Use of eductors with ballast water management systems making use of Active Substances
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Background and Introduction to Eductors

Ballast tanks maintain a ship's capability in terms of stability and trim. Tank design is dependent on ship type and size but all share a complex network of structural members; the tank must be of sufficient strength to support the ship's structural integrity and to safely carry the weight of the ballast water pumped into it. As a result of this, ballast tanks can consist of a labyrinth of cavities and chambers fitted with openings and channels designed to allow water to enter all areas of the tank during ballasting operations and to then drain back to the pump suction point during deballasting.

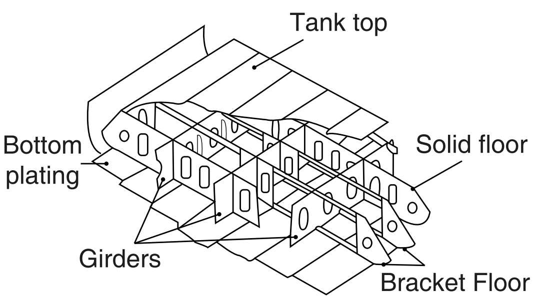

Figure 1 – Typical double bottom ballast tank construction

Figure 2 – Tank internal structures create many compartments and chambers linked by openings and drain channels

The ballast water is supplied to, and drawn from, the tank by a pump and pipe work system. This penetrates the tank structure and usually terminates in a combined delivery and suction pipe, most commonly situated in a structural bay at the after end of the tank.

The bottom of this pipe is open and is commonly known as an 'Elephant's foot' due to its shape. There is a gap between the end of the pipe and the tank bottom to allow the ballast water to enter or leave the tank when the ballast pump is in operation.

Figure 3 – 'Elephant's foot' forming the pipe opening

The geometric shapes created by the structure of the ballast tank do not normally present any flow issues during ballasting operations; the water enters the tank at the bottom via the elephant's foot and then, under the pressure created by the pumping system, progressively floods all the chambers and cavities until the tank is full.

When emptying the tank, there is often an operational need to remove as much water as possible. This may be for reasons such as enhancing the ship's stability characteristics or to maximize the overall carrying capacity of the vessel.

When the tank is being emptied by the ballast pump, the ballast water will flow following a pattern created by the tank structural members. This will not normally have any detrimental effect on the pumping rate until towards the end of the process.

Diagram 1 shows a simplified line diagram of deballasting arrangements.

