Best Practices for Operation of Ballast Water Management Systems

Identified during ABS 2nd BWMS Workshop, Houston

American Bureau of Shipping

Global Marine

Date: August 10, 2017

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Legend for Appendix A:
Text colored yellow represents isolated comments concerning problem or failure
Text colored red represents repeated comments concerning problem or failure

Introduction

ABS hosted its 2nd Ballast Water Management Workshop in Houston on April 26, 2017. Twenty representatives from thirteen companies participated. Those invited to participate in the workshop were owners who have installed and are operating ballast water management systems.

The objective of the workshop was to identify the best practices in the operation and maintenance of ballast water management systems (BWMS). Participants were encouraged to focus on the operational and installation aspects of the ballast water management systems which support successful operations.

To help focus discussion and drive the agenda, workshop participants completed a BWMS Operational Experience Questionnaire prior to the event. Questionnaire participants were asked to provide information for each of their vessels that have an installed BWMS. The final questionnaire results included responses from a parallel event held in Greece.

Leveraging the questionnaire results and the collaborative discussions from the workshops allowed ABS to aggregate information on 220 BWMS, ABS was then able to address: installation, commissioning, crew training, in-operation experience, after sale service, and post operation experience and challenges. After analyzing the responses, ABS learned that 57 percent of the systems installed on the vessels of 27 owners are currently being operated or are considered operational on demand. The remaining systems were either inoperable or considered problematic.

The workshop accomplished the following:

- Participants shared experiences and discussed challenges for BWMS installation and operation.
- Through collaboration and extensive sharing of experiences, participants gained deeper insights on the technologies applied and their related challenges with regard to ship type/size, operational environment and conditions, operating frequency, ship board crew competency and BWMS maintenance.
- Discussions revolved around the contributing factors to the successful operation of a BWMS, including installation, commissioning, operating, training, maintenance considerations, and system design limitations.
- Participants gained a more informed understanding of the operational readiness of BWMS and best practices.

Comments and suggestions raised from the discussion were captured and compiled as best practices in the following sections. Each section is guided by the slides, which were presented in the workshop.

HIGHLIGHTS FROM QUESTIONNAIRES

While the following sections of this report concentrate on Best Practices identified during the workshop, it is important to note that several repeated challenges were reported and captured in the questionnaire results. These remarks are detailed in the appendix. It was agreed that proper planning, design, installation, training and maintenance practices address many of these challenges. However, it is important to note that there are recurring themes that deserve attention.

Firstly, many systems employ TRO (total residual oxidant) measurement during neutralization and some systems use TRO measurement to determine disinfectant dosage during ballast water uptake. Many owners responded that the reagents used for TRO measurement were highly susceptible to improper storage and handling. This had an apparent knock-on effect on TRO sensor abnormalities.

Through a number of responses we learned that sensor calibration is a repeated problem for both TRO and oxygen measurement, where applicable. Additionally, owners with UV systems reported that the cost and frequency of UV lamp replacement was a significant concern.

Reduction of ballast water throughput during both uptake and discharge is a recurring theme. In many cases this appears linked to filter clogging and cleaning. It was noted that this may also be associated with the ballast practices.

Owners acknowledged that proper crew training was an important consideration.

Lastly, ABS found a number of reports relating to vendor after-service networks and support which in repeated examples were stated to be less than expected which substantially contributes to chronic inoperability.

The results from the questionnaires were imported into an excel spreadsheet with the quantifiable items, such as dates and sizes, refined and made sortable. If not initially indicated, the descriptive sections were deciphered and interpreted to support a more comprehensive analysis. Depending on the categorization, data was pulled into numerical terms and presented graphically. A more detailed analysis can be found in Appendix A.

