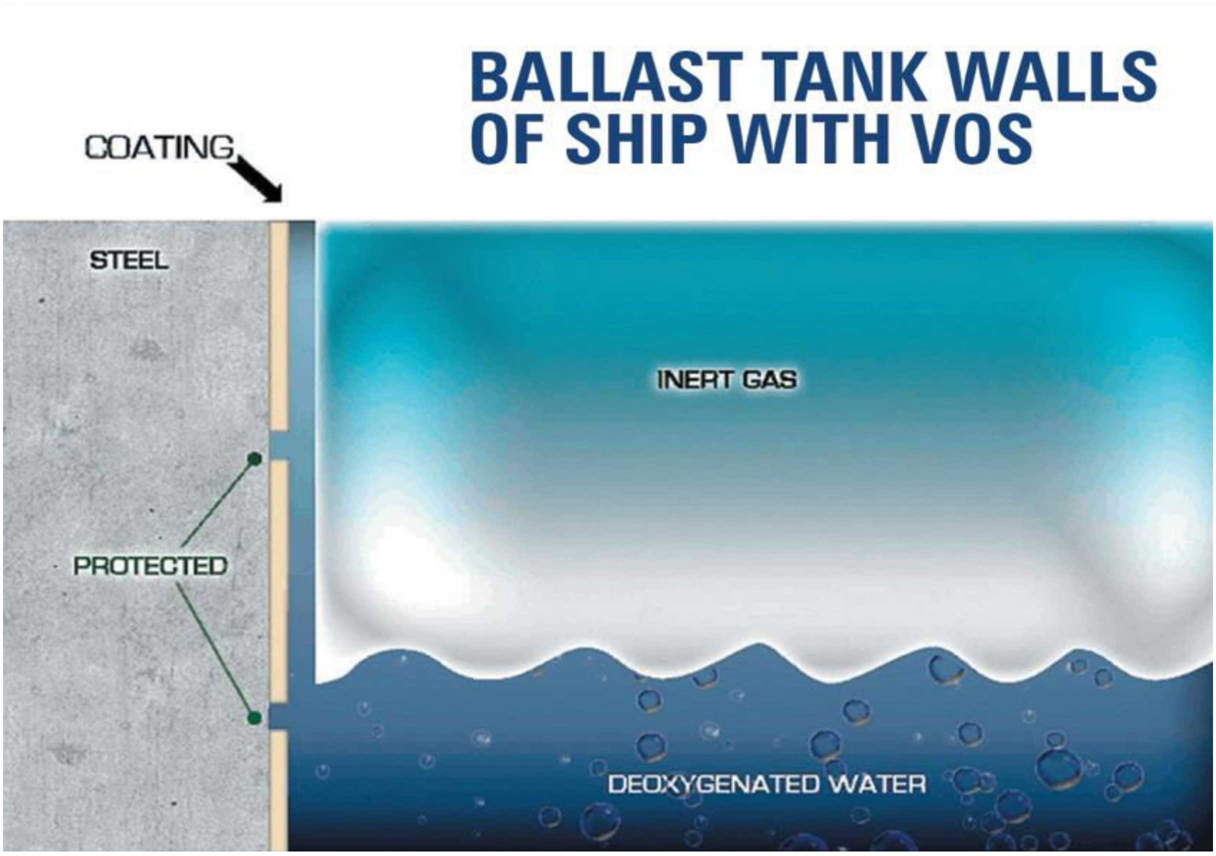


Figure 14: Ballast tank wall condition with VOS [41]

5.4. Alternate BWMS

5.4.1. Port Reception Facilities

Ballast Water can be received in port through the reception facilities. This system can be an alternative to installing treatment system onboard ships. BWMC, B.3.6 [1] states that the regulations of this convention do not apply to ships which have opted to such facilities.

In the IMO Guidelines for Ballast Water Reception Facilities G5 [Resolution MEPC.153(55)] following general requirements are mentioned for the provision of such facilities.

(a) A ballast water reception facility should be capable of receiving ballast water from ships so as not to create a risk to the environment, human health, property and resources arising from the release to the environment of Harmful Aquatic Organisms and Pathogens. A facility should provide pipelines, manifolds, reducers, equipment and other resources to enable ships wishing to discharge ballast water in a port to use the facility. The facility should provide adequate equipment for mooring ships using the facility and when applicable safe anchorage.

(b) Each party shall report to the organization and, where appropriate, make available to other Parties, information on the availability and location of any reception facilities for the environmentally safe disposal of ballast water.

5.4.2. No Ballast Ship Concepts (NOBS)

There are three projects in which the concept of a ship with zero ballast water has been developed (GESAMP Reports, 2011): (i) Delft University of Technology (DUT)-Monomaran Hull (ii) Det Norske Veritas (DNV) – Volume Cargo Ship (iii) Daewoo Shipbuilding & Marine Engineering (DSME) – Solid Ballast Ship. Also, Ballast free ship concept (SNAME, 2004) has been developed by replacing ballast tanks with longitudinal structural ballast trunks that surround the cargo holds below the ballast draft. These trunks are connected to an intake plenum near the bow and a discharge plenum near the stern. These ballast trunks are flooded in the ballast condition to decrease the ship's buoyancy.

5.5. Innovative BWMS

5.5.1. Invasave

Damen InvaSave [42] is an external ballast water treatment unit designed primarily for use in ports. The system shown in figure 15, receives ballast water from inbound vessels and treats it to IMO D-2 standard to eliminate potentially invasive marine micro-organisms. It can also deliver water treated to the same standard to outbound vessels. Its mobile, containerised format means that it can be operated from the dockside or from onboard a vessel alongside. Also, it can be tranported by trucks from one location to other location. It’s based on continuous filtration combined with ultraviolet treatment.

Figure 15: Damen-Invasave 300 [42]

5.5.2. Ballast Water Containers

The BWC Bute mobile ballast water management system [43] is designed to be used in a number of ways - as a permanent deck mounted retrofit, as a mobile deck mounted system, or as a port based shared system. This project to containerise a Ballast Water Management System may allow easier compliance for vessels with limited space.

Deck Mounted-Permanent Installation: For vessels with limited free space available within the machinery space, a deck mounted, containerised ballast water management system as shown in figure 16 represents an efficient and economic means of compliance. This system can be installed as a semi-permanent retrofit onto the deck of the vessel, with simple pipe and electrical modifications required to connect this system with the vessel's systems.

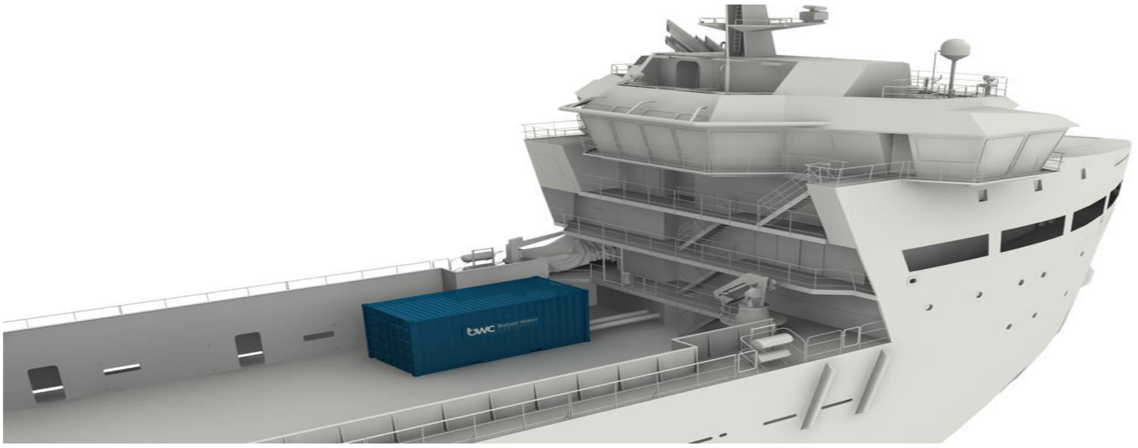


Figure 16: Deck Mounted-Permanent Installation [43]

Deck Mounted-Shared Mobile System: For vessels operating on fixed routes, or vessels seldom trading internationally, the use of a shared mobile ballast water management system as shown in figure 17 represents a significantly more cost-efficient method of compliance than retrofitting each vessel in the fleet. This system can be simply lifted on and off each vessel as required, to treat the ballast water prior to sailing or on arrival.

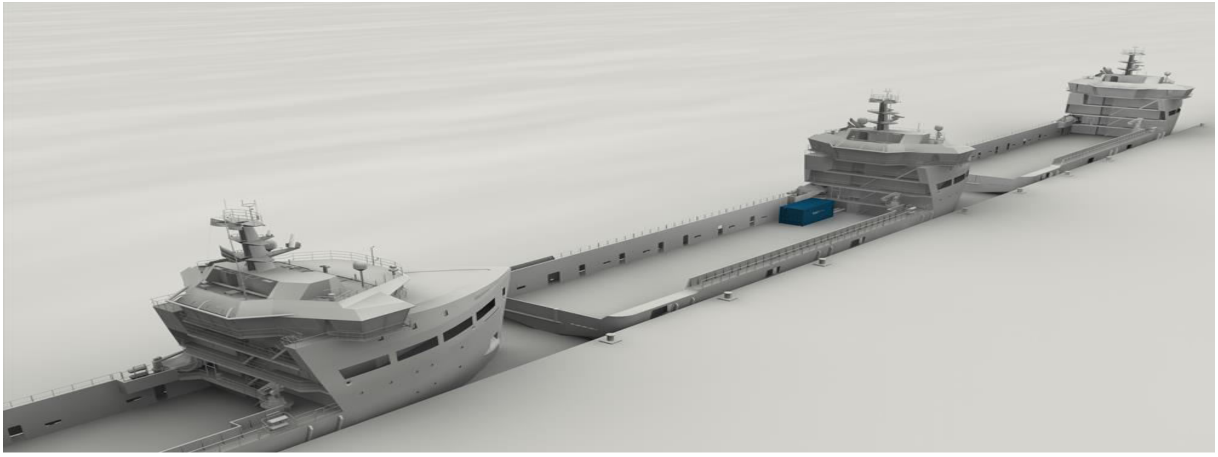


Figure 17: Deck mounted-shared mobile system [43]

Port based-Shared Mobile System: For vessels on a fixed route between a number of ports, a port based mobile system offers a cost effective means of compliance, particularly where a number of vessels trade in and out of the same ports. This system shown in figure 18 can be installed on the quayside, offering vessels the ability to quickly and easily hook up to the system, to treat their ballast water prior to sailing or on arrival.

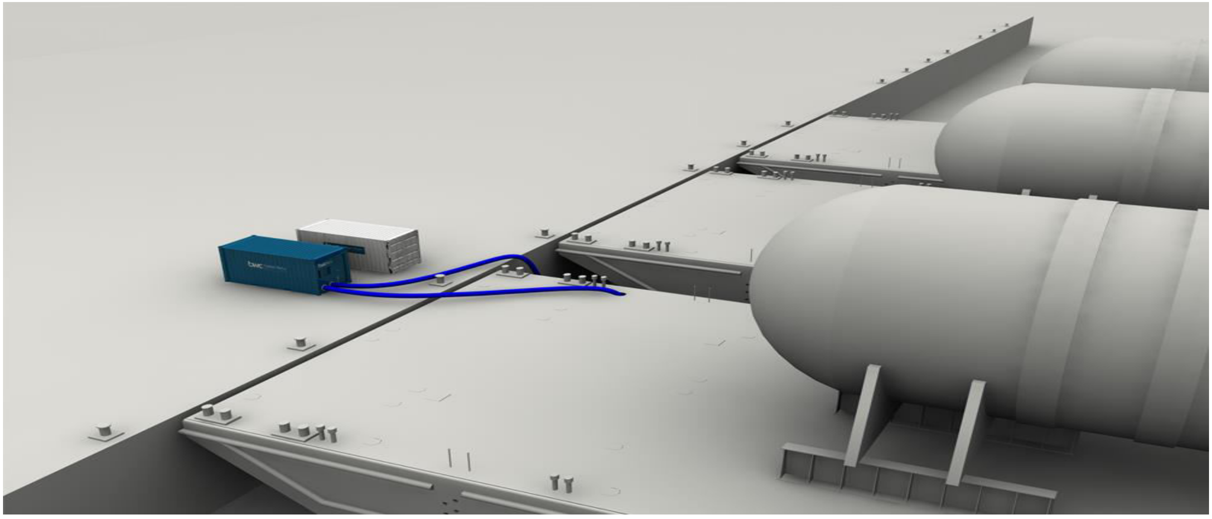


Figure 18: Port based-share mobile system [43]

5.5.3. Envirocleanse inTank system

Envirocleanse has developed a Ballast Water Treatment System (BWTS) in collaboration with Glosten Marine to prevent the transfer of invasive aquatic species via ship's ballast water [44]. This system has patented nozzles inside the ballast tanks and a robust hypochlorite generator as shown in figure 19. In vessels using this system, uptake of ballast water into the tanks takes place without any change to existing operating procedures. Treatment process occurs during the voyage. A small portion of ballast water is suctioned from one ballast water tank at a time, passed through the circulation module, and returned to the same ballast water tank through in-tank mixing nozzles. This system ensures disinfection of ballast water tanks and piping through the application of a targeted CT, which is the product of disinfection Concentration (in milligrams per liter, mg/L) and disinfection contact Time (in hours) measured as total residual oxidant (TRO). Key benefits: (a) No filteration requirement, (b) Less time in dry-dock, (c) Minimal impact in Engine Room, (d) Low power consumption, (e) Low cost of the system

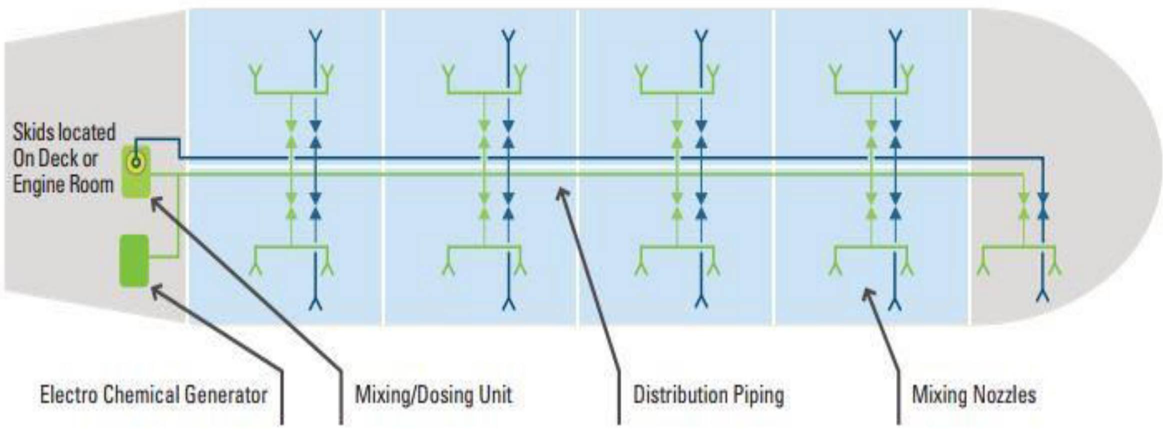


Figure 19: Envirocleanse inTank system [44]

5.6. FACTORS FOR THE SELECTION AND INSTALLATION

Based on discussions with experts from the industry, internship experience and suggestions from International Chamber of Shipping [19] following important factors should be taken into consideration by ship owners or any other organizations who are involved in the selection and installation of ballast water treatment system.

(a) Necessity for the BWTS: Based on the vessels trading area, ship owner should check whether the vessel is applicable to get an exemption from the regulations. If the vessel is operating in fixed route and the ports are equipped with shore based reception facilities, then owner can consider those facilities. If the facilities are not available in the ports, ship owner has to opt for the treatment system.

(b) Vessel's trading pattern: If the vessel is intending to operate US water, it must have USCG approval for the treatment system. If the vessel is not intending to operate in US waters, only IMO type approval from an administration will be sufficent .

(c) Type approval: It will be better for the ship owner to consider BWTS approved in accordance with the Revised G8, 2016 Guidelines. In few years, it will become mandatory to have treatment systems onboard ships which have received type approval based on those guidelines.

(d) Status of type approval: Ship owner should ask for details concerning current BWMS approvals and status of USCG approval to the manufacturer. If the manufacturer intends to get USCG approval they should be able to provide a copy of the USCG Letter of Intent and a copy of the contract between the company and the Independent Laboratory (IL) approved by the USCG, as well as provide the current status and results of their testing to date.

(e) Limited operating conditions: Ship's intended area of operation and water parameters should be kept in mind while selecting the BWTS. It's important to check whether BWMS being considered has 'Limiting Operating Conditions' (LOC) related to salinity and water temperature which can restrict the ballast water to be treated by the system. Also, it's better to check whether the system has been tested and approved for effective performance in the following salinity ranges: fresh water (< 1 PSU), brackish water (10 – 20 PSU) and sea water (28 – 36 PSU). In addition to that, check that the system is effective in treating ballast water with temperatures across the full range of 0°C to 40°C (2°C to 40°C for fresh water). Temperature range is an important factor especially for vessels intend to operate in polar regions.

(f) System design limitations: Ship owner must be aware of any 'System Design Limitations' (SDL) including water quality (e.g. UV transmittance, levels of suspended solids etc.) and/or operational parameters.

(g) Details of type approval certificate: If the BWMS is approved as per 2016 G8 Guidelines or the BWMS Code, then the type approval certificate should mention any LOC relating to ballast water salinity or temperature, and details of any SDL which can affect the efficacy of the system. USCG Type Approval certificates should contain details of any operational limitations imposed.

If the BWMS has been approved as per earlier version of the G8 Guidelines, adopted by resolution MEPC.174(58), then the LOC and SDL information may not be mentioned on the type approval certificate and it must be requested by the shipowner from the manufacturer. In addition to that, shipowners should request the following details from the manufacturer: (a) where the original biological testing for IMO approval was conducted (b) Copy of test report with results.

(h) Contingency measures: Ship owners can discuss about contingency measures with the manufacturer for example, Low UV transmittance or LOC and SDL parameters are exceeded due to area of operation and waters to be treated.

(i) Treatment capacity: Suitable treatment capacity has to be determined by carefulr careful consideration of number of ballast pumps and redundancy of the system in case of malfuntion. After evaluating the required treatment capacity, it is recommended to find out various options provided by the manufacturer and their history in terms of capacity and efficacy of the system.

(j) Treatment mode: Ship owner must pay attention to mode of operation, whether treatment is carried out only during uptake or uptake as well as discharge, to ensure that treatment system compliance at all times. There is a chance of regrowth of organism during the voyage, so it's recommended to choose for sytems treating ballast water during uptake as well as discharge.

(k) Ship specific factors: In the case of bulk carriers with top side tanks discharged by gravity, it is a challenge to ensure adequate treatment of ballast water to comply with D-2 standard considering re-growth of organisms. In the case of chemical systems, even though this issue is not of major concern, it is a requirement to neutralize residual oxidants during the discharge process. In the case of tankers deciding to install the treatment system on deck, the treatment system must be explosion-proof (Ex) certified and in the case of ships with anti-heeling system, extra precaution is necessary with respect to pipeline and valves arrangement.

(l) Hazards: Consider various hazards such as evolution of hydrogen and ozone, exposure to chemicals and their mitigation during the selection of treatment system.

(m) Service network: Also, consider the reliability of BWMS supplier and the financial strength of their operations, service network (including supplier of active substances) and ability to provide, both in the short and long term, technical support globally.

(n) Simplicity of the system: Consider the simplicity of the system interms of operation and maintenance, requirements for crew training and contingency measures that can be adopted in case of system failure or the discharge fails to meet the compliance standard, despite the BWMS being operated and maintained correctly.

(o) Sampling arrangement: The sampling arrangement of BWMS should be in accordance with Guidelines for Ballast Water Sampling G2 [MEPC.173(58)] and also ensure that the sampling points are easy for access and maintenance.

(p) Verification of biological efficacy: There is no statutory requirement to verify the biological efficacy of the system soon after installation and commissioning of the system. Even though, it is recommended to include this as a requirement while signing the contract with manufacturer/shipyard. If the samples fail to meet the D-2 standard, the reason should be ascertained, corrective action has to be taken and the process must be repeated until reliability of the system is proven interms of biological efficacy.

(q) Additional factors: In addition to those factors mentioned earlier, ship owner can consider various other factors during discussion with manufacturers which are:

- If the system price is negotiable, even small discount could be more beneficial for ship owners with large fleet
- Operational cost of the system
- Space needed and the flexibility of installation
- Backpressure issues for ballast pumps with large discharge capacities
- Compatibility between BWMS automation system and the ship's automation system.
- Start-stop procedures including contingencies for disinfection component failures and alarm management
- Scheme of installation
- Scope of supply (including laser measurements)
- Effect on tank coatings especially for chemical systems
- Supply of test kit for monitoring the compliance of discharge standards

5.7. IACS Unified Requirements for Installation of BWMS

International Association of Classification Societies (IACS) has developed unified requirements (UR) [20] for installation and isolation arrangements of BWMS. The purpose of this UR is to uniformly implement the installation of BWMS by IACS members: (a) where an application for approval for the plans of BWMS is made on or after 1 January 2017 or (b) which is installed in ships contracted for construction on or after 1 January 2017.

Based on treatment method, there can be two different arrangements for ballast water management system onboard ships. They are,

(a) BWMS which doesn’t require after treatment: In this arrangement shown in figure 20, ballast water is treated only during uptake, it’s not required to treat the ballast water during discharge.

(b) BWMS which requires after treatment (Injection type): In this arrangement shown in figure 21, ballast water is treated during uptake and discharge.

Following are some of the general requirements for BWMS as mentioned in UR [20]:

(a)The BWMS has to be operated at a flowrate within Treatment Rated Capacity (TRC) range specified in the type approval certificate of the issued by the flag administration.

(b) The BWMS has to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected.

(c) Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in hazardous areas. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

(d) In the case of BWMS operating method involves the generation of a dangerous gas certain requirements has to be followed.

(e) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

(f) For tankers, the interconnection between ballast piping in hazardous areas and non-hazardous areas may be accepted if an isolation arragement is provided either by spool piece, liquid-seal or double-block valve as shown in figure 22.