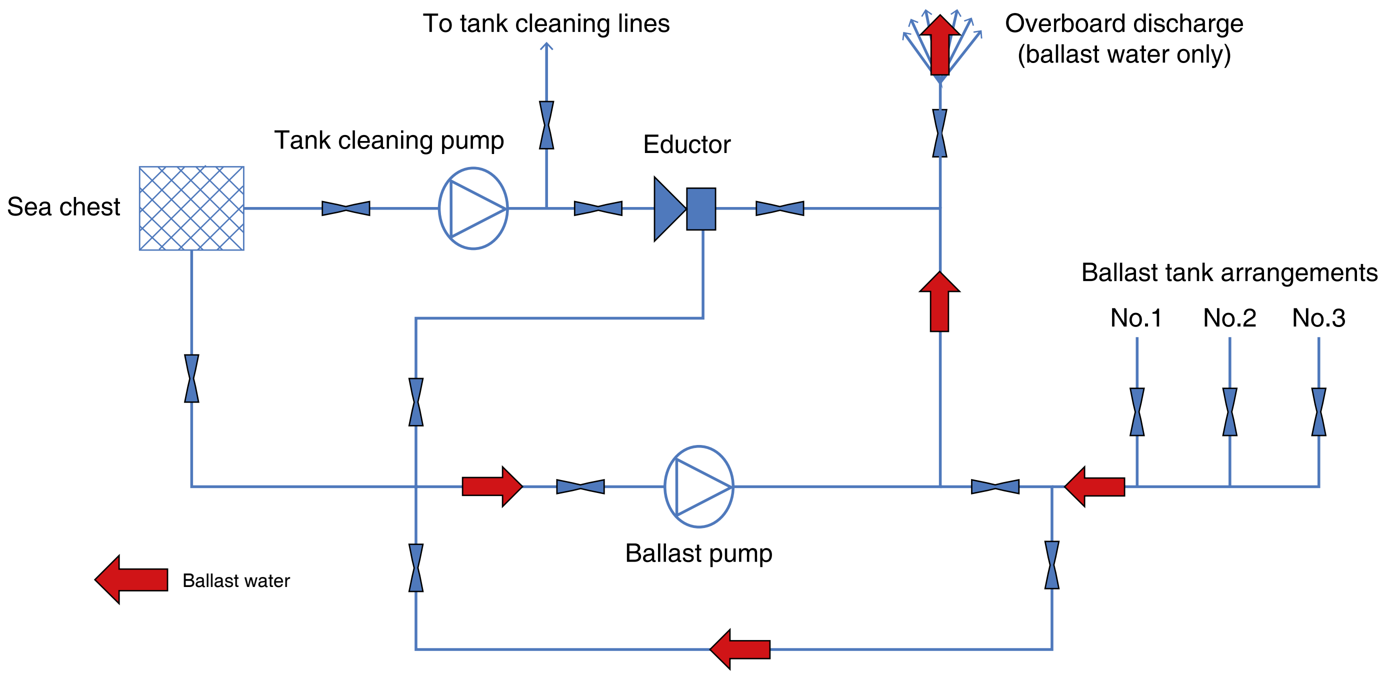

Diagram 1 – Simplified ballast system – deballasting with main ballast pump

Towards the end of the deballasting procedure, the delivery of ballast water to the suction pipe starts to become restricted. This is due to the structure of the bottom of the tank, where drain channels between the compartments limit the amount of water that flows towards the suction pipe in the final bay. This situation can be exacerbated where sediment build up has formed blockages in these drainage channels, further restricting the flow.

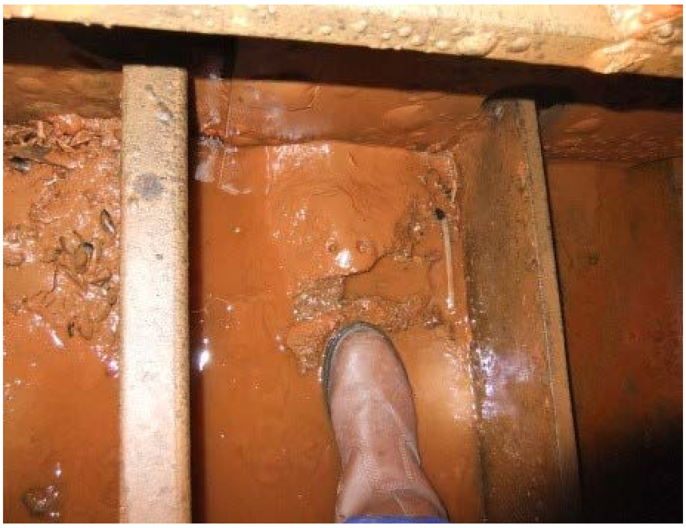

Figure 4 – Drainage arrangements through tank floors (left) and typical sediment build-up reducing the free flow of water between chambers and bays (right)

Figure 5 – Illustration of poor internal ballast tank condition – rust and scale deposits can also lead to the blocking of designed draining arrangements.

The overall reduction in flow results in the tank suction becoming occasionally uncovered as the water cannot drain down through the tank at a sufficient rate to keep pace with the pump speed. When this occurs, air is drawn into the pumping system. This can cause the pump to lose suction and to surge in speed as the load on the pump motor becomes irregular.

For a period of time, the pump operator may be able to control this process by slowing the pump speed or priming the ballast pump from another water source. However, there will come a point when the flow of water in the tank towards the suction point becomes so low that the pump ceases to operate altogether and has to be closed down to prevent internal damage.

At this point, to more effectively drain the tank and further reduce the quantity of ballast water remaining, a process known as 'stripping' may be undertaken using either an eductor connected directly to the vessel's main ballast pipework, or either a network of dedicated smaller pipes fitted in addition to the main system.

The eductor is a device powered by high-pressure sea water. This can be supplied either by a dedicated pump or by utilising an existing piece of equipment, such as the tank cleaning pump shown in Diagram 2. The eductor unit converts high-pressure water into a high-velocity jet. This creates a vacuum within the body of the eductor unit. The vacuum is first applied to the ballast pipework and then to the suction point in the ballast tank.