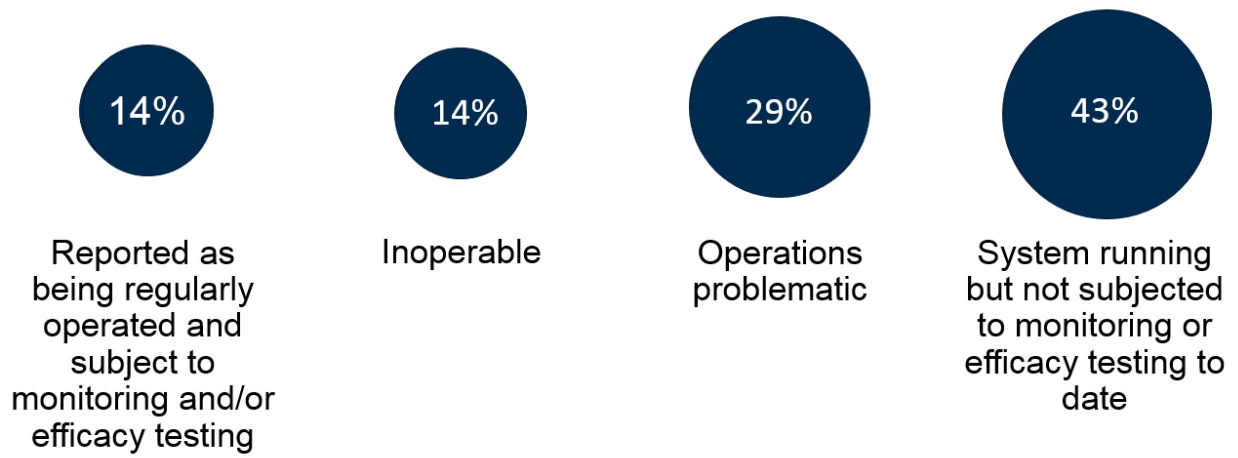


Figure 1 BWMS Operability

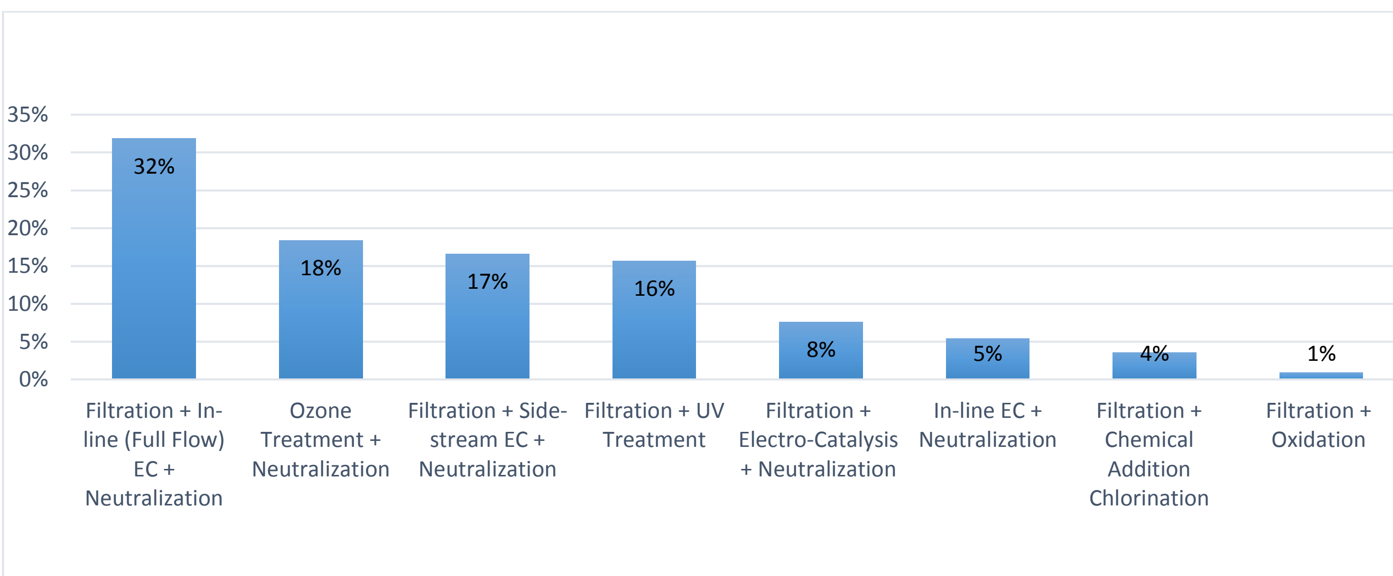


Figure 2 Technology Types

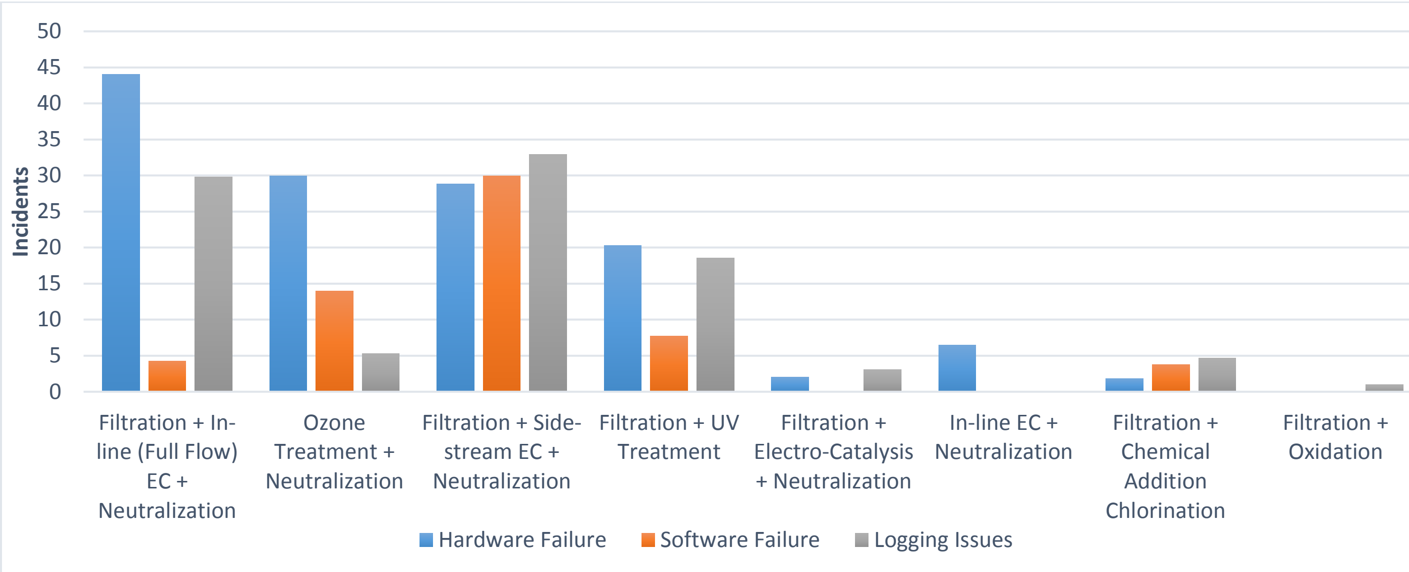


Figure 3 Operational Incidents Reported

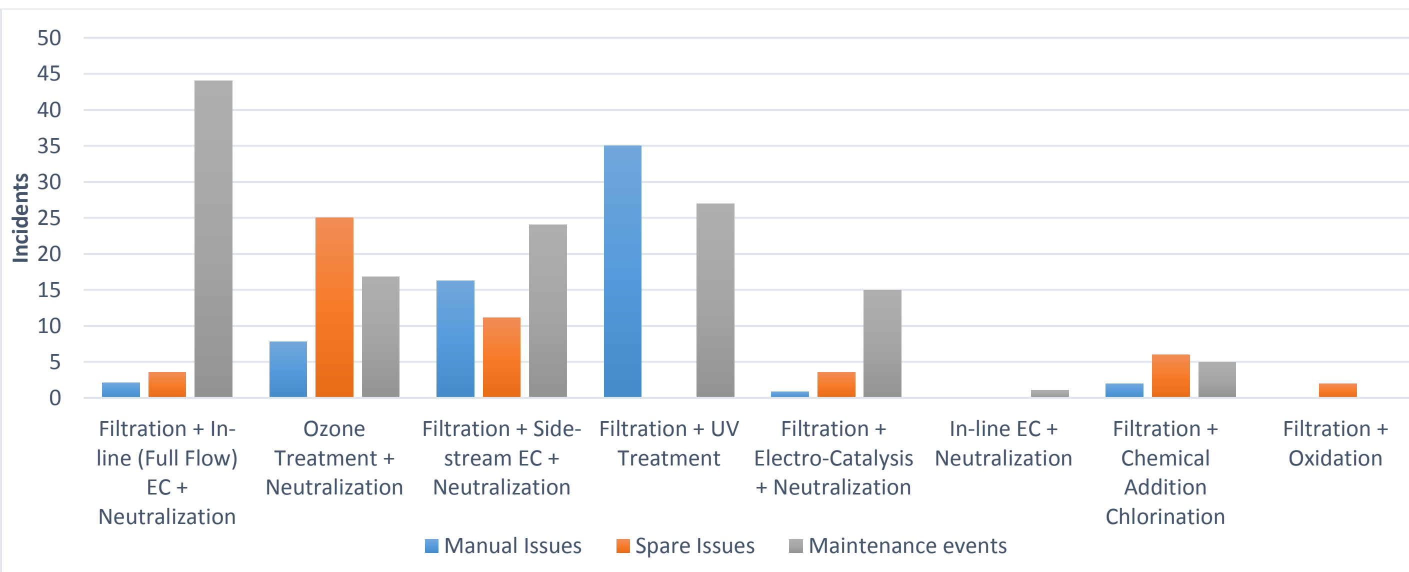
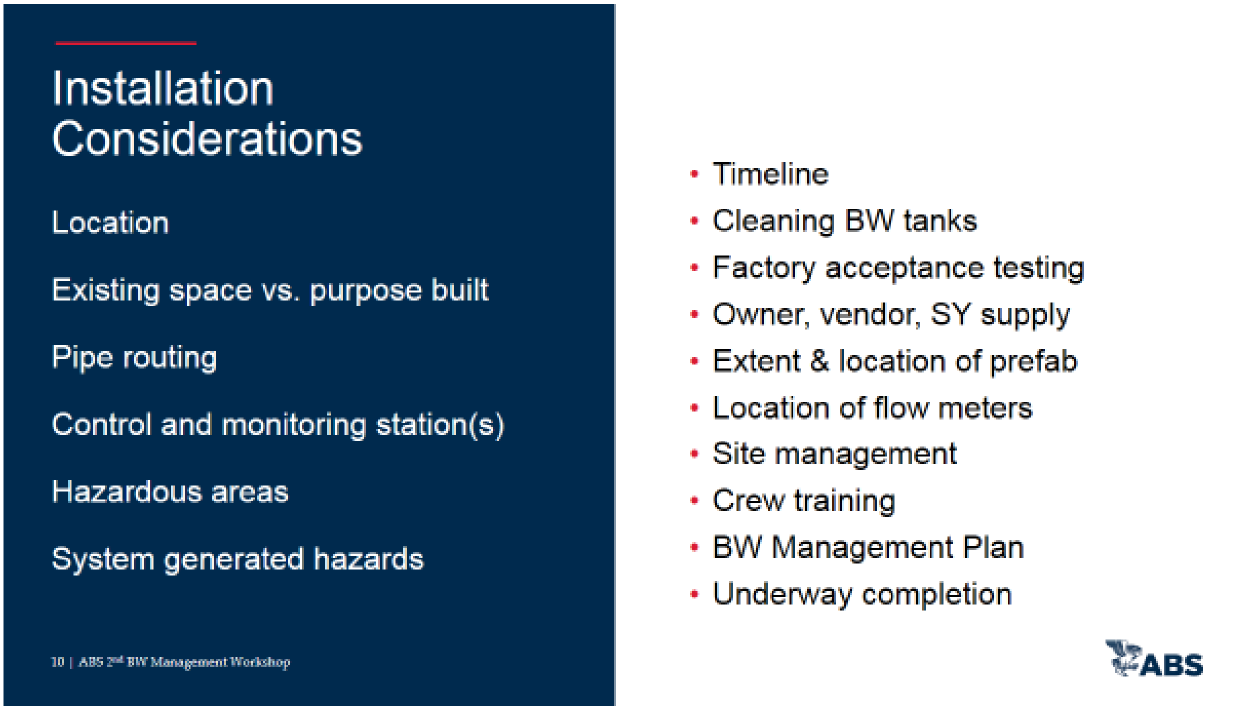


Figure 4 Maintenance Incidents Reported

1 INSTALLATION CONSIDERATIONS



The group discussed the difference in installation considerations for a newbuild compared to a retrofit. It was generally agreed that for the companies represented, most newbuild installations to date were carried out aboard designs not originally planned to have a BWMS. In this regard, while most observations were in the context of newbuilding, these observations may be equally valuable for retrofit projects.

Design Considerations

Some aspects of the installation issues can be avoided if identified early in the design phase. Design and installation should be completed with maintenance and repair in mind. The development and finalization of a ballast water installation plan should be completed during the design phase. For instance, design should consider all of the spaces necessary to accommodate BWMS filters. The Total Residual Oxidant (TRO) sampling lines should also be reviewed to make sure they are large enough for in-service cleaning.

Programming

Some pumps, such as the fire and general service pumps, may go offline when the ballast water treatment (BWT) system is tripped off. This can be avoided if the control system, which is integrated with the ship system is programmed in such a way that it will remain online with the ship system. The start-up and shut-down sequence should be considered and carefully programmed before and/or during installation. Improper shut-down sequence will cause unnecessary damage to BWT systems and consumables. Control logic may be adjusted to delay shut-downs where necessary. Software changes and parameter changes can often affect each other in negative ways, owners should ensure validation of such changes before putting into effect.

Environmental Controls

The shipyard environment can have an effect on installation. Owners and shipyards should pay attention to the environmental control in the installation space, especially in preparation for extreme weather conditions such as rain, freeze, humidity and heat. Deck installation, as an example, can be challenging in tropical locations; the enclosure and machinery space cooling is affected by the high humidity and temperature. Also owners and shipyards should configure the cooling methods, whether it be air or water. If cooling with air, the cleanliness and suitability of circulated air should be considered; the air should be filtered and allowed to dry sufficiently. Vacuum breaks may be considered for ultraviolent technology systems in deck installation as the insufficient water flow in UV reactors and chambers can cause inadequate UV bulb cooling.

The TRO samples and cleaning chemicals should be disposed of appropriately.

Management

Owners should work with and seek support from manufacturers who have extensive knowledge on the various systems. In addition, the bill of material (BOM) per type approval documentation should be validated by both the owner and shipyard prior to installation.

Maintaining at least two service engineers (mechanical, electrical/software) at the installation yard can save valuable time. Shipboard crew involvement during installation is encouraged to help ensure their understanding of the BWT system. This provides the necessary knowledge to help prepare for maintenance and repair in the future. Additionally, the ballast water maintenance plan should be validated during installation, as this will avoid any inconsistency in the plan, which routinely occurs when the plan is developed after installation is completed.

Contract

Owners are encouraged to sign an agreement with shipyards or vendors to include details necessary to ensure delivery of a fully functional, tested system. ABS offers optional notations (i.e. BWT, BWT+), the full extent of the notation requirements should be expressed in the contract for both the manufacturer and shipyard. The scope of supply and roles of the vendor, yard, and owner should be defined in the contract to facilitate integration with shipboard systems. Factory Acceptance Testing (FAT) is strongly recommended for manufacturers with limited experience to determine if the requirements specified in the contract are met. The contract should also clearly list all of the spare parts required onboard. Moreover, a definition of a successful trial run of the BWTS installed is recommended to be included in the contract. From the questionnaire, some owners mentioned that operating a BWTS can significantly reduce the ballast water throughput. This should be addressed in the contract and validated during commissioning.

Newbuild

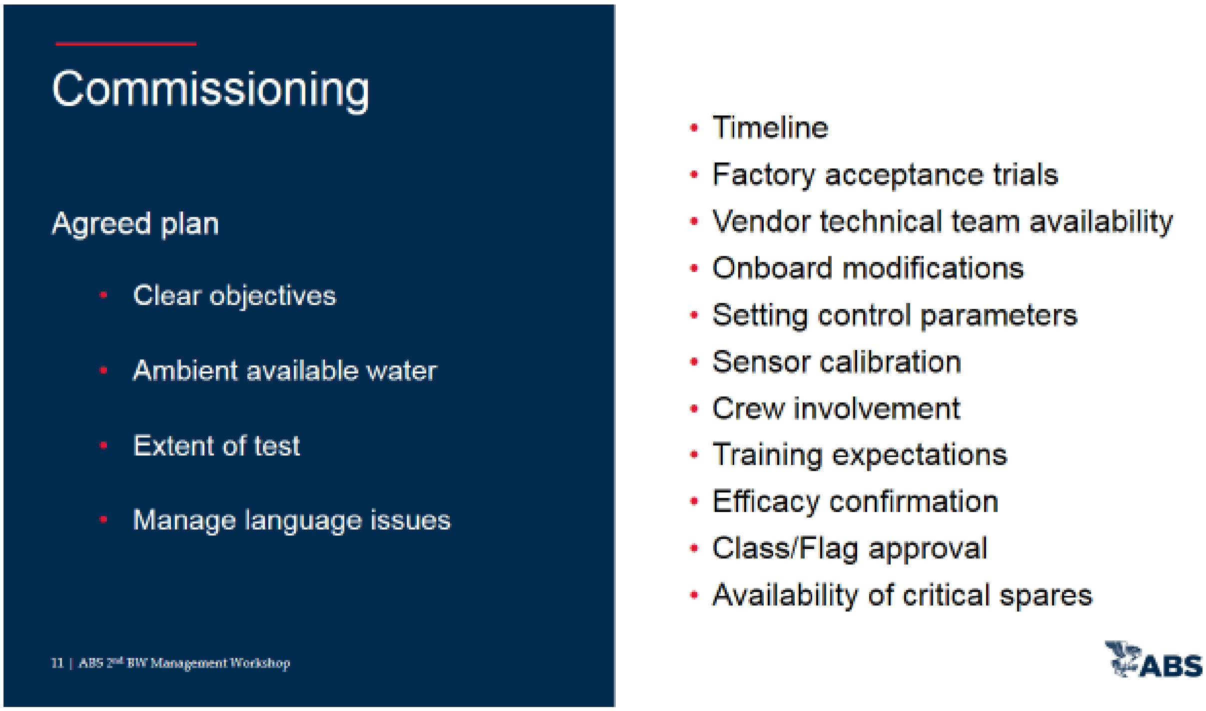
The successful installation on the first vessel in a series of newbuilds is important; upon the completion of the first vessel, the installation on the sister vessels can typically be installed faster and easier. Owners and shipyards are strongly encouraged to pay close attention to the first installation and record every step to apply lessons learned in future installations.

Retrofit

When scheduling a retrofit installation, engineering quality and class approval turnaround should be considered, as they may be more time consuming than in the case of a newbuild. Owners can anticipate the retrofit to be done across several yards. In fact, open tenders with multiple shipyards can provide flexibility for the vessel, and its last pre-drydock operation can be used for retrofit if prearranged. In addition to the location, pre-packaged components and equipment of BWMS can be manufactured remotely in accordance with the relevant type approval documents to save time. The engineering of the retrofit process should be carefully planned ahead and rehearsed before dry-docking.

