

## **POLLUTION-FRIENDLY SHIPS**

### **Summary**

The aim of this paper is to focus on simple providences, in the form of constructive modifications in ballast water (BW) tanks and installation of accessory equipment, that can be taken by ship owners and shipyards, with regard to treatment of BW at sea, specially on new constructions of ships, with views to facilitate the integral compliance with the Rules of the new BW Convention by mariners. The proposed modifications are specially applicable to bulk carriers and general cargo vessels, but can also be introduced in every ship that needs to carry BW. Since larger crude carriers, such as VLCCs and ULCCs with double hulls, have come into active duty, possessing separate tanks for the sole carriage of ballast water (BW), the so-called Segregated Ballast Tanks (SBT) of ever-increasing size, emphasis is placed on the need of safe and practical pollution protection already considered in design and construction or, in the jargon of Class Societies, the to be denominated “Pollution-Friendly Ships”.

*Key words:* VLCC, ULCC, ballast waters, classification,

## **EKOLOŠKI PODOBNI BRODOVI**

### **Sažetak**

Cilj je ovog članka da se usredotoči na jednostavne prilagodbe brodova u obliku konstruktivnih promjena u balastnim tankovima (WB) i ugradnju pripadajuće opreme koja se može preuzeti od brodovlasnika ili brodogradilišta, s obzirom na tretman balastnih voda (BW) na moru, osobito na novim brodovima, s osvrtom na cjelovito usaglašavanje s propisima klasifikacijskih društava prema novoj konvenciji o balastnim vama. Predložene prilagodbe su pogotovo primjenjive na brodovima za rasute terete i brodove za opće terete, ali se mogu primijeniti i na svim drugim brodovima koji moraju koristiti vodeni balast. Kako veliki tankeri kao VLCC i ULCC s dvostrukim stijenkama ulaze u službu s posebnim tankovima samo za balastne vode, označeni kao Segregirani balastni tankovi (SBT) sve većih izmjera, u članku je naglasak dan potrebi za sigurniju i praktičniju zaštitu od onečišćenja već kod projektiranja i konstrukcije, ili jezikom klasifikacijskih društava, podobnim brodovima protiv zagađenja.

*Ključne riječi:* VLCC, ULCC, balastne vode, klasifikacija

## 1. Introduction

Accidents with crude oil carriers have led to more stringent regulations being passed by several governments over the years [1], instituting the mandatory gradual use of double-hulled tankers for the transport of that commodity, with the consequent phasing-out of single-skinned tankers.

With the aim to allow adequate and proper access to the structures of new huge caverns of steel, in the form of Segregated Ballast Tanks (SBT), also of ever-increasing size, for the purposes of “Close-up” inspections by Surveyors of the relevant Classification Society, emphasis was placed in the past on the need of safe and practical accesses to the structural components of these compartments by the fitting of intermediate platforms and other safeguards, resulting in what, in the jargon of Class Societies, are denominated “Surveyor-Friendly Ships”.

With the coming into force of the new International Convention on Ballast Water [2], promoted by the International Maritime Organization – IMO, hereafter referred to as the “Convention”, apart of other restrictive steps taken by individual governments on the same issue, new technologies and methods have to be found and implemented to deal with the requirements of these legal documents, aiming to allow ship owners, shipyards and, above all, ships’ crews to execute the requirements of the Convention in a correct but simple manner.

Also, simple alterations on the structures of ballast tanks can be introduced, either in new constructions or retro-fitted on existing ships, that tend to alleviate the problems that will be encountered during the management of the ballast waters carried by ships, ultimately leading to a concept of “Pollution-Friendly Ships”.

## 2. Ballast Water Exchange at Sea

It is to be noted that the most effective method, so far, of dealing with the problem of invasive noxious species and pathogens eventually contained in ballast waters, is the exchange of BW in oceanic waters. For this reason, the Marine Environment Protection Committee (MEPC) of IMO had issued its Resolution A.868(20), containing the “Guidelines” [3], now superseded by the Convention, in which two basic methods of BW exchange are recommended, namely, the Sequential Method and the Flow Through Method, which are believed to attain abt. 95% of the renewal of the existing BW on board, if feasible to execute under prevailing sea and weather conditions and if properly followed.

