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Control and Management of Ballast Water on Commercial Ships

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Abstract: Following the industrialization and development of world economies, pollution factors which endanger the environment have increased to an alarming degree. Therefore, various measures have been proposed and taken by local, national and global authorities to remedy and control pollution and ecological balance. One of these measures taken worldwide to limit and prevent environmental disasters, was the decision proposed and approved by the Marine Environment Protection Committee (MEPC) at IMO (International Marine Organization) Convention in 2004 by the Ballast Water Management (BWM) Convention. Basically, new rules have been introduced on the control and management of ballast water of commercial ships. The paper presents aspects on how to control and manage ballast water in some types of commercial ships.

Keywords: ballast water; management; ships; IMO Convention

1. Introduction

During the exploitation of the ship, situations may arise when the ship has to sail without merchandise, in which case both the stability and the ensuring of the ship draft of the stern necessary for the operation of the propeller are ensured by embarking water in the ballast tanks through the ballast installation.

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In addition, the ballast installation corrects the trim resulting from loading merchandise, filling tanks or fuel consumption from tanks, reducing longitudinal or transverse inclinations, which affect both the movement of the ship and the operating conditions for personnel and some installations.

In general, ballast installations, figure 1, are classified into 2 categories[1]: general ballast installations, which are found on general cargo ships, in order to change the average draft and to correct inclinations (longitudinal and transverse) and specialized ballast installations, which are found on icebreaker ships, container ships, barges, floating docks and submarines.

Figure 1. Ballast Water System

Source: https://www.baluco.com/ballast-water-management/

There are ships in which the ballast installation has an additional functional role. For example, at the icebreaker ships, slow transverse oscillations are created through the ballast installation that do not allow the ship to be caught in the ice, and the longitudinal oscillations, also created with the ballast installation, can be used to break the ice. At the large container ships, the ballast installation corrects the transverse trim after unloading each container, ensuring normal conditions for maneuvering the containers, and at the submarines the ballast installation is essential for entering and exiting in/from immersion and for correcting the trim in both surface navigation and in immersion.

Figure 2 shows the arrangement of the ballast installation on a ship board, having the following notations: *1* - ballast tank from afterpeak; *2* - the whirlpool of the ballast installation; *3* - ventilation pipes; *4* - valves; *5* - ballast installation pump; *6* -

[1] Ballast installation characteristics (Caracteristicile instalației de ballast). *Web page.* https://pdfslide.tips/documents/c4-instalatia-de-balast-11.html, date: 21.07.2021.

Kingstone filter; *7* - ballast tank from forepeak; *8* - Kingstone valve; *9* - valve box; *10* - side non-return flap.

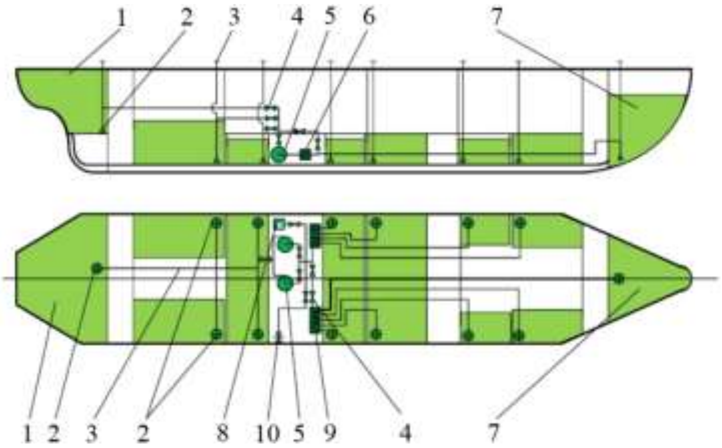


Figure 2. Ballast System on a Shipboard

Source: https://pdfslide.tips/documents/c4-instalatia-de-balast-11.html

2. Environmental Control and Certification Organisms in Shipping Industry and Shipbuilding Industry

In accordance with the new standards for the protection of the marine environment imposed by the IMO (International Marine Organization), under the BWM (Ballast Water Management) Convention of 13 February 2004[1], IMO decisions A.868(20), MEPC.173(58)-G2, MEPC 174(58)-G8 and MEPC 169(57)-G9[2] stipulate that, from 2009, all merchant ships which are being built (rules D1/D2), as well as from 8 September 2017, ships that are in operation under the flag of the countries which have ratified the Convention or are operating in the areas of influence of the IMO (D2 rules), will be provided with ballast water treatment facilities.