The installation of large filters with backflush must consider both low and high sea chests as well as the athwartship orientation. Consideration must be given to the potential presence of silt and primary berthing orientation. Owners should try to avoid tying filter backflush overboard into ballast discharge overboard piping; this defeats the purpose of keeping backflush from one operating area separate from treated ballast water overboard discharged to another operating area.

2 Commissioning, Planning & Execution



Similar to installation, the first newbuild vessel in a series remains a key milestone for commissioning as well. More vendors' attendance and participation from the crew of the next in line vessels are strongly advised.

Systems may work during commissioning, but fail after leaving the shipyard. To minimize the likelihood of the above situation, in depth commissioning steps were discussed among the group. Meeting the class and flag requirements were also noted.

Compliance

BWMS installations may be commissioned either at quayside, onboard during sea trial, or both. Irrespective of the commissioning site, the owner and shipyard should have a clear understanding of the scope of commissioning. The roles and responsibilities of all involved parties (owners, vendors, shipyards, etc.), as well as the acceptance criteria, such as agreed time and volume should be specified in the contract. The same idea extends to compliance; an actual demonstration of compliance specified in the contract can be reassuring.

The details of the testing procedure and requirements should be developed before commissioning and delivery. A minimum consideration recommended by experienced BWMS owners is for the system to display full ballasting and deballasting with no malfunctions.

Control Checklist

Before final commissioning, several subjects should be reviewed by owners. First of all, both electrical and mechanical teams should be onsite during commissioning. Service engineers and shipboard crews should conduct maintenance walk-throughs to verify adequate clearance and maintenance access and confirm appropriate spare parts are onboard, especially during sea trials. It has been noted that some crews had to make tools to have proper access for some components due to tight installation. In fact, it is recommended to keep vendor's team in attendance until the final stage of commissioning.

Despite the best intentions and agreeable contractual terms, sometimes due to system design limitations, owners are not aware of realistic commissioning challenges. That includes setting and reaching agreement on the control parameters. The ballast water management plan should be validated by owners before commissioning. Where required, owners should insist on revision and resubmission for approval. Shipboard crews should be acquainted with the BWTS operation, in particular ship-specific BWTS operation, before commissioning. Ideally, shipboard crews should perform hands on training with the BWTS while vendors are still onboard.

Testing Operability

The two testing locations, in port and/or at sea, face slightly different scenarios. In each case, it is suggested to run at least a full ballast and deballast cycle, including a stripping operation as stated above. Efficacy testing is a challenge that should be carefully considered.

A topic that was discussed during the seminar was whether testing should be done in representative water or in open sea. Some argue that at sea, BWMS commissioning is not an adequate challenge – since vessels in reality ballast more often in port than in open sea. But most shipyards are not suitable, both in depth and water quality, for conducting proper BWMS testing. Sea trials may not demonstrate efficacy in high silt loading (port) condition either, therefore owners will have to make a decision on the proper testing location and incorporate the requirements into the contract.

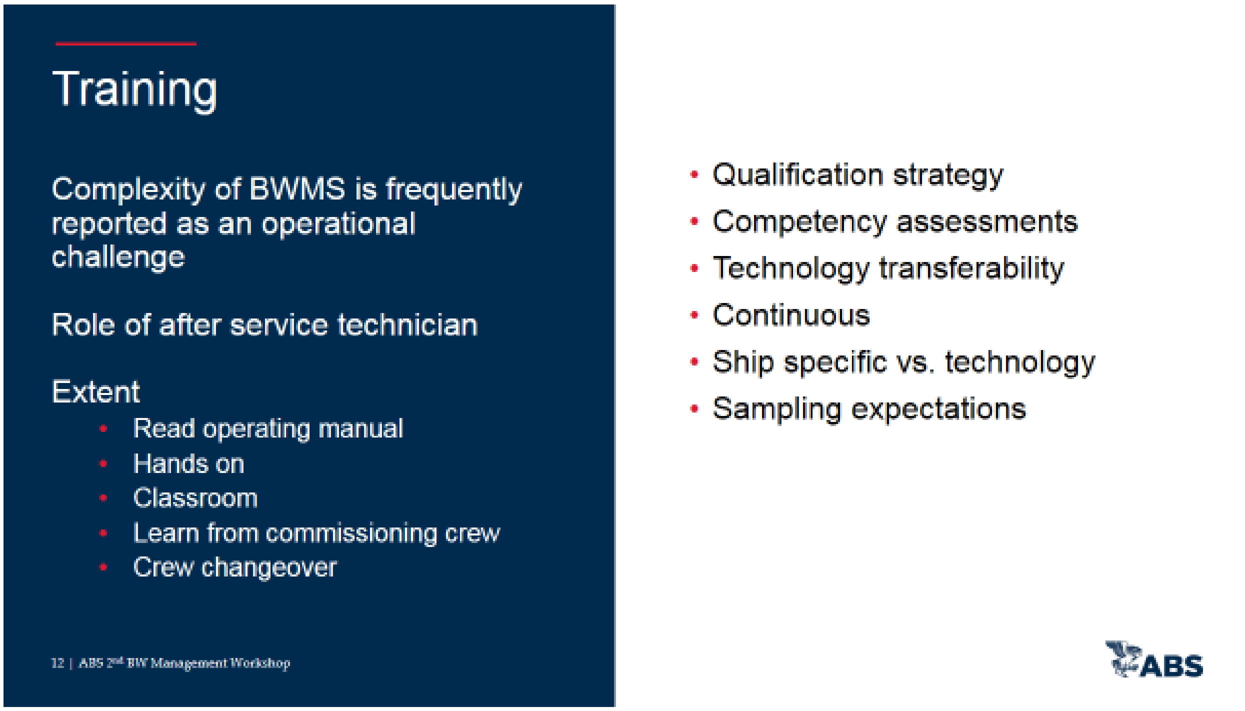
For ultraviolet, technology system types, validating the proper UV lamps warm up and verifying cool down capabilities before turning them on for the first time is encouraged. For chemical systems, the TRO monitoring should be started early.

Further Consideration

Owners should be vigilant during onsite activities, testing and commissioning phases to ensure full functionality at final delivery. In addition, owners should ensure that the BWMS has been thoroughly tested before delivery.

It's important to clean the ballast tanks before putting the system in service. Final examination confirming that all the vital components are intact and functional is essential. Although it is tempting to have shipboard crews undergo training during testing, it is not recommended, as it can impact the result, adding uncontrollable variables to the testing.

3 Training



Many owners have commented on the lack of uniformity in training methods, especially when the BWMS is ship specific. Discussions revolved around current practices and expectations, exploring possibilities for future training.

Delivery Methods

Current training methods include lectures with visual aids (video), hands-on practice, and computer-based approaches. A partnership with manufacturers to have simulators made available to mimic real BWTS operation was another delivery method mentioned. Though these methods are reported as effective, owners desire more comprehensive training materials, including a well-written, ship-specific, operating instruction manual that is both detailed and updated after the installation.

Owners operating large fleets that consist of different BWTS, may have shipboard crews that are trained for one type of BWTS, but may not be able to apply their knowledge when working on a different vessel with another type of BWTS. Therefore, placing shipboard crew onboard different vessels with different BWTS, will allow them to gain exposure and a more diversified experience conducting various BWTS operations.

Audience

It is often assumed that training is only for shipboard crews. However, owners should consider including managers and port engineers in the training program as well. Manufacturers sometimes have training sessions at their facilities, but often with limited availability. Owners can encourage the vendors to train technical managers in the shipyards or port. The technical managers can then pass along the training to shipboard crews. Having technical managers that are competent in BWTS operation, and even multiple system types, will greatly benefit owners.

Competency

One aspect that is missing from the current training curriculum is the proof of competency. Regardless of the training methods and duration, without a clear outline of minimal standards, there is no guarantee or proof of how much material is retained by the trainees. A computer standardized test at the end of the session can provide evidence and records for management.

Another concern is process competency. Understanding the technical aspect of BWTS might not always be enough for immediate operation, especially for a retrofit BWTS that has been modified. Training should focus on the operation of BWTS.

Future: Sampling

From the questionnaire results, it was reported that 43 percent of running BWTS are not being sampled and tested. Though it is not an international requirement as of now, with D-2 compliance approaching, a sampling protocol should be included in the training. A detailed instruction of proper sampling procedures would be helpful along with hands-on training and a defined record keeping process.

Other alternative sampling methods, such as third-party sampling onboard or onshore can be explored as well. Shipboard crews are urged to familiarize themselves with the third party and understand their process.

4 OPERATIONS

With a proper ballast water management plan, operation issues raised can be resolved and prevented. In this section, the group discussed operation with a focus on sequencing, filtration issues, data storage and consumables.

Sequencing

As mentioned previously in the installation section of this report, the start-up and shut-down sequence is essentially a programming issue that should be established during the design phase. Many owners expressed concerns with inadequate shut-down sequence plans that have caused improper cooling of lamps and have even triggered the BWTS to go offline. It is difficult to reprogram the sequencing during operation, therefore the program ought to be designed and tested during installation and validated during commissioning.

Filtration

The workshop explored the different experiences in using backflushing filters for ballasting. There was general agreement that the backflush lines should be led directly overboard. The backflushing rate should be carefully monitored and adjusted when needed. This can be achieved by using appropriate sea chests, changing pressure settings, switching between filter candles and other adjustments. Performance of pipe flushing helps with sediment. Care is needed to avoid damaging BWTS components, such as UV lamps.

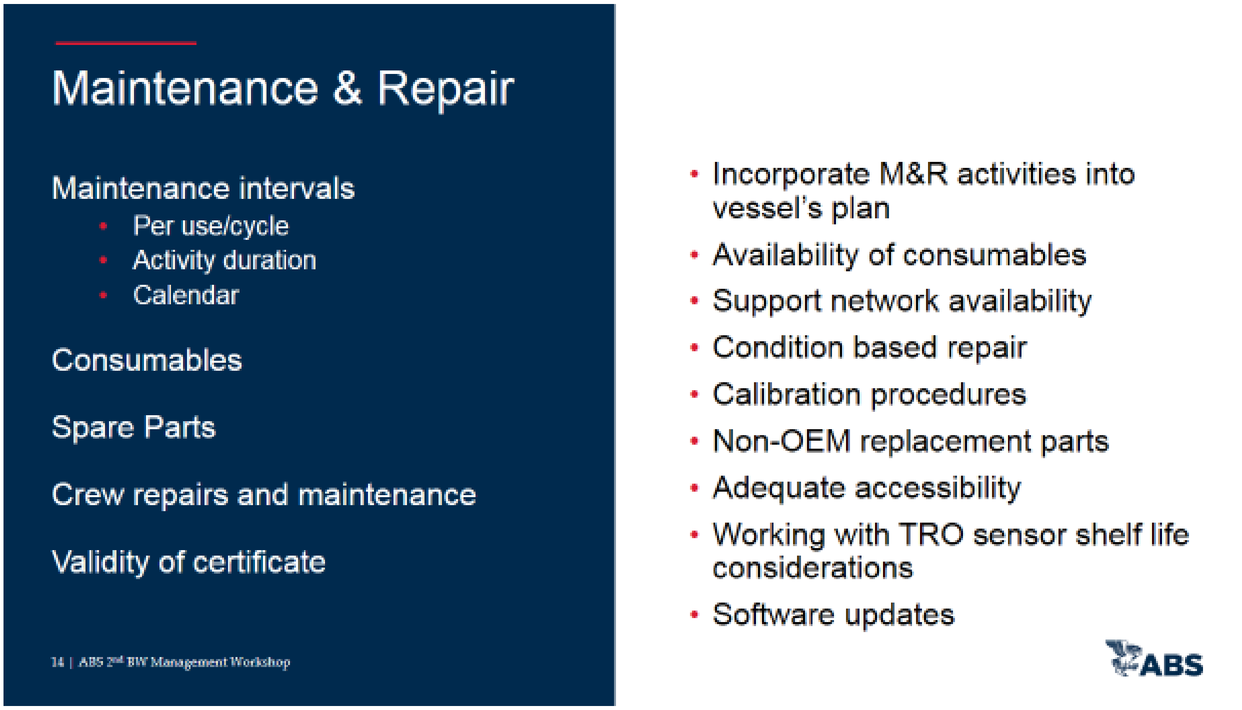
Data Storage

Many of the current BWTS are installed with data auto-log, however, proper data storage is sometimes neglected. Owners should check and verify the data logging regularly and each system should store at least one month of data. This data may be requested for port state control and USCG review. Data is also important to the owners as they can identify valuable trends regarding the performance of the BWTS.