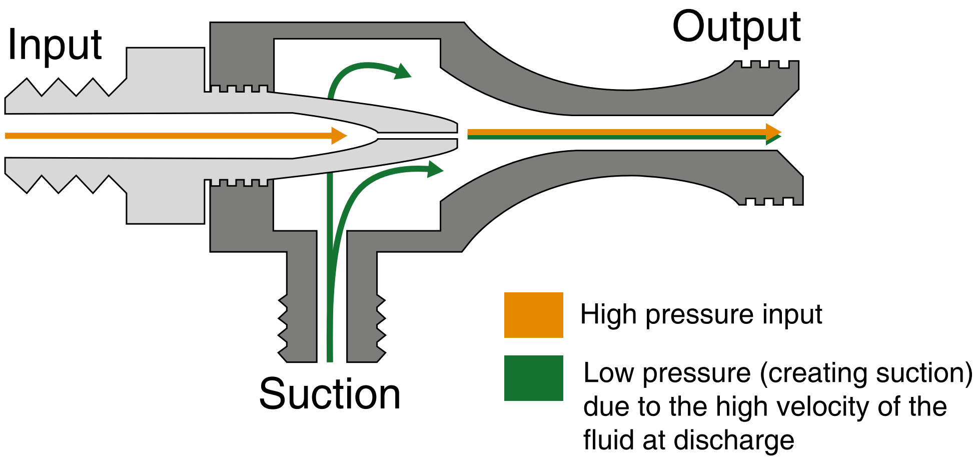

Figure 6 – Eductor Principle

Diagram 2 shows an eductor driven by pumped seawater from the local environment which is then discharged overboard at high pressure. The diagram also shows that, when connected to the ballast pipework for stripping purposes, the overboard discharge from the eductor will also contain ballast water from the tanks.

Once an eductor is supplied with high-pressure water, it can operate for indefinite periods and maintain a constant vacuum on the ballast line, which will continually draw up small quantities of water as they arrive at the suction point in the tank. This persistent drawing up of water results in a more effective draining of the tank and removes most of the remaining ballast water from the tank.