As demonstrated in [4], it has been noted that the theoretical assessment of the effects of BW exchange at sea indicates the possible occurrence of excessive stresses on longitudinal structures of hulls and/or excessive dynamic loads on dividing bulkheads in several particular cases, preventing the exchange to be carried out under safe conditions.

With the purpose to circumvent the exchange of BW at sea, numerous studies and researches are simultaneously being carried out around the world on other methods of BW treatment, for use either on board or in shore-based facilities, among which the most significant are those considering the employment of ultraviolet light, biocides, boiling, filtering, and introduction of copper ions, as effective methods of eliminating pathogens and live noxious species.

The above considerations signify that the problem of dealing with BW carried by ocean going ships is not an easily resolved task, requiring joint efforts from the organized entities to achieve a solution based on common-sense and easy to implement on ships, without burdening ships’ crews with unnecessary extra amounts of paperwork.

The subsequent chapters will present several suggestions to improve the BW exchange at sea.

### 3. Physical Arrangement of Ballast Tanks

In the course of the numerous Draught Surveys carried out by the author, it has been noted that a tendency exists, in new constructions of ships, to decrease the number of ballast tanks, with particular emphasis on Bulk Carriers, thereby increasing the lengths of Top Wing Tanks - TWTs (as also Double Bottom Tanks - DBTs) and, as consequence, the individual volumes of water contained by said compartments. Independently of the errors introduced in the sounding of these tanks by the nowadays inadequate short lengths of the respective sounding pipes protruding above the exposed decks, the sheer size of these BW tanks, specially at the midship regions, when those alone are emptied at sea, tend to introduce stresses on the hull girder that can easily exceed the allowable bending moments and shearing forces established in the Loading and Stability Booklets, when ships face rough weather, Fig. 1. As consequence, the exchange of BW by the Sequential Method cannot always be carried out, for fear of causing damages to the hull. Similarly, the use of the Flow-Through Method, under adverse conditions of sea, may also result in the allowable stresses on the transverse and longitudinal dividing bulkheads being surpassed, by either the slamming or overpressure of large volumes of water, with the same negative consequences.

### 4. Interconnected Ballast Tanks

Eventually considered a simplification in the BWM – Ballast Water Management, numerous ships destined for bulk cargoes possess a common drain/filling duct between TWTs and respective adjacent DBTs, creating the so-called Combined Ballast Tanks – CBTs Fig. 2. This arrangement eliminates the need for gravity discharge of BW through the side shells and the corresponding discontinuities in the shell plating required for the overboard valves and piping, but, at the same time, also eliminates the possibility of emptying a DBT without first having to drain the corresponding TWT. Conversely, it is not possible to fill only a TWT without also having to fill its corresponding DBT. Taking into consideration that the exchange of BW at sea must always be carried out under safe conditions, the implications to the integrity of the hull girders by the discharge of the greater combined volume of BW contained in the mentioned CBTs, instead of dealing individually with TWTs and DBTs, are not to be overlooked.

### 5. Retention of Sediments in Ballast Tanks

The uptake of BW by ships, until present days, has normally been carried out without any significant considerations being given to the joint uptake of the solid sediments contained in these waters. It is quite normal for ships to be ballasted as soon as a cargo discharge is completed, meaning that the uptake is usually carried out in harbour or coastal waters, where the water depths are much less than of those at open sea. As consequence, the solid particles, either laying on the harbour bottom, or in suspension as result of local currents, are also sucked into the BW piping system, ultimately deposited on the bottom plating of the ship's BW tanks and there remaining until the next dry docking of a ship, unless forcibly eliminated throughout the voyages. Mentioned sediments, apart of constituting a commercially prejudicial semi-permanent solid ballast, are fertile grounds for numerous marine species of bentonic origin, reason why [2] requires attention to the need of those sediments to be regularly eliminated from the BW tanks, and not only during dry dockings, to prevent the accidental and undesired migration of noxious elements into new environments.