The purpose of these installations is to destroy or reduce, to an acceptable minimum, the micro-organisms, bacteria and viruses existing in the ballasted or de-ballasted water, from the ballast tanks of merchant ships, mainly.

[1] Ballast Water Management Convention (Convenția privind gestionarea apei de ballast). *Web page.* Retrieved from https://ro.abcdef.wiki/wiki/Ballast_Water_Management_Convention.

[2] Presentation of the ballast water treatment installation (Prezentarea instalației de tratare a apei de balast). *Web page.* Retrieved from https://pdfcoffee.com/prezentarea-instalatiei-de-tratare-a-apei-de-balast-pdf-free.html.

This measure aims to protect the seas and local ecosystems from the invasive potential, but also the potential of viable organisms to reproduce and settle in the maritime area where they were unloaded, following naval commercial activities.

The National Invasive Species Act (NISA)[1] is a law designed to prevent invasive species from entering inland waters through ballast water carried by ships.

Ballast water discharges are considered to be the main source of invasive species in marine waters, thus representing risks to public health and the environment, as well as significant economic cost for industries such as water and electricity services, commercial and recreational fishing, agriculture and tourism.

Organisms targeted by NISA are classified as aquatic disease species. One of the most well-known invasive species transported in the ballast water of ships, in wastewater pipes and on waterways, is the zebra mussel, figure 3 which, in addition to the negative ecological impact, causes major problems to the industrial sector by clogging and blocking supply pipes of the water intake systems[2].

Figure 3. Zebra Mussel

Sources: http://portiledefier.ro/ias/?p=763; https://alien-csi.eu/sites/default/files/2395%20Invasive%20species%20mini%20guide%20Romanian.pdf

As a technical implementation solution, a ballast water treatment system is designed and installed in such a way that all the water to be used in the ballast system corresponds to the minimum indicators required by the IMO Convention, according to table 1.

The ballast water treatment installations also have two water sampling points, which are provided before and after the ballast water treatment.

[1] National Invasive Species Act. *Web page*. Retrieved from https://en.wikipedia.org/wiki/National_Invasive_Species_Act, date: 21.07.2021.

[2] Invasive allogeneic species (Specii alogene invazive). *Web page*. Retrieved from https://ec.europa.eu/environment/pubs/ pdf/factsheets/Invasive%20 Alien%20Species/Invasive_Alien_RO.pdf, date: 23.07.2021.

These samples are collected according to a procedure approved and certified by a local authority (usually port authority) accredited for these tests in the area of the countries where the respective commercial ships can sail.

The water samples collected will be tested and determined in laboratories that are certified for this purpose according to the IMO standard and the limits presented in table 1.

Table 1. Standard Accepted by the IMO Convention.

Data required before treatment	Results required by IMO
Zooplankton (>50 µm)	
10^5 - 10^6 per. 1 m^3 water (five species from three different phyla/division)	Less than de 10 per. 1 m^3
Phytoplankton (10-50 µm)	
10^3 - 10^4 per. 1 ml apă (five species from three different phyla/division)	Less than 10 per. 1 ml
Bacteria and viruses	
Toxigenic vibrio cholera	Less than 1 cfu/100 ml
E-coli	Less than 250 cfu/100 ml
Intestinal Enterococci	Less than 100 cfu/100 ml

3. Ballast Water Treatment Systems

Globally, there are several types of ballast water treatment systems that are produced, tested, certified or under test and certification by various companies and firms, and the construction and operating principle of the systems may be different, with the condition of respecting the rules imposed by the decision-making and certification organism in the Navigation Industry and the Shipbuilding Industry.

These ballast water treatment systems are based on 2 working stages: stage I - mechanical separation and stage II - physical, chemical and combined treatment.

Stage I of mechanical separation of ballast water is usually done with the help of a particle separator, which can be a filter that has various shapes and types of construction, having a certain degree of particle separation precalculated, according to international standards. The filters are equipped with mechanical and pressure self-cleaning systems, according to pre-established parameters from construction or controlled by the control unit. The particle separator can also be a hydrocyclone, figure 4, this being a device for sorting granular materials in which the separation of granules is done under the action of a centrifugal force, exerted by a water current. Cyclonic separation is usually used for those particles with a specific gravity greater than that of water.