Consumables

Consumables, especially chemical consumables are a vital part of operation for some technology types. It is important to understand the shelf life of these consumables and develop an appropriate restocking schedule. As mentioned before, shipboard crews should have training in good handling procedures.

5 Maintenance & Repair



Following the above slide presented in the workshop, owners commented on the importance of establishing a maintenance schedule, preplanning sediment control and considering consumables. It was also noted that owners should look out for system generated hazards, and the servicing of dedicated enclosures in hazardous areas. This is often overlooked and not included in the safety plan. A lay-up plan and operation can also be considered to avoid potential maintenance and repair (M&R) issues.

Maintenance Routine

In preparation of safety plans for M&R activities, owners and manufacturers should consider performing an annual inspection of their BWMS. During the inspection, different service engineers can come onboard to check different components of the BWTS, update software, walk the shipboard crews through critical areas that need more attention and refresh the crews for potential troubleshooting aspects. Identifying the root cause of failure is imperative in any failure event.

Preplan - Sediment Management

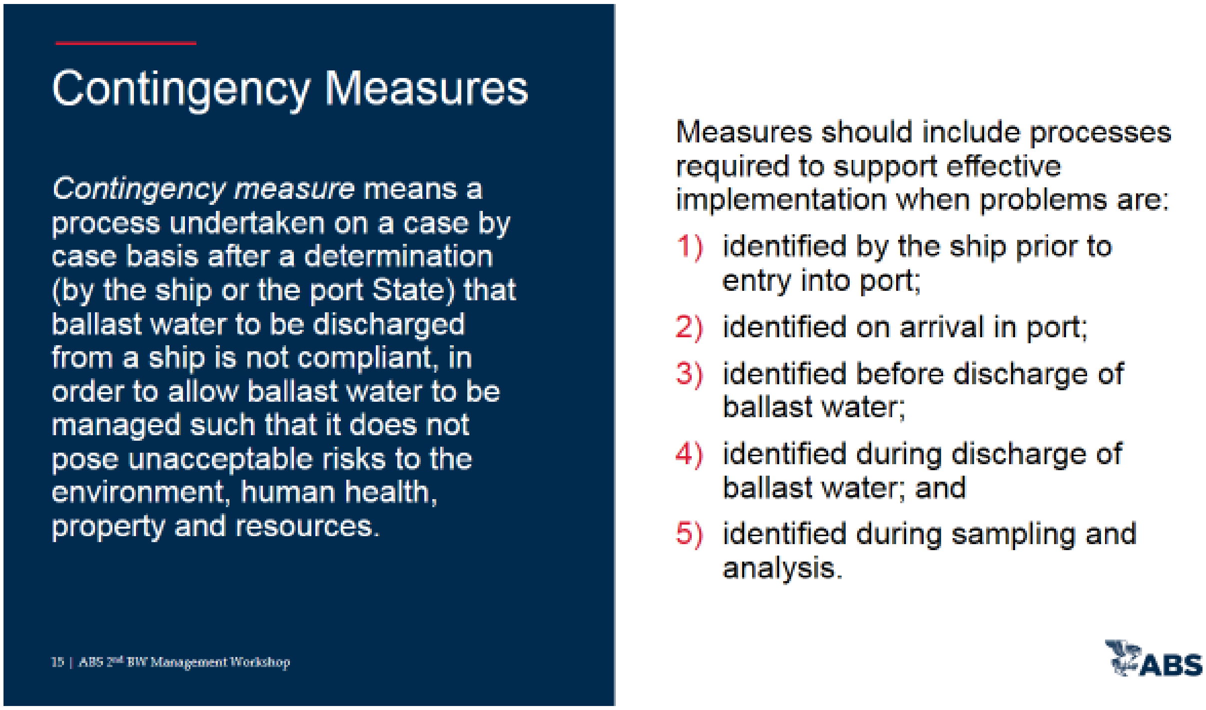
Since ballast water is not exchanged in the case of BWTS, sediment control once again becomes a problem. Fine filtration rates (40 micron) support the filtration and removal of large microorganisms, but will not prevent the build-up of fine silt in the tanks. Additionally, some owners have used ultrasonic cleaners for the filters to remove heavy sediment buildup.

Consumables

Following the discussion in the previous section, consumables remain a big topic for maintenance and repair. In addition to chemical consumables, UV lamp bulbs often need to be replaced, especially in systems where one lamp outage leads to system failure. Owners mentioned that UV bulbs are not meeting their expected life-cycle durations. This may be associated with cooling water interruptions and frequent start up and shut down sequences. This was also commented on in the previous section. Owners are urged to validate the replacement components before and after installation.

Some owners mentioned that they have had better experiences with smaller equipment manufacturer companies for claims and after sale support. On the other hand, owners are concerned about future hardships with systems if the maker goes out of business. Thus, it is crucial to have reassurance concerning vendor support, perhaps to have vendor profiles fully evaluated before purchasing to ensure long term support.

6 Contingency Measures



The group spent a good amount of time discussing contingency measures that they have either learned or have been practicing. A clearly written contingency plan for all foreseeable maintenance and repair (M&R) events will be helpful. As a last resort, shipboard crews may practice ballast water exchange as a fallback for ballast water treatment. The BWMP should anticipate this and include details on notifying and obtaining concurrence from concerned flag states and ports. The group also discussed the possibility of having a ballast manifold on deck, alternative BWTS, and special statutory requirements.

Alternative BWTS

Due to ongoing issues with the placement of BWTS, some owners are looking into alternative methods to comply with the D-2 compliance, including the use of a shore-based BWTS facility.

Mobile facilities that come alongside to receive and treat ballast water for vessels is a possible alternative to onboard systems. Receiving treated ballast water from a verified third-party vendor is an option. However, responsibility for discharging non-compliant ballast water would likely remain the responsibility of the owner and not the BW supplier.

Statutory Requirements

Owners should pay attention to each country's specific requirements. For instance, Argentina recently announced a requirement that all ballast water must be treated with chlorination before discharging. The practicality of this requirement is not fully understood.

7 Post Meeting Notes

MEPC 71 Conclusions

The IMO Maritime Environment Protection Committee (MEPC) tentatively accepted an amended implementation scheme for ships to comply with the D-2 biological standard under the Ballast Water Management Convention. The scheme, if approved by the committee on July 7th, will be circulated to Member States for adoption during MEPC 72 scheduled to be help from April 9-13, 2018.

Under the proposal, ships constructed on or after September 8, 2017 are to comply with the D-2 standard on or after September 8, 2017. Referring to the Illustration below, ships constructed before September 8, 2017, are to comply with the D-2 standard at the first MARPOL IOPP renewal survey completed on or after:

- September 8, 2019 (Reg B-3/10.1.1); or
- September 8, 2017, only if a MARPOL IOPP renewal survey is completed on or after September 8, 2014 but prior to September 8, 2017 (Reg B-3/10.1.2).

If the survey per Reg b-3/10.1.2 is not completed, then compliance with the D-2 standard is required at the second MARPOL IOPP renewal survey after September 8, 2017, only if the first MARPOL IOPP renewal survey after September 8, 2017 is completed prior to September 8, 2019 and a MARPOL IOPP renewal survey was not completed on or after September 8, 2014 but prior to September 8, 2017 (Reg B-3/10.2).

For ships constructed before September 8, 2017 and which are not subject to the MARPOL IOPP renewal survey, compliance with the D-2 standard is required no later than September 8, 2024 (Reg B-3/5).

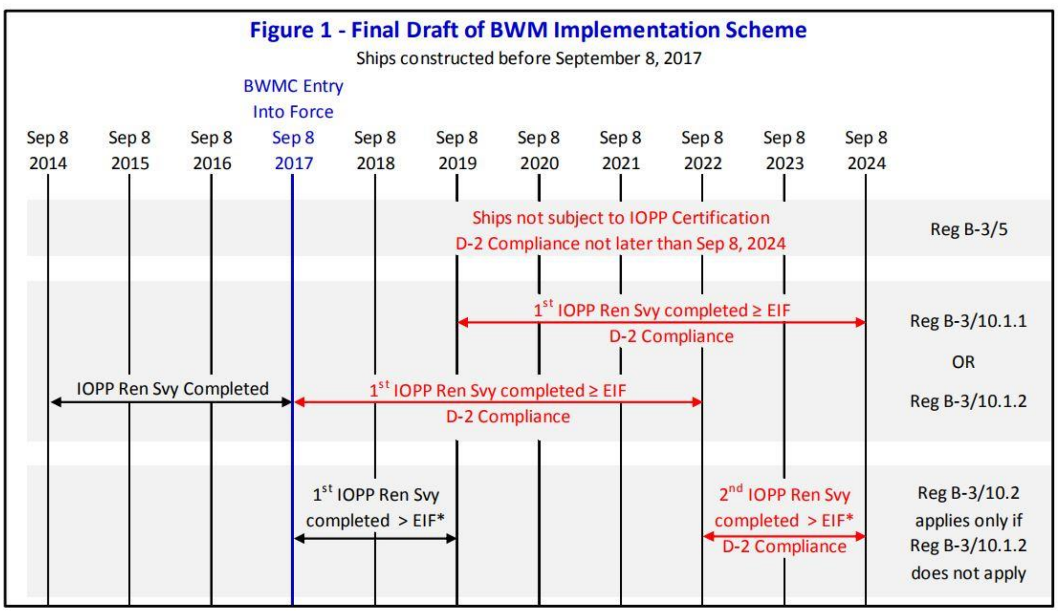


Figure 1 - Final Draft of BWM Implementation Scheme

Appendix A BWMS Operational Experience Questionnaire Results-By Technology Type

A1 Summary of Appendix

To help form an accurate picture of the current progress with ballast water management compliance, ABS sent out a questionnaire to shipowners inquiring about the challenges the industry has faced regarding these systems and what they believe to be lessons learned. ABS received responses from 27 shipowners regarding 220 vessels including: bulk carriers, tankers, container ships, LNG carriers, and gas carriers. The questionnaire results were anonymized and aggregated to help identify trends amongst the received responses.