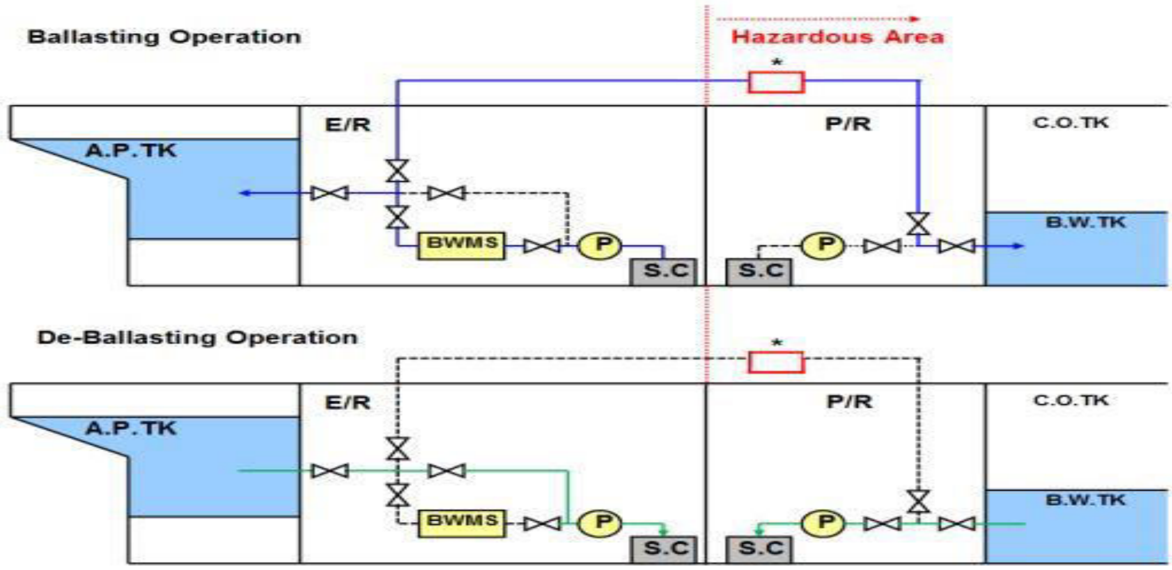


Figure 20: BWMS which doesn't require after-treatment [20]

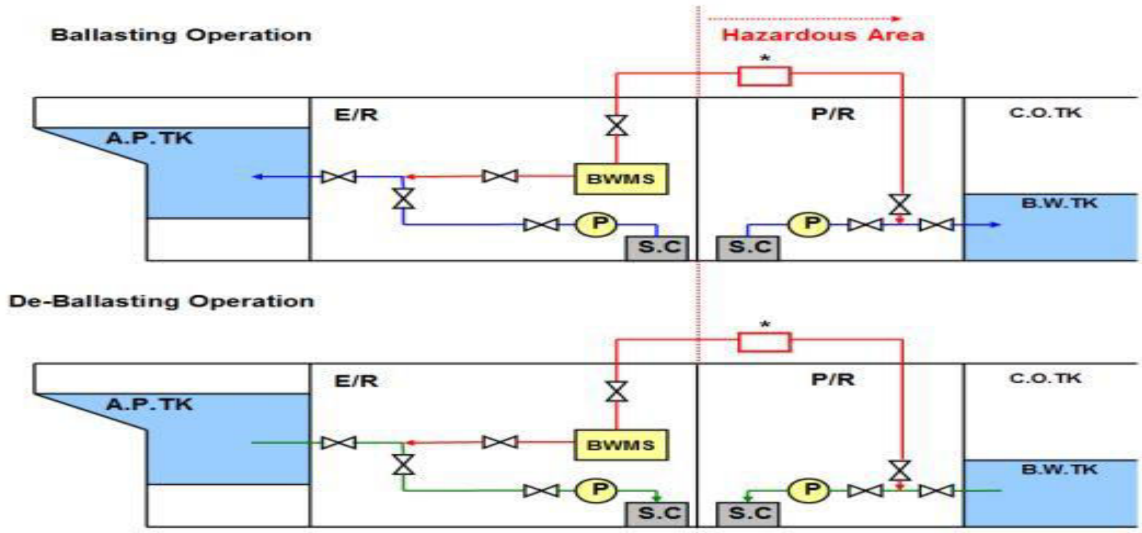


Figure 21: BWMS which requires after-treatment [20]

*Appropriate Isolation Means: Two (2) screw down check valves in series with a spool piece or a liquid seal, or automatic double block and bleed valves as shown in figure 22.

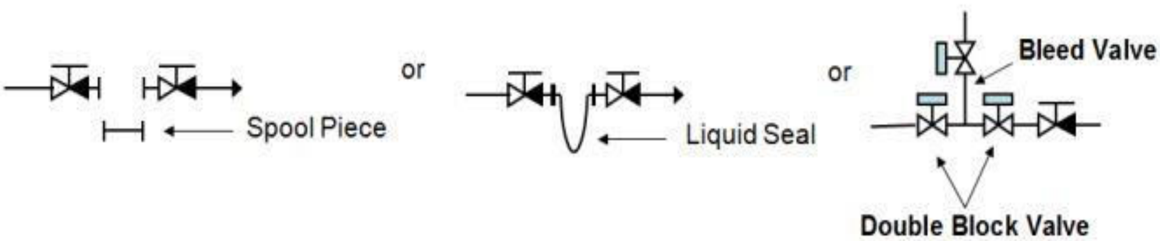


Figure 22: Means of Isolation [20]

This page is intentionally left blank.

6. SEDIMENTS MANAGEMENT

IMO Technical Guidelines G1 deals with the general requirements, provisions, capabilities and training requirements for the sediment reception facilities. But, these guidelines does not state clearly any standard treatment or disposal procedures for ballast tank sediments.

General Requirements for Reception facilities: (a) IMO BWMC [1], Article 5 requires that the operation of reception facilities should not cause unnecessary delay to ships and they should provide safe disposal arrangement for sediments to avoid any damage to the environment, human health, property or resources. (b) These facilities should provide resources to enable their use by all ships wishing to discharge sediment from ballast water tanks. (c) Concerned parties of the BWMC should report to IMO and they should keep the information and location of any reception facilities readily available for the environmentally safe disposal of sediments.

Removal and disposal of sediments can be carried out according to BWMP and applicable law such as international, national and local regulations either at sea or ports/shipyard reception facilities and also it can be stored onboard vessels. It is important to not allow sediments entering sea during the removal and disposal at ports/shipyards, necessary risk assessment should be carried out before starting this process.

Even though, actual name of the ballast water management convention mentions about control and management of sediments, they are usually ignored aspect during the implementation of the convention. If the sediments from ballast water tanks are not removed before installing the ballast water treatment system, it will definitely reduce the efficiency of the treatment system and the discharge standard can not be guaranteed. During type approval process, land based testing doesn't deal with sediments and ship board testing is done on new build or vessels which had their tank cleaned.

USCG has specific rules [13] which require sediment disposal procedures to be included in ballast water management plan and record keeping must be necessary if the sediment is discharged. In addition to that anchor and anchor chains must be rinsed when they are retrieved to get rid of organisms and sediments at their places of origin.

This page is intentionally left blank.

7. RETROFITTING SHIP

Retrofitting: Retrofitting is defined as [53] the installation onboard ships of state-of-the-art or innovative components or systems and could in principle be driven by the need to meet new regulatory standards or by the ship owner interest to upgrade to higher operational standards. Retrofitting is not a complicated process if it has been planned well before set deadline, though some of the retrofitting systems require higher degree of modification and arrangement of existing ships particularly spaces such as Engine room. The usual life cycle of a ship is around 25 years, there will be many new developments in technology and regulations at international, national and local level during this period which requires the update of systems onboard ships. Most of the time, it becomes mandatory for the ship owners to retrofit ships. The main challenge for ship owners is to select a suitable system for retrofitting ships and install them economically within short time.

The retrofit installations will require significant investments from shipowners and operators and early planning will be essential in this regard. A carefully planned and executed retrofit project saves money and minimizes installation time, while ensuring legislation compliance, safe operation and optimum maintenance. There are various stages in this process as shown in figure 23 which mainly includes four distinct phases to optimize ship retrofits. They are (a) System selection (b) Preliminary design (c) Detailed design (d) Installation

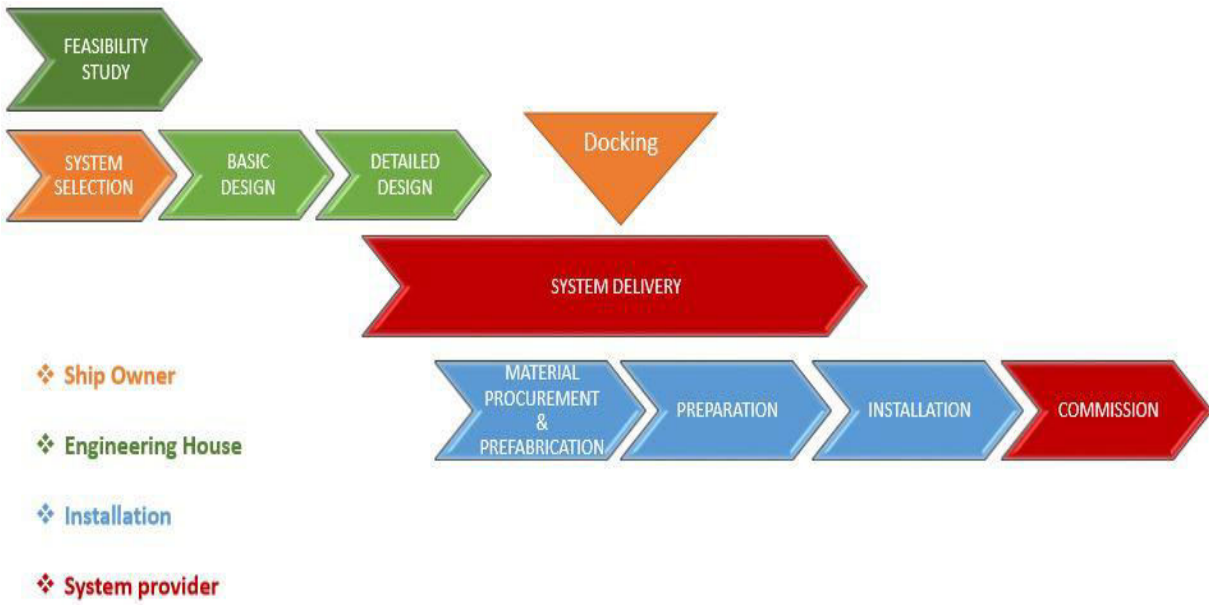


Figure 23: Retrofitting process [21]

7.1. System Selection

Shipowners around the world are in different mentality when it comes to ballast water treatment system compliance. Some of them are pro-active to comply where as others are not, but proper selection of ballast water treatment system and planning the retrofit will save time and costs. Ballast Water Managemnet convention has entered into force on 8th september 2017. Consequently, ship owners have to install them onboard as early as possible and comply with the convention. Usually, they send enquiry to design offices or service providers requesting them to find suitable system for their ship. Some of the treatment system manufacturers are directly providing this service with or without the help of specialist companies. Ship Owners who are already familiar with treatments systems usually prepare a list of systems they would like to have onboard their vessels and then request the design office to find the best solution from that list. Once the query has been received from ship owners, design office usually request for set of ship documents (table 15) from them.

Table 15: List of ship documents required

S.No.	Documents/Drawings
1	Ship's technical particulars
2	General Arrangement Plan
3	Tanks Plan
4	Loading manual
5	Hull structure drawings (except superstructure, bow and stern structure)
6	Hydraulic system (remote butterfly valves - ballast system)
7	Instrument air system
8	Inert gas system (for tankers)
9	SW cooling system
10	Fresh Water(Low Temperature) cooling system
11	Technical water system
12	Automation and Service Compressed Air Diagram
13	Power Distribution Schematic Diagram
14	Short Circuit Calculation
15	Main Switchboard Schematic Diagram
16	Main Switchboard Arrangement Plan
17	Electrical Sub-Distribution Schematic Diagram
18	Ballast Electrical Control System
19	Electrical Installation of Fire Alarm System
20	Ship Alarm and Monitoring System
21	Installation of ER and Cargo Spaces Lighting System
22	Electrical Equipment Arrangement Plan
23	Cable Routing Plan

This list is not limited, it may include more or less number of documents depending upon the type of ship, location of installation and various other factors. After receiving all the necessary documents, design office conducts feasibility study to find out the best treatment system that suits better for the particular ship or fleet.

7.1.1. Feasibility Study

In this feasibility study, vehicles carrier M.V. Main Highway as shown in figure 24 has been taken into consideration and the ship particulars are given in table 15. Ship owner has signed a contract for design work with Westcon Design Poland for retrofitting BWTS. This vessel has undergone scheduled dry-docking at Marine Ship Repair Yard Gryfia in Szczecin, Poland and ballast water treatment system installation has been carried out during that period. The purpose of feasibility study is to assess the practicality of the proposed ballast water treatment system considering various factors such as cost, technology and time required for installation etc. Personnel from the design office have carried out an initial inspection of the vessel few months before the scheduled dry-docking, then the feasibility study and basic design has been developed. After getting necessary approval from owners and class society further engineering work done to proceed for installation as soon as the vessel arrived at dry-dock. The vessel particulars and organizations involved are mentioned in table 16.

Figure 24: M.V. Main Highway at MSR Gryfia, Szczecin

Table 16: Ship Particulars [22]

Description	Particulars
Vessel Name	M.V.Main Highway
Type	Vehicles Carrier
Flag	Cyprus
Owner/Manager	Stargate Ship Management GmbH
Scheduled Dry-docking -Yard	MSR Gryfia, Szczecin
Design for BWTS Installation	Westcon Design Poland
Length Overall	100 m
Breadth	20 m
Year Built	1998
GT	9233
DWT	3347
Bilge, Ballast & Fire Pumps (2 No.'s)	200/130 m^3/h – 4.3/5.2 bar
Stripping Bilge, Ballast & Fire Pump (1 No.), Piston type	50 m^3/h – 6.0 bar

Ballast water treatment system capacity has been chosen as 250 m^3/h which is meant for only one pump operation. This capacity matches with available standard equipment and it can be attained by the ballast pump. Ship owner has opted to use a system based on UV treatment method. Based on ship owner's request, initially a list of ballast water treatment systems from 20 different manufacturers has been prepared by design office and then it has been sent to ship owner. Out of which ship owner has selected the following manufacturers based on their knowledge and previous experience. Later on, design office contacted these manufacturers and received price quotation from them and it is mentioned in the following table 17.

Table 17: Price of selected systems [22]

S. No.	Systems selected by ship owner	Price (Euros)
1.	GEA, BallastMaster ultraV 250, Germany	120600
2.	TROJAN MARINEX, BallastMaster marineX 250, Canada (Partner in Europe-GEA)	103800
3.	WARTSILA, Aquarius UV 250, Finland	87000
4.	PANASIA, GloEn-Patrol P250, Korea	152900

7.1.2. Brief description of selected systems

GEA: The BallastMaster ultraV [45] shown in figure 25, is based on UV treatment method with 2-stage system. In the first stage, a mechanical filtration process removes all organisms and sedimentary particles larger than 20 microns. The filter module is cleaned automatically by vacuum extraction (self-cleaning process). In the second stage, the pre-filtered ballast water is then disinfected by UV-C radiation. The monochromatic UV-C radiation eliminates organisms such as bacteria or phytoplankton. This system utilizes more number of UV lamps and the ballast water has to pass through filter and UV treatment unit during uptake and discharge as well. This system has IMO Type Approval and USCG AMS acceptance letter.

Figure 25: GEA BallastMaster [45]

Trojan-Marinex: The BallastMaster marineX shown in figure 26 & 27, is a product from Trojan Technologies who are in partnership with GEA for European market. This system has 2-step mechanical and physical system for treating ballast water. Main features of this system [46] are single compact arrangement for filter and UV chamber and low power requirement. Also, this system is fitted with patented TrojanUV Solo lamp. Low-pressure lamps offer high efficiency and long lamp life. Medium-pressure lamps have higher UV output. As per manufacturer, this TrojanUV Solo Lamp combines the best features of both.

Figure 26: A-BallastMaster marineX [46]

Figure 27: B-BallastMaster marineX [46]

Wartsila: The AQUARIUS UV shown in figure 28, is a modular system with two stages for treating ballast water. In the first stage, filtration takes place with 40 micron screen and in the second stage UV light is used to disinfect the organisms by altering their DNA structure (or RNA in the case of viruses) disrupting growth and reproduction. This system can be operated automatically with the minimum of operator input using a Programmable Logical Controller (PLC). The modules can be configured to enable vessels of various types and trading patterns and of differing ballast water requirements and flow rates to operate on salt, fresh or brackish water.

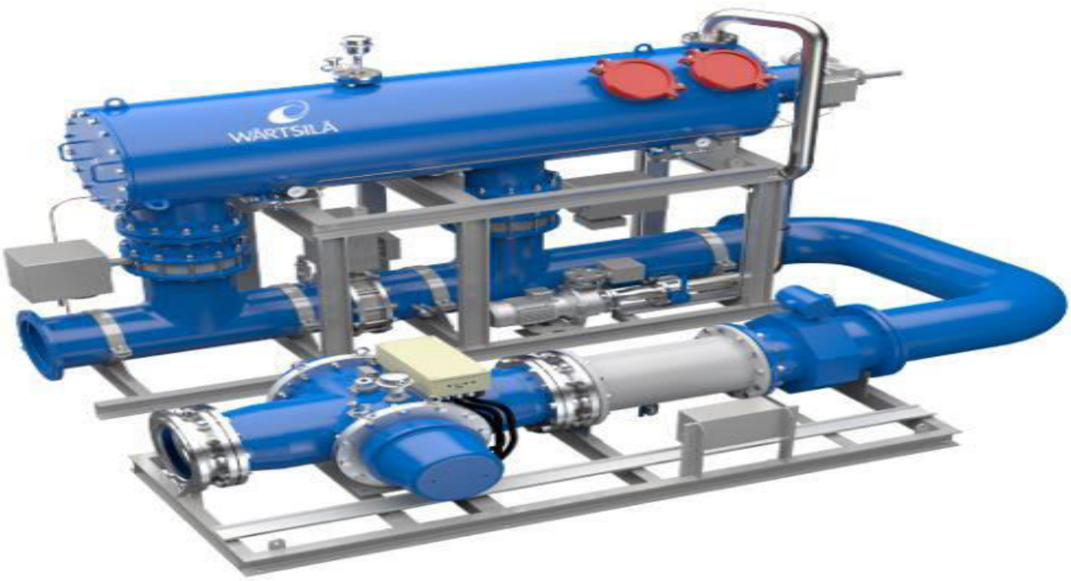


Figure 28: Wartsila AQUARIUS [47]

Panasia: The GloEn-Patrol system shown in figure 29, is a combined filtration unit with 50㎛ filter element and medium pressured UV lamps. This system has four type of flow arrangement and automated back-flushing of filter and cleaning of UV lamps. This system has IMO type approval and also USCG Alternate Management System (AMS) acceptance for all water qualities: fresh water, brackish water and marine water.

Figure 29: Panasia GloEn-Patrol [49]

7.2. Preliminary Design of BWTS

In this section, Preliminary design for Wartsila system is shown in figure 30 and other three systems are attached in the Appendix G, H & I. In this system, discharge from ballast pumps and stripping pump passes through the filter, flow meter and then to the UV unit. During discharge phase, by-pass of filter can be used. Filter is fitted with back-flushing pump arrangement for regular cleaning and discharge of back-flushing is discharged through overboard valves. Prelimnary design of all treatment systems selected for the study are almost appear similar to each other except minor difference interms of arrangement. However, Wartsila system is simple as compared to other systems and it doesn't require the treatment during discharge phase, treatment during uptake is sufficient to attain the discharge standards.

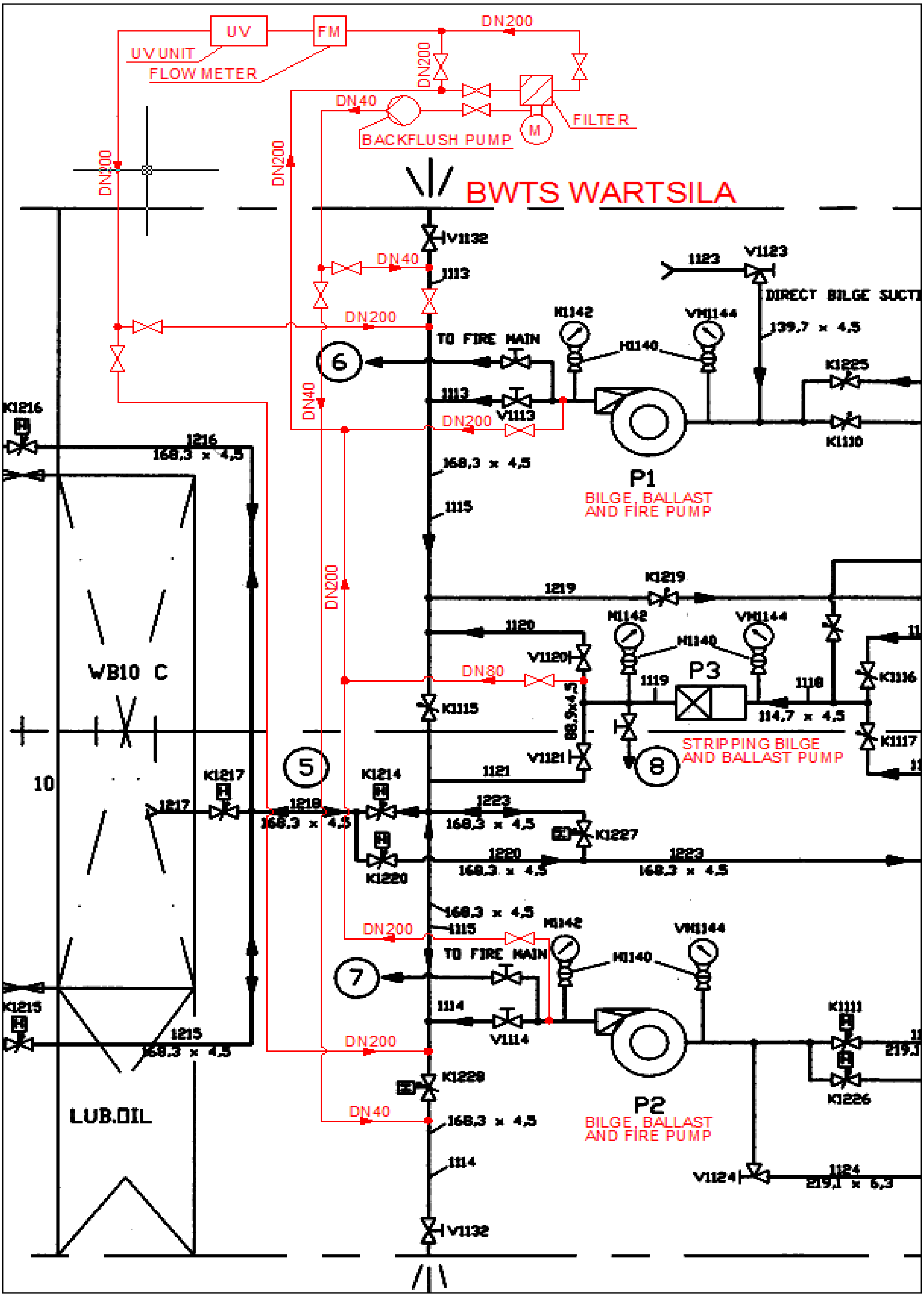


Figure 30: Preliminary Design for Wartsila AQUARIUS System [22]

7.2.1. Location

During the intial survey of vessel, it has been decided to consider two locations for the purpose of feasibility study. This particular vessel is a vehicle carrier, the main open deck is far away from the existing ballast water system, so it was not considered for the study, but the Engine room and cargo hold are taken into consideration for the study.

(a) Engine Room: It has been decided to select a location in the Engine Room which has less or no impact on the exisiting arrangement. To install the BWTS on Deck 3 starboard side next to Engine Control Room which is not far away from the existing ballast system. But, a new platform has to be built on this deck to install the system. The treatment system location in Engine Room in different views are shown in figures 31, 32, 33 & 34.

(b) Cargo hold: To install the BWTS in a new compartment adjacent to Engine Room but located in Cargo Hold on Deck 1 as shown in figure 35. There will be considerable loss of cargo space if this location is opted for the treatment system. The connection through the opening in bulkhead between ER and compartment will be small and it will be difficult for the arrangement. Also, it’s not possible for equipment transportation from compartment to Engine Room or cargo hold without cutting off the bulkhead incase of major repair or replacement.

Both options mentioned above does not require any cut-out in the hull for transporting treatment system, so the retrofit can be carried out without dry-docking. But, in this case, the vessel is already due for scheduled dry-docking and the installation of BWTS has been planned along with scheduled dry-dock work. Following are the standards considered by design office based on experience and requirements.