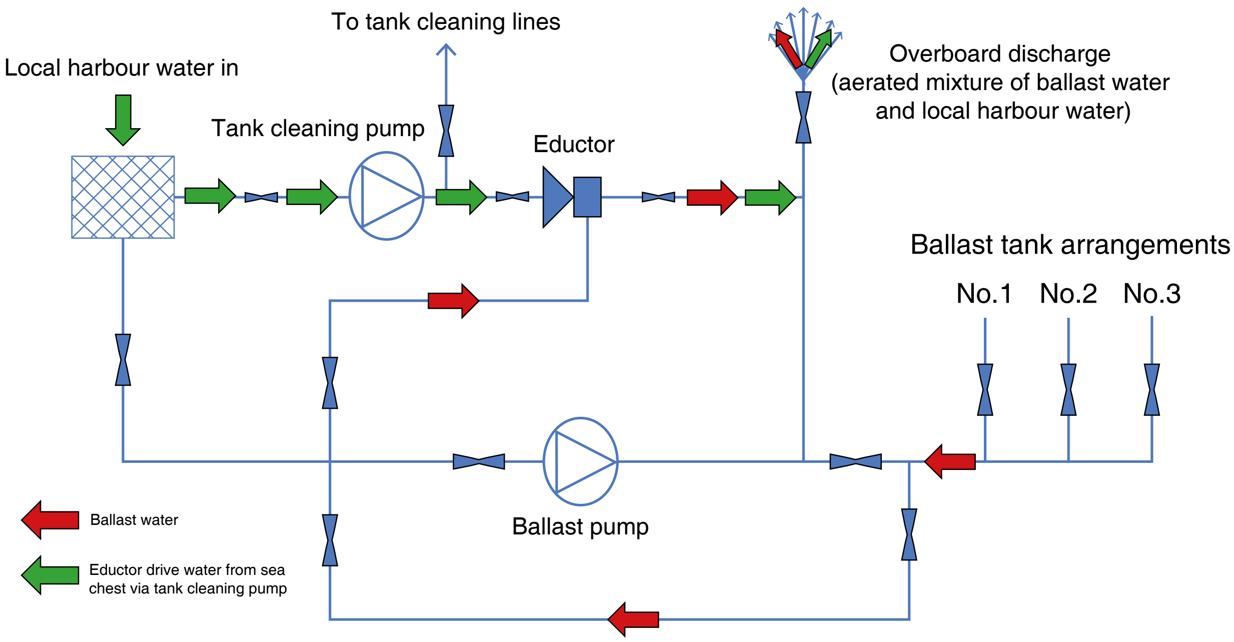

Diagram 2 – Simplified ballast system – deballasting (stripping) with eductor

Issues for Ballast Water Management Systems Making use of Active Substances

Eductors may be a useful tool for the final removal of ballast water from tanks but their operation involves certain features that may disrupt the effective functioning of a ballast water management system.

This is particularly true for ballast water management systems employing Active Substances, where the ballast water is treated with a disinfecting chemical or other agent at ballast uptake and has a control mechanism that applies a neutralising compound to condition the subsequent ballast discharge for environmental acceptability.

When ballast water is treated with a disinfectant chemical, or other agent that needs monitoring during discharge to ensure that the maximum allowable discharge concentration (MADC) of the additive is not exceeded, a sensing device for total residual oxidants (TRO) may be fitted to the ballast discharge line. This is normally linked to a central processing unit that controls the application of a chemical neutraliser substance to the outgoing ballast water to maintain the MADC of oxidants to within acceptable limits.

Diagram 3 shows such a sensing and neutralising system in operation during deballasting stripping operations using an eductor.

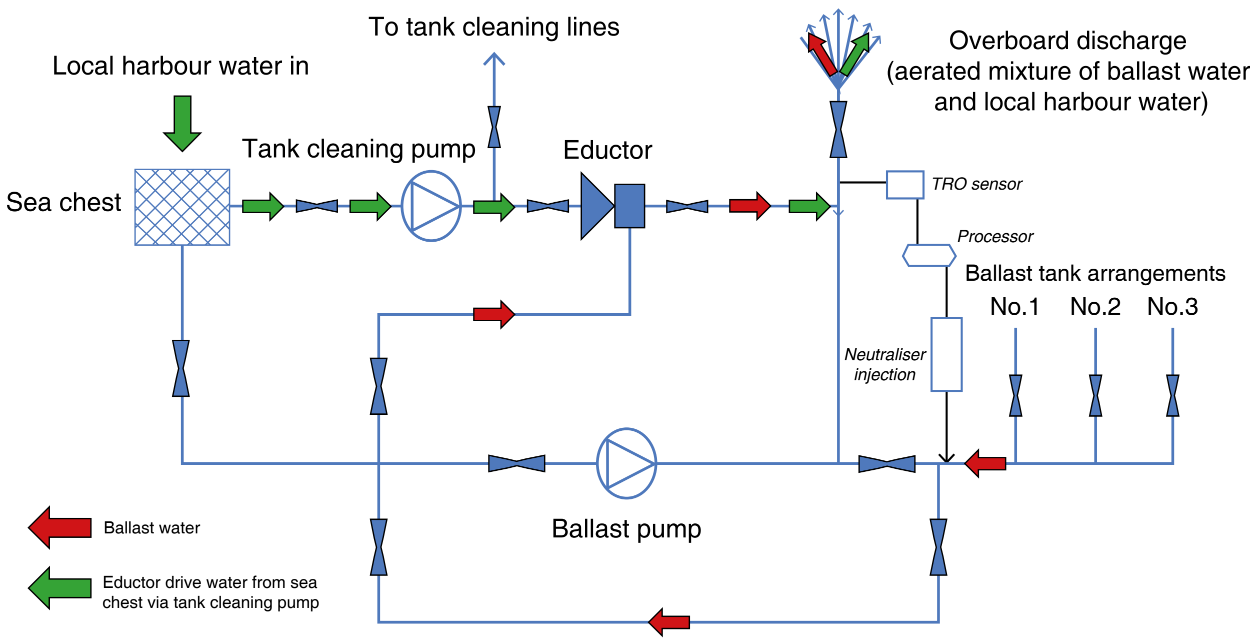

Diagram 3 – Simplified ballast system – deballasting (stripping) with eductor and neutraliser injection

When using an eductor, the resultant discharge overboard will normally be a mixture of local harbour water and that drawn from the ship's ballast tanks. The physical character of the discharge will be that of a comparatively high-velocity plume of aerated water (as a result of the eductor process), which is often discoloured with tank sediment material, as shown in figures 7 and 8.