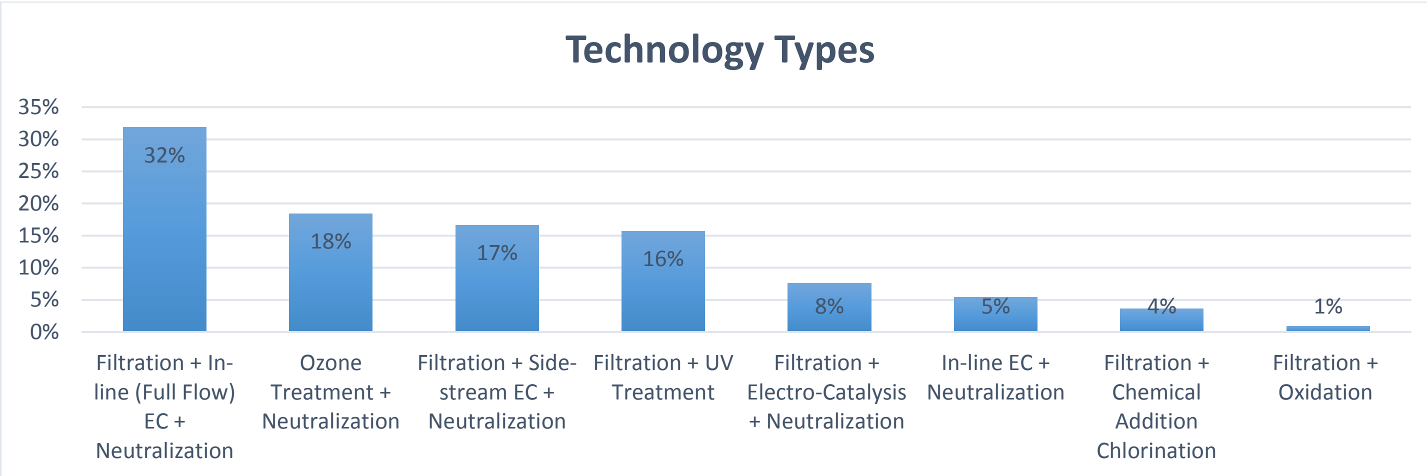
The common challenges owners reported facing dealt with: installation, commissioning, crew training, in-operation experience, after-sale services, and post-operation experiences. The following systems were all included in a various percentage of the 220 vessels in the feedback:

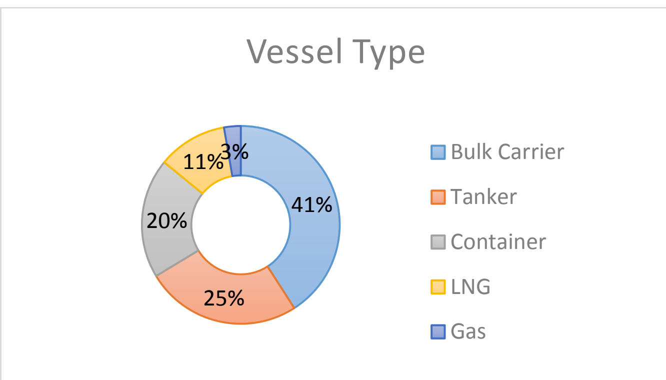
- Filtration + In-line (Full Flow) EC + Neutralization (32%)
- Ozone Treatment + Neutralization (18%)
- Filtration + Side-stream EC + Neutralization (17%)
- Filtration + UV Treatment (16%)
- Filtration + Electro-Catalysis + Neutralization (8%)
- In-line EC + Neutralization (5%)
- Filtration + Chemical Addition Chlorination (4%)
- Filtration + Oxidation (1%)

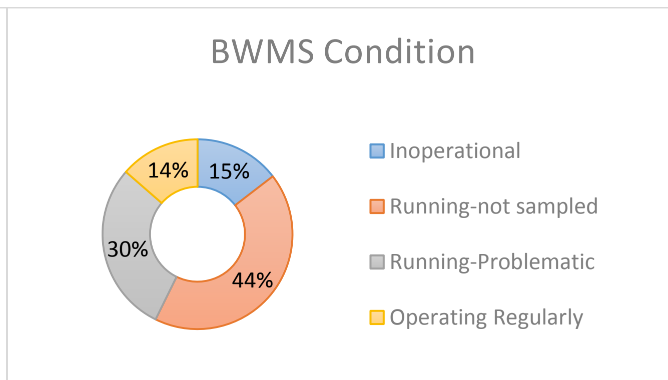
In reviewing the responses, ABS learned that 57 percent of the systems were being operated, the remaining systems were either inoperable or considered problematic. The more prevalent challenges that shipowners and operators have faced with these systems are related to software, hardware, and the crew's ability to operate the systems correctly. The software integrated into the ballast water management systems which were analyzed in this study often required extensive updates, and experienced system malfunctions. System operators have had a difficult time with hardware maintenance and maintaining appropriate spare parts onboard. When maintenance issues have occurred, owners have had difficulty assuring the system manufacturer is able to board the vessel and service the needed equipment. The importance of maintaining a good working relationship with the system manufacturer is key to navigating after-sale system issues.

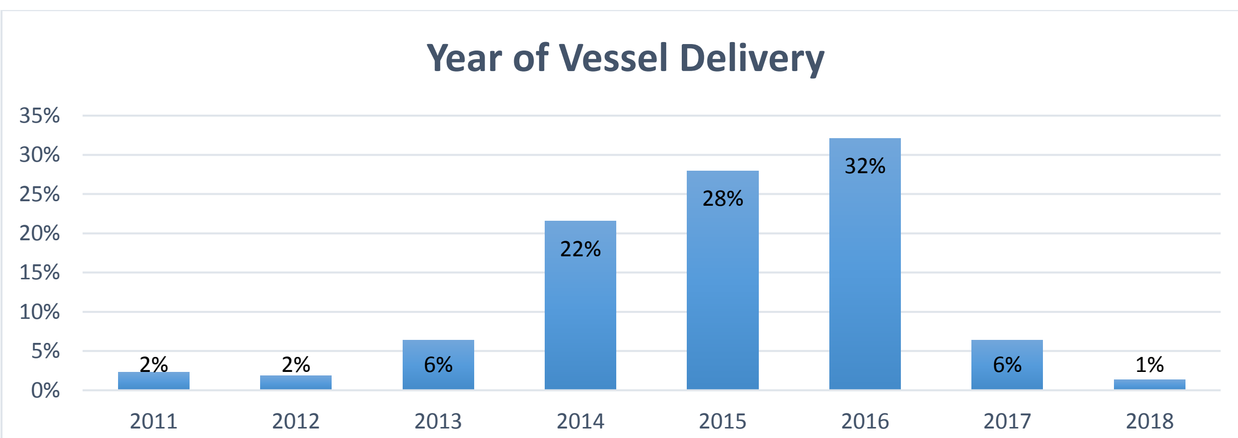
The biggest takeaway resulting from the responses was the necessity of maintaining an effective training system to ensure crew members can operate the equipment properly and safely. Crew members are constantly on rotation not only on and off the ship but on and off different ships with a variety of ballast water systems. This variety can lead to confusion on operational procedures and maintenance schedules. To minimize human errors, effective training methods must be put into place to ensure each crew member is up to speed on the vessel's BWM system before sailing. Improved training methods and clearly written system manuals will lead to a decrease in the number of issues stemming from operational errors.

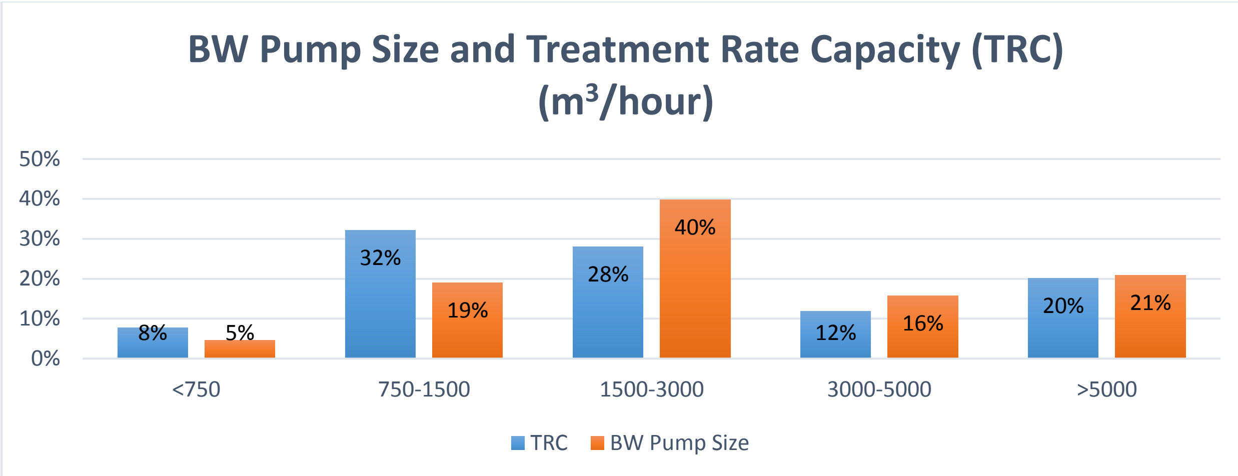
Through the ABS BWMS Operational Experience Questionnaires, ABS received input on 220 vessels from 27 owners. From the given information, the results were aggregated according to the eight technology types. All data was anonymized and presented as percentages.

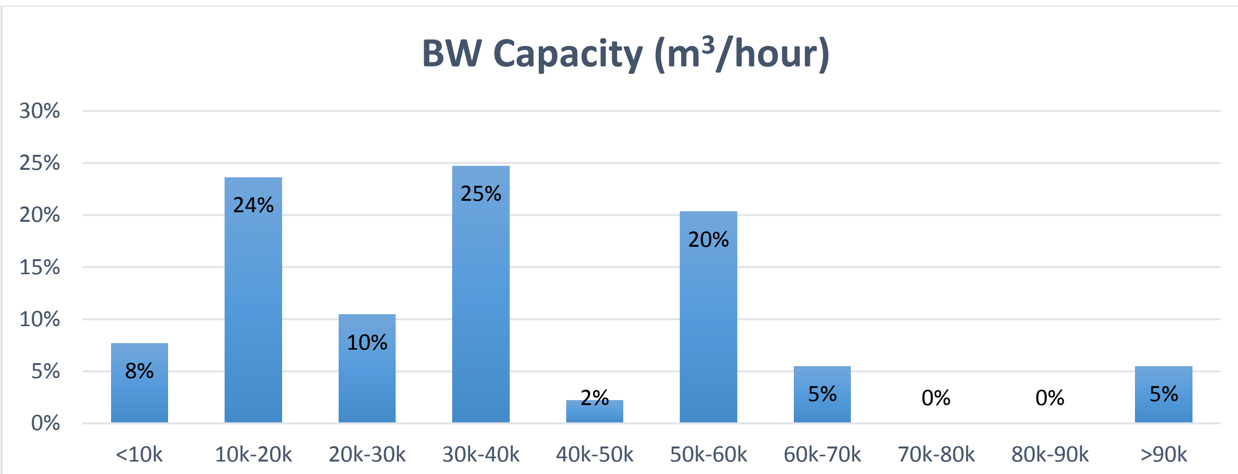









BW Pump Size and Treatment Rate Capacity (TRC) (m³/hour)
50%
40%
30%
20%
10%
0%
8%
5%
32%
19%
28%
40%
12%
16%
20%
21%
<750
750-1500
1500-3000
3000-5000
>5000
TRC
BW Pump Size