- Two control panels (Engine Room & Deck office)
- Pipe size DN200, Steel galvanized, flow velocity of 2.2 m/s at 250 m^3/h
- Flow meter and regulating valve
- Positioning of inlet and outlet pipes above the treatment system (to ensure the system is always filled with water to avoid UV lamps overheating)

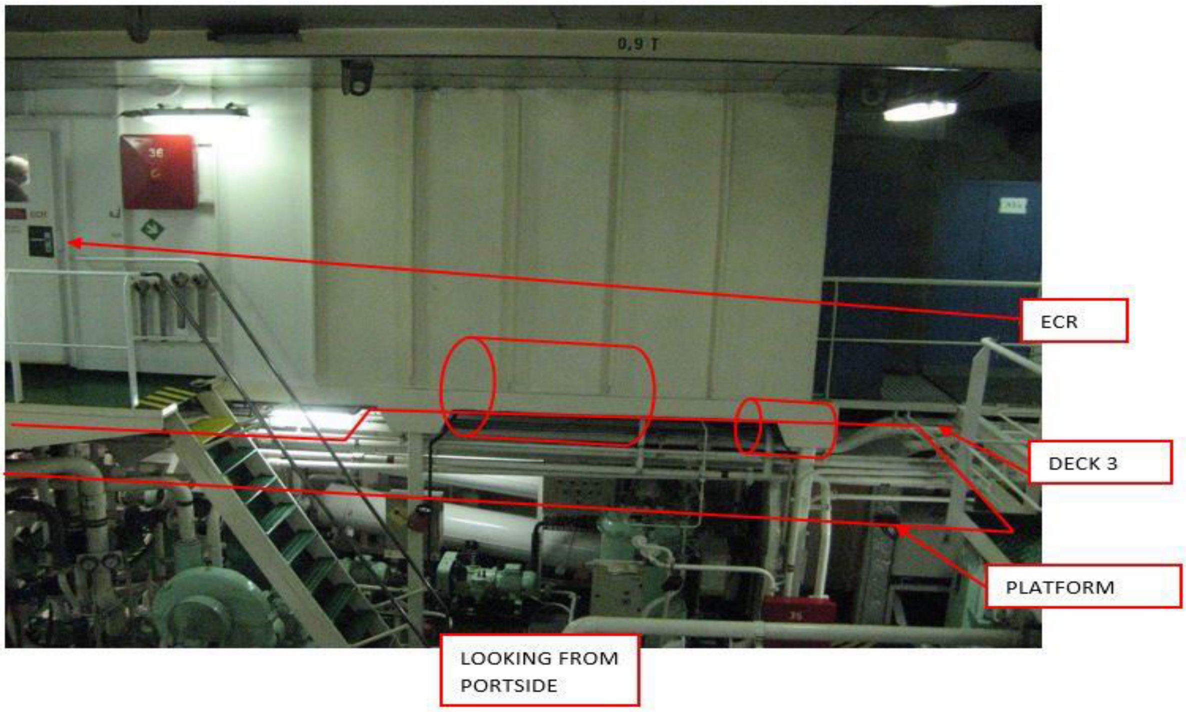


Figure 31: Engine Room-view from portside [22]

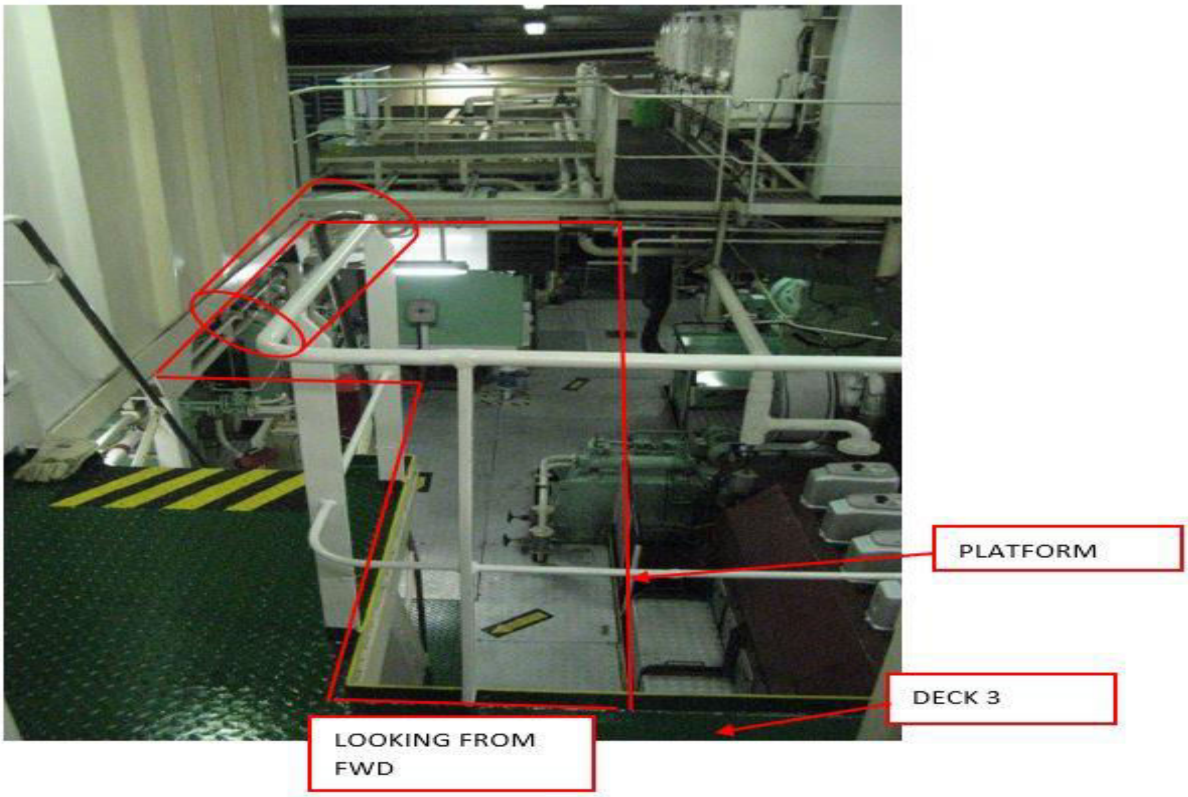


Figure 32: Engine Room-view from forward [22]

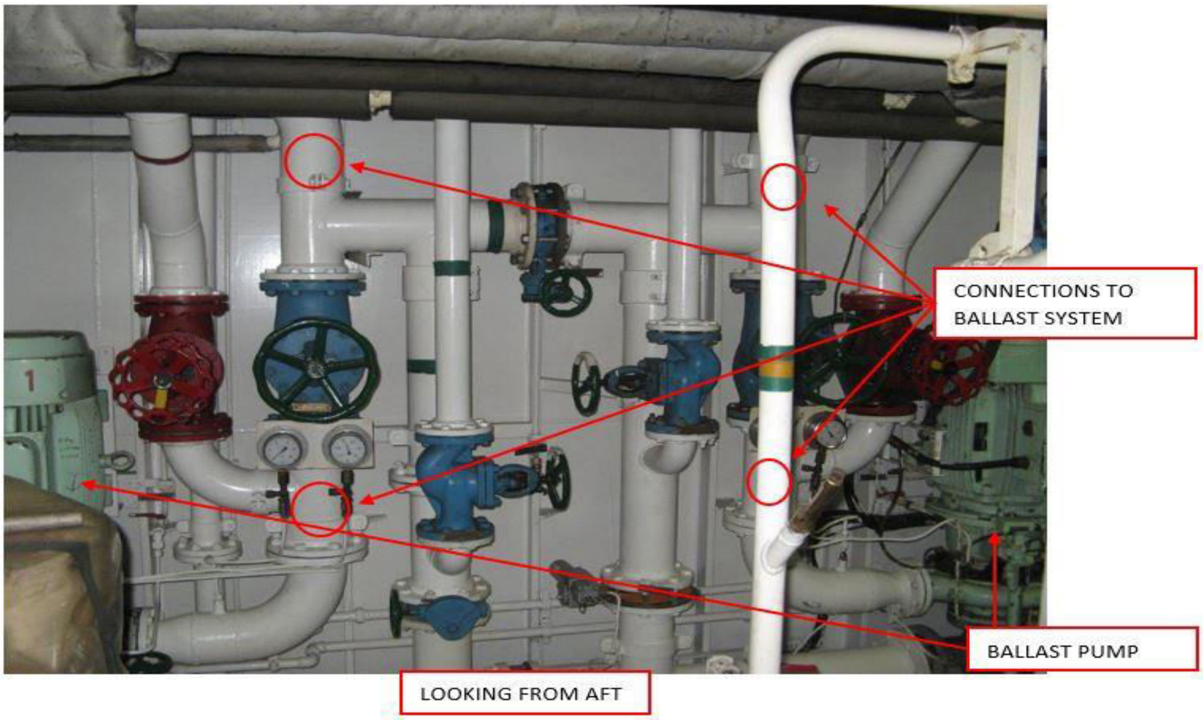


Figure 33: Engine Room-connections to existing ballast system [22]

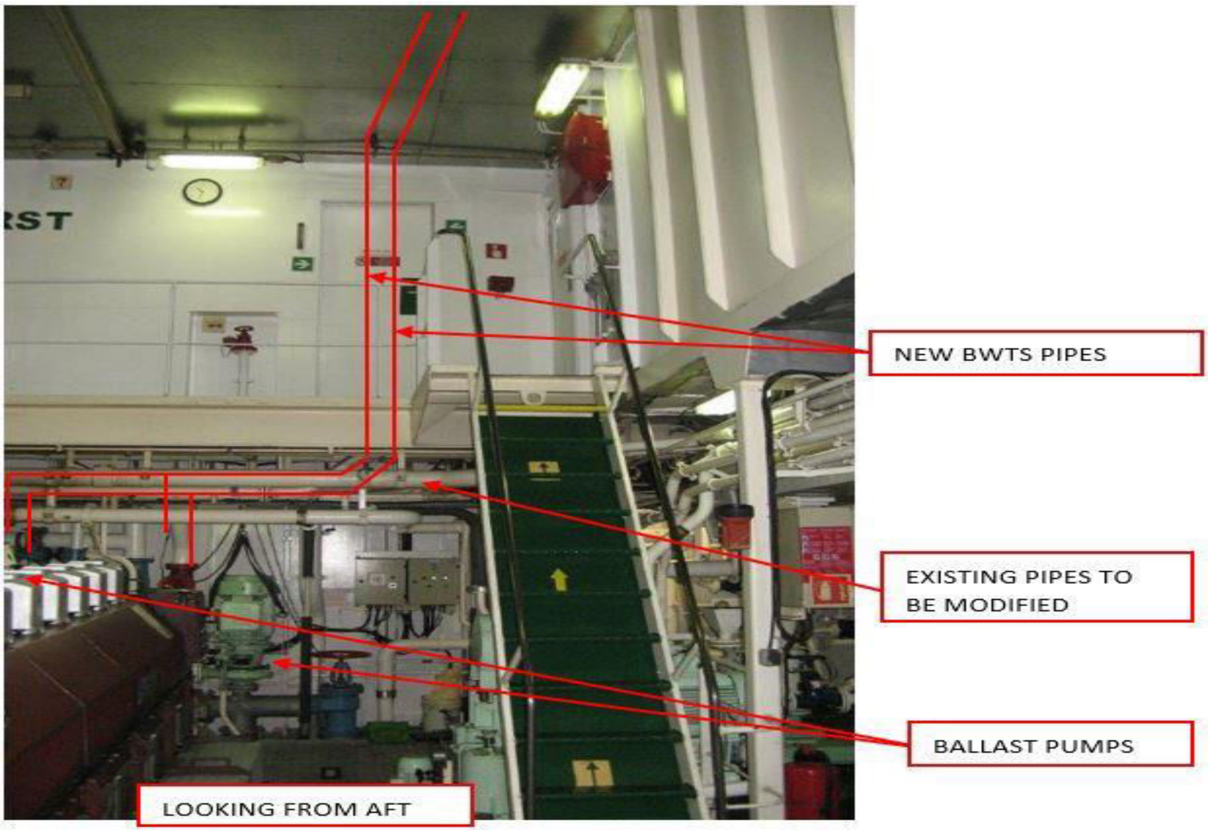


Figure 34: Engine Room-view from aft [22]

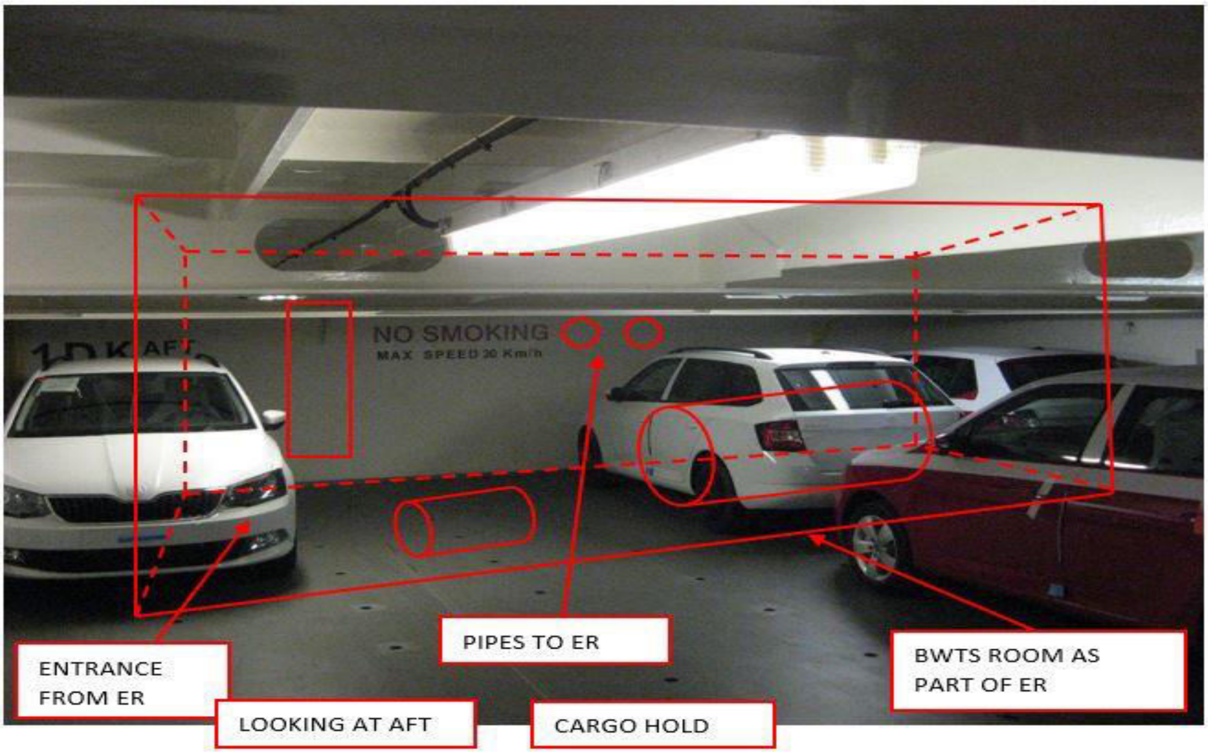


Figure 35: Cargo Hold-Arrangement of BWMS [22]

7.2.2. General arrangement

In this section, basic arrangement for BWTS in Engine Room (top view) for the selected treatment systems are shown in figures 36, 37, 38 & 39.

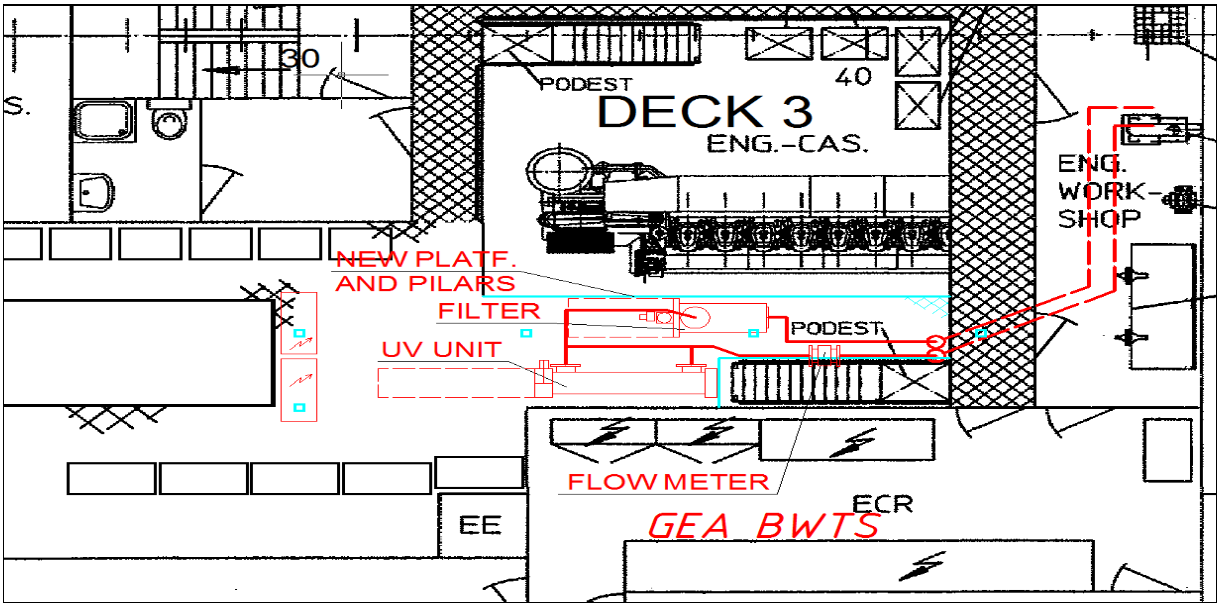


Figure 36: GEA-Arrangement in Engine Room [22]

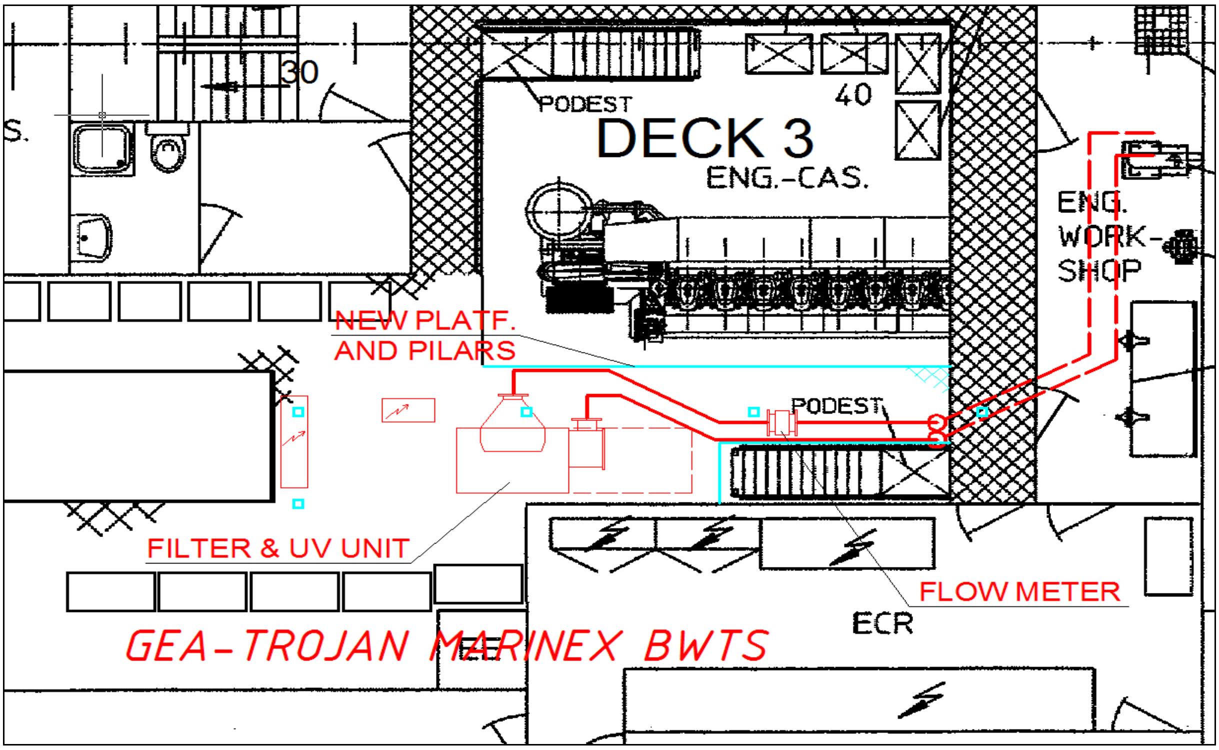


Figure 37: Trojan Marinex-Arrangement in Engine Room [22]

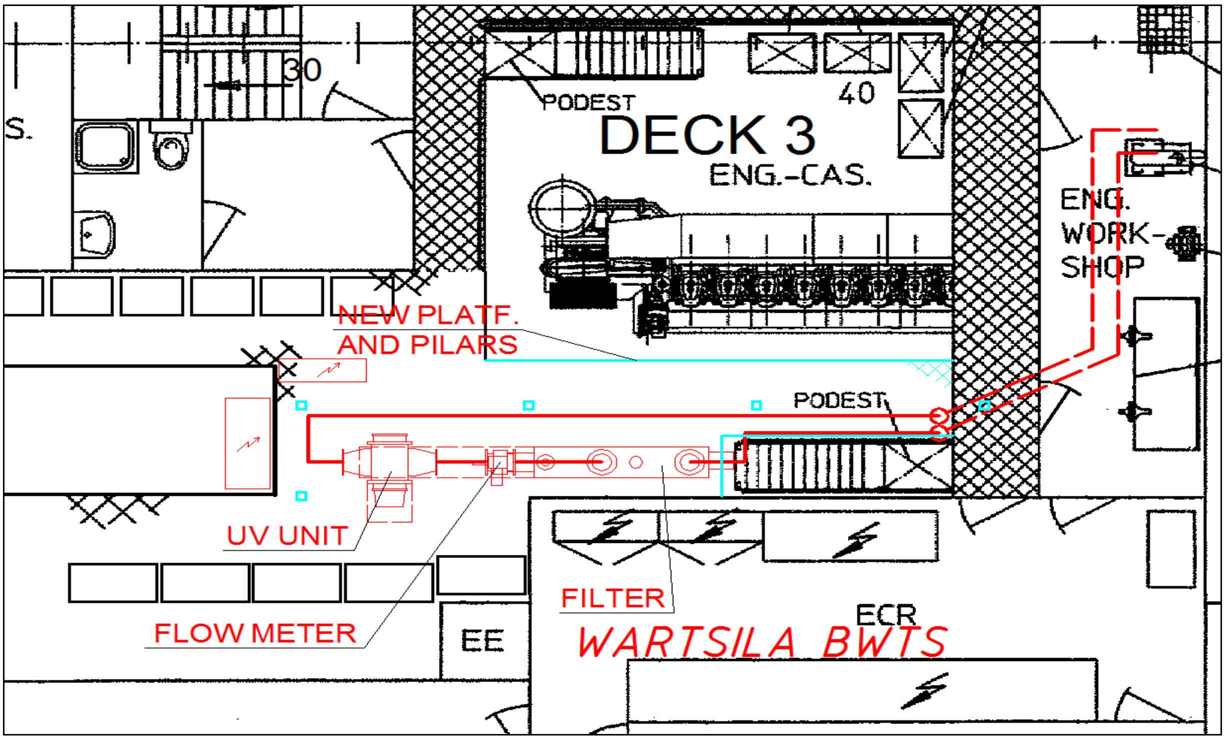


Figure 38: Wartsila-Arrangement in Engine Room [22]

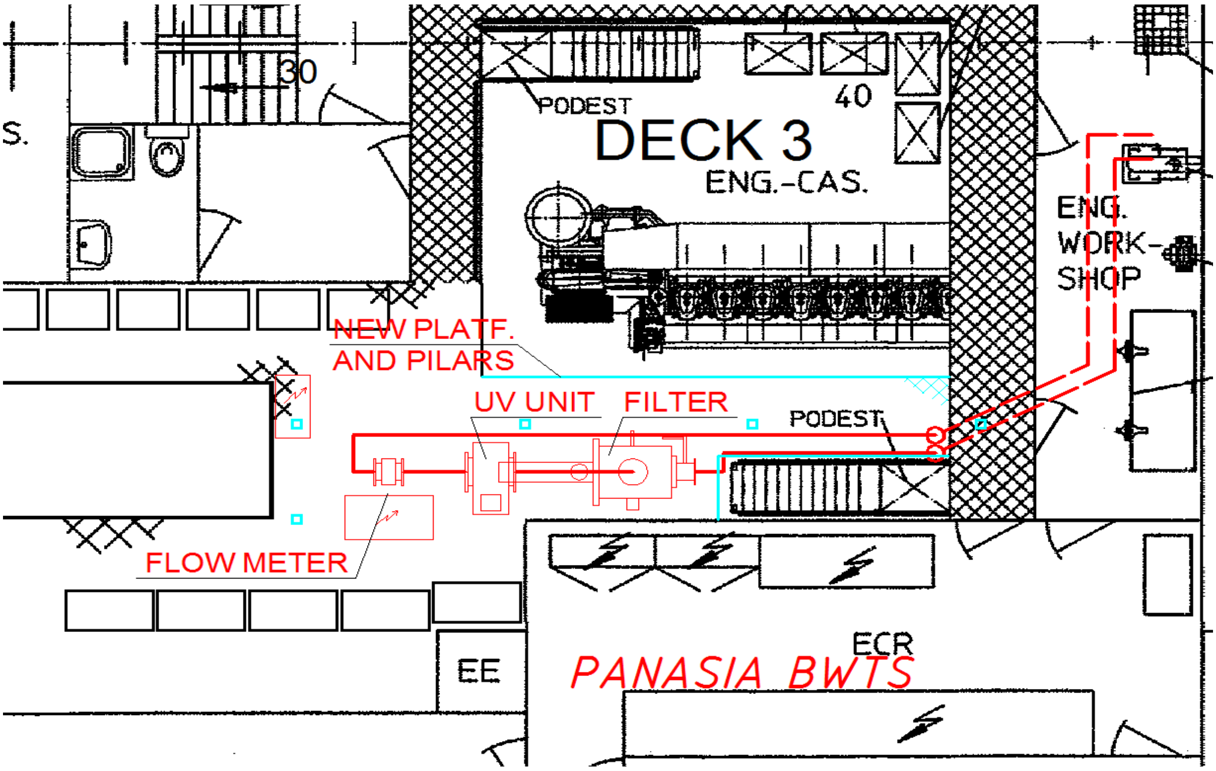


Figure 39: Panasia-Arrangement in Engine Room [22]

7.2.3. Transportation

(a) Engine Room: Transportation of the treatment system from shore to ship also plays an important role during the retrofitting process. If the size of the BWTS is huge, then it will be difficult to transport the system in to Engine Room. It's advisable to use the existing opening to transport the system than cutting-off the hull. In this particular vessel, treatment system has been transported to the cargo hold through stern ramp and then it has been brought inside the engine room through an existing door between car deck and engine room (figure 40).