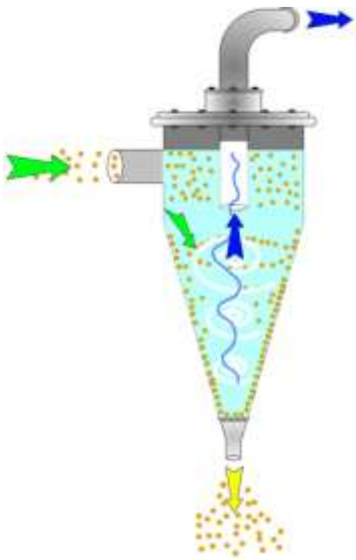


Figure 4. Hydrocyclone[1]

Source: https://link.springer.com/content/pdf/10.1007/s13202-020-00848-x.pdf

Stage II of physical, chemical or combined treatment is performed to obtain the final treatment of the ballast water, in order to obtain a final result in accordance with the rules of application of the standard allowed by the IMO Convention. Physical treatment of ballast water is done by applying a dose of UV (ultraviolet) radiation, figure 5, ultrasonic waves, heat radiation, by passing water through a special container built for this purpose.

[1] Patel, M. et al. (2020). Membrane-based downhole oil–water separation (DOWS) technology: an alternative to hydrocyclone-based DOWS. Journal of Petroleum Exploration and Production Technology. 10, pp. 2079-2088. *Web page*. Retrieved from https://link.springer.com/content/pdf/10.1007/s13202-020-00848-x.pdf, date: 20.07.2021.

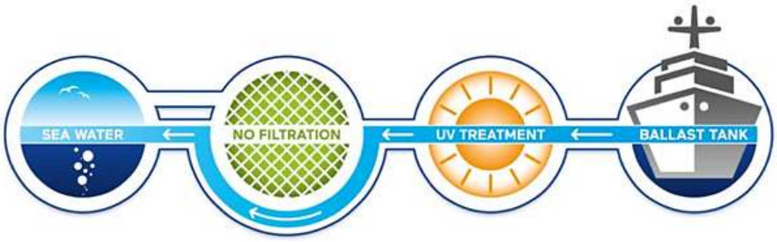


Figure 5. Physical treatment by UV radiation

Source: https://www.ballast-water-treatment.com/en/bwt-technology

Chemical treatment is done using special equipment for chlorination, electro-chlorination, figure 6, ozonation or oxidation, in accordance with the required standard.

Figure 6. Chemical Treatment by Electro-Chlorination

Source: https://www.wilhelmsen.com/marine-products/water-treatment-solutions/ballast-water-treatment/

The combined treatment results from the application of both previous methods on the ballast water and may or may not precede the first stage of mechanical separation, depending on the need of the carried out process.

The construction of ballast installations must satisfy the following functional requirements:

- allow the embarkation and disembarkation of water to ensure the draft and stability of the ship (for this purpose, ballast tanks are provided, the capacity and location of which will be determined following the hydrostatic calculations of the ship);

- allow the transfer of ballast between tanks, in particular between those located at the extremities of the ship, bow-stern and port-starboard, to adjust the longitudinal and transverse trim, respectively;

- not to make overpressures or underpressures in tanks during the ballast maneuver; for this purpose, each tank is provided with a vent pipe that connects to the atmosphere;

- not to allow the embarkation of the water by aerations in case of flooding of the bridge;

- to allow the measurement of the amount of ballast in tanks in any navigation situation;

- ballast tanks embedded in the ship's structure must have cuts in the structure to allow access to water to the whirlpools and air to the vents, so that the amount of ballast after emptying is minimal and there are no free surfaces in the tank when filling;

- the inner surface of the tanks must be protected with paint and provided with access openings for maintenance purposes;

- the installation and the tanks must be completely separated from the installations transferring the fuel, in order to avoid hydrocarbon contamination of the tanks and the ballast installation.

4. The Structure of Ballast Installations

The structure of the ballast installations will correspond to the operation requirements, being correlated with the type and constructive particularities of the ship. A ballast installation consists of the power group, the ballast maneuvering system and the ballast tanks.