Figure 7 – Overboard discharge of eductor when running on local harbor water with ballast tank lines closed – an aerated plume of comparatively clean water – courtesy Douglas Smith

Figure 8 – The same discharge water when the eductor is connected to a ballast tank - the discharge is now both aerated and discolored by sediments in the connected ballast tank – courtesy Douglas Smith

Observations

The use of eductors raises issues for the design and operation of treatment systems using Active Substances, which require specific monitoring and control safeguards to protect both the marine environment and persons exposed to ballast tank discharge.

The following points should be considered when an eductor is used in conjunction with a ballast water treatment system:

1. Given the comparatively high velocity of the eductor discharge of mixed ballast and local water, compared to that of a normal ballast pump, can a conventional TRO sensor be effectively employed for monitoring purposes?

   Colorimetric DPD monitors
   Air bubbles in the discharge, accompanied by the possibility of sediment presence, may result in a discoloration of sample water that could interfere with the sensing capabilities of the system and possibly give a false reading or render the unit inoperable.

   Amperometric monitors
   These may be similarly affected by the nature of the medium being measured. These units may be more prone to fouling with the presence of iron and manganese in the sample, as well as the possible presence of high turbidity, and this will result in the need for increased cleaning and calibration to avoid readings drift.

2. As the eductor works on a constant vacuum, there will be periods when the suction pipe contents are a mixture of air and water, this intermittent flow of liquid may again interfere with the correct operation of a TRO sensor.

3. If the neutralizer control system has detected levels above the MADC of the Active Substance during the bulk of the discharge, requiring the injection of neutralizer during the ballast discharge period, should the treatment system have the capability to record the overall neutralizer levels applied and look to injecting similar concentrations into the ejector discharge water? This would mean that neutralizer was being continually injected into the pipeline system despite the fact that the water flow may be intermittent, with a resultant increased environmental burden of neutralizer application and an effective waste of chemical resource.

   Or, would it be acceptable to allow the water discharged by the eductor to go untreated with neutralizer as the volumes to be treated may only represent say 1% of the total ballast load?

4. If neutralization is to be applied to eductor induced ballast water, should it be injected into the eductor discharge or further upstream in the system?

5. If independent stripping lines are employed, there may be a need for a second TRO monitor if a separate discharge line is involved.

6. Sampling points for eductor water will require some design consideration.

Note that the diagrams show a simplified eductor system, the actual layout and configuration of equipment and pipework may vary from ship to ship but the same principles will apply.

Current IMO Considerations

IMO document PPR 1/WP.6 was produced by the drafting group on Ballast Water Management in February 2014 and presented to the 66th meeting pf the IMO Marine Environment Protection Committee (MEPC 66/WP.6) for consideration. It includes an annex that proposes some draft guidance relating to stripping operations using eductors. Paragraph 11 of the draft guidance specifically considers aspects of eductor use with ballast water management systems using Active Substances:

'When ballast water is treated with a disinfectant chemical or other conditioning treatment at uptake only and the monitored discharge proves there is no need for the application of a neutralizer chemical to condition the discharge for environmental acceptability, then following the discharge of the bulk of the ballast water from a tank or group of tanks through the ballast water main system, it is accepted that the remainder of the ballast water in the tanks will also be compliant and may be discharged via an eductor system using local water as motive water without additional monitoring'.

This guidance was carried over to MEPC 67 (MEPC 67/20) where further documents were presented for consideration. These included comments from other parties relating to the technical challenges of sampling during stripping operations, and the practical application of eductors (which only represent the final stages of a deballasting procedure and not the bulk of the discharged ballast water).

Following deliberations, MEPC 67 agreed that there was no need to develop any guidance on stripping operations using eductors and it was recommended that ballast water sampling should not be performed during stripping operations.

Futher examples of sediment build up in ballast tanks.

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