(b) Cargo Hold: It will be very difficult to transport the system from custom-built BWTS Room to Engine Room through openings in bulkhead, due to many equipments and piping installed close to Engine Room's bulkhead. So, the transportation should have to be arranged to Cargo Hold through temporary opening in BWTS Room bulkhead or by fitting a new watertight door. If this location is considered for installation, later on during the serive life of BWTS, if there is any major replacement or repair of the equipment is required, it will be difficult to transport or carry out repairs locally due to space constraints.

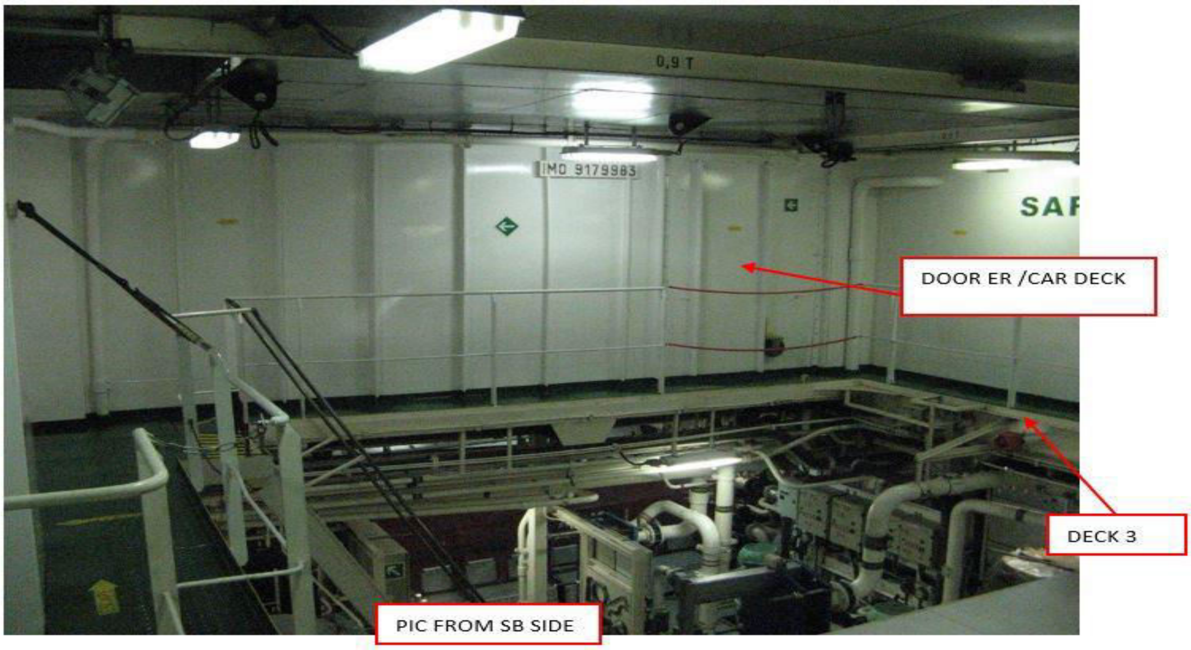


Figure 40: Transportation-Engine Room [22]

7.2.4. Structural Arrangement

Construction of a new platform in Engine Room: A new platform has to be built between frame 30-44 on the starboard side at the Deck 3 level. For the construction, steel structure made of IPE240 profiles supported by pillars SQR100x6.3 with grating on the top has been proposed at this stage. Structural arrangement for new platform at deck 3 level is shown in figure 41 as top view. Figures 42 & 43 shown are sectional views at 6m and 4.8m from centreline in the longitudinal direction of the ship. Transverse section view at frame 38 is shown in figure 44.

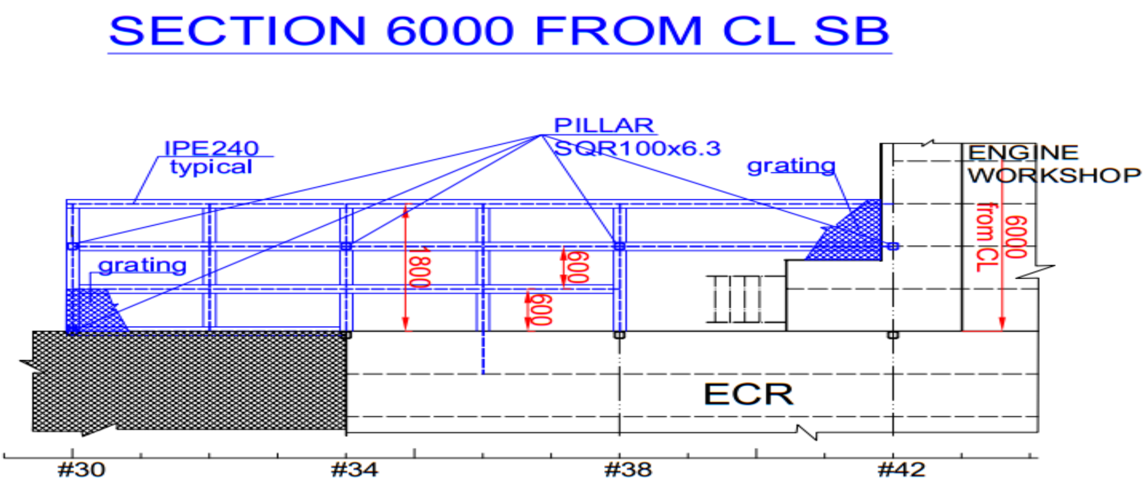


Figure 41: Engine Room - New platform top view at deck 3 level [22] *Blue colour-New structure

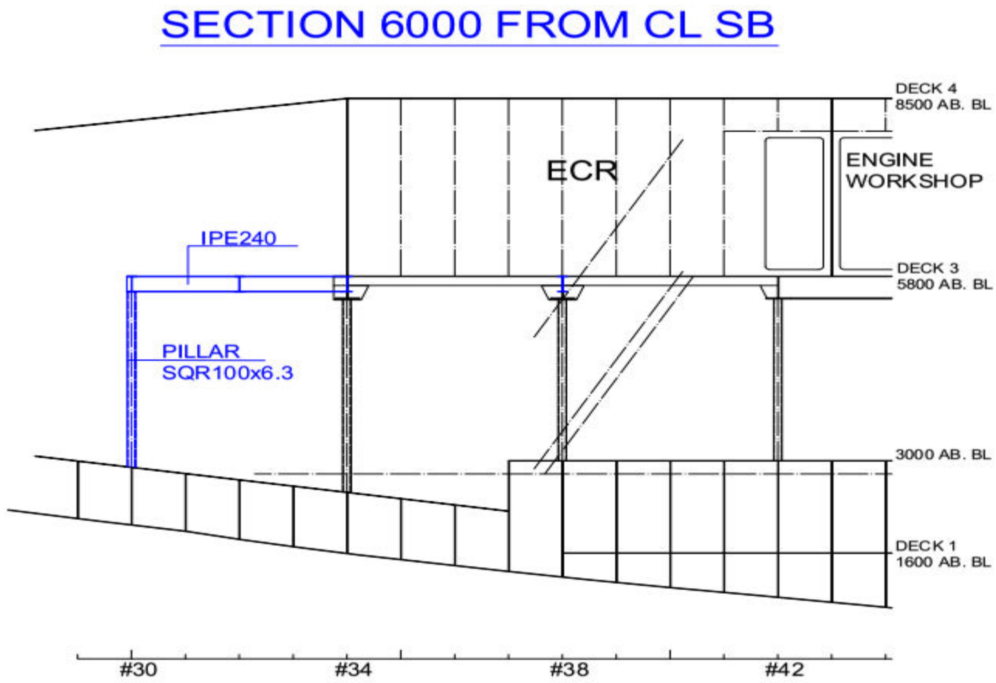


Figure 42: Section 6000 from center line-longitudinal view (starboard) [22]

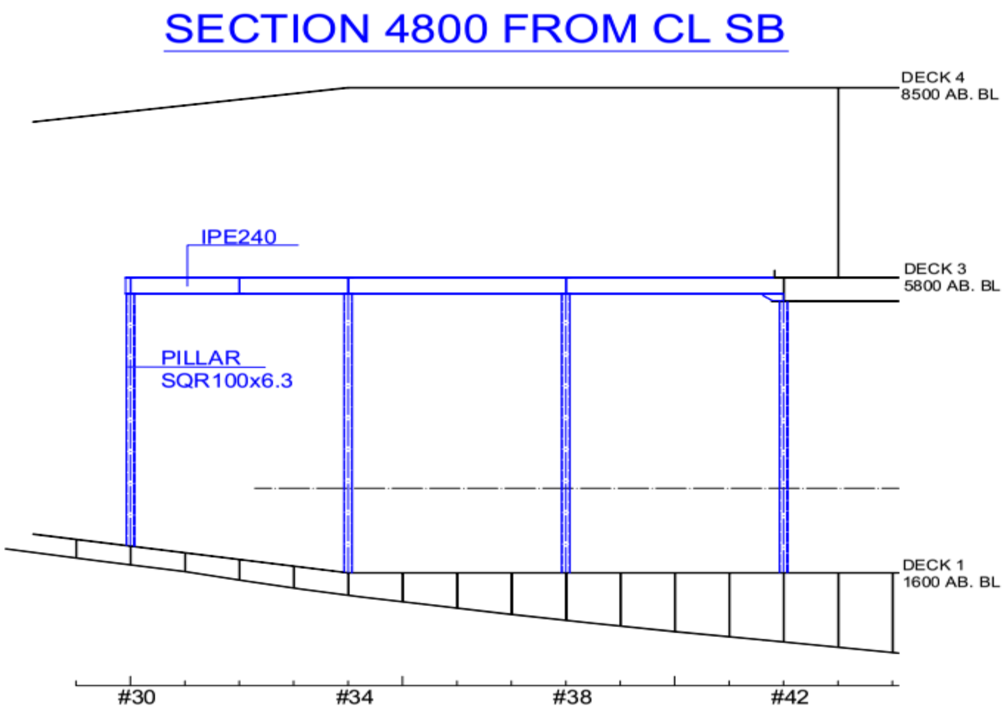


Figure 43: Section 4800 from centreline-longitudinal view(starboard) [22]

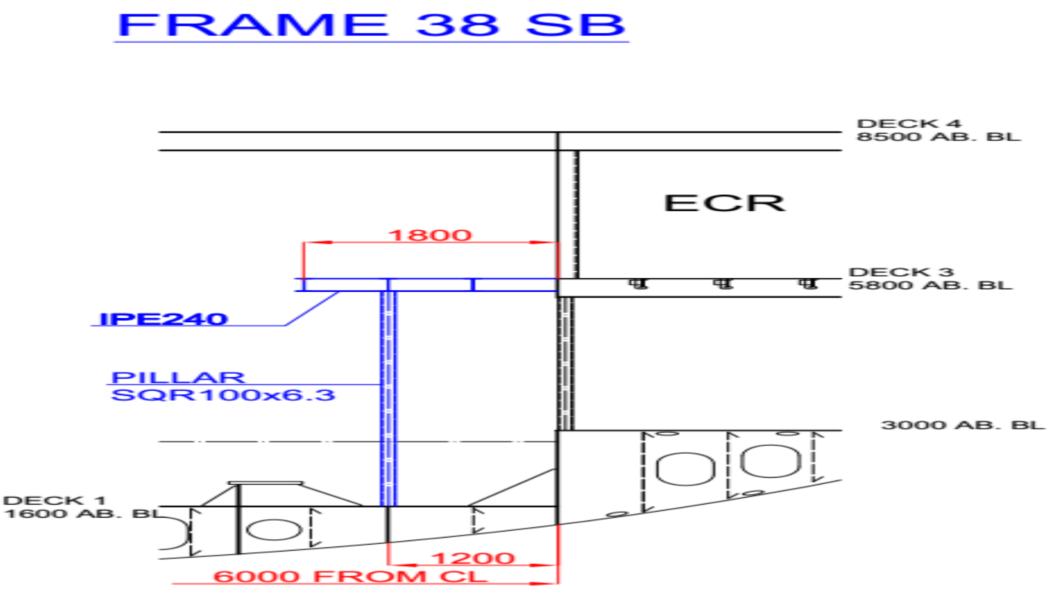


Figure 44: Frame 38 Transverse view (starboard) [22]

Construction of new BWTS Room in Cargo Hold: A new compartment has to be arranged between Deck 1 and Deck 2 in the aft part of cargo hold, separating the cargo hold with watertight bulkheads as shown in figure 45. Also, this compartment has to be connected with Engine Room by providing a passage.

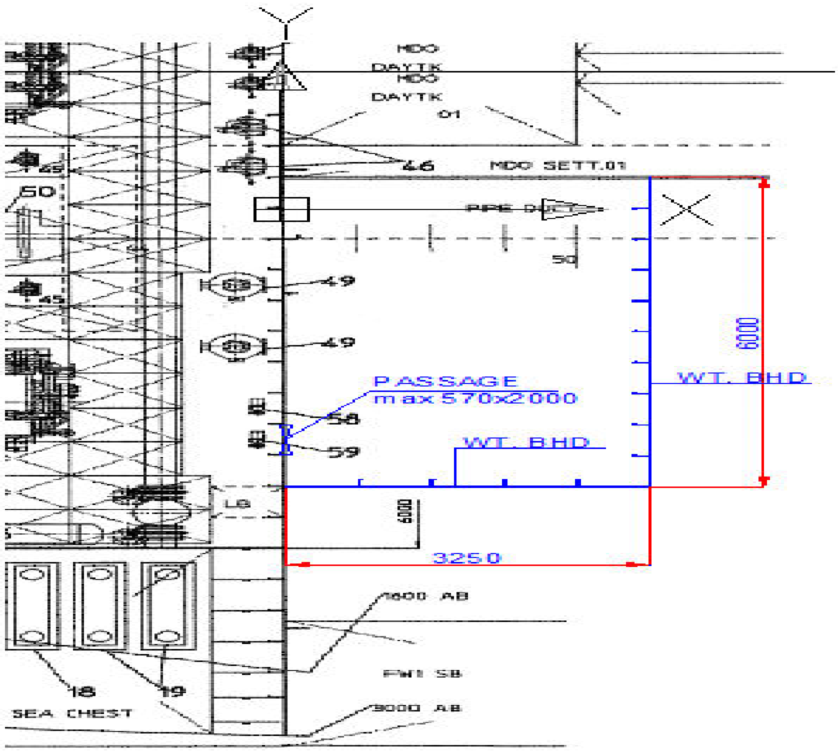


Figure 45: Cargo Hold - New compartment on starboard side [22]

7.2.5. Electrical and Automation

It is important to verify the compatibility of the electrical system of ship with the electrical requirements of the BWTS. For ships which does not have much spare electrical power, choosing BWTS with low power requirement becomes an ideal choice and obviously this criteria becomes the priority. Also, the specifications of power system plays an important role during the selection of treatment system. Main power supply onboard this particular vessel is of 3-phase, 60 Hz alternating current with insulated neutral system. This vessel has different group of equipments with different supply voltage, they are mentioned as follows.

- Main power consumers and partly domestic appliances: 3-phase, 440 V, 60 Hz
- Lighting system and partly domestic equipments, electric heaters, radio and navigational equipment: 3-phase or 1-phase, 230 V, 60 Hz
- Automation system, radio equipment: 24 V DC

From the table 18, maximum power requirement is 40 kW (Wartsila BWTS) which corresponds to 66A of supply current. In the Main Switchboard Panel 2 there are two spare circuit breakers. One of the two spare circuit breakers 2Q11(63A) or 2Q12 (63A) can be used for BWTS supply as mentioned in the figure 46.

Table 18: Power Requirements [22]

S. No.	Treatment Systems Selected by Ship Owner	Power Requirements
1.	GEA, BallastMaster ultraV 250, Germany	33kW, 3x440V, 60Hz
2.	TROJAN MARINEX, BallastMaster marineX 250, Canada (Partner in Europe-GEA)	13.3kW, 3x440V, 60Hz
3.	WARTSILA, Aquarius UV 250, Finland	40kW, 3x440V, 60Hz
4.	PANASIA, GloEn-Patrol P250, Korea	27kW, 3x440V, 60Hz

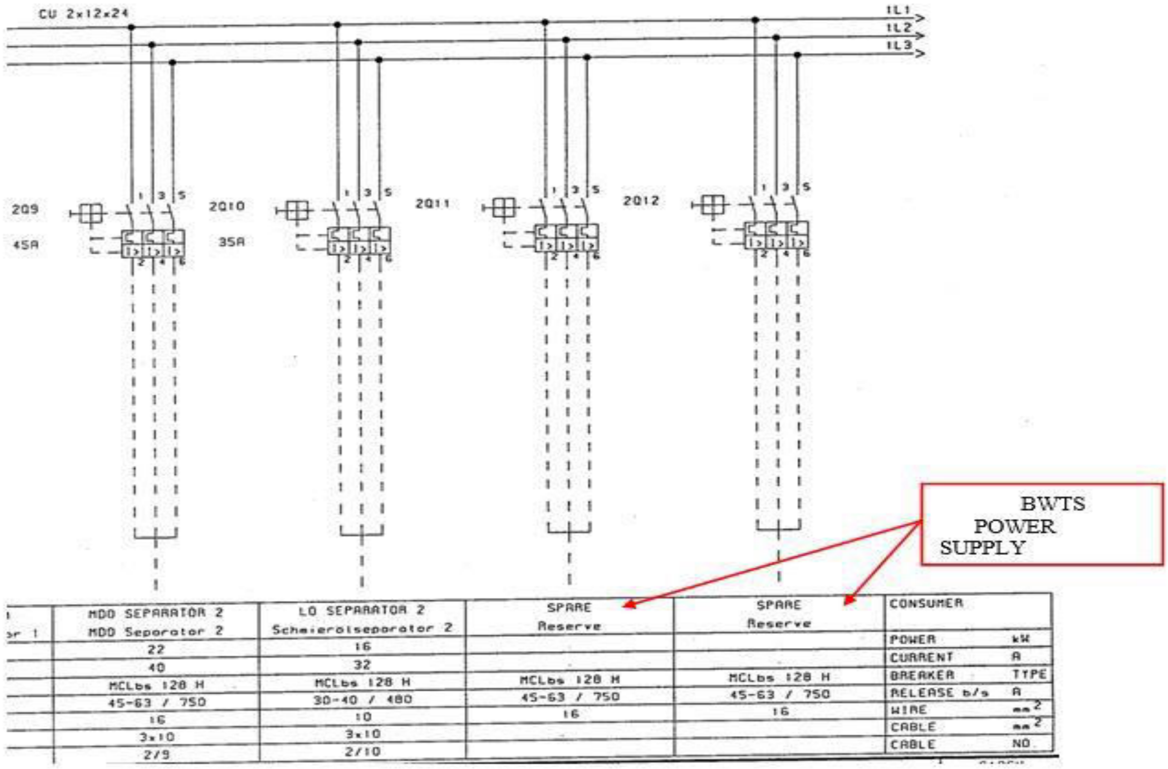


Figure 46: Main Switch Board-Panel 2 [22]

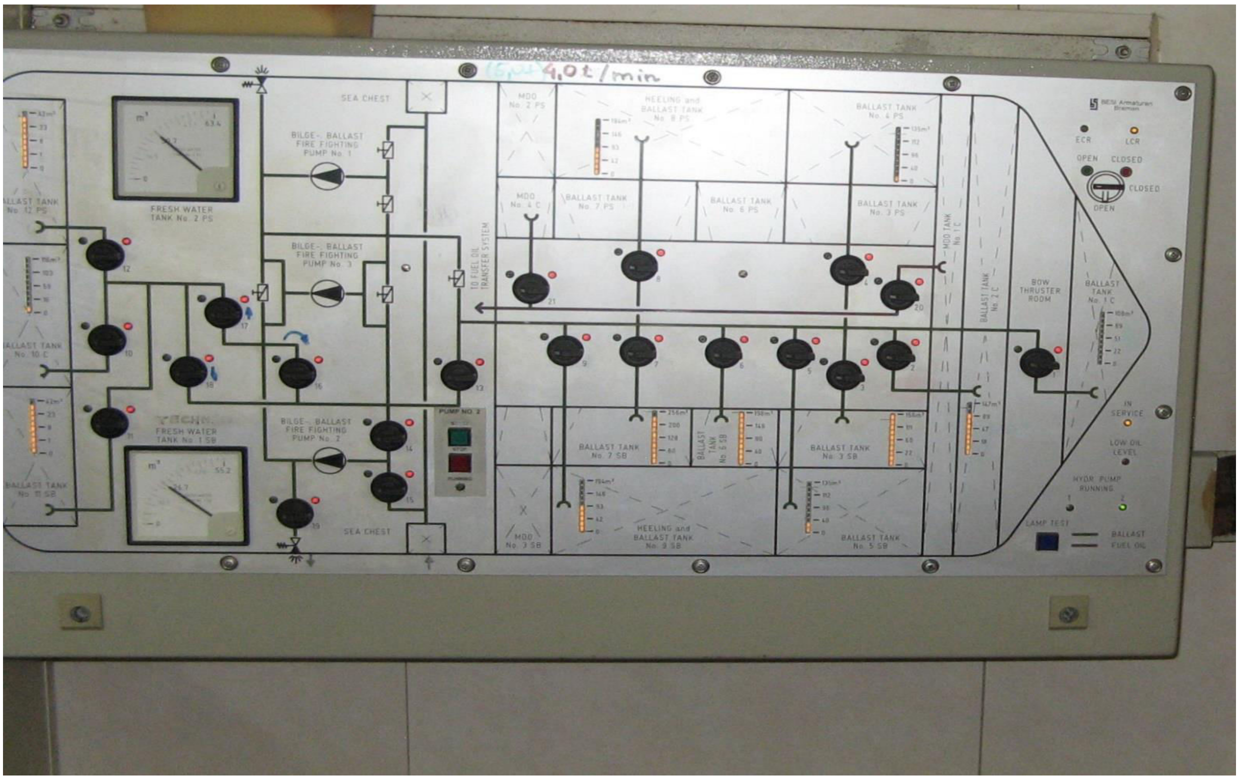


Figure 47: BWM Control Panel in the Deck Office [22]

Control Panel: Most of the treatment system manufacturers deliver two independent control panels along with the treatment system. One of the control panels usually installed in deck office near the existing ballast water system control panel as shown in figure 47 and other one is installed near the treatment system. Also, it is important to connect this control panel and the alarm system with Engine Room alarm and monitoring System by providing a common alarm channel.

7.2.6. Analysis and Final Selection

Location: Installing the BWTS outside the Engine room could be most probably cumbersome interms of transportation and arrangement. Also, loss of cargo space, arrangements for ventilation and additional requirement for safety systems are main concern while considering the cargo hold for BWTS installation. So, it has been decided by owner to install the treatment system in Engine Room. Also, choosing Engine room for installation, will help in avoiding the construction of additional compartment in cargo hold which would require additional man power, time and cost.

Treatment System: Based on feasibility study which has been sent to the ship owner, followed by further discussions with design office, owner has selected Wartsila-AQUARIUS as a final choice for their vessel. Even though the power consumption is higher for this system as compared to other systems, ship owner might have selected this particular system due to the previous experience and reputation of this brand in the industry. Also wider service network offered by them also makes them an attractive system manufacturer. Selection also depends on whether the owner and charterer of the vessel are same or different. If the vessel owner is not operating the vessel, then charterer has to deal with operating cost. In that case, ship owner is bothered only about capital expenditure. Wartsila system seems to be more simple interms of arrangement and during discharge, ballast water does not have to flow through the filter again. Following section explains about the selected system with more details.