BW Capacity (m³/hour)
30%
25%
20%
15%
10%
5%
0%
8%
24%
10%
25%
2%
20%
5%
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<10k
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80k-90k
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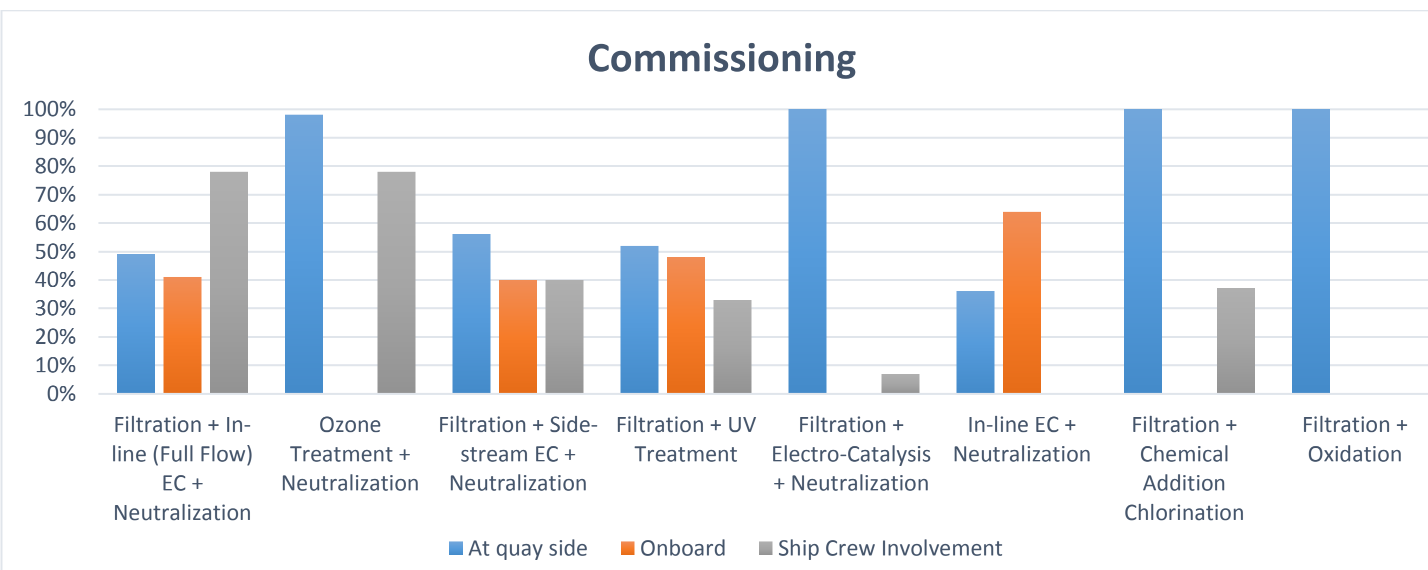
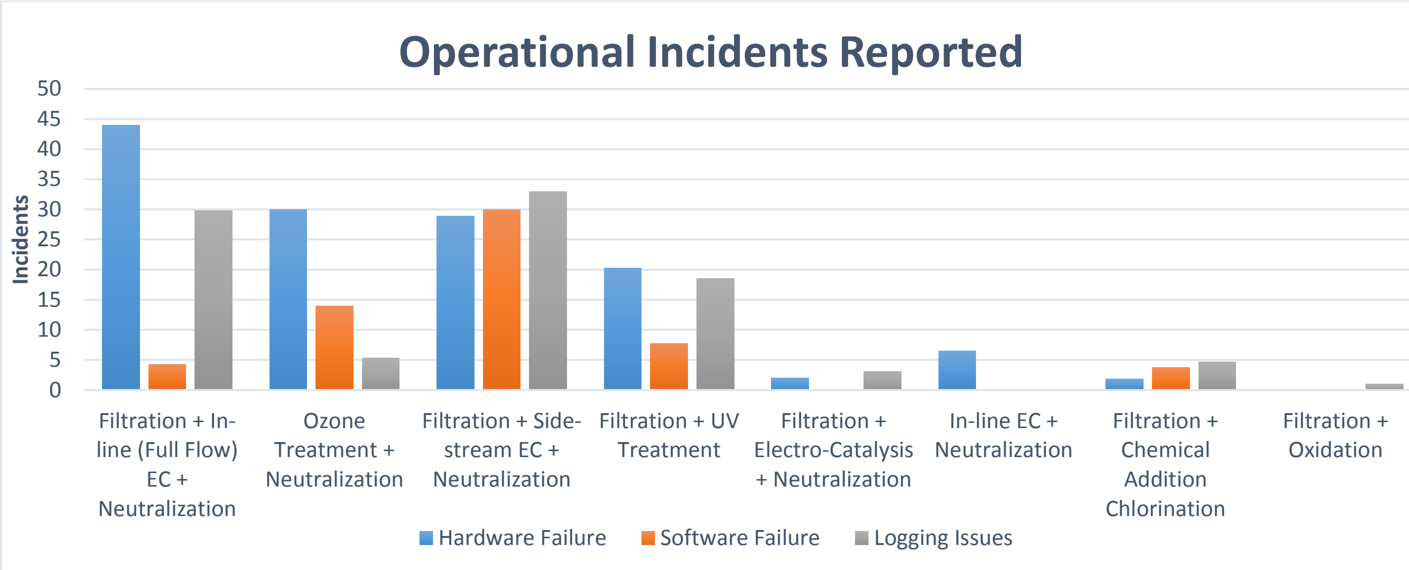
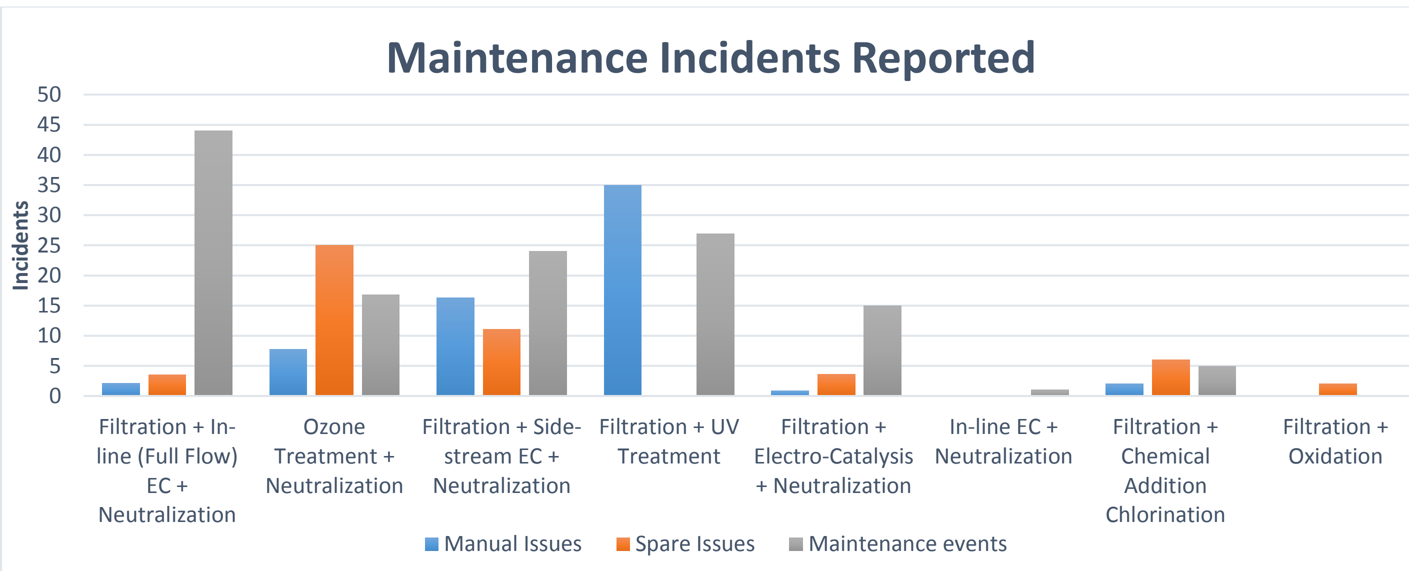
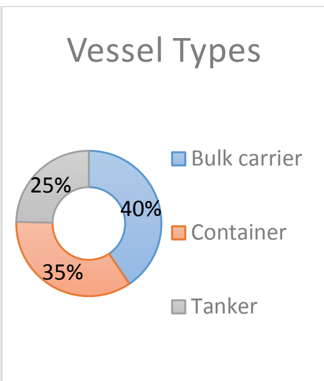

Commissioning
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + In-line (Full Flow) EC + Neutralization
Ozone Treatment + Neutralization
Filtration + Side-stream EC + Neutralization
Filtration + UV Treatment
Filtration + Electro-Catalysis + Neutralization
In-line EC + Neutralization
Filtration + Chemical Addition Chlorination
Filtration + Oxidation
At quay side
Onboard
Ship Crew Involvement

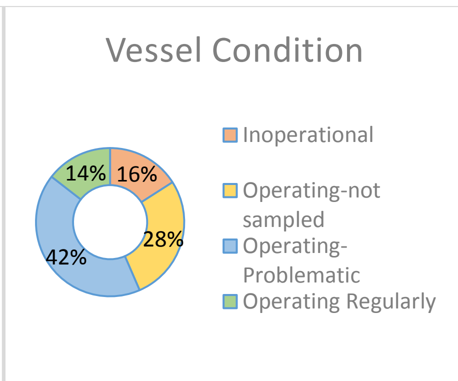

Operational Incidents Reported
Incidents
50
45
40
35
30
25
20
15
10
5
0
Filtration + In-line (Full Flow) EC + Neutralization
Ozone Treatment + Neutralization
Filtration + Side-stream EC + Neutralization
Filtration + UV Treatment
Filtration + Electro-Catalysis + Neutralization
In-line EC + Neutralization
Filtration + Chemical Addition Chlorination
Filtration + Oxidation
Hardware Failure
Software Failure
Logging Issues

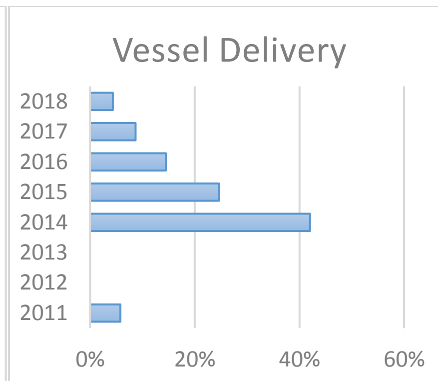

Maintenance Incidents Reported
Incidents
50
45
40
35
30
25
20
15
10
5
0
Filtration + In-line (Full Flow) EC + Neutralization
Ozone Treatment + Neutralization
Filtration + Side-stream EC + Neutralization
Filtration + UV Treatment
Filtration + Electro-Catalysis + Neutralization
In-line EC + Neutralization
Filtration + Chemical Addition Chlorination
Filtration + Oxidation
Manual Issues
Spare Issues
Maintenance events

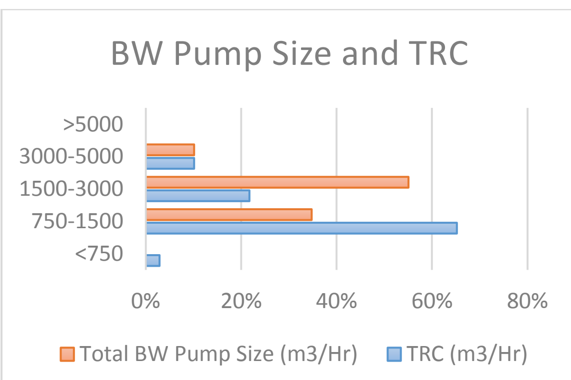
A2 Filtration + In-line (Full Flow) EC + Neutralization

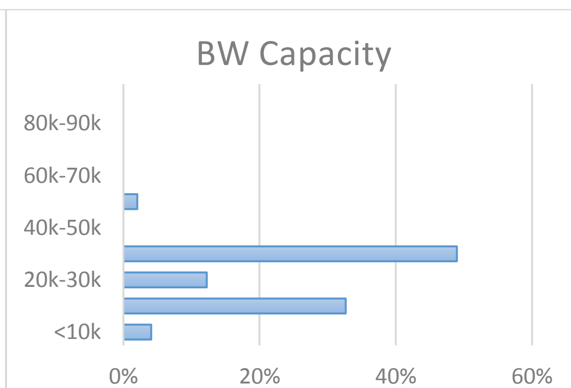
Filtration + In-line (Full Flow) EC + Neutralization	**32%**
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	8%
In-line EC + Neutralization	5%
Filtration + Chemical Addition Chlorination	4%
Filtration + Oxidation	1%











Installation work

- (90%) Installed in E/R, others in open deck (safe), open deck (hazardous), E/R 2nd Deck
- (100%) Installed in dry dock during NB stage