The major impediment faced during voyages, for the discharge of the sediments contained in BW tanks, is the fact that these solid particles are deposited among the various structural steel components that constitute the tanks, where they remain confined, very often

creating solid layers of more than 20cm high. It has been noted, in the course of numerous surveys of ballast tanks, that the major reason for the retention of the sediments in these sub-compartments of a tank is the small size and the usual obstruction with rust scales of the so-called “scallops”, which are the quarter-circle apertures at the jointing of transverse floors to bottom longitudinals or framing of the BW tanks. Scallop are normally cut out in these plates with “radii” of about 50mm in order to allow adequate assembly of the various components without the crossing of weld fillets, as required by solid engineering. The expected normal flow of BW to the aft end of a tank during deballasting operations, carrying along the solid sediments, is jeopardized by the complete or partial obstruction of these openings. It is proposed that scallops at the bottom of tanks be opened with a “radius” of, at least, 150mm, Fig. 3. Against eventual questioning that the proposed increase in size of the bottom scallops could adversely affect the strength of the transverse floors and bottom longitudinals, to which the scallops belong, it is to be noted that the cutting out of lightening holes in same structural elements produces a much greater reduction in the respective section modulus of these elements.

## 6. Discharge of Ballast Water and Sediments

It is normal for ships to attempt the elimination of solid sediments in the ballast tanks whilst at sea, by the partial filling and subsequent discharge of such tanks, expecting that the movements of the ship will stir the solids into the ballast waters. This is not always successful. The discharge of BW from DBTs is always carried out through the vacuum created in one single suction mouth at the lowest aft end of a tank, connected to the ballast manifold of the ship. This configuration of the deballasting system is chosen for all ships, since the emptying of ballast tanks normally induces a trim by stern, allowing a gravity-aided flow of the ballast water to aft. It was to be expected that the flow of BW to aft would also carry along the solid residues (sediments) laying on the bottom of such tank, for the subsequent discharge overboard. Such is not the truth. As can be verified by examining the designs of DBTs, the physical sub-division of their structures by solid transverse floors and bottom longitudinals transforms the arrangement of a DBT in the, so-named, “egg-crate” configuration, favouring the isolation of the sediments in smaller squares, of difficult removal. If, to this situation, is added the problem of constricted flow, imposed by too small scallops, examined in previous chapter, it is not difficult to envisage the unfavourable situation faced during the dry docking of ships, when enormous volumes of sediments have than to be removed from confined spaces, with a significant cost. Furthermore, [2] also stipulates that efforts should be made to avoid the dumping of sediments into harbour or shipyard waters for fear of introducing noxious species in new environments.

While there is a certain, but small, shifting of sediments from forward to aft during discharge of BW, limited by the size of the existing scallops, the lateral transfer of sediments, to the longitudinal void space at the aft end of which the suction mouth is located, is nearly impossible. The small number of small scallops located at the lower edges of the bottom longitudinals prevents the sideways shifting of sediments from one “corridor” to another.

To allow an adequate elimination of sediments from ballast tanks it is submitted that the fitting of a suction mouth at the aft end of every “corridor” created by adjacent bottom longitudinals should considerably improve the removal of these solids during deballasting operations, Fig. 4. The sum of the individual cross section areas of these various smaller suction mouths should be equal to that of a specifically designed sole mouth. It is further submitted that the physical configuration of these smaller mouths should be wider narrow rectangles, resembling the mouths of household vacuum cleaners, in order to encompass a wider bottom area.

## 7. Ballast Water Treatment at Sea

As demonstrated in previous Chapters 3 and 4, it will not always be possible to perform the exchange of BW at sea without endangering the integrity of the ships' hulls. As result, in consequence of eventual requirements from the next port of call, it may be necessary to perform the treatment of the BW by another suitable method, whilst still at sea.

Simultaneously, in compliance with the stipulated in the Annex VI of the MARPOL-73/78 Convention [5], ships of over 400GT will also be required to comply with the Regulations for the Prevention of Air Pollution from Ships contained in mentioned legal document, with particular emphasis on the emission of nitrogen and sulphur oxides, the so-named NO<sub>x</sub> and SO<sub>x</sub>, specially resulting from the burning of Intermediate or Heavy Fuel Oils in low-speed marine diesel engines.

Studies performed on the exhaust gases of marine diesel engines by [6] show that average exhaust gases contain, among other components of lesser importance here, about 1500ppm of NO<sub>x</sub> and 600ppm of SO<sub>x</sub>, as well as solid particles of ashes and fuel residues at the approximate rate of 0,8 – 1,0 g/kWh. It is further noted in those studies that the nitrogen and sulphur oxides are soluble in water, rendering nitric and sulphuric acid.