Wartsila-AQUARIUS: This is a modular ballast water management system [47] and the main elements of the system are shown in figure 49 & 50. The system is installed in a bypass loop to the main ballast line to provide a safe, flexible and economical process for the treatment of ballast water and eradication of aquatic invasive species. Figure 48 describes the two modes of operation of the system. Based on manufacturers manual, ballast water treatment with the AQUARIUS UV BWTS is achieved through a simple and efficient two stage process:

Filter Module with automatic back flushing filter unit that includes all required instruments and control devices wired to a terminal box. Cross-sectional view of the filter is shown in figure 51.

Treatment Module with UV chamber that includes an assortment of instruments and flow control devices wired to a terminal box. Before discharge, water from the ballast tanks passes through the UV chamber only for a second time. UV lamps replacement work is shown in figure 52. The complete flow arrangement of the system is shown in figure 53.

Key features: (a) Model: Aquarius UV 250, (b) Ballasting – filtration and UV treating, (c) Deballasting – UV treating (filter is by-passed), (d) Filter 40 µm, backflush automatic vacuum scanner, (e) UV medium pressure lamps, Quantity of UV lamps – 12, (f) Power installed 40 kW, (g) Maximum internal pressure drop 0.8 bar

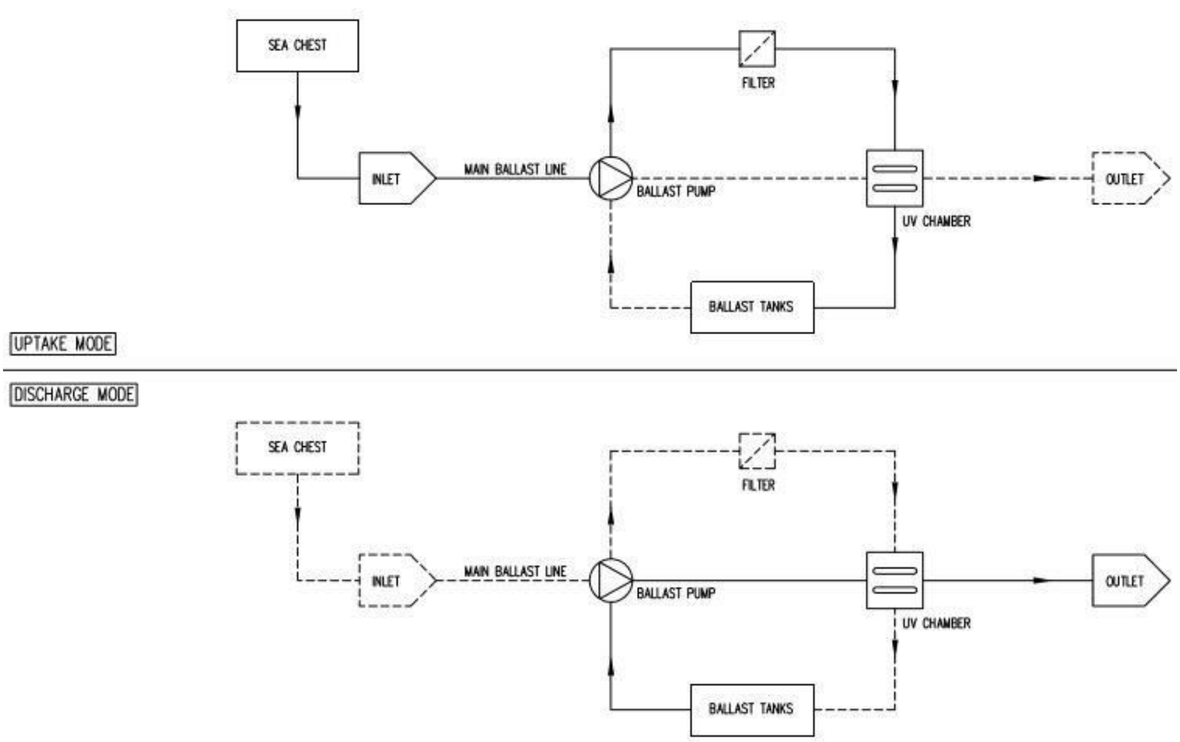


Figure 48: AQUARIUS UV Block Diagram [24]

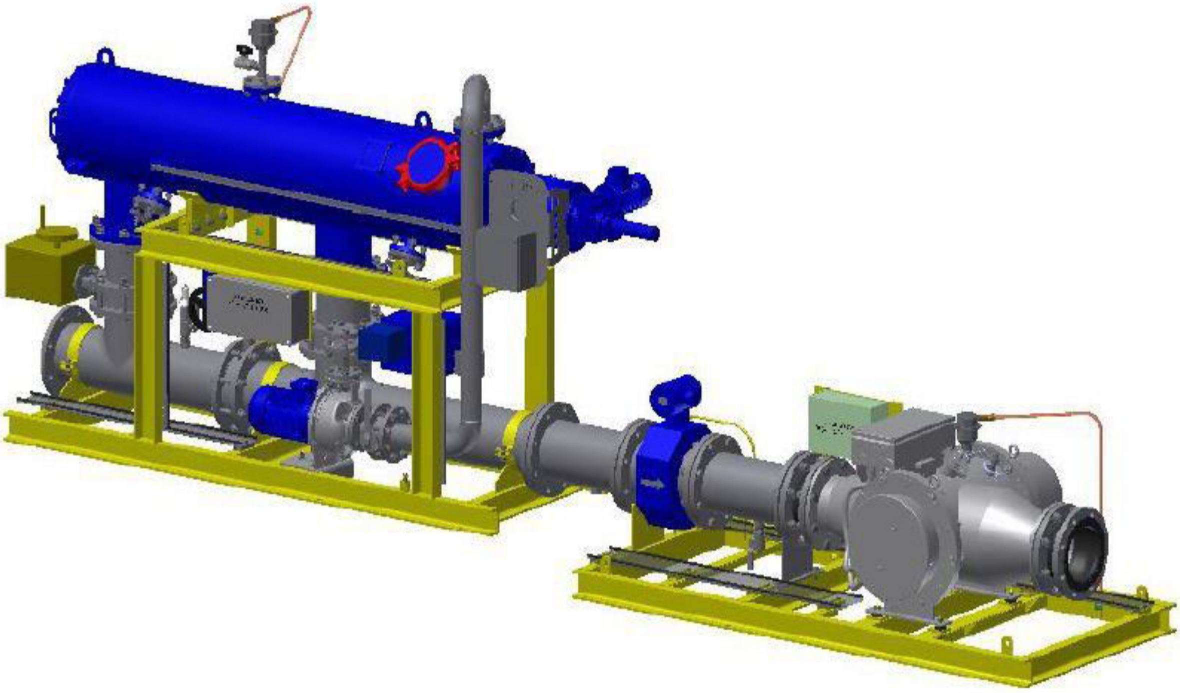


Figure 49: AQUARIUS UV Configuration [24]

Figure 50: AQUARIUS UV-Main Elements [24]

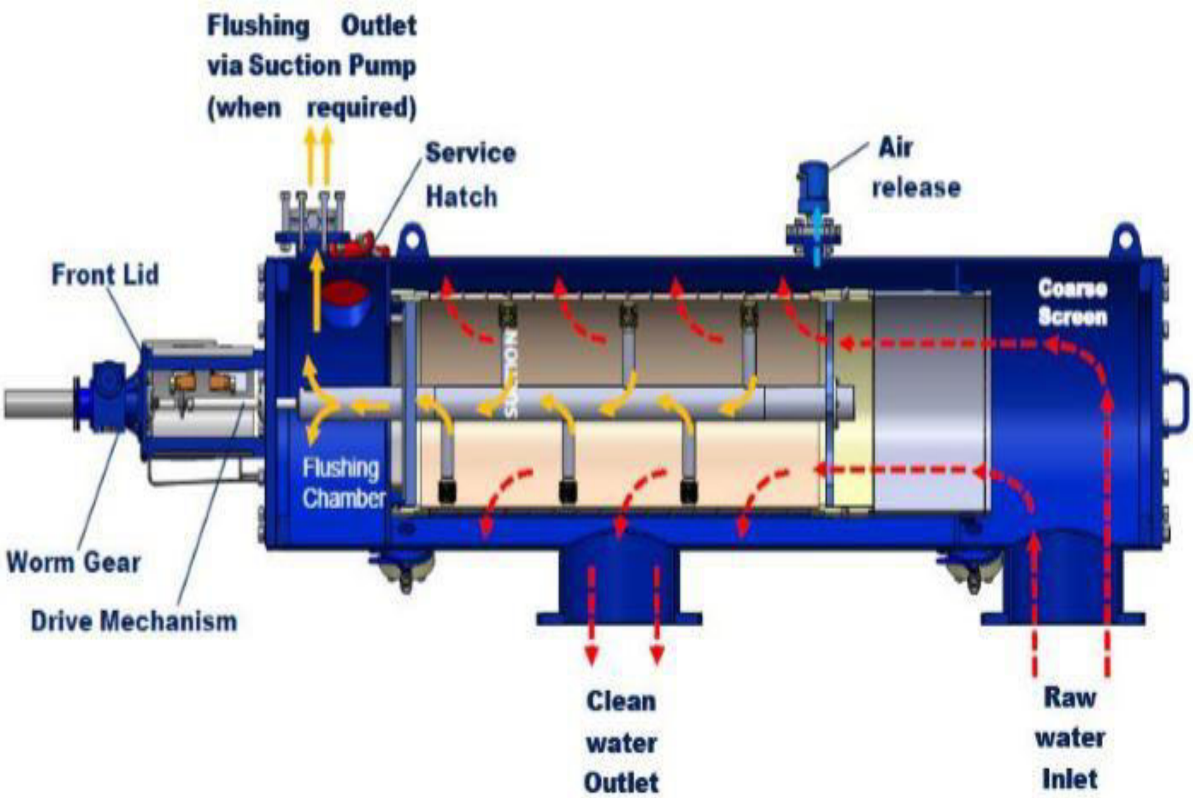


Figure 51: AQUARIUS UV-Smaller Filter [24]

Figure 52: AQUARIUS UV-Lamp [24]

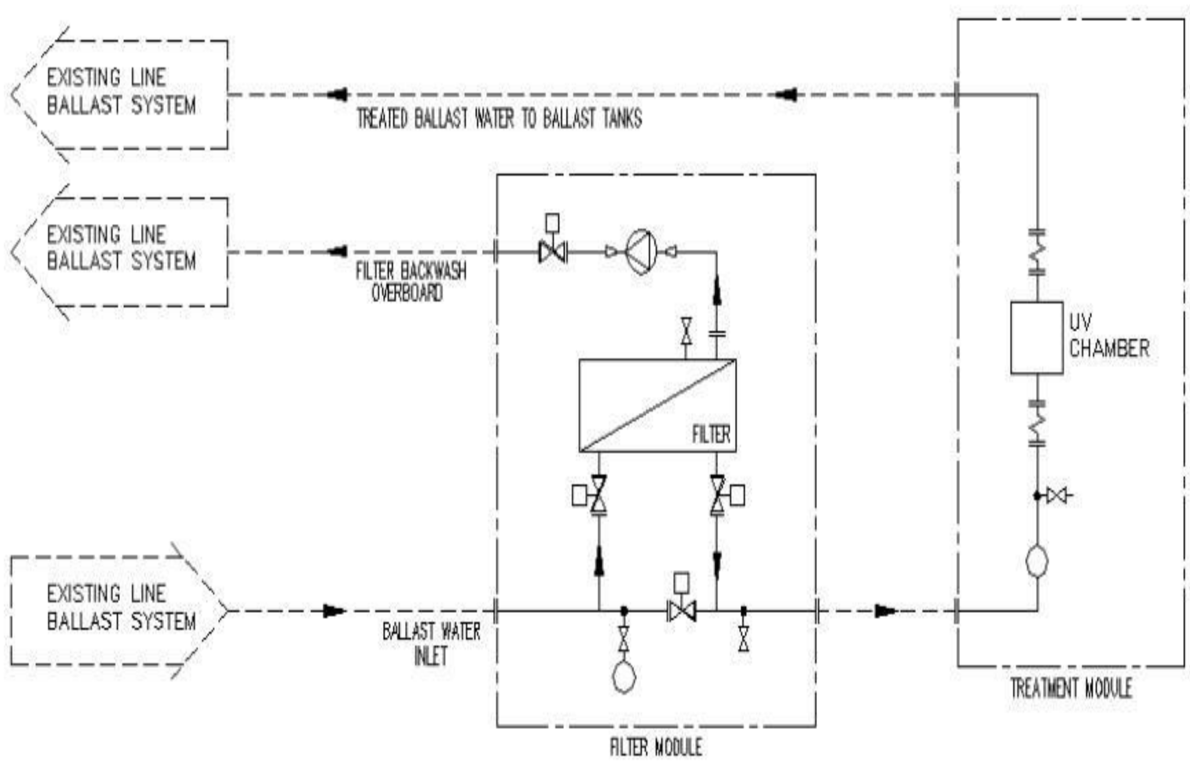


Figure 53: AQUARIUS UV-Flow arrangement [24]

7.2.7. 3D Laser Scanning

Before creating 3D model, the installation space can be scanned by means of 3D Laser technology. Measurements can be done manually as well, but 3D laser scan has many advantages such as less time consumption, accuracy etc. Manual measurement requires more time and it can be suitable for simple and smaller spaces, but for a larger space, 3D scan will be more easier. Also, it's possible to create even panoramic view of the space using laser scanning technology.

This is an accurate and efficient solution to determine the feasibility, impact and problems associated with installing ballast water treatment system on board ships. It also eliminates most of the risks associated with manual measurement done to create workshop documentation. Scanning can generally be done (figure 54) without any disruption to the vessel's operations. Scanned data can also be used for retrofitting other systems such as exhaust gas scrubber system etc. It is economical to carry out laser scanning during initial survey of the vessel. So, the cost of transportation of personnel and bureaucracy in dealing with ship visit at ports or anchorage can be minimized.

Figure 54: Laser Scanning onboard ship [49]

It is beneficial to carry out scanning during initial survey of the vessel, if the space available onboard is particularly critical. It also minimizes the number of ship visits and ensures that reliable design work can be carried out in the office. It should be emphasized that a 3D design is not a mandatory requirement in this retrofit process, however, it is advantageous while preparing detailed design. Documents required for pre-fabrication and workshop can be extracted from the created model. 2D designs may be sufficient in less complex cases where well prepared up-to-date drawings are available.

7.3. Detailed Design of BWTS

7.3.1. 3D Modeling

Data obtained from 3D laser scan has been used to model the system into the existing space. After the creation of model, the shipowner and chief engineer will be able to clearly see that the chosen system location will not interfere with normal ship functions and also it can be used to verify available space for maintenance. Either one chosen system can be modeled or few more treatment systems can be modeled to show owners for their perusal and then to select an optimal solution for the space which has been taken into consideration. Since, this particular vessel M.V. Main Highway was not a complex case, only manual measurement has been carried out to develop 3D models. 3D scan data and point cloud representation are not available for this vessel. In the following figure 55, point cloud representation is shown for a different vessel called M.V. Elbe Highway as an example, this vessel is also from the same fleet. The design work for this vessel is still under progress at Westcon Design Poland.

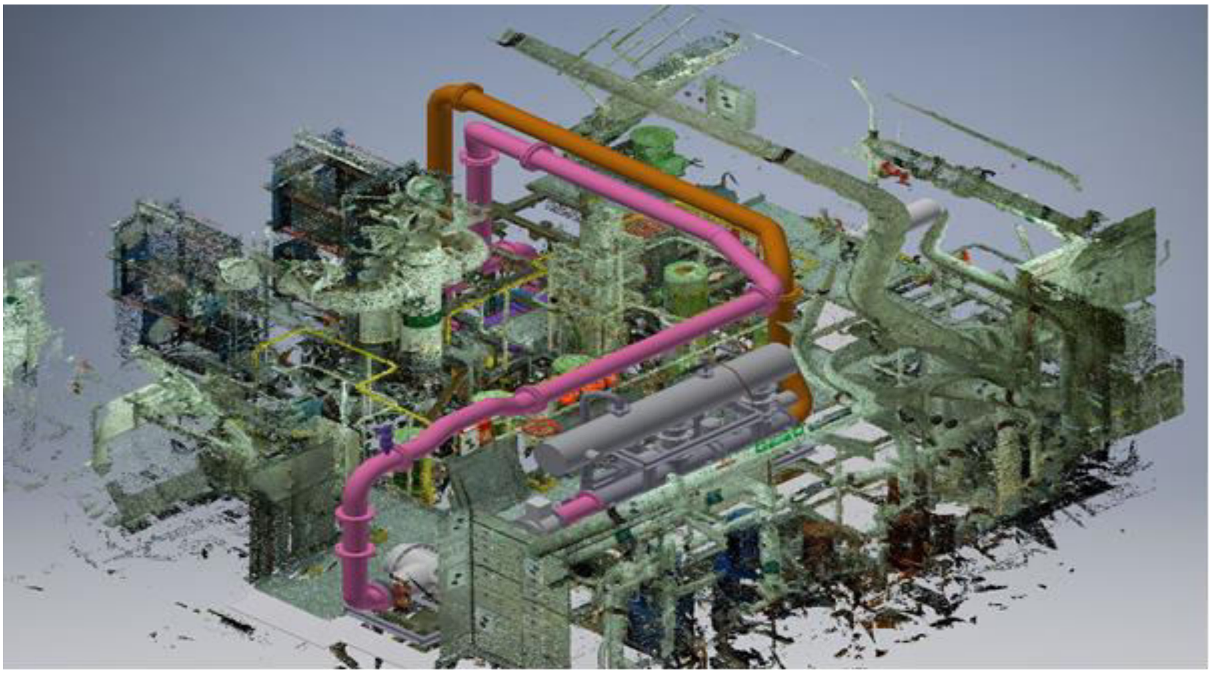


Figure 55: 3D Model in Point Cloud - M.V. Elbe Highway [23]

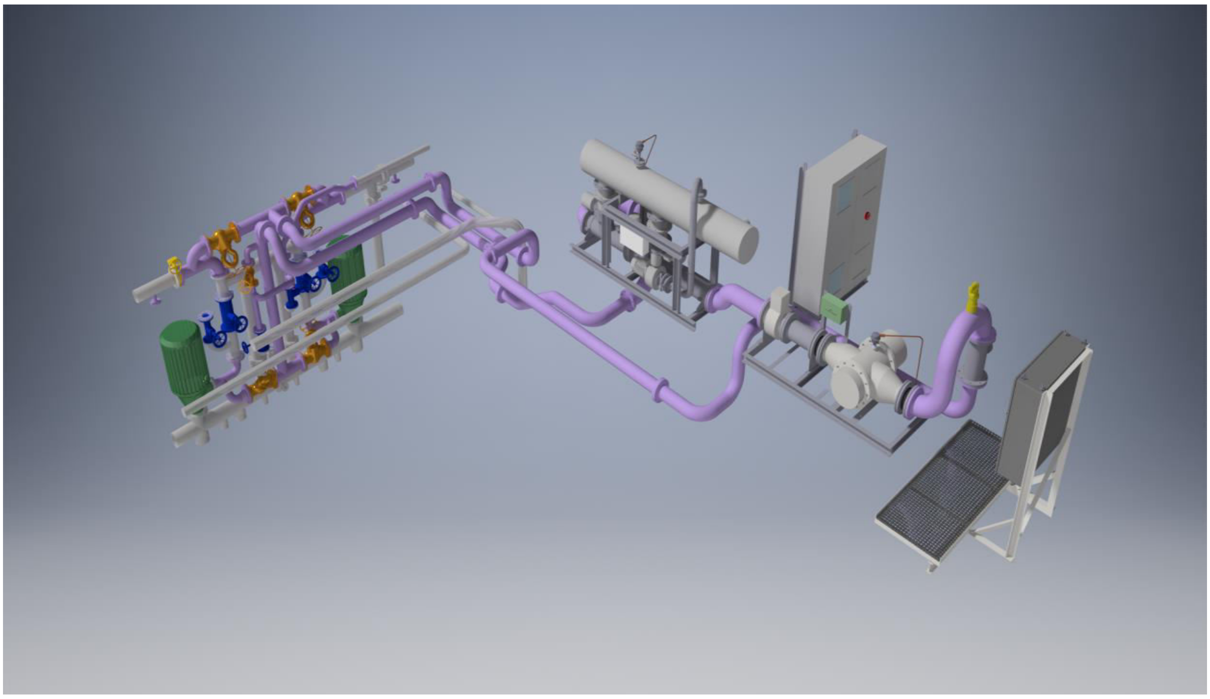


Figure 56: 3D Model of Complete System [22]

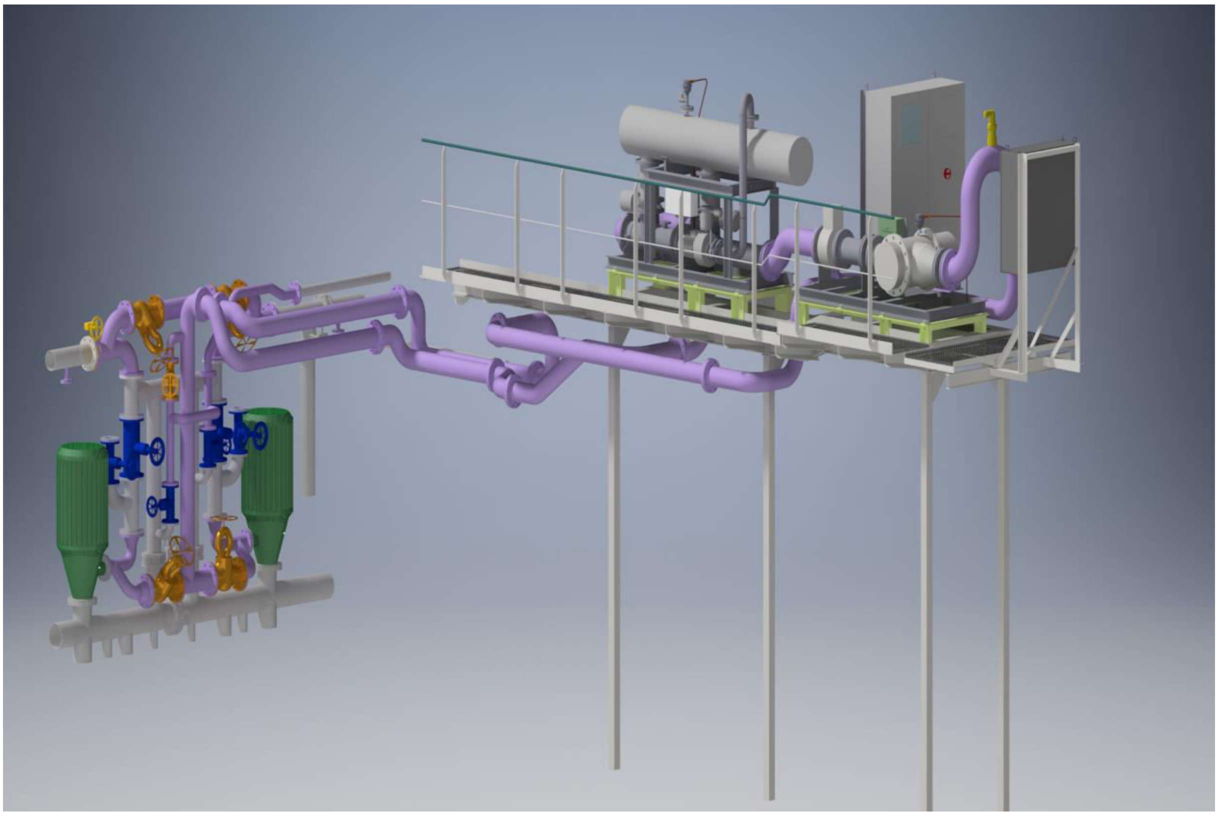


Figure 57: 3D Model of complete system with foundation [22]

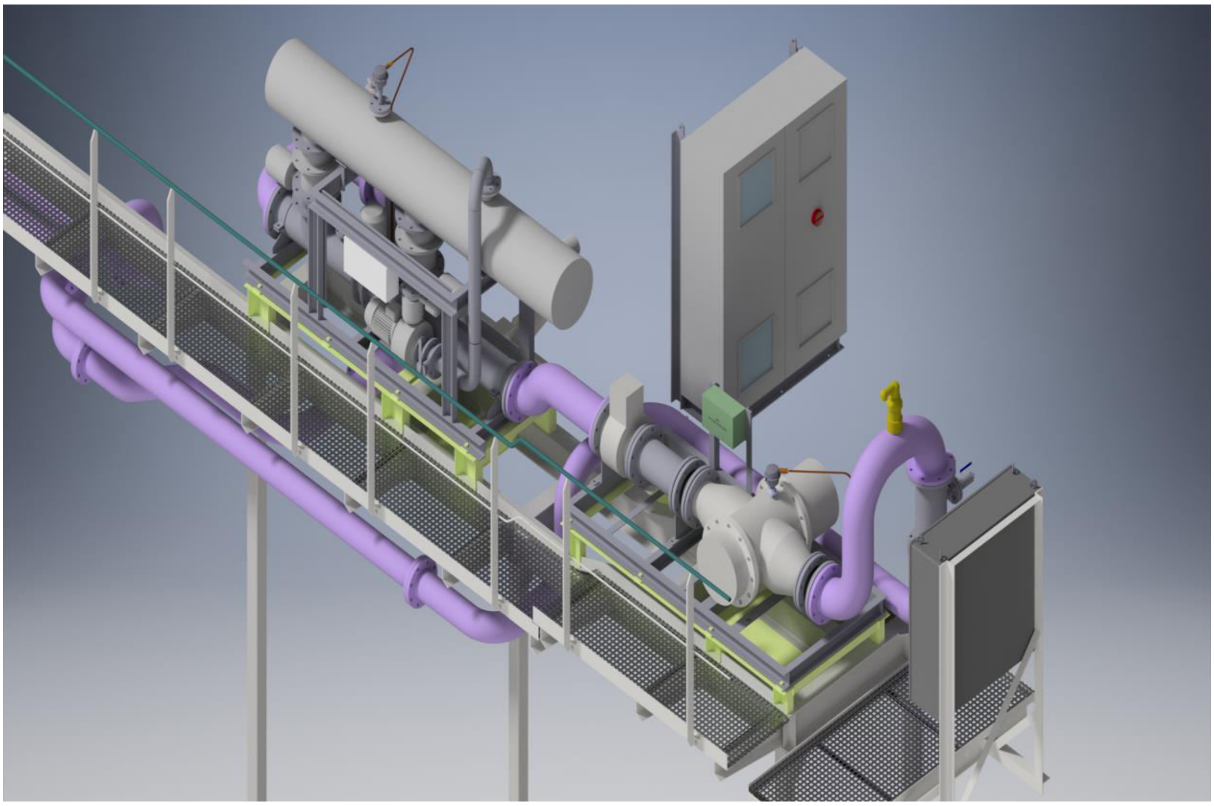


Figure 58: 3D Model of treatment unit [22]

3D Model of treatment system for vessel M.V. Main Highway with different views are shown in figures 56, 57 & 58. During the model creation, data fed into the system simultaneously regarding the material,size and standards. It's possible to create the 2D or 3D drawings from the model. Autodesk-Inventor has been used to create these models. Once the mechanical/electrical drawing with parts list and other important data were available from the treatment system manufacturer, ship owner has been contacted for approval to proceed further to the next process.