Commissioning

- (49%) Commissioning at quayside, (41%) onboard during voyage, and others both at quayside and onboard during voyage
- (78%) Shipyard crew involvement
- On average, commissioning was reported to take 5 days, during sea trials
- Some reported taking up to one year to fully complete commissioning trials

- (58%) Reported Challenges:
    - Vessel ballast discharge is restricted to a single overboard discharge
    - Setting/adjusting parameters
    - Shipyard cooperation
    - Required software upgrades
    - System problems and time duration required for supplier to resolve the issue

Crew training

- 65% Trained onboard, others onshore
- Training period ranges between 3 to 8 hours
- Training carried out/continued onboard, by attending service technicians, also for troubleshooting in shipyard; by maker's instruction book, maker's representative, service engineer, CD/DVD
- Based on ballast management plan and manuals onboard
- Joining crew relied on departing crew for familiarization and training
- Onshore in crewing office seminar
- Sea trials
- Challenges:
    - Different systems according to fleet types, different quality of training materials, different technology requires different basic training, plus crew operation interfaces vary across systems
    - Limited convenient ports and available time at ports
    - Training was repeated many times due to the change of crews and loss of information
    - New equipment for most staff, requires increased exposure and familiarization
    - Practical training would include, running the BWTS for ballasting /de-ballasting operation and troubleshooting of the faults in the system, which would enable better understanding of the actual running operation of the BWTS
    - Vessel was in fresh water port and aft peak tank kept filling up with sea water when trying out. Since the vessel was portside alongside, the portside BWT system was not operated as the sample water overboard falls on the jetty side

Hardware failure (62% Reported)

- TRO sensor
- Filters clog in certain ports/rivers
- Hydrocyclone level float
- Filter inlet pressure transmitter
- Backflushing solenoid valves
- Valve calibration
- Electrode scaling
- FMU high flow rate
- Unspecified sensor failure
- ESJ Module
- Booster transformer
- Filter inlet/outlet pressure alarm

- TSU (TRU sensor unit)

Software failure (6% Reported)

- Valve order out of sync
- Rectifier communication
- Software upgrades required for USCG compliance after handover
- Questionable valve location sensors require active monitoring prior to startup:
    - The BWMS control system reacts too fast for feedback signals from valve position sensors on the ballast system valves controlled by the BWMS. When commencing ballasting or de-ballasting, the BWMS shuts down before the valves are opened or closed (i.e., software timing is incorrect).

Human error (6% Reported)

- System is very complicated, equipment is installed in separate locations onboard the vessel and is subject to human errors during operation

Health and safety issues (4% Reported)

- Chemicals used during operations

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate (43% Reported)

- Only when ballasting cargo hold
- 10% Reduction

Other issues and challenges (42% Reported)

- Systems do not notify when working out of parameter for effective treatment
- TRO Reagent shelf life
- Electromagnetic valve on Monitor Unit No.2
- TRO dosage either low/too low or high/too high for de-ballasting
- In BWTS mode, which is considered the actual mode in which the system is to be run, the system shuts off periodically and thereby causes the duty officer to pay more attention to the ballasting / de-ballasting operation rather than the actual cargo operation
- Complicated system
- Installation of system equipment in separate locations (cargo pump room, deck, engine room, engine room decks)
- Several sensitive sensors, transmitters, indicators, etc. are installed on the system and those are very likely to fail in the event of poor maintenance, system consumes additional chemicals
- System equipment needs continuous calibration
- System equipment consumes large volume in engine room and cargo pump room
- System operation requires continuous crew attendance and careful watch-keeping during operation

Corrective action and contingency measures (52% Reported)

- Replacement of defective TRO sensor
- Filter unit investigation is in progress
- TRO sampling pipes were blocked and chlorine testing was interrupted on several occasions. There were a few cases of filter leakage, causing the filters to be overhauled
- TRO concentration low, replaced CLX reagent and cleaned drain
- Replaced TRU sensor unit
- For the problem with faulty feedback signal for valves, manually changed the valve setting to match with the valve position
- Additional crew required during ballast operations
- Minimum spare parts kept onboard at all times
- ESD module failed due to burned PRU- Disabled ECU No.1
- Unable to perform treatment when ballasting in fresh water
- High differential pressure across filters
- Overhauled electromagnetic valve and ordered 4 parts for spare
- Working with makers to fix systems, asked some suppliers to improve training material
- Maker sent service engineers to fix/replace parts

Systems logs regularly monitored (75% Reported)

- (25%) Satisfied with regular system logs
- System counting the bypass operating time when the breaker is on without any operation
- Adjustment of valves to adjust pressure for hydrocyclone filters to work properly. Problems with TRO sampling, alarm given

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (87% Reported)

- (97%) Satisfied with manual
- Actual troubleshooting requires experienced crew support or service attendance

Spare parts availability/after sales service (78% Reported)

- (94%) Satisfied with spare parts
- Vessel needs to have at least one TRO sensor as spare onboard
- Some of the control equipment is expensive

Sampling

- Devices
    - Gooseneck type arrangement provided on ballast line for sampling
    - Sample valve, sample cock
    - System is installed with its own sampling equipment
- (100%) Sampled in-line
- (83%) Sampled in discharge line, others in addition via manhole
- (61%) Results tested and found satisfactory, others not tested
- Challenges:

- Water samples collected from TRO unit exceed 15ppm. This results in water leading back to the bilge holding tank, which in turn will affect the operational condition of Oily Water Separator (OWS)
- Calibration of monitoring equipment, supply of calibration equipment

Number of BWMS maintenance events, issues and challenges (62% Reported)

- Systems could not be used since new vessel delivery due to several errors of installation and service requirements with spare parts. Poor installation by shipyard affected the system
- 6-7 claims per vessel. After 2 years in operation problems minimized. Regular monitoring
- Sensors, transmitters, indicators, etc. are very sensitive and likely to fail in case of poor maintenance
- TRO sensor has been changed
- System consumes additional chemicals
- Not monitored, too many to log, recorded in planned maintenance system
- System equipment needs continuous calibration
- After sales network hardly meet basic standards
- Regular maintenance as per maker's instruction

Consumable replenishment, issues, and challenges (23% Reported)

- Chemical supplies are required as a consumable
- Required chemicals are not easily permitted for delivery in some ports
- Apart from the neutralization, no other consumables are required
- Neutralization chemical solidified due to humidity
- TRO sensors parts require replacement every 6 months
- After sales quality is low

A3 OZONE TREATMENT + NEUTRALIZATION

Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	**18%**
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	8%
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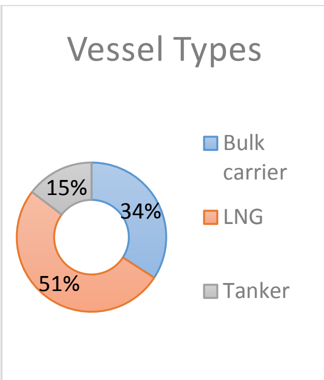

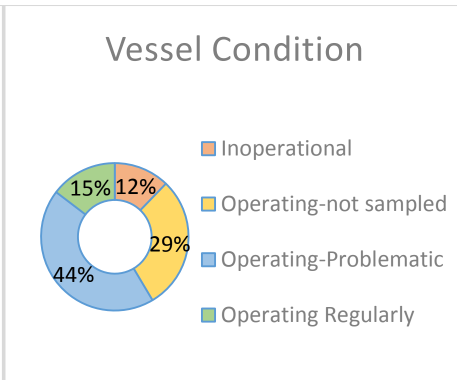

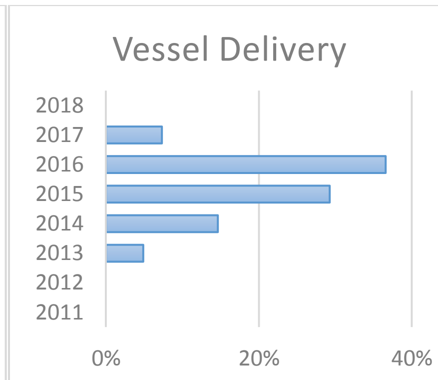

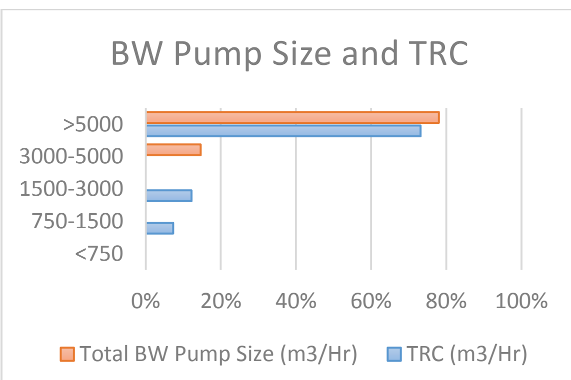

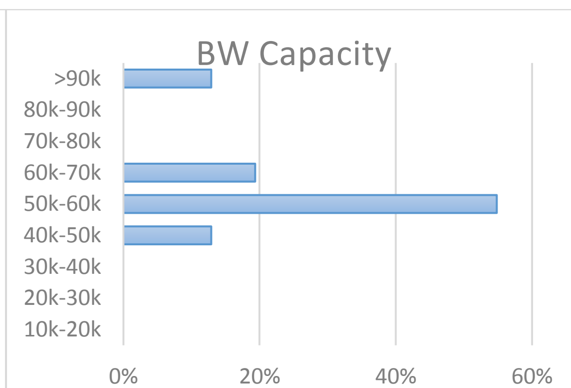

Installation work

- Location
  - (66%) Installed in E/R
  - (34%) Installed in BWTP room (engine casing), open deck (safe), P/R, steering gear, In BWTS room on aft deck, and E/R 2nd Deck
  - (100%) Installed in dry dock (at building stage)
- Challenges:
  - Limited Space (in E/R area)
  - Pipe routing/location of panels
  - Electrical components

    - Bypass arrangements
    - TRO sampled water
    - Components maintenance footprint

Commissioning

- (98%) Commissioned at quayside
- Commissioned on average about one week
- (78%) Shipboard crew involvement
- Challenges:
    - Draft affecting operation at quayside
    - Shipyard reluctant to run full trials in NB stage
    - No sampling performed
    - De-ballasting
    - Troubleshooting
    - Wiring
    - Pipe tightness
    - Language barrier

Crew training

- (100%) All trained onboard
- Training hours range from 3 hours to 4 days
- Material include instructions, videos, hands on (shore-based) training, simulation and actual testing, theory and practice onboard by maker's service engineer
- Challenges:
    - Different types across fleet
    - Limited time and resources due to imminent delivery
    - Language barrier
    - Training on sampling, monitoring
    - Lack of material
    - Inexperienced instructor
    - Frequent changes for crew, continuous training, engineers lack of attention
    - Maintenance training before delivery

Hardware failure (73% Reported)

- Oxygen sensor/analyzer
- Ozone sensor
- Water chiller
- TRO Analyzer & sensor
- Ozone generator
- Ozone injection
- High/low dew point sensor
- Sampling system
- High temperature sensor
- Side stream valve actuator

- Pressure transmitter
- Breaker trips
- Mixing thermostatic valve
- Air dryer
- Low O_2 pressure

Software failure (34% reported)

- Low ozone output
- System data can't be saved
- Inaccurate output of log files
- Injection pump has no signal
- PLC failure, O_3 production fail in auto mode
- De-ballasting mode failed to read while pump running
- De-ballasting happens while ballasting, triggered TRO
- Auto sequence in de-ballasting mode not operational
- Heavy water hammering during startup of BWTS due to absence of delay between starting the recirculation pumps and opening the recirculation outlet valve
- During ballasting, auto start mode BWTS could not perform initial leakage test. Leakage test could not start automatically

Human error

- Nil

Health and safety issues

- Nil

Impact on ballast tanks coating of piping (7% Reported)

- O_3 injection pipe holed
- Neutralizer solution pipes in P/R void were replaced due to pin holes