The role of the energy group is to take the ballast water with the help of the pumps and to distribute it in the ballast installation through the specific maneuvers of filling-emptying the tanks or transferring between the tanks. Usually, the power group is located in the machine compartment near to the energy sources, a situation in which the piping, which connects the tanks, can be very long, in the case of large ships, which can affect the operation of the installation.

In such situations, it is acceptable to place the pumps outside the machine compartment in special areas closer to the ballast tanks.

The energy group, figure 7, consists of pumps (which are generally with high flow rates and small size, capable of maneuvering the ballast in a reasonable time), the maneuvering valves of the ballast (which must ensure the circulation of water in both directions and introduce minimum hydraulic losses) and the seawater intake system.

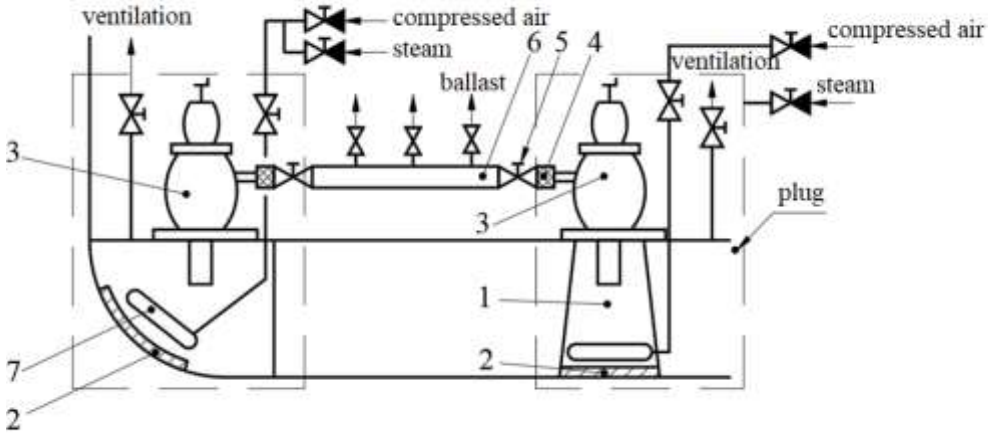


Figure 7. Water capture system: 1 - Kingstone caisson; 2 - grill; 3 - Kingstone valve; 4 - filter; 5 - valve with drawer; 6 - thoroughfare; 7 - perforated annular tube for defrosting by blowing with steam or compressed air.

The ballast maneuvering system consists of valves and associated piping connected in a scheme that allows the following maneuvers, figure 8: filling any ballast tank with the main or spare pump; gravitational filling of ballast tanks below the waterline; transfer of the bow-stern ballast to adjust the longitudinal trim; transfer of ballast between tanks on the edges to adjust the transverse trim.

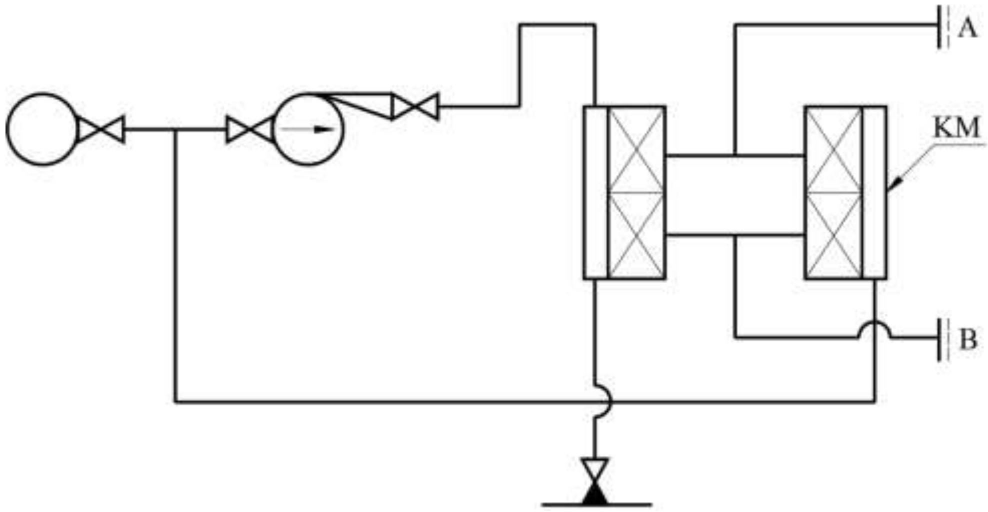


Figure 8. System for Ballast Maneuvering

Characteristic of the maneuvering system is the fact that it has to reverse the direction of water circulation in the tanks to achieve filling, respectively emptying, using one-way flow pumps (centrifugal pumps). Reversing the direction of water flow can be done using shunt boxes located between the pump and the thoroughfare or between the pump and the distribution boxes.