Ocean water, according to technical literature [7], contains about 660 metric tons of sulphur per cubic kilometre and lesser quantities of nitrogen compounds. This implies that the dumping of small quantities of sulphuric and nitric acids into oceanic waters does not introduce strange elements into that environment, but returns them to their natural source. Dissociation of nitric acid into its basic components and subsequent evaporation returns nitrogen to its native element, the atmosphere.

On the other hand, the introduction of sulphuric and nitric acids into confined volumes of sea water tends to decrease its pH from its normal range of 7,8 – 8,2 which, depending on the introduced amounts, may result in a slight acidity, with lethal consequences to the eventually contained living species in these waters, accustomed to alkaline surroundings.

Based on the above preambles, it is to be considered that another method of treating BW at sea, apart of the numerous other proposed treatments, could be the exposure of the exhaust gases from main engines to a counter-flow of BW, or vice-versa, resulting in a scrubbing process, not uncommon in chemical industries, as well as in inert gas generating plants of tankers and product carriers. As shown on attached diagram of the proposed Ballast Water Scrubber – BWS, Fig. 5, to be fitted in the funnel of a ship, a flow of water drawn from a particular ballast tank is circulated, by the ship's ballast pump, through the BWS in opposite flow of the exhaust gases of the main engine by use of sprinklers, than collected at the bottom of the equipment and returned by gravity to the same tank.

The immediate positive results produced by this scrubbing process are:

1 – On the Exhaust Gases:

- Partial or total elimination of solid particulates and ashes, absorbed by the water sprays;
- Exposure of the sulphur and nitrogen oxides in the gases to the water sprays, rendering sulphuric and nitric acids, carried away by the water to the original tank;
- Decrease of the exhaust gas temperature.

2 – On the Ballast Water:

- Partial heating of the BW by thermal shock, considered favourable towards the extermination of live species and pathogens eventually contained in the water;

Introduction of sulphuric and nitric acids into the ballast tank, reducing its pH and, by the normal circulation of the water inside the tank, also inducing mortality among the live species and pathogens still remaining inside the treated tank.

The overall results of the proposed method are:

Cleaner emissions of main engines into the atmosphere and, simultaneously,  
Treated Ballast Water.

Preliminary calculations were performed on the theoretic continuous scrubbing of a tank containing 1000m<sup>3</sup> of BW, at a rate of 200m<sup>3</sup>/hour, using the exhaust gases produced by the theoretic combustion of 30MT/day of Intermediate Fuel Oil (IFO) in a Main Engine, corresponding to a 24-period of steaming by a ship. This scrubbing would produce about 15kg/hour of HNO<sub>3</sub> and 23kg/hour of H<sub>2</sub>SO<sub>4</sub>, which acids, retained by the scrubbed BW and returned to same tank, would render a final pH in the BW of about 3,5 – 4,0, already highly acid, on the completion of the 24-hour period. In view of the obtained highly acid pH, the calculations demonstrate that the 24-hour exposure would be excessive, being required only a scrubbing during abt. 2-3 hours to reduce the pH from alkaline to acid values.

Although it may be argued that the introduction of acids into BW Tanks may harm their steel structures by chemical corrosion, it is to be observed that, in modern days, normally all tanks are protected internally by coatings of epoxy-type resins, the condition of which is assessed on a yearly basis by the respective Classification Society during Annual Class Surveys. Furthermore, it is not to be expected that the introduction of small amounts of acids into the BW will result in a very low pH, unless the same BW is re-circulated several times in excess through the BWS.

The installation on board of the proposed BWS can be either effected “in-line” with the normal uptake of the main engine or, if so desired, in parallel with the main exhaust duct, also in one or more smaller units, allowing the simultaneous treatment of more than one single tank. The arrangement itself of the BWS consists of a vertical steel vessel with an increased diameter relative to the inlet pipe of the exhaust, in order to reduce the velocity (and consequently the pressure) inside the scrubbing chamber, allowing the pressurized downward spray of BW to overcome the upward flow of the exhaust gases, to which it is exposed. Safety devices and sensors are to be fitted to the installation in order to monitor and operate the system as required.