After getting confirmation from the owner, drawings have been sent to the class society for approval. Subsequently, the workshop documentation has been prepared after getting approval from the class. The accuracy of the 3D scan output helps in creating an accurate production documents containing drawings which shows all foundations, mechanical and electrical components and other parts needed for installation. These documents have been sent to shipyard later on to proceed for pre-fabrication. Piping, connections and foundations can be pre-fabricated with high precision and it eliminates the time-consuming pipe fitting process.

7.4. Installation of BWTS

Installation can be done at dry dock, along-side or at sea, the selection of which depends upon the location to be installed, space constraints, system size and various other factors. The installation of equipment and related systems is usually carried out by a repair yard or dedicated specialist contractor. Some of the treatment system manufacturers may also offer installation work. It is important to minimize the off-hire period of the ship and modification designs should take this into account. It's ideal to do retrofit during scheduled dry-docking, but this is not always possible, as the ship's docking schedule may be in different from the legislation compliance schedule. In such cases installations at sea become an attractive option.

In this case, installation has been planned during scheduled dry-docking and the vessel arrived to Marine Ship Repairyard (MSR) Gryfia, Szczecin (Poland). It was very convenient for the design office to be located in the same city to collaborate with the shipyard, though it is not necessary to have design office located close to shipyard. During the installation, ship owner invited representative of design office to over see the installaion. The author along with internship supervisor carried out an inspection (figure 59, 60 & 61) of the installation and they were satisfied with the progress made by shipyard interms of installation.

Figure 59: Installaion onboard M.V. Main Highway[22]

Figure 60: Engine Room of M.V. Main Highway [22]

Figure 61: Inspection of installation by Mr. Andrzej Sobieraj (Internship supervisor) and author

7.4.1. Commissioning

After the installation, vessel had to sail out from the drydock due to commercial obligations without completing the treatment system commissioning work. In accordance with draft amendments of recent MEPC 71 meeting [28], there is sufficient time available for the vessel to comply with ballast water management convention. Even though, it is an ideal and standard procedure to do commissioning/trials of the system soon after installation. If the treatment system is not going to be operated for long period of time, it has to be kept in appropriate condition as mentioned in manufacturers manual. Ship owners and Shipyard must avoid any delay during the installation and take appropriate measures to complete the commissioning and trails soon after the installation. It is highly recommened to have the presence of commissioning expert from the treatment system manufacturer during this work. In addition to commercial obligations, there are various other reasons such as discrepancies in detailed design and misinterpretation of drawings by shipyard, ignoring risk assessment procedures during the transportation of treatment system and during other critical work, unskilled labour employed for welding and other piping work, Inexperienced electrical and automation specialists which may delay the installation.

After commissioning and trials, the international ballast water management certificate has to be updated with a mention of D2 in addition to existing D1. Later on, D1 has to be removed and only D2 will remain in the certificate once the vessel reaches her actual compliance date. Administration or Recognized Organization should be contacted by the ship owner and the certificate has to be modified accordingly.

7.4.2. Service and Training

After-sales service and spare parts supply depends on the manufacturer, some of the treatment system manufacturers have wider service network around the world. So, it's an advantage to choose their products. Others provide service through third party organizations. It depends on the contract between ship owner and treatment system manufacturers, guarantee period and any other special offers based on number of treatment systems purchased by the ship owner.

Ship owner must pay particular attention to after-sales service and availability of spares, it has to be considered as an important criterion during system selection. It is important to note that one of the treatment system manufacturer called Optimarin has announced that they will provide 5 years parts and service guarantee for their products [50].

IMO's Ballast Water Management Convention includes references to training requirements. In the technical guidelines G4, it has been mentioned that ship's Ballast Water Management Plan "should include training and education on ballast water management practices and the systems and procedures used on board the ship." These guidelines address the ballast water management and development of ballast water management plans and include a number of provisions for crew training and familiarization.

There are general requirements such as maintaining the Ballast Water Record Book and some specific requirements such as training on the operation and maintenance of installed ballast water treatment systems and on the safety aspects associated with the particular systems and procedures used on board the ship. Similar training goals have been identified by the USCG. To support these objectives, a wide range of training options are available worldwide, provided by treatment system manufacturers, class societies, maritime administrations and maritime training institutes.

Training Methods: In this project, author has suggested few types of training methods as mentioned below through which personnel involved in the operation of ballast water treatment system can be trained effectively.

(a) Training at treatment system manufacturer's site: Usually manufacturers site is a place where everything is available including real equipment, technicians and facilities. Therefore, it is easy for them to provide detailed training to the vessel owners or operators.

(b) Training during commissioning: This is a basic step of training which can be carried out during commissioning of treatment system onboard ship. Atleast 5 hours training is recommended for operators of the system to have a real-time experience and clarification also can be obtained from manufacturer's service representative during this period.

(c) Maritime Training Institutes: Many classification societies, ship management companies, treatment system manufacturers and maritime training institutes are offering various training programmes about ballast water management. They provide theoretical and practical based training for vessel owners and seafarers.

(d) Computer Based Training (CBT): Computer Based Training can be provided by means of installing ready-made lectures, presentations or exercises onboard ships and also at shore based offices. Seafarers can be trained either onboard ship or at shore offices to train them before they join the vessel. This can also be used to train shore based personnel to get themselves familiar with ballast water management.

(e) Globallast: Globallast partnerships has been involved in educating regional officials from maritime administration by conducting training programmes. Online training on the operational aspects of ballast water management is available at GloBallast Partnership Programme website. This is a four-module course covering the Introduction and Operational Aspects, Survey and Certification, and finally Compliance Monitoring and Enforcement. The course can be completed online or can be downloaded for use offline, which would be useful for seafarers who may not always have internet access on board ships.

(f) IMarEST: In addition to various options for training, Ballast Water Expert Group has been established by Institute of Marine Engineering, Science & Technology (IMarEST) to support crew training, approval process of systems, support sampling and monitoring of ballast water.

7.4.3. Timeline for Turnkey Project

Based on experience during internship period and discussions with experts from different fields, author has developed the following timeline in table 19 which shows the approximate time required at each step for retrofitting process. But, in practice some of the steps are carried out in parallel sequence, so the total time required will be considerably less than the estimation. It may not be similar in every case, it can be very less, if the owner wants to install in rapid pace and it can be more than the estimated period if the owner wants to install the system in slow pace. It is important to note various commercial factors such as supply of resources, logistics and availability of stock while estimating time line especially when more number of installation projects are in progress at same period of time.

Table 19: Timeline for turnkey project

Description	**Timeline**	**Responsible Party**
Ship Owner Enquiry/Survey of the Vessel/3D Scanning	2-4 weeks	Ship Owner/Design Office
Feasibility Study/Preliminary Design (Concept Design)	1-2 weeks	Design Office
System Selection/Liason with BWTS Manufacturer	1-2 weeks	Ship Owner/Design Office
3D Modeling/Class Approval of Documents	4-8 Weeks	Design Office/Ship Owner
Workshop Documentation	1-2 weeks	Design Office
Selection of Shipyard	1-2 weeks	Ship Owner
Material Purchase	1-2 weeks	Shipyard
Pre-fabrication	2-3 weeks	Shipyard
Installation	2-3 weeks	Shipyard
Commissioning/Trials	1-2 weeks	Shipyard/Ship Owner
Total time required	16-30 weeks (4-7 Months)	

This page is intentionally left blank.

8. BALLAST WATER COMPLIANCE MONITORING

8.1. IMO Port State Control Inspection

Port state has a major role in the effective implementation of ballast water management convention. Basedn on the guidelines for port state control under ballast water convention, as contained in resolution MEPC. 252(67), their responsibility mainly deals with compliance monitoring and enforcement, training of port state control officer, regional and international co-operation, sediment reception facilities, protecting port area interms of socio-economic activities. There are four different stages of port state control inspection with respect to ballast water management convention which are described as follows.

(a) Initial Inspection: During an intial inspection onboard ship, Port State Control may verify the following particulars.

- Ballast Water Management Plan (BWMP), International Ballast Water Management Certificate & Ballast Water record book (BWRB)
- Check that an officer has been designated for the BWM on board, Check whether the designated officer and crew are familiar with the BWMS, Visual inspection of overall condition of the ship, the equipment and arrangements mentioned in the Certificate, BWMP and BWRB

(b) Detailed Inspection: During an initial inspection, if the port state control officer come across any clear grounds, he/she will proceed further for detailed inspection. For example,

- the condition of the ship or its equipment does not correspond substantially with the particulars of the Certificate or
- the master or the crew are not familiar with essential shipboard procedures relating to Ballast Water Management or have not implemented such procedures; a detailed inspection may be carried out by port state control officers.

During detailed inspection, PSC may verify the following particulars, but the inspection is not limited only to this list.

- Clarify whether detailed BWMP operational procedures are followed
- Check if BWM has been conducted according to the BWMP
- Check of BWMS operational record, including self-monitoring devices
- Follow up on bypass and emergency issues

(c) Indicative Analysis: PSC officer may take a limited sample and verify using portable analytical instruments. But, the time required to analyse the samples shall not be used as a basis for unduly delaying the operation, movement or departure of the ship.

(d) Detailed Analysis: Full verification of compliance may involve large scale sampling typically requiring specialists involved in the testing who will assist the PSC officer. These samples for compliance testing are sent to laboratories onshore and it will require more time for analysis.

8.2. USCG Inspection

Vessels arriving ports in US should keep in mind that US requirements may change at any time, so it has to be verified prior port calls. Also, it is advisable to consult Safety Management System (SMS) onboard or shore management should be contacted for clarification.

Check List for US Port calls

- Documentation
- Ballast Water Management Plan
- Current extension letter granted to the vessel, if it's applicable
- Vessel certificates
- Contracts and/or records verifying date of last drydock
- BWMS installation documents and Vessel log books

If the vessel has not installed BWMS at original compliance date, there must be a letter of extension of the vessel's compliance date or if the vessel is using an "other accepted method" formal documentation must be available onboard, for example, receipts from reception facility or public water utility.

If the vessel has installed a BWMS, there must be USCG approval certificate for BWMS or a proof of compliance as an Alternate Management System (AMS) for the IMO approved BWMS.

In addition to the IMO PSC requirements, vessel has to demonstrate knowledge on the following details:

- Tentative schedule of next drydocking or the installation schedule for BWMS
- Expiration of extension and other permits
- Other required documents which are subject to evaluation during compliance assessments incuding familiarity of the crew, system installation, maintenance operation and discharge standards.
- Documentation and records related to VGP: Any vessel greater than 300 GT or more than 8 m^3 ballast tank must submit Notice Of Intent to EPA to discharge in compliance with VGP.

Contingency Measures: If the installed BWMS stops operating properly during a voyage or the vessel's BWM method is unexpectedly unavailable, the vessel owner/operator must report the problem to the nearest Captain of the Port (COTP) as soon as possible. It is strongly recommended to include "contingency plans" in the BWMP.

8.3. Monitoring test kit

Ballast water monitoring has become an important aspect of the port state control function, as inspectors test treated water for compliance. For example, vessels discharging ballast water in Saudi Aramco ports (Saudi Arabia) will be required to present a ballast water report and sample since 16 August 2017. Saudi Aramco [51] has selected FastBallast Portable ballast water analyzer designed and manufactured by Chelsea Technologies Group (CTG) to conduct spot checks on indicative sampling undertaken by third-party sampling companies.

Another company from France called Aqua-tools [52], in collaboration with SGS Group (Switzerland) and LuminUltra (Canada), has developed a ballast water monitoring kit using a Rapid Adenosine Tri-Phosphate based detection method called ATP-metry 2nd

Generation (ATP 2G). This innovative rapid method was developed and scientifically validated to indicate the number of living organisms in ballast water. It can be used on board ships to provide clear indications of compliance or non-compliance with the discharge regulations of IMO and USCG.

Figure 62: Ballast Water Monitoring Kit B-AQUA [52]

This kit shown in figure 62 uses bioluminescence techniques to monitor ATP, a molecular structure that is found in all living organisms. Other kits are ineffective in high salinity waters and not reliable to test the efficacy of ballast water treatment systems. This system, uses a unique method for extracting the ATP from all marine organisms, including those with hard shells, which takes only five minutes. Results are available 40 minutes after the test. Using this technology available which provides 100% indicative but accurate readings more or less immediately, samples are not required to be sent to laboratories. It is recommened to purchase these kits even before the system is put into service and check the discharge sample during commissioning/trials of ballast water treatment system.

9. CONCLUSIONS

Based on the overview, comparison and analysis of IMO and USCG regulations, author would like to conclude that alignment of USCG regulations with IMO regulations will benefit many treatment system manufacturers. Especially, acceptance of MPN method of testing and reducing the time taken for approving the treatment system by USCG will reduce the burden for treatment system manufacturers to comply with two different regulations.

Even though, there is an encouraging trend of some ship owners trying to comply with regulations as early as possible, most of them have exploited the regulations by conducting IOPP renewal survey few weeks or months before the date of entry into force of ballast water management convention to postpone the compliance for another five years. It may be financially an attractive option, but undertaking the installation process as early as possible will bring more indirect benefits for the ship owners such as no penalties for non-compliance, creating better image for their clients and raise in the value of the vessel.

Even though, different type of ballast water treatment systems can be accepted for certain vessel types, it is clearly evident from the comparison and analysis of some of the treatment systems that there is no single system which can be an ideal option for all kind of vessels. Each treatment system has its own advantages and disadvantages, so the ship owners must be clear about their requirements to choose an optimal solution with the help of experts. They must pay particular attention to various limitations of the treatment system and their effect on the treatment system while operating in different types of water. Because, there are various parameters such as turbidity, salinity, temperature etc. are challenges to which the treatment system is subjected to and the efficacy of the treatment system depends on those parameters.

From the retrofitting experience obtained during internship with Westcon Design Poland, author has developed a timeline for turnkey project. It may not be an ideal timeline for every case, though it will give an overall idea to plan for retrofit. During feasibility study, it is important to select treatment systems which doesn't require major change to the existing arrangement of ship. Also, author would like to request all stake holders involved in retrofitting ship to try their best to reduce carbon foot print involved during this process and be committed to sustainable shipping.

This page is intentionally left blank.

10. RECOMMENDATIONS

The author would like to recommend ship owners to conduct feasibility study and find out the most suitable system available in the market well before the compliance deadline. In the case of tankers, carrying out laser scanning during dry-docking can reduce additional expenses for Ex-Scanning (Explosion proof) which is mandatory if the vessel is in service. If the ship owners are planning to install any other equipment for compliance such as exhaust gas scrubber, they can carry out 3D scanning considering such future installations as well to reduce the cost involved in this process.

The author would like to recommend classification societies and ship owners not to encourage de-coupling of ballast water management survey from harmonized system for survey and certification. Selecting suitable space with the help of design offices or service providers as early as possible will save costs and time. So, the small investment made in the beginning will be very economical in the end. So, it will be better for ship owners to proceed for installation of treatment system as early as possible. The cost of installation would obviously increase when it gets closer to the deadline, so it’s better to not wait until the compliance deadline.

The author would like to recommend treatment system manufacturers to develop partnership with other stake holders as well rather than focusing only to sell more number of systems. Developing a good partnership with design office, shipyard and or other service organizations to provide turn-key solution can attract more number of ship owners to choose their product. Also, providing after-sales service for a certain period of time will also strengthen their position in the market. For example, Optimarin from Norway has announced recently that they will offer parts and servicing guarantee for 5 years.

This page is intentionally left blank.

11. FUTURE PROSPECTS

Finite Element Analysis: Analysis of additional structures which are required on existing ships to install ballast water treatment systems can be considered for further studies using finite element method. It can ensure the strength and integrity of the installation and enhance the reliability of the installation from the view point of structural strength.

Computational Fluid Dynamics: In the case of ballast water treatment methods using chemicals, rapid and effective mixing of the chemical component with the ballast water is an important factor to achieve a homogeneous concentration of the biocide. Study about mixing of chemical and ballast water in pipes during the ballasting operation can be done along with simulation and it can help in determining the appropriate pipe specifications to ensure homogeneous mixing.

Usually, treatment system manufacturers create mathematical models for the internal flow in the equipment during type approval process. But, it will be better to verify the functionality of the equipment along with associated piping systems with sharp bends to avoid back pressure or reduction in capacity.

Sediments usually tend to collect in ballast water tanks over a period of time. They reduce the deadweight of vessel to certain extent, restriction of water flow which will delay de-ballasting process and higher fuel consumption due to increase in draft. So, detailed analysis can be done to reduce sediment accumulation in ballast tanks.

Multi-objective optimization: During the selection and installation of BWTS, there are various factors to be considered. By devloping a tool using multi-objective optimization methods, it will be possible to select an optimum choice of treatment system for the benefit of ship owners or design office during the system selection process.

This page is intentionally left blank.

12. ACKNOWLEDGEMENTS

I would first like to thank my supervisor Prof. Zbigniew Sekulski of the Faculty of Maritime Technology and Transport at the West Pomeranian University of Technology, Szczecin for his guidance and constant support throughout the period of this thesis work.

I would like to thank Mr. Andrzej Sobieraj, Westcon Design Poland and Capt. Niko Bensein, OMCS Class for assisting me to develop this work. Also, I would like to thank Prof. Maciej Taczała, Dr. Alfred Jazukiewicz and others at Westcon Design Poland for helping me with an internship opportunity.

I am also very grateful to Prof. Philippe Rigo and other EMship Professors for their guidance. I specially thank Mr.Giles Candy, Giles Environmental, LLC for his inputs and support. Finally, I would like to express my sincere gratitude to my family and friends. This thesis would not have been possible without them.

This thesis was developed in the frame of the European Master Course in “Integrated Advanced Ship Design” named “EMSHIP” for “European Education in Advanced Ship Design”, Ref.: EMJMD 159652 – Grant Agreement 2015-1687.

.

This page is intentionally left blank.

13. REFERENCES

[1] International convention for the control and management of ships ballast water and sediments, 2004, IMO London

[2] S. Gollasch, Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries, IMO/GEF/UNDP Project Report, 1997

[3] T.P. Mackey *et al.,* The Development and Type Approval Testing of a Ballast Water Treatment Technology, WMTC, 2009 http://imare.in/media/30648/paper-no-4b-1-mr-tom-mackey.pdf

[4] J. Kazumi, Ballast Water Treatment Technologies and Their Application for Vessels Entering the Great Lakes via the St. Lawrence Seaway, Transport Research Board, Canada, 2007 http://onlinepubs.trb.org/onlinepubs/sr/sr291_kazumi.pdf

[5] E. Tsolaki *et al.,* Technologies for ballast water treatment: A review, Journal of Chemical Technology & Biotechnology 85(1):19-32, January 2010 https://www.researchgate.net/publication/229442810_Technologies_for_ballast_water_treatment_A_review

[6] R. Balajt *et al.,* Emerging ballast water treatment technologies: A review, Journal of Sustainability Science and Management 6(1):126-138, June 2011 https://www.researchgate.net/publication/288404653_Emerging_ballast_water_treatment_technologies_A_review

[7] J. Janutėnienė *et al.,* Ballast water treatment technologies comparative analysis, January 2012 https://www.researchgate.net/publication/286941995_Ballast_water_treatment_technologies_comparative_analysis

[8] Bureau Veritas, Ballast Water Management Systems Guidance Note NI 538, 2011

[9] Ballast Water Self Monitoring, 2011. EPA 800-R-11-003, table 11

I10] IMO Resolution MEPC.174(58) Adopted on 10 October 2008 Guidelines for Approval of Ballast Water Management Systems (G8)

[11] IMO Resolution MEPC.169(57) Adopted on 4 April 2008 Procedure for Approval of Ballast Water Management Systems that make use of active substances (G9)

[12] Emerging Ballast Water Management Systems, Proceeding of the IMO-WMU Research and Development Forum, January 2010, Malmo, Sweden

[13] Federal Register/Vol. 77, No. 57/Friday, March 23, 2012/Rules and Regulations, Part V, Department of Homeland Security, Coast Guard 3, 3 CFR Part 151, 46 CFR Part 162, Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters; Final Rule

[14] Lloyd's Register Summary – Ballast Water Treatment System Type Approval Version 1.1 – June 2015

[15] DNV-GL, Technical and Regulatory News No. 28/2015 – Statutory MPN method

[16] Lloyds Register, Understanding BWM Guidance for ship owners and operators, 4th Edition, September 2016

[17] American Bureau of Shipping, Guide for Ballast Water Treatment, August 2014

[18] A.D. Shah *et al.,* Formation of disinfection by-products during ballast water treatment with ozone, chlorine, and peracetic acid: influence of water quality parameters, Environ. Sci.: Water Res. Technol., 2015, Advance Article

[19] International Chamber of Shipping, Ballast Water Management Frequently Asked Questions Version 2, September 2017

[20] IACS Unified Requirements for Installation of BWMS M74, Revision.1, 2016

[21] U.M. Blom, The Maritime Group, Presentation for 16th BWMC, Antwerp, 2016

[22] Westcon Design Poland, Retrofitting BWTS for M.V. Main Highway, 2017

[22] Westcon Design Poland, Retrofitting BWTS for M.V. Elbe Highway, 2017

[24] Wartsila AQUARIUS UV Technical Manual, Wartsila water systems ltd.