Systems logs regularly monitored (78% Reported)

- (87%) Satisfied with system logs
- Sensors faults and Output log file not correct

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (92% Reported)

- (79%) Satisfied with the manual
- Not vessel specific, troubleshooting procedures are very scant and require service engineer
- Not user friendly
- Requires constant update

Spare parts availability/after sales Service (78% Reported)

- (22%) Satisfied with the after sale service
- (78%) Poor after sale service, service engineer not attending due to schedule/availability

Sampling

- Device: samples collected by technicians; sampling during operation at discharge line and from tank via sampling points; sampling valve; TRO analyzer
- (40%) In-line, (60%) In-line and In-tank sampling
- (28%) Discharge line, (6%) Discharge line and sampling cock, (60%) Discharge line and via Manhole and via Sounding pipe, (12%) Discharge line and sample point in pump room
- Results:
    - 48% Results meet the standard
    - Enterococci out of limits
    - High TRO concentration
- Challenges:
    - Lack of onboard equipment
    - Limited lab network
    - Sampling cost variation
    - Crew familiarization-training for sampling

Number of BWMS maintenance events, issues and challenges (41% Reported)

- TRO analyzers creates difficulty, require constant cleaning
- Maker has difficulty attending the events and replacements
- Poor after sale network, limited support
- Software updates

Consumable replenishment, issues, and challenges (37% Reported)

- (13%) All consumables have been supplied
- Low after sale quality
- Reagent limited lifetime
- Limited supply network
- Chemical agent for TRO analyzers is constantly required
- Adequate quantities of neutralizer and stabilizer reagents to be readily available onboard in adequate quantities
- TRO analyzers' correct operation is important for the correct measurement of the remaining oxidants and thus for the correct consumption of the neutralizer and the stabilizer

A4 Filtration + Side-stream EC + Neutralization

Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	**17%**
Filtration + UV Treatment	16%
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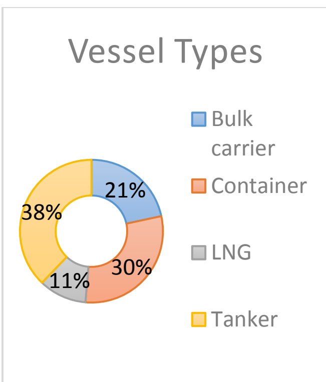
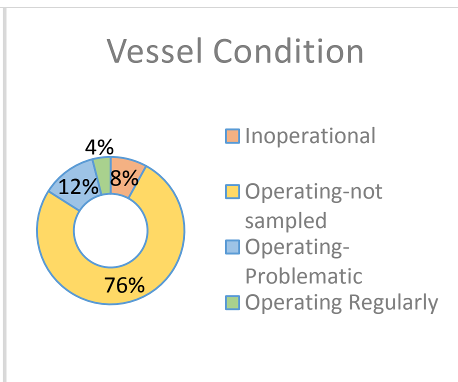
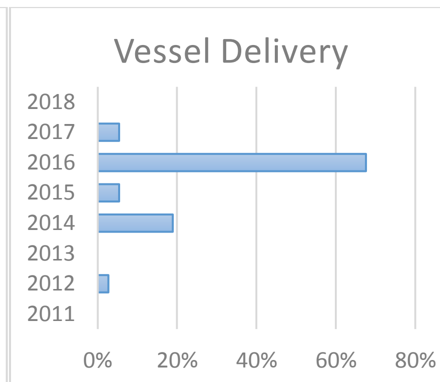
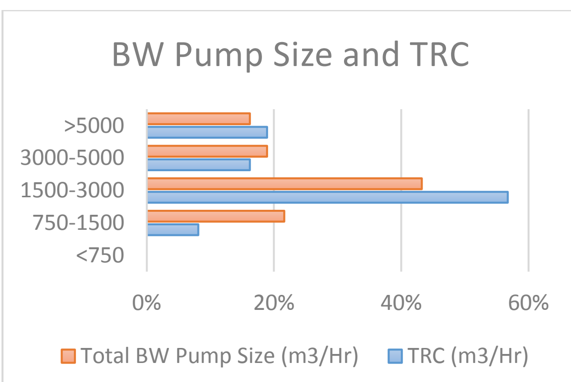
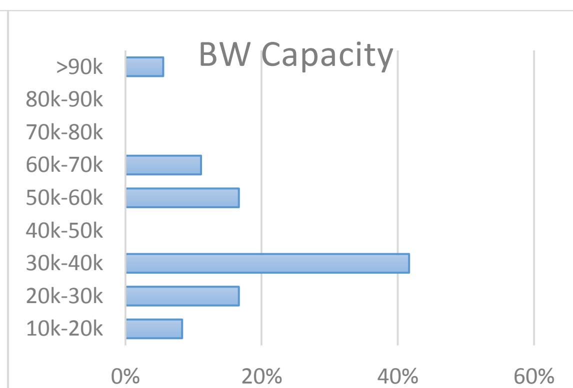










Installation work

- (73%) Installed in E/R
- Others in open deck (hazardous), P/R, designated BWTS room in engine casing, in BWTS room on main deck, E/R 2nd Deck
- (100%) Installed in dry dock
- Challenges:
  - E/R area needed space
  - Location of panels
  - TRO sampled waters
  - Bypass arrangements

- Components maintenance footprint
- Oversized filters
- Sampling pump drain waters
- Location of room on deck, results in lack of heating

Commissioning

- (56%) Commissioned at quayside, (40%) onboard during sea trials
- Commissioning on average 5 days; some first vessels took 15 days, the rest took 5 days; though some systems took up to 1 year
- (40%) Shipboard crew involvement
- Challenges:
  - Language barrier
  - Yards are reluctant to operate the system for the whole trials at NB stage
  - Limited extent of onboard operation and safety/control tests, unless otherwise requested by the buyers in contract specification for newbuilds
  - Improper commissioning and testing of logged parameters
  - No sampling and testing at delivery of the system
  - Confirmation of installation, electric connections and mimics correction as per drawings
  - Setting/adjusting parameters
  - System problems and time required to get supplier for repair works

Crew training

- (49%) Trained onboard, (32%) onshore, others both onboard and onshore
- Training period ranged from 2 to 3 days
- Methods:
  - Mostly hands on
  - By yard technicians
  - Maker's representative include software
  - Onshore seminar + onboard training
  - In house, classroom, sea trials
  - Videos, simulations
- Challenges:
  - Crew commented that there was no proper training given by the maker and that the system was not properly commissioned. Language barrier was another issue
  - Trainers and commissioning engineers are two different things with different disciplines and different expertise. The commissioning engineer is not a suitable classroom trainer (or even a suitable onboard trainer)
  - Different systems in fleet, differing quality of training materials, differing technology requires different basic training, plus crew operation interfaces vary across systems
  - Adaptability of crew, no past experience, new approach and working principal
  - Detailed instruction manual not available. Maker commissioning engineer not fully conversant with the system
  - Yard was situated in a fresh water area hence the complete work of the system could not be demonstrated

- Limited duration

Hardware failure (78% Reported)

- Ballast pump delivery valves and valves after filter are throttled (automatically controlled by BWTS through IAS) to maintain the flow rate in accordance to BWTS rated capacity. The upper filter plate was distorted. The material was changed from plastic. Makers use their own proprietary filters hence they do not buy from any sub-suppliers.
- The main cause of flowmeter fluctuation and TRO sensor trips was poor mixture between chlorine and sea water caused by the piping arrangement. An electromagnetic type flowmeter can be used to accurately measure the flow rate of liquids which have electrical conductivity. Thus, poor mixture of two different liquids (sea water, NaOCl) may affect the accuracy of the flowmeter. There was installation of new injection pipe and an adjusted response time of the flowmeter. Maker improved injection pipe with holes to improve the mixing of NaOCl and seawater.
- Electrolysis flowmeter fluctuation occurs while running (this is the flowmeter in the electrolysis unit not the flowmeter of the ballast water), this was caused by dirty de-mister in cyclone. Dismantled upper part of hydrocyclone which separates H_2 gas and chlorine water to ventilate the remained H_2 gas in hydrocyclone. Cleaned inside the de-mister and reassembled it. After that, the electrolysis flowmeter was working well.
- Sea water salinity sensor has poor accuracy. When running port rail salinity around 2.6% and when running starboard rail indicated salinity around 2.0% in normal sea water condition. It should be around 3% in normal sea water.
- The salinity signal channel, and the temperature sensor signal channel were interchanged to avoid noise of electrolysis flowmeter before reassembling de-mister.
- TRO sensor sampling valve electromagnetic control valves sensitive to corrosion and sticking. Pasted grease inside valve electric moving parts and also must ensure proper drain inside TRO cabinet as any moisture inside will create corrosion.
- Flowmeter faulty - low reading that will cause alarm unreasonably
- Fuse for rectifier
- PSU flowmeter
- Filter drain line holes
- Valve actuator
- Gas sensors
- Neutralization Unit pumps
- Various pumps
- Rectifier
- Sewage pump stuck and repaired by ship staff, AFU blender motor
- Spare motor received and replaced
- Automatic back wash filters, hydrogen blower failure
- Defective circuit breaker of blower causing H_2 release during electrolysis and blower to exhaust the gas out
- Filters clog in certain ports/rivers, scaling of electrodes

Software Failure (81% Reported)

- During the initial testing of the system there were problems with the operation of the sensors and the system controlling the neutralization process resulted in a substantial wastage of neutralizing agent
- Time delay settings (default) very often not enough to bring the treated water to acceptable limits which causes system shutdown
- During de-ballasting the TRO sensor gives alarm (malfunction) for a short period. After a few seconds the sensor is operational again (sensor checked chemical level). The alarm is not shutting down the system
- An update on the software was needed in order to deal with new method of TRO and rectifier
- Blower pressure alarm low activated with fan stopped.
- BWTS and IAS communication should be specified by 2 different communication channels to avoid time consuming searching of a lost communication channel
- The main computer requires regular restarts (before operation).
- LOP monitor defective, TRO sensor fails due to communication fail, frequent false alarms activated during operation
- Readings and stabilization
- Rectifier unit under alarm
- Server error

Human error

- Nil

Health and safety issues (13% Reported)

- Chlorine and hydrogen gas production
- Handling of toxic and corrosive chemicals
- The H_2 vent pipe has been marked in yellow color with warning label

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate (43% Reported)

- When de-ballasting with the full ballast tanks, there is a large head pressure due to the filled level of the water in the tanks and the de-ballasting capacity is higher than the nominal capacity of the pumps. That is to say, during the de-ballasting operation (full ballast tanks), high ballast water rates, which are relatively higher than the pumps' nominal rating and the BWTS certified rating could be achieved. Such desired capacity could not be reached due to the capacity limitation as indicated in the Type Approval Certificate.
- The neutralizing agent dosage pump capacity is enough to increase the capacity but regulations currently do not allow this. This should be explained to the authorities and larger discharge capacities should be allowed. Flow control valves create vibration, strain, wear and tear, which threaten the integrity of the piping equipment.
- After installing the system, one side rail has a capacity difference as compared with the other side

- Sizes of ballast pump electric motors are very large. If the motor trips once it has a timer of 15 minutes before it can be re-started. After a 2nd trip, the timer is set at 40 minutes before the motor can be started for a 2nd time. When BWTS is in operation many trips can be triggered by the system from TRO sensor reading from flowmeter readings, from salinity sensors, system shut downs due to low flow, communication error, TRO (suddenly going to 0 ppm and trip) reading instability and heavy vibration. Cl_2 high ppm trip during de-ballasting
- Regulatory bodies and charterers should consider the impact of needing 40 minutes to restart a ballast pump
- Large ballast water rate reductions

Other issues and challenges (67% Reported)

- During ballasting or