The ballast tanks, figure 9, are placed along the ship according to several criteria: their capacity must ensure the required drafts of stability and propeller immersion, in the case of ballast navigation; their position on board must ensure the correction of the longitudinal or transverse trim with a minimum amount of ballast (for this purpose the tanks for adjusting the longitudinal trim are arranged at the extremities of the ship and those for correcting the transverse trim are arranged in boards); to correct the position of the ship's center of gravity, ballast tanks shall be provided under the deck so that the kinematic parameters of the roll correspond to the rules.

The interior arrangement of the tanks includes the ventilation pipe, mounted in the highest part of the tank, which has at the end of the ship deck a device that retains the penetration of water into the tank when the deck is flooded.

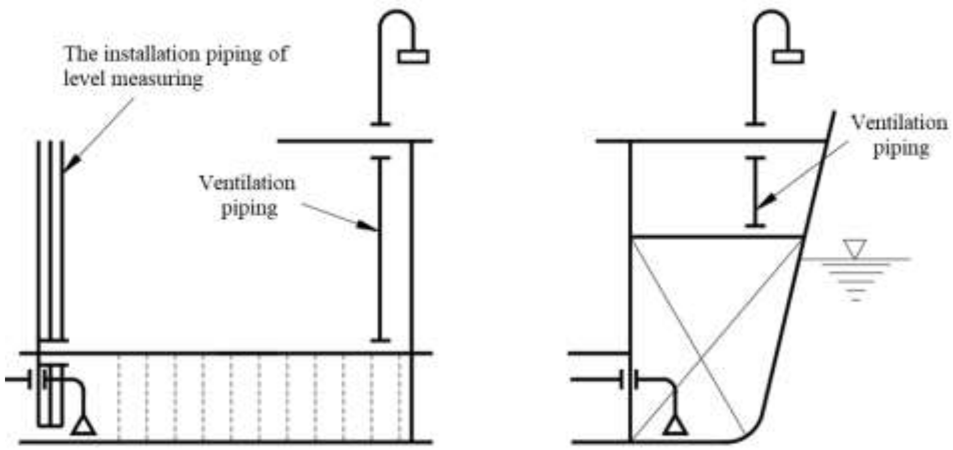
The area of the ventilation pipe section must be larger than that through which the ballast is introduced or evacuated. The connection with the ballast installation is made through one or more whirlpools, located in the lowest points of the tank, through which the water is introduced and evacuated.

The placement of the ballast tanks in the double bottom or in double shell, figure 9, in the central area of the ship, far from the diametrical plane, is used for:

- correction of the transverse trim after loading the ship, with small quantities of ballast offering small free surfaces;

- correction of the transverse edge during loading or unloading (anti-heeling installation from container ships);

- roll amortization when the tanks are used as anti-roll, passive or active tanks; in the case of passive ones, the moment of recovery is introduced by the movement of the water from the tanks, produced by the oscillations of the ship and out of phase with them; in active ones, the recovery moment is obtained by the forced movement of water between the two tanks, by means of a pump or compressed air.



a. b.

Figure 9. Arranging a ballast tank: a - by double bottom; b - by double siding.

4. Conclusions

In conclusion, as the conditions of ships operation are such that they are put in a situation of fully loaded, empty or partially loaded, it was necessary to create an installation that could ensure the ship's best possible stability.

It is known that the ship is calculated to sail with a certain load having its center of gravity in a position that ensures the ship a positive stability and thus it can face the sometimes difficult conditions encountered in its voyages.

In order to maintain this stability, a quantity of sea water is embarked or disembarked in tanks specially designed for this purpose. Thus, the ballast installation moves the center of gravity of the ship, to bring it to the desired trim, by embarking, moving or disembarking the ballast consisting of sea water.

5. Acknowledgement

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