Apart of the installation of the BWS itself and its piping system, no need exists for the fitting of additional pumps in the engine room of a ship, which already possesses a number of General Service, Ballast and Fire pumps, all of sufficient capacity for the required circulation.

The operation and maintenance of the BWS is simple, requiring no special training by the ship’s crew. Details and data of operations are to be entered in the respective Ballast Water Recording Form, as specified in vessel’s Ballast Water Management Plan, according to the requirements of the Convention [1]. In the case where no treatment of BW is required, the installation of several smaller BWS directly “in-line” with the exhaust pipe of the vessel’s main engine can perform only the scrubbing of the produced gases, rendering cleaner emissions into the atmosphere, as recommended by [5].

#### Underwater Cleaning of Hulls

Although this chapter bears no relation to possible direct improvements on ships towards a “Pollution-Friendly” situation, attention is called to the fact that the underwater cleaning of ships’ hulls is also conducive towards the pollution and fouling of marine environments. As allowed for by the Rules of the various international Classification Societies, ships can eventually replace an Intermediate Dry Docking by the “Inwater Survey En Lieu of Dry Docking”, subject, amongst others, to an underwater inspection of the hull and appendages to the satisfaction of the attending Class Surveyors. This implies that the hull subjected to survey must be free of marine growth and barnacles, to which effect an underwater cleaning of the shell is normally carried out in advance.

As usually occurs, the residues of the cleaning, scraping and/or brushing of the marine growths from the shells, including adhering live species and/or larvae, are simply dropped to the local bottom, without any considerations being given as to their origin or nature and, on their own, may constitute a pollution hazard to the environment into which they are deposited.

Also, for the sake of a needed underwater visibility, mentioned cleanings are, by force, carried out in clean waters instead of in polluted harbour or estuary areas, with a double prejudice. Under these adverse consequences to the marine surroundings, it is submitted that the equipment employed in underwater cleaning of hulls should be supplemented with a suction system, capable of pumping the entire volume of residues with water into barge-borne tanks, where it is to be adequately screened or filtered, for the subsequent removal of the solid residues ashore for disposal.

## 8. Conclusions

The author takes leave to postulate the following conclusions, based upon above text:

- For the purposes of a more adequate BWM, ship owners and shipyards should avoid the reduction of the number of ballast water tanks, specially at the midship's regions, to allow the exchange of smaller quantities of BW instead of large volumes.
- Also, for the purposes of BWM, interconnected Top Wing Tanks and Double Bottom Tanks are a basic faulty arrangement.
- It is strongly recommended, for adequate BWM, that the scallops in structural members of ballast tanks be opened with a radius of not less than 150mm, either on newbuildings or retro-fitted on existing ships during dry dockings.
- The fitting of several smaller and wider suction mouths for the BW discharge system, at the aft end of ballast tanks, instead of one big suction mouth, improves the removal of sediments from these tanks.
- The management of BW, for compliance with the Convention can be achieved by heat treatment through a Ballast Water Scrubber, employing exhaust gases from main engines.
- The dumping of solid residues resulting from the underwater cleaning of hulls is in conflict with the principle of cleaner seas.

## REFERENCES:

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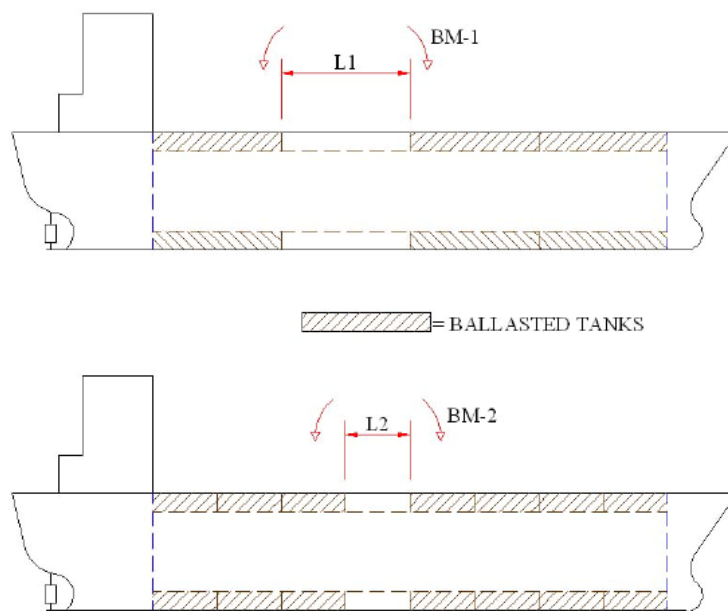