[25] http://www.un.org/sustainabledevelopment/biodiversity/

[26] http://www.imo.org/en/MediaCentre/HotTopics/BWM/Pages/default.aspx

[27] http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Pages/AquaticInvasiveSpecies(AIS).aspx

[28] http://www.imo.org/en/MediaCentre/MeetingSummaries/MEPC/Pages/MEPC-71.aspx

[29] http://www.imo.org/en/MediaCentre/HotTopics/BWM/Documents/BWM infographic_FINAL.pdf

[30] https://ww2.eagle.org/content/dam/eagle/regulatory-news/2017/MEPC%2071%20Brief.pdf

[31] http://www.gesamp.org/work-programme/workgroups/working-group-34

[32] http://archive.iwlearn.net/globallast.imo.org/globallast.imo.org/resources/globallast-monographs/index.html

[33] http://omcsclass.org

[34] https://cgmix.uscg.mil/EQlabs/Default.aspx

[35] http://www.dco.uscg.mil/Portals/9/MSC/BWMS.Approval.Status.pdf

[36] http://mariners.coastguard.dodlive.mil/2015/12/14/12142015-coast-guard-decision-on-use-of-most-probable-number-method/

[37] https://www.epa.gov/npdes/vessels-vgp

[38] https://www.cleanshipsolutions.com/ballast-water-management-compliance-calculator/
[39] http://trojanmarinex.com

[40] http://desmioceanguard.com

[41] http://nei-marine.com

[42] http://www.damengreen.com/en/bwt/port-solutions#gallery
[43] http://ballastwatercontainers.com

[44] http://eco-enviro.com

[45] https://www.gea.com/en/products/ballastmaster-ultraV.jsp

[46] http://trojanmarinex.com

[47] https://www.wartsila.com/products/marine-oil-gas/ballast-water/bwms/wartsila-aquarius-uv-bwms

[48] http://worldpanasia.com

[49] https://www.cleanshipsolutions.com/ballast-water-management-lp001/

[50] http://optimarin.com/press-release-2017-11-20-optimarin-shakes-up-bwt-sector-with-unique-promise-for-shipowners/

[51] https://www.chelsea.co.uk/applications/green-shipping/ballast-water-compliance-monitoring

[52] http://aqua-tools.com

[53] http://cordis.europa.eu/project/rcn/102012_en.html

APPENDICES

Appendix A: Ballast Water Record Book

FORM OF BALLAST WATER RECORD BOOK

INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS

Period From: .... To: ....

Name of Ship ....

IMO number ....

Gross tonnage ....

Flag ....

Total Ballast Water capacity (in cubic metres) ....

The ship is provided with a Ballast Water Management plan ☐

Diagram of ship indicating ballast tanks:

RECORD OF BALLAST WATER OPERATIONS

SAMPLE BALLAST WATER RECORD BOOK PAGE

Name of Ship: ....

Distinctive number or letters ....

Date	Item (number)	Record of operations/signature of officers in charge

Signature of master ....

Source: IMO BWMC, 2004

Appendix B: International Ballast Water Management Certificate

INTERNATIONAL BALLAST WATER MANAGEMENT CERTIFICATE

Issued under the provisions of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (hereinafter referred to as "the Convention") under the authority of the Government of

....
(full designation of the country)

by ....
(full designation of the competent person or organization authorized under the provisions of the Convention)

Particulars of ship[1]

Name of ship ....

Distinctive number or letters ....

Port of registry ....

Gross Tonnage ....

IMO number[2] ....

Date of Construction ....

Ballast Water Capacity (in cubic metres) ....

Details of Ballast Water Management Method(s) Used

Method of Ballast Water Management used ....

Date installed (if applicable) ....

Name of manufacturer (if applicable) ....

1 Alternatively, the particulars of the ship may be placed horizontally in boxes.
2 IMO Ship Identification Number Scheme adopted by the Organization by resolution A.600(15).

Source: IMO BWMC,2004

The principal Ballast Water Management method(s) employed on this ship is/are:

- ☐ in accordance with regulation D-1
- ☐ in accordance with regulation D-2
  (describe) ....
- ☐ the ship is subject to regulation D-4

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with regulation E-1 of the Annex to the Convention; and

2 That the survey shows that Ballast Water Management on the ship complies with the Annex to the Convention.

This certificate is valid until .... subject to surveys in accordance with regulation E-1 of the Annex to the Convention.

Completion date of the survey on which this certificate is based: dd/mm/yyyy

Issued at ....
(Place of issue of certificate)

....
(*Date of issue*) *Signature of authorized official issuing the certificate)*

(Seal or stamp of the authority, as appropriate)

Source: IMO BWMC, 2004

Appendix C: Type Approval Certificate [MEPC. 174(58)]

The Netherlands

TYPE APPROVAL CERTIFICATE OF BALLAST WATER MANAGEMENT SYSTEM

This is to certify that the Ballast water management system listed below has been examined and tested in accordance with the requirements of the specifications contained in the Guidelines contained in IMO resolution MEPC.174(58). This certificate is valid only for the ballast water management system referred to below.

This certificate is issued to:

Producer	**Wärtsilä Water Systems Ltd**
Address	Fleets Corner, Poole Dorset BH17 0JT England
Ballast water management system supplied by	**Wärtsilä Water Systems Ltd**
Under type and model designation and incorporating:	Wärtsilä AQUARIUS® UV ballast water management system using mechanical filtration and ultraviolet radiation models AQ-50-UV to AQ-1000-UV
Ballast water management system manufactured by	**Wärtsilä Water Systems Ltd**
to equipment/assembly drawing	Single system P&ID: UV-T-001;Issue 3 **Date:** 21.05.2012 Multiple system P&ID: UV-T-002; Issue 3 **Date:** 21.05.2012 Typical P&ID Symbols: UV-T-003 1 **Date:** 29.05.2012
Other equipment manufactured by	See attachment
to equipment/assembly drawing No.	See attachment
Treatment rated capacity	50 to 1000 m^3/h Capacities up to 6000 m^3/h achieved by using multiple units installed in parallel

A copy of this Type Approval Certificate should be carried on board a vessel fitted with this ballast water management system at all times. A reference to the test protocol and a copy of the test results should be available for inspection on board the vessel.

Issued at Rotterdam, **March 12 2013**, under no. **11288/2012**.

This certificate remains valid, provided no alternations or modifications are made, until **December 20, 2017**

THE MINISTER OF INFRASTRUCTURE AND THE ENVIRONMENT,
On behalf
THE UNIT MANAGER MARITIME SHIPPING PERMITS,
on behalf,

M.C. Vink
Senior Inspector
Enc. Ratings, Components and Copy of the original test results

Source: Wartsila water systems Ltd

Attachment to Certificate of Type Approval No. 11288/2012

The undernoted documents have been appraised for compliance with IMO Resolution MEPC.174(58) and forms part of the Type Approval Certificate for the Ballast water management system issued to Wärtsilä Water System Ltd.

PLACES OF PRODUCTION

Wärtsilä Water Systems Ltd
Fleets Corner, Poole
Ltd Dorset, BH17 0JT
England

Wärtsilä Suzhou Ltd
No. 77 Hongxi Road
New District of Souzhou
215151 PR China

Ratings

The below table details the filter and UV reactor unit used at each module size on the Wärtsilä AQUARIUS® UV ballast water management system product range. For all models, the filter mesh is a 40 micron weave of 904L duplex construction.

AQ Module Size	TRC m^3/h	Filtration Unit		UV Reactor Model	UV Lamps		
		Filter Type	Flange size (DN)		No. Of Lamps	Lamp Model	Lamp Power (kW)
AQ-50-UV	50	BS-025H-03	80	BWT IL+ 125	6	B2020H	2.3
AQ-80-UV	80	BS-050H-04	100				
AQ-125-UV	125	BS-050H-06	150				
AQ-180-UV	180	BS-070H-06	150	BWT IL+ 250	12	B3535LV	2.7
AQ-250-UV	250	BS-100H-08	200				
AQ-300-UV	300	BS-100H-T-08	200	BWT IL+ 300	12	B3535LV	3.2
AQ-375-UV	375	BS-150H-10	250	BWT IL+ 375	12	B3535H	3.2
AQ-430-UV	430	BS-150H-T-10	250	BWT IL+ 430	12	B3535H	3.6
AQ-500-UV	500	BS-200H-12	300	BWT IL+ 500	12	B3535H	4.4
AQ-550-UV	550	BS-200H-T-12	300	BWT IL+ 750	18	B5050LV	3.8
AQ-750-UV	750	BS-300H-14	350	BWT IL+ 750	18	B5050LV	3.8
AQ-850-UV	850	BS-300H-T-14	350	BWT IL+ 1000	18	B5050H	4.7
AQ-1000-UV	1000	BS-400SH-14	350	BWT IL+ 1000	18	B5050H	4.7

System Application

The Wärtsilä AQUARIUS® UV ballast water management system is designed for use on any vessel type or size and the above range is designed for use in 'safe area' applications.

System application parameters are tabulated below:

Normal Liquid Inlet Temperature	-2 to 45°C
Operating Ambient Temperature	0° (min) to 55°C. (max)
Water Salinity	No Limitations
Operating Relative Humidity	10% to 90%.

Source: Wartsila water systems Ltd

Appendix D: Type Approval Certificate [MEPC. 279(70)]

BADGE OR CIPHER **(Limiting Operating Conditions Apply)**
(delete as appropriate)

NAME OF ADMINISTRATION

TYPE APPROVAL CERTIFICATE OF BALLAST WATER MANAGEMENT SYSTEM

This is to certify that the ballast water management system listed below has been examined and tested in accordance with the requirements of the specifications contained in the Guidelines contained in IMO resolution MEPC.279(70). This certificate is valid only for the Ballast Water Management System referred to below.

Name of Ballast Water Management System: ....

Ballast Water Management System manufactured by: ....

Under type and model designation(s) ....
and incorporating:

To equipment/assembly drawing No.: .... date: ....

Other equipment manufactured by : ....

To equipment/assembly drawing No.: .... date: ....

Treatment Rated Capacity (m^3/h): ....

A copy of this Type Approval Certificate, should be carried on board a ship fitted with this Ballast Water Management System. A reference to the test protocol and a copy of the test results should be available for inspection on board the ship. If the Type Approval Certificate is issued based on approval by another Administration, reference to that Type Approval Certificate shall be made.

Limiting Operating Conditions imposed are described in this document.

(Temperature / Salinity)

Other restrictions imposed include the following:

This equipment has been designed for operation in the following conditions:
(insert System Design Limitations)

Official stamp

Signed ....
Administration of ....
Issued this .... day of .... 20 ......
Valid until this...........day of .... 20.....

Enc. Copy of the original test results.

Source: IMO G8 Technical Guidelines

Appendix E: USCG Approval Certificate

U. S. Department of Homeland Security

United States Coast Guard

Certificate of Approval

Coast Guard Approval Number: 162.060/1/0 Expires: 02 December 2021

BALLAST WATER MANAGEMENT SYSTEM
Filtration/Ultraviolet

Optimarin AS
Sjoveien 34
4315 Sandnes NORWAY

Optimarin OBS/OBS Ex

This is to certify that the above listed BWMS with the listed treatment capacities has been satisfactorily examined and tested by Independent Lab DNV GL in accordance with the requirements contained in 46 CFR 162.060. The system shall be installed and operated in accordance with the manufacturer's listed Operation, Maintenance, and Safety Manual for each model.

Capacities:
167/334/500/667/834/1000/1167/1334/1500/1667/1834/2000/2167/2334/2500/2667/2834/3000 m3/h

OBS: Optimarin OMS Manual 105, Rev. 3, Dated 02 November 2016
OBS Ex: Optimarin OMS Manual 204, Rev. 3, Dated 02 November 2016

Operational Limitations:
- Salinity: Not Applicable
- Temperature: 0 - 55 Degrees C
- Hold Time: >3 days
- Filter Pressure: >1.5 Bar
- UV-Intensity: >600 W/m2

The BWMS does not meet the requirements of 46 CFR 111.105 and may not be installed in hazardous locations on a U.S. flag vessel. The OBS Ex model may be installed in hazardous locations on a foreign flag vessel subject to approval of the foreign administration.

The BWMS must be marked in accordance with 46 CFR 162.060-22.

A copy of this Type Approval Certificate shall be carried on board a vessel fitted with the ballast water management system at all times.

*** End ***

THIS IS TO CERTIFY THAT the above named manufacturer has submitted to the undersigned satisfactory evidence that the item specified herein complies with the applicable laws and regulations as outlined on the reverse side of this Certificate, and approval is hereby given. This approval shall be in effect until the expiration date hereon unless sooner canceled or suspended by proper authority.

GIVEN UNDER MY HAND THIS 02nd DAY OF DECEMBER 2016, AT WASHINGTON D.C.

Source: USCG

Appendix F: List of BWMS which received Type Approval Certification by their respective Administrations [MEPC.175(58) & MEPC.228(65)]

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
1	June 2008	Det Norske Veritas, on behalf of the Norwegian Administration	PureBallast System	Provided (MEPC 61/INF.3)	Yes, please refer to MEPC 58/2/2, annex 5	MEPC 56/23, paragraph 2.8
2	10 June 2008	Federal Maritime and Hydrographic Agency, Germany	SEDNA® Ballast Water Management System (Using Peraclean® Ocean)	Provided (MEPC 58/INF.17)	Yes, please refer to MEPC 57/2/10, annex 7	MEPC 57/21, paragraph 2.16
3	2 September 2008 19 January 2010	Office of the Maritime Administration, Marshall Islands Merchant Shipping Directorate of Malta	NEI Treatment System VOS-2500-101	Available at request Provided (BWM.2/Circ. 25)	No Active Substances used according to the communication received from the Administration of Marshall Islands (Letter of 10 Dec. 2008) Please refer to circular BWM.2/Circ.25	Not applicable Not applicable
4	31 December 2008	Ministry of Land, Transport and Maritime Affairs, Republic of Korea	Electro-Clean™ System	Provided (MEPC 59/INF.6)	Yes, please refer to MEPC 58/2/7, annex 7	MEPC 58/23, paragraph 2.8
5	17 April 2009	Det Norske Veritas, on behalf of the Norwegian Maritime Directorate	OceanSaver® Ballast Water Management System	Provided (MEPC 59/INF.17 and MEPC 62/INF.15)	Yes, please refer to MEPC 58/2/8, annex 4	MEPC 58/23, paragraph 2.10
6	24 November 2009	Ministry of Land, Transport and Maritime Affairs, Republic of Korea	NK-O3 BlueBallast System (Ozone)	Provided (MEPC 60/INF.14)	Yes, please refer to MEPC 59/2/16, annex 6	MEPC 59/24, paragraph 2.8.
7	4 December 2009	Ministry of Land, Transport and Maritime Affairs, Republic of Korea	GloEn-Patrol™ Ballast Water Management System	Provided (MEPC 61/2/19)	Yes, please refer to MEPC 60/2/11, annex 4	MEPC 60/22, paragraph 2.7
8	5 March 2010	Ministry of Land, Infrastructure, Transport and Tourism of Japan	Hitachi Ballast Water Management System (ClearBallast)	Provided (MEPC 61/INF.21)	Yes, please refer to MEPC 59/2/19, annex 4	MEPC 59/24, paragraph 2.8

Source: IMO

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
9	26 May 2010 and 25 March 2011	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	JFE BallastAce® Ballast Water Management System	Provided (MEPC 62/INF.25)	Yes, please refer to MEPC 60/2/12, annex 5	MEPC 60/22, paragraph 2.7
10	1 September 2010	Federal Maritime and Hydrographic Agency, Germany	CleanBallast® 500-1 ballast water management system (formerly named RWO Ballast Water Management System (CleanBallast))	Provided (MEPC 67/INF.29)	Yes, please refer to MEPC 59/2/16, annex 5	MEPC 59/24, paragraph 2.8
11	28 January 2011	China Maritime Safety Administration	BalClor™ Ballast Water Management System	Provided (MEPC 62/INF.29)	Yes, please refer to MEPC 61/2/15, annex 9	MEPC 61/24, Paragraph 2.7.3
12	19 April 2011 Renewal 18 January 2013	The South African Department of Transport The South African Department of Transport	Resource Ballast Technologies System	Provided (MEPC 62/INF.18) Provided (MEPC 65/INF.28)	Yes, please refer to MEPC 60/2/11, annex 7	MEPC 60/22, paragraph 2.7
13	29 April 2009	Lloyd's Register, as delegated by the Administration of the United Kingdom	Hyde GUARDIAN™ ballast water management system	Provided (MEPC 59/INF.20)	No Active Substances used according to the communication received from the Administration of United Kingdom (please refer to MEPC 59/INF.20)	Not applicable
14	12 November 2009	Det Norske Veritas, on behalf of the Norwegian Maritime Directorate	OptiMarin Ballast System (OBS)	Provided (MEPC 61/INF.4)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 61/INF.4)	Not applicable

Source: IMO

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
15	16 February 2011	China Maritime Safety Administration	Blue Ocean Shield Ballast Water Management System	Provided (MEPC 62/INF.28)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 62/INF.28)	Not applicable
16	10 March 2011	Det Norske Veritas, on behalf of the Norwegian Maritime Directorate	PureBallst 2.0 and PureBallast 2.0 Ex	Provided (MEPC 62/INF.14)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 62/INF.14)	Not applicable
17	16 March 2011	The Ministry of Land, Transport and Maritime Affairs, Republic of Korea	EcoBallast Ballast Water Management System (Hyundai Heavy Industries Co., Ltd.)	Provided (MEPC 63/INF.5)	Yes, please refer to MEPC 59/2/16, annex 8	MEPC 60/22, paragraph 2.13
18	28 March 2011	China Maritime Safety Administration	BSKY™ Ballast Water Management System	Provided (MEPC 62/INF.30)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 62/INF.30)	Not applicable
19	29 April 2011	Federal Maritime and Hydrographic Agency, Germany	Ocean Protection System® OPS-250	Provided (MEPC 67/INF.27)	No Active Substances used according to the communication received from the Administration of Germany (please refer to MEPC 67/INF.27)	Not applicable
20	6 June 2011	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	FineBallast® OZ (the Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version)	Provided (MEPC 63/INF.12)	Yes, please refer to MEPC 61/2/15, annex 6	MEPC 61/24, paragraph 2.7
21	27 July 2011	Federal Maritime and Hydrographic Agency, Germany	BalPure® BP-500	Provided (MEPC 64/INF.20)	Yes, please refer to MEPC 61/2/21, annex 7	MEPC 61/24, paragraph 2.7

Source: IMO

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
22	6 August 2011	Office of the Maritime Administrator, Republic of the Marshal Islands	NEI Treatment System VOS-500 to VOS-6000	Available at request	No Active Substances used according to the communication received from the Administration of Marshall Islands (Letter of 9 August 2011)	Not applicable
23	31 October 2011	The Ministry of Land, Transport and Maritime Affairs, Republic of Korea	Purimar™ System	Provided (MEPC 63/INF.6)	Yes, please refer to MEPC 62/2/18, annex 6	MEPC 62/24, paragraph 2.5
24	7 November 2011	Det Norske Veritas, on behalf of the Norwegian Maritime Directorate	OceanGuard™ Ballast Water Management System	Provided (MEPC 65/INF.2)	Yes, please refer to MEPC 61/2/21, annex 5	MEPC 61/24, paragraph 2.7
25	4 November 2011	Federal Maritime and Hydrographic Agency, Germany	Ecochlor® Ballast Water Treatment System, Series 75	Provided (MEPC 67/INF.26)	Yes, please refer to MEPC 61/2/21, annex 6	MEPC 61/24, paragraph 2.7
26	11 November 2011	The Ministry of Land, Transport and Maritime Affairs, Republic of Korea	HiBallast™ Ballast Water Management System	Provided (MEPC 63/INF.4)	Yes, please refer to MEPC 62/2/18, annex 5	MEPC 62/24, paragraph 2.5
27	22 December 2011	Det Norske Veritas, on behalf of the Norwegian Maritime Directorate	OceanSaver® Ballast Water Management System	Provided (MEPC 64/INF.4)	Yes, please refer to MEPC 58/2/8, annex 4	MEPC 58/23, paragraph 2.10
28	10 May 2012 Amended 15 January 2015	Hellenic Republic, Ministry of Development, Competitiveness and Shipping, General Secretariat of Shipping, Merchant Ships Inspection General Directorate, Design and Construction Directorate	ERMA FIRST BWTS	Provided (MEPC 64/INF.26) Amended (MEPC 68/INF.19)	Yes, please refer to MEPC 63/2/11, annex 5	MEPC 63/23, paragraph 2.7

Source: IMO

29	30 May 2012	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	MICROFADE™ Ballast Water Management System	Provided (MEPC 64/INF.17)	Yes, please refer to MEPC 63/2/11, annex 6	MEPC 63/23, paragraph 2.7
30	12 June 2012	China Maritime Safety Administration	Cyeco™ Ballast Water Management System	Provided (MEPC 64/INF.12)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 64/INF.12)	Not applicable
31	15 June 2012	The Ministry of Land, Transport and Maritime Affairs, Republic of Korea	AquaStar™ Ballast Water Management System (subsequently changed to AquaStar™ BWMS and MACGREGOR WATER BALLAST TREATMENT SYSTEM)	Provided (MEPC 64/INF.18)	Yes, please refer to MEPC 63/2/11, annex 7	MEPC 63/23, paragraph 2.7
32	12 July 2012	The Ministry of Land, Transport and Maritime Affairs, Republic of Korea	ARA PLASMA BWTS Ballast Water Management System	Provided (MEPC 64/INF.33)	Yes, please refer to MEPC 61/2/15, annex 8	MEPC 61/24, paragraph 2.7
33	27 August 2012	Federal Maritime and Hydrographic Agency, Germany	BallastMaster ultraV 250 ballast water management system (formerly named AquaTriComb BW 250)	Provided (MEPC 67/INF.28)	No Active Substances used according to the communication received from the Administration of Germany (please refer to MEPC 67/INF.28)	Not applicable
34	20 September 2012	The Norwegian Maritime Authority	CrystalBallast® Ballast Water Management System	Provided (MEPC 65/INF.13)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 65/INF.13)	Not applicable
35	7 November 2012	The Danish Maritime Authority and the Danish Nature Agency	DESMI Ocean Guard OxyClean Ballast Water Management System	Provided (MEPC 65/INF.5)	Yes, please refer to MEPC 64/2/6, annex 4	MEPC 64/23, paragraph 2.6

Source: IMO

36	12 December 2012	The Norwegian Maritime Authority	MMC Ballast Water Management System	Provided (MEPC 66/INF.9)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 66/INF.9)	Not applicable
37	20 December 2012	The Netherlands Ministry of Infrastructure and the Environment	Wärtsilä AQUARIUS® UV ballast water management system	Provided (MEPC 65/INF.11)	No Active Substances used according to the communication received from the Administration of the Netherlands (please refer to MEPC 65/INF.11)	Not applicable
38	5 February 2013	China Maritime Safety Administration	BALWAT Ballast Water Management System	Provided (MEPC 66/INF.15)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 66/INF.15)	Not applicable
39	5 June 2013	French Ministry of Ecology Sustainable Development and Energy	BIO-SEA® Ballast Water Treatment System	Provided (MEPC 66/INF.10)	No Active Substances used according to the communication received from the Administration of France (please refer to MEPC 66/INF.10)	Not applicable
40	26 June 2013	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	JFE BallastAce	Provided (MEPC 66/INF.30	Yes, please refer to MEPC 64/2/7, annex 5	MEPC 64/23, paragraph 2.6
41	22 August 2013	China Maritime Safety Administration	HY™-BWMS	Provided (MEPC 66/INF.14)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 66/INF.14)	Not applicable
42	10 October 2013	China Maritime Safety Administration	NiBallast™ Ballast Water Management System	Provided (MEPC 66/INF.12)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 66/INF.12)	Not applicable