FIG.01: AS RESULT OF  $L1 \gg L2 \Rightarrow BM-1 \gg BM-2$

Fig. 1 As result of  $L1 \gg L2 \Rightarrow BM-1 \gg BM-2$

Slika 1. Kao rezultat  $L1 \gg L2 \Rightarrow BM-1 \gg BM-2$

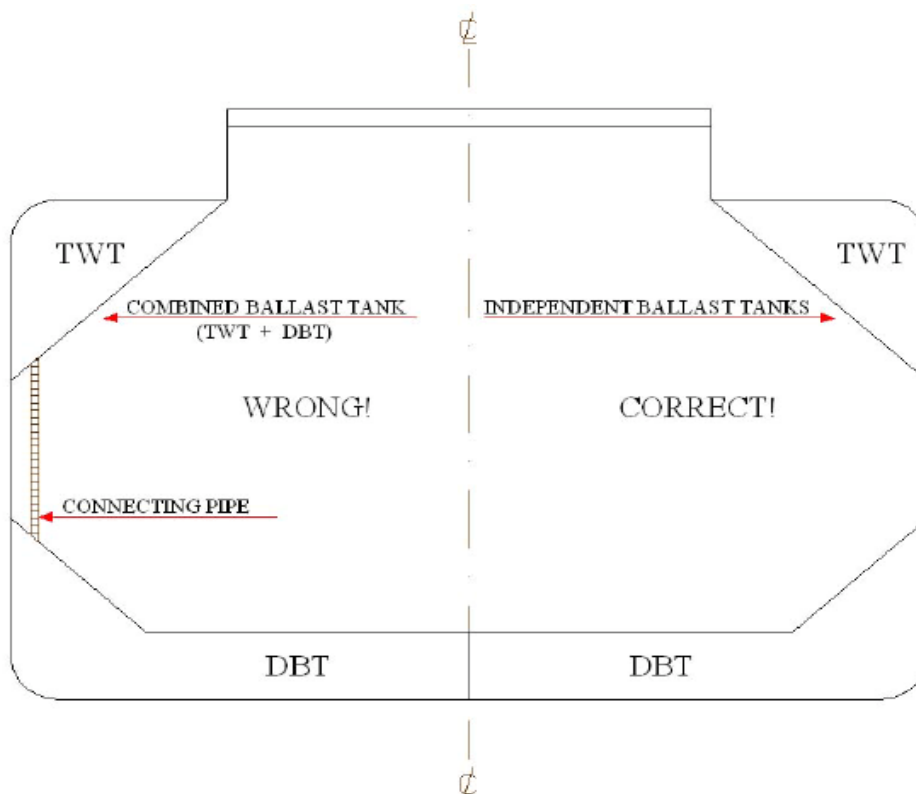


FIG.02: WRONG & RIGHT ARRANGEMENTS OF BW TANKS

Fig. 2 Wrong and right arrangements of BW tanks

Slika 2. Pogrešan i ispravan raspored balastnih tankova

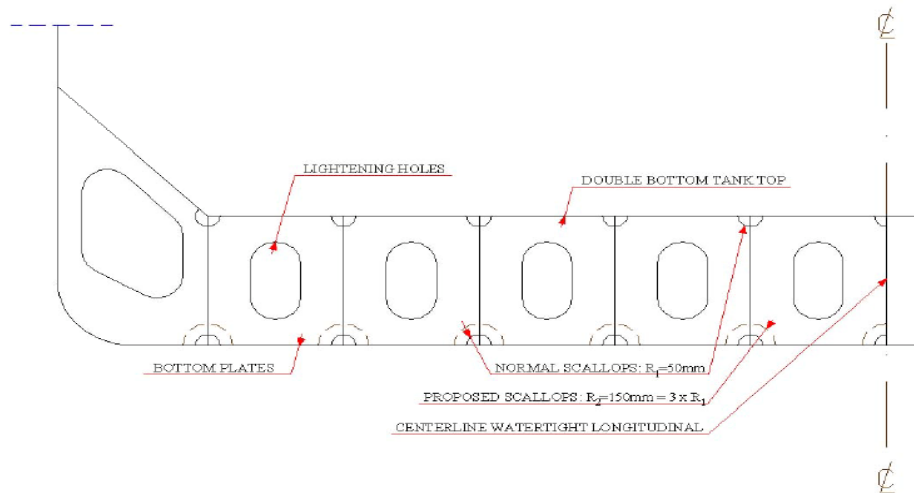


FIG.03: PROPOSED TYPICAL SCALLOP ARRANGEMENT FOR SOLID FLOORS IN WATER BALLAST DOUBLE BOTTOM TANKS

Fig. 3 Proposed typical scallop arrangement for solid floors in water ballast double bottom tanks

Slika 3. Predloženi tipičan raspored skalopa punih rebrenica u balastnim tankovima dvodna

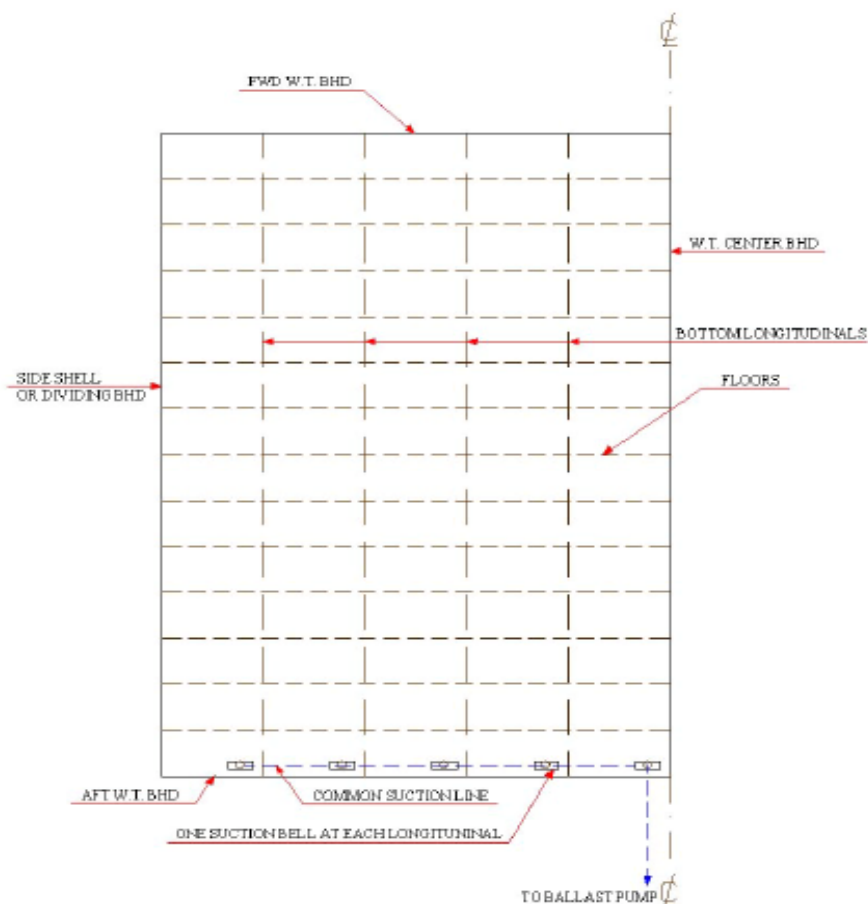
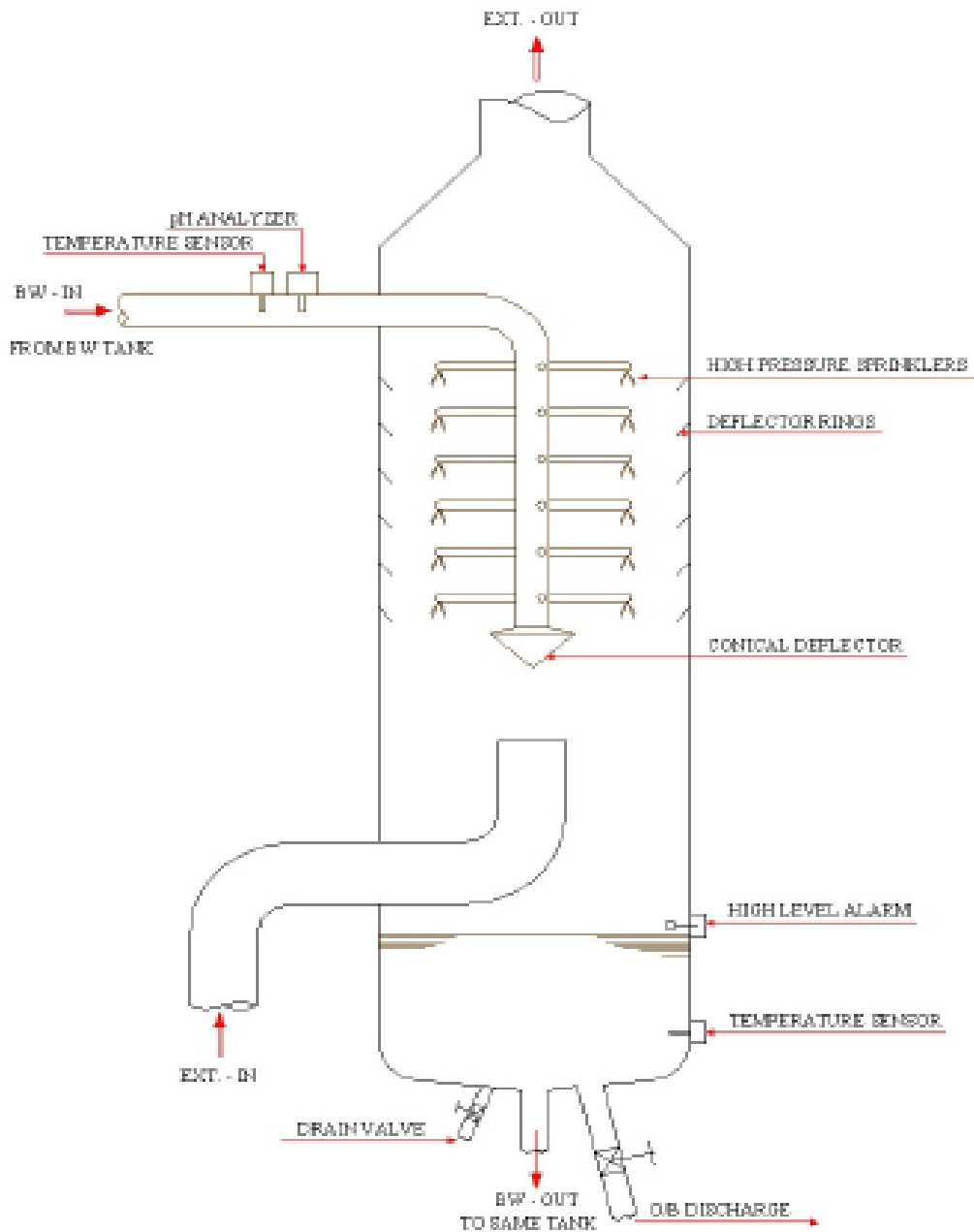


FIG.04: PROPOSED ARRANGEMENT OF BW DISCHARGE FROM DBT<sub>e</sub>

Fig. 4 Proposed arrangement of BW discharge from DBT

Slika 4. Predloženi raspored izbacivača balasta iz tankova dvodna



**FIG.05: BALLAST WATER SCRUBBER**  
 THE UPWARD FLOW OF EXHAUST GAS FROM M/E CAUSES THERMAL SHOCK TO INVASIVE SPECIES IN DOWNWARD FLOW OF BALLAST WATER, WHILE STRONG ACIDS ARE PRODUCED, OBTAINED FROM  $\text{NO}_x$  &  $\text{SO}_x$  IN GASES, THAT ARE DRAINED TO THE SAME TANK, DECREASING THE pH OF ITS CONTENTS TO ACID VALUES.

**Fig. 5** Ballast water scrubber

**Slika 5.** Prečistač balasta