Source: IMO

43	4 November 2013	China Maritime Safety Administration	Cyeco™ Ballast Water Management System	Provided (MEPC 66/INF.16)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 66/INF.16)	Not applicable
44	5 November 2013	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	FineBallast MF	Provided (MEPC 66/INF.28)	No Active Substances used according to the communication received from the Administration of Japan (please refer to MEPC 66/INF.28)	Not applicable
45	14 November 2013	The Norwegian Maritime Authority	KBAL Ballast Water Management System	Provided (MEPC 65/INF.12)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 65/INF.12)	Not applicable
46	2 December 2013	China Maritime Safety Administration	Seascape Ballast Water Management System	Provided (MEPC 66/INF.13)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 66/INF.13)	Not applicable
47	20 December 2013	The Norwegian Maritime Authority	Trojan Marinex™ Ballast Water Management System	Provided (MEPC 67/INF.6)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 67/INF.6)	Not applicable
48	24 February 2014	Federal Maritime and Hydrographic Agency (BSH)	SeaCURE BWMS SC-1500/1	Provided (MEPC 69/INF.13	No Active Substances used according to the communication received from the Administration of Germany (please refer to MEPC 69/INF.13)	MEPC 63/23, paragraph 2.7
49	27 March 2014	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	Miura BWMS ballast water management system	Provided (MEPC 67/INF.20)	No Active Substances used according to the communication received from the Administration of Japan (please refer to MEPC 67/INF.20)	Not applicable

Source: IMO

50	30 April 2014	Federal Maritime and Hydrographic Agency, Germany	Cathelco Ballast Water Management System – A2	Provided (MEPC 67/INF.30)	No Active Substances used according to the communication received from the Administration of Germany (please refer to MEPC 67/INF.30)	Not applicable
51	18 June 2014	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	ECOMARINE ballast water management system	Provided (MEPC 67/INF.21)	No Active Substances used according to the communication received from the Administration of Japan (please refer to MEPC 67/INF.21)	Not applicable
52	30 June 2014	The Norwegian Maritime Authority	Alfa Laval PureBallast 3.0 Ballast Water Management System	Provided (MEPC 67/INF.5)	No Active Substances used according to the communication received from the Administration of Norway (please refer to MEPC 67/INF.5)	Not applicable
53	11 July 2014	China Maritime Safety Administration	PACT marine™ Ballast Water Management System	Provided (MEPC 68/INF.5)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 68/INF.5)	Not applicable
54	5 September 2014	The Danish Maritime Authority and The Danish Nature Agency	RayClean™ BWTS	Provided (MEPC 68/INF.10)	No Active Substances used according to the communication received from the Administration of Denmark (please refer to MEPC 68/INF.10)	Not applicable
55	21 October 2014	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	SKY-SYSTEM®	Provided (MEPC 68/INF.28)	Yes, please refer to MEPC 66/2/7, annex 4 and Corr.1	MEPC 66/21, paragraph 2.5
56	17 November 2014	China Maritime Safety Administration	OceanDoctor® Ballast Water Management System	Provided (MEPC 68/INF.4)	Yes, please refer to MEPC 65/2/19, annex 7	MEPC 65/22 paragraph 2.8

Source: IMO

57	5 January 2015	The Danish Maritime Authority and The Danish Nature Agency	Bawat™ BWMS	Provided (MEPC 68/INF.9)	No Active Substances used according to the communication received from the Administration of Denmark (please refer to MEPC 68/INF.9)	Not applicable
58	27 January 2015	China Maritime Safety Administration	AHEAD®-BWMS ballast water management system	Provided (MEPC 69/INF.2)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 68/INF.2)	Not applicable
59	6 February 2015	United Kingdom, Maritime & Coastguard Agency	Coldharbour GLD™ Ballast Water Management System, incorporating types SeaGuardian™ IGG500 to IGG6000	Provided (MEPC 68/INF.27)	No Active Substances used according to the communication received from the Administration of the United Kingdom (please refer to MEPC 68/INF.27)	Not applicable
60	28 February 2015	China Maritime Safety Administration	YP-BWMS ballast water management system	Provided (MEPC 69/INF.5)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 69/INF.5)	Not applicable
61	8 May 2015	Ministry of Oceans and Fisheries of Republic of Korea	EcoGuardian™ Ballast Water Management System	Provided (MEPC 69/INF.31	No Active Substances used according to the communication received from the Administration of the Republic of Korea (please refer to MEPC 69/INF.31)	MEPC 65/22, paragraph 2.8
62	8 September 2015	Ministry of Oceans and Fisheries of the Republic of Korea	BlueZone™ Ballast Water Management System	Provided (MEPC 69/INF.32	No Active Substances used according to the communication received from the Administration of the Republic of Korea (please refer to MEPC 69/INF.32)	MEPC 67/20, paragraph 2.6
63	12 September 2015	China Maritime Safety Administration	NiBallast™ Ballast Water Management System	Provided (MEPC 69/INF.3)	No Active Substances used according to the communication received from the Administration of China (please refer to MEPC 69/INF.3)	Not applicable

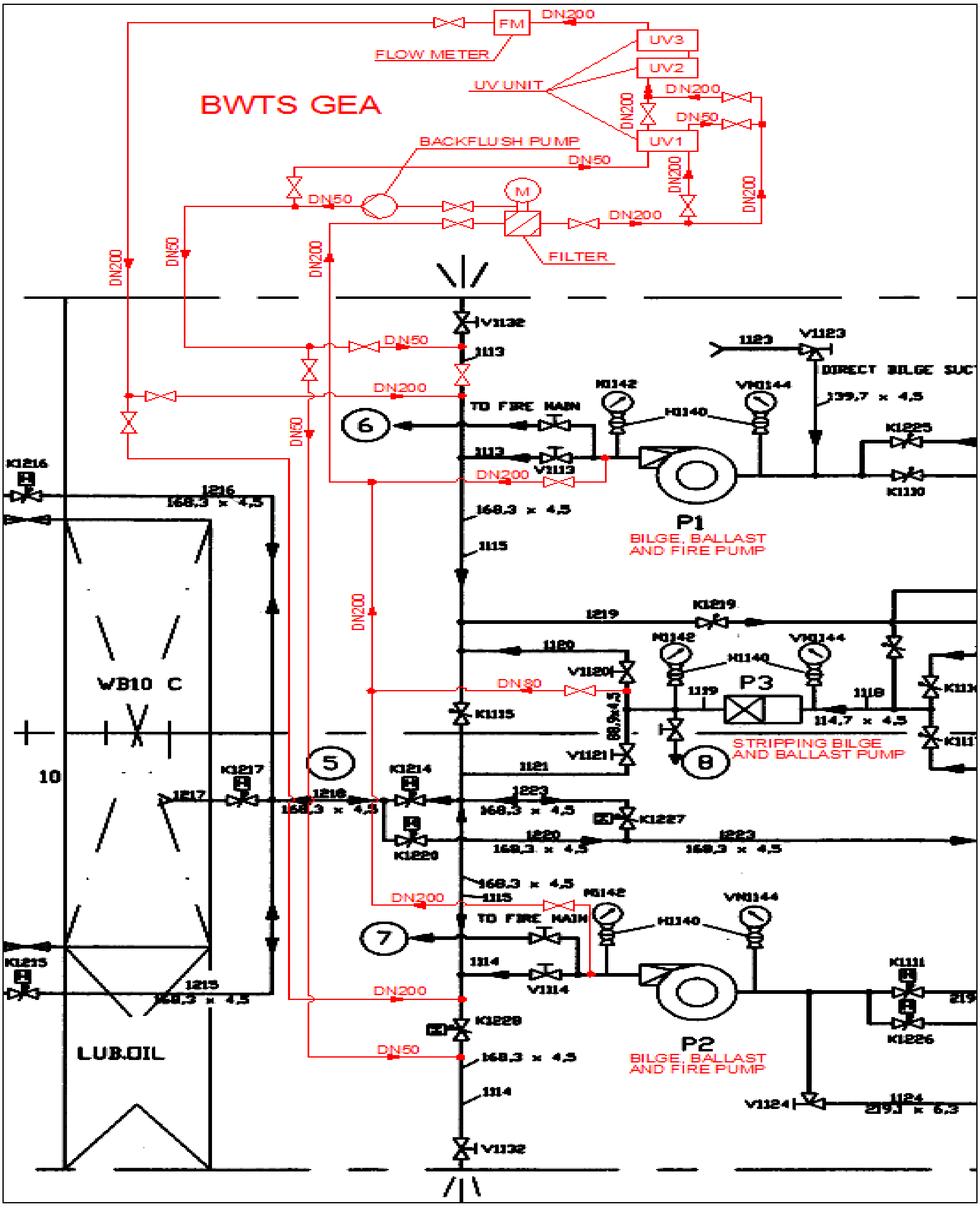
Source: IMO

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
70	12 January 2017	Singapore	Semb-Eco LUV 500 & Semb-Eco LUV 500 ballast water management system	Provided (MEPC 71/INF.12)	No Active Substances used according to the communication received from the Administration of Singapore (please refer to MEPC 71/INF.12)	Not applicable
71	13 January 2017	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	KURITA BWMS	Provided (MEPC 71/INF.26)	Yes, please refer to MEPC 67/2/4, annex 6	
72	19 March 2017	Netherlands Shipping Inspectorate, Ministry of Infrastructure and the Environment	Damen InvaSave 300	Provided (MEPC 71/INF.4)	No Active Substances used according to the communication received from the Administration of the Netherlands (please refer to MEPC 71/INF.4)	Not applicable
73	30 March 2017	Inspection and Measurement Division, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan	ATPS-BLUE$_{sys}$	Provided (MEPC 71/INF.27	Yes, please refer to MEPC 69/4/5, annex 6	

Note: all lists above updated in August 2017.

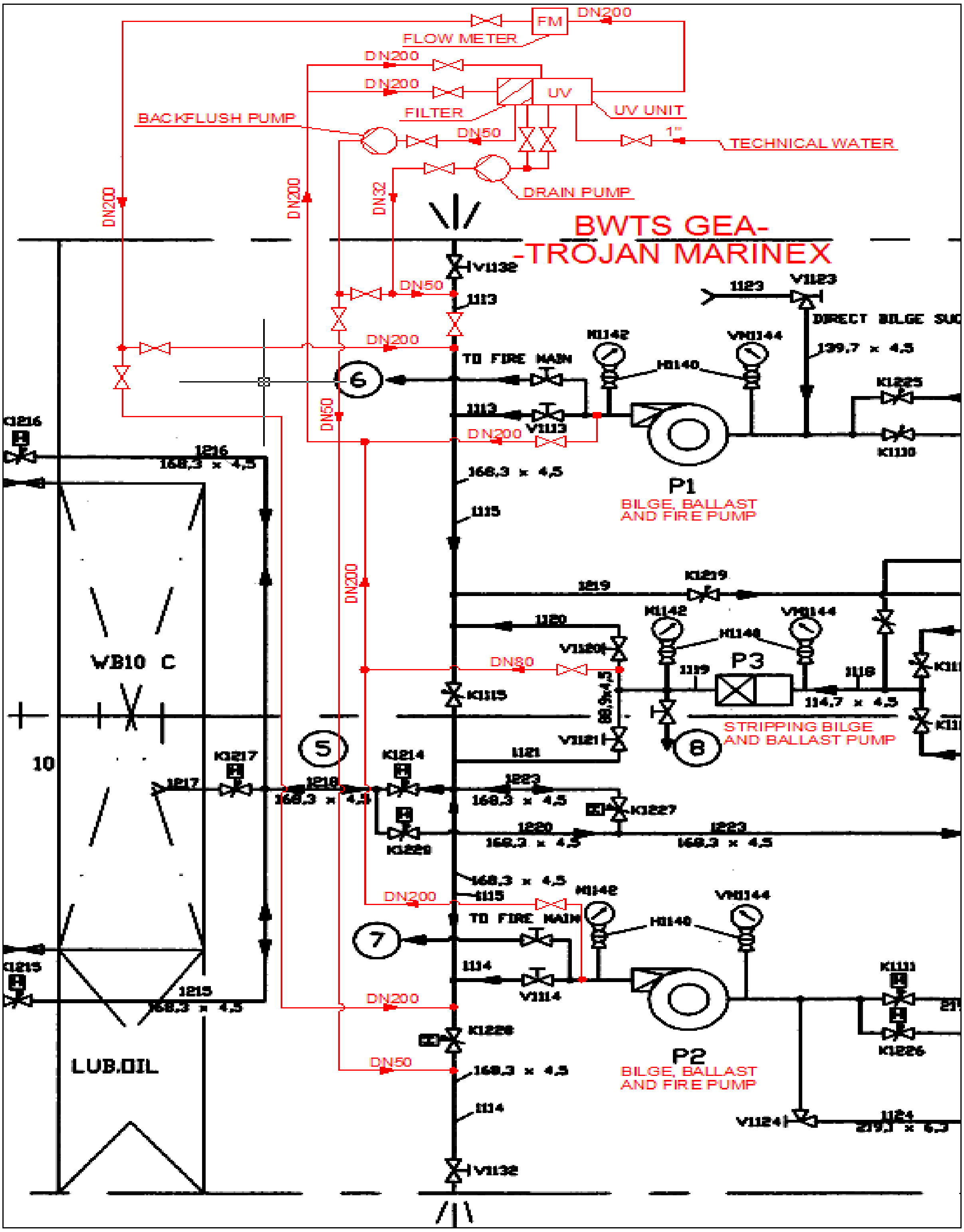
Source: IMO

Appendix G: Preliminary Design of GEA system



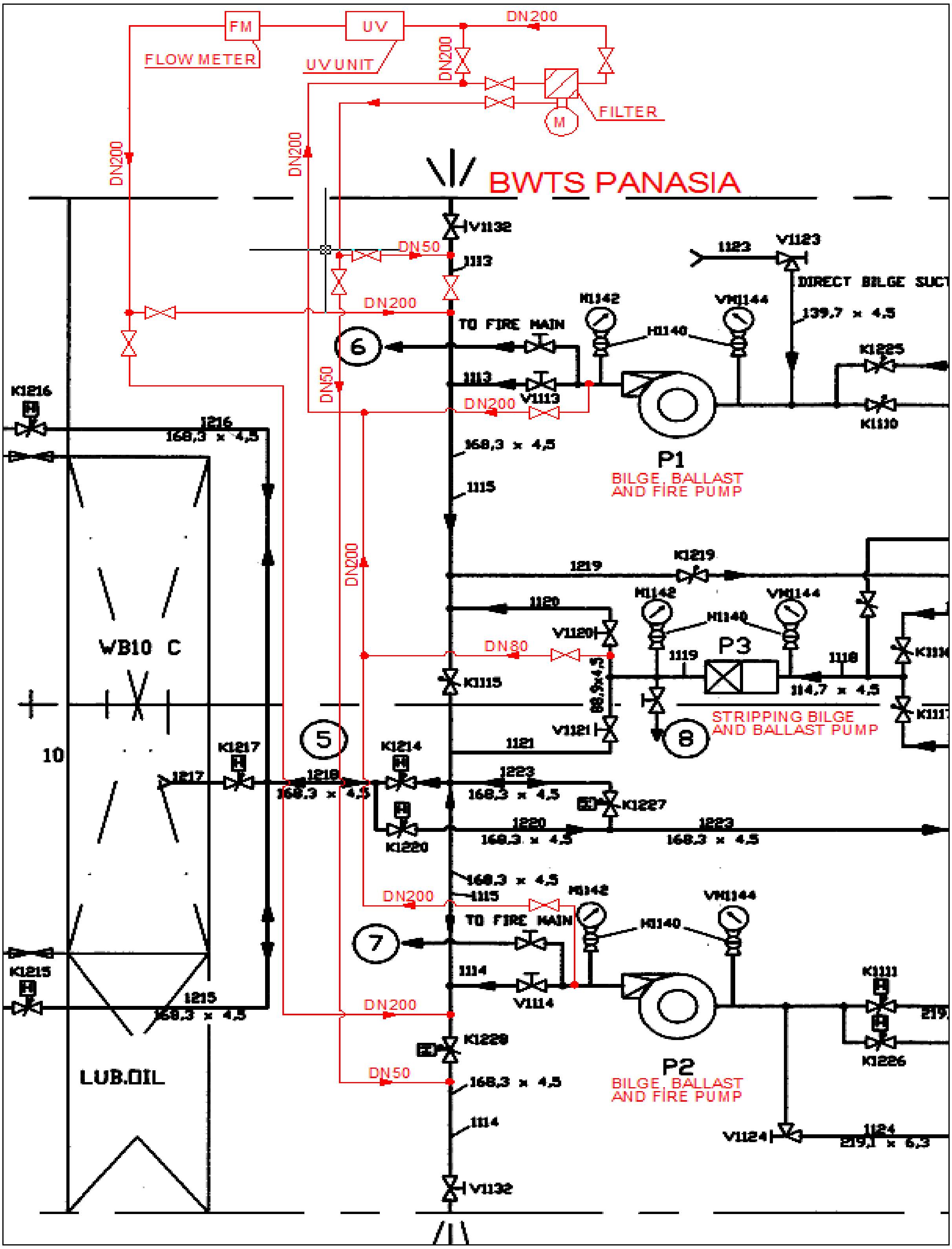
Source: Westcon Design Poland

Appendix H: Preliminary design of Trojan-Marinex system



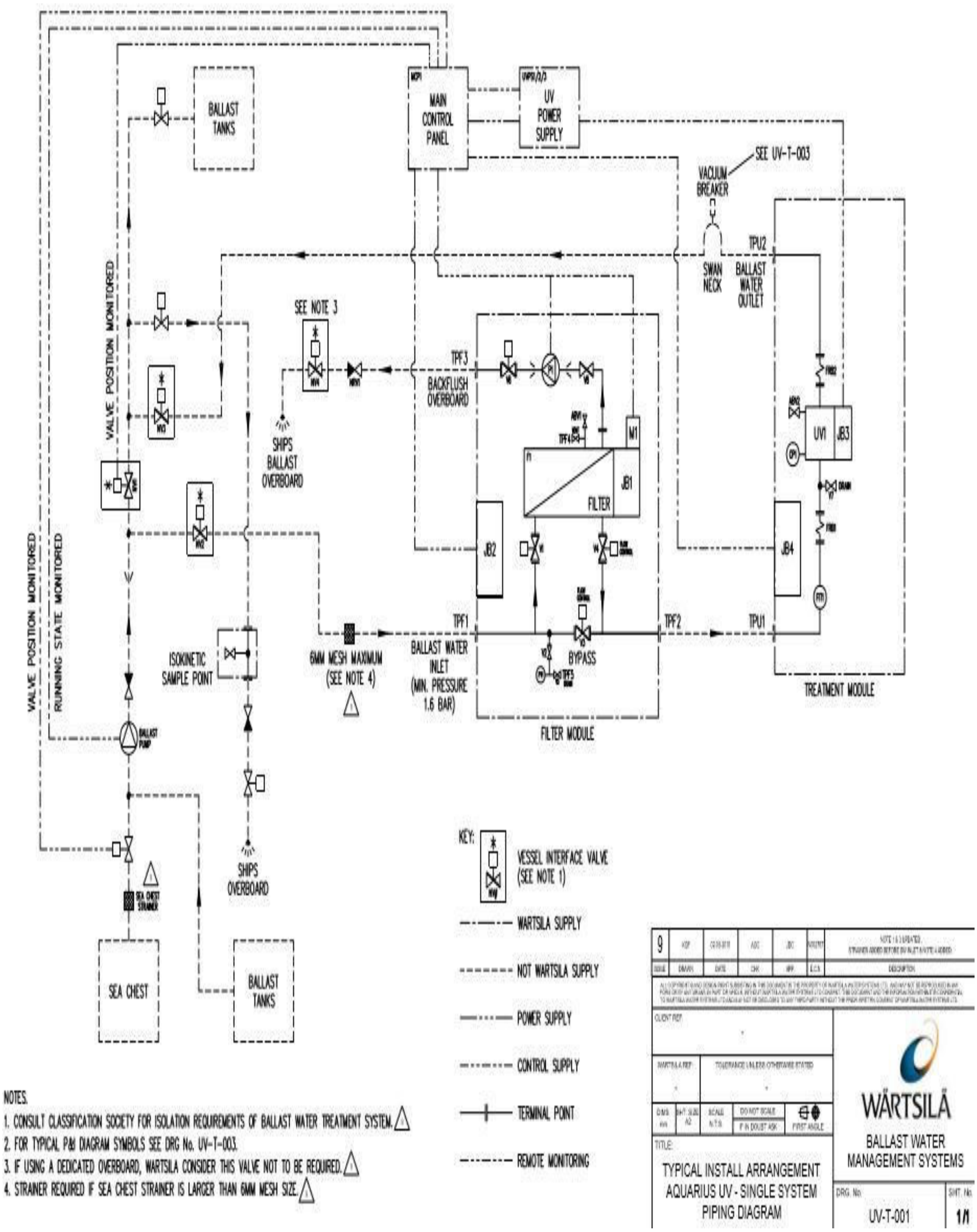
Source: Westcon Design Poland

Appendix I: Preliminary design of Panasia system



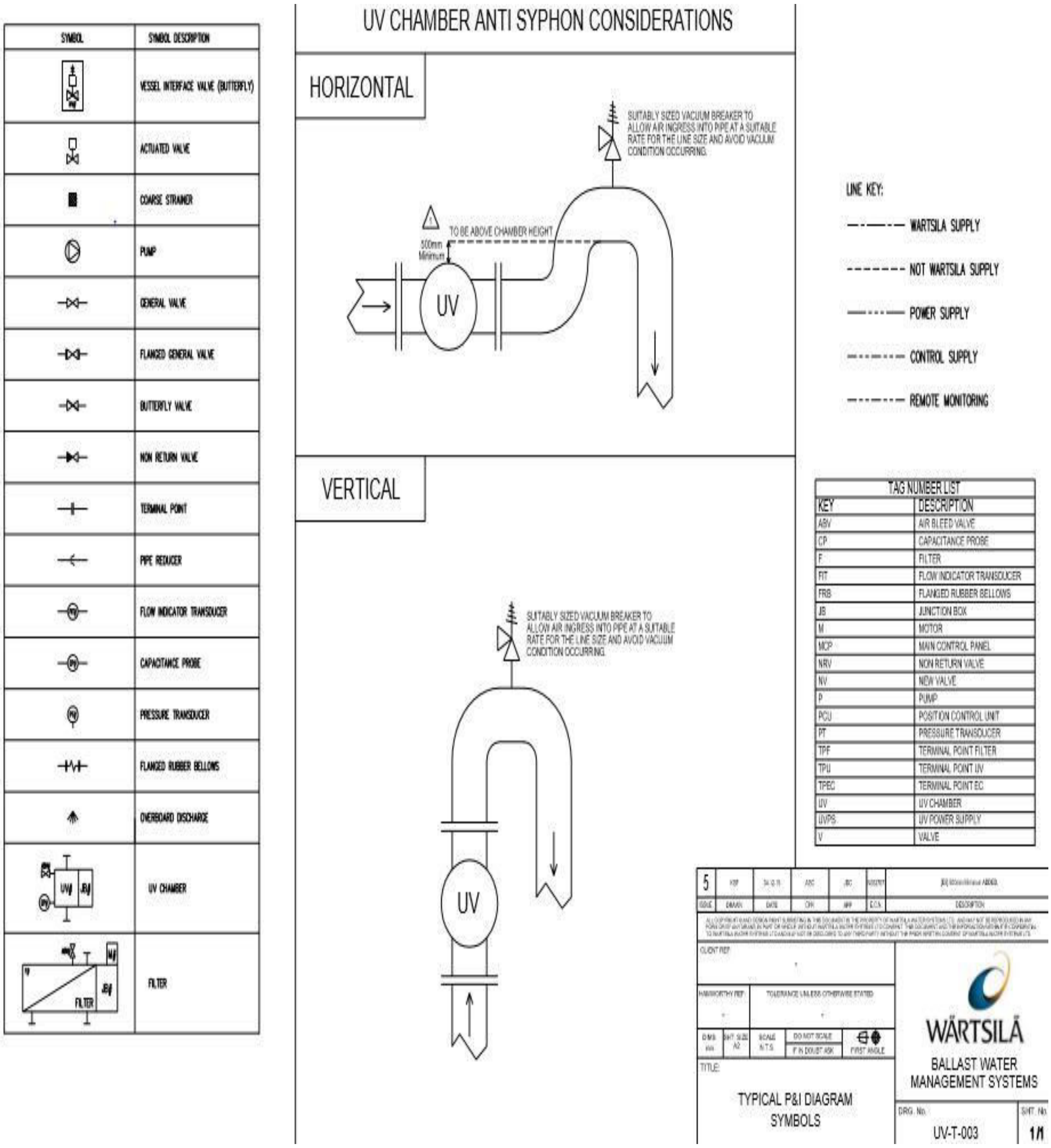
Source: Westcon Design Poland

Appendix J: Wartsila AQUARIUS Typical Installation Arrangement



Source: Wartsila water system Ltd

Appendix K: Wartsila AQUARIUS Typical P&I Diagram Symbols



Source: Wartsila water system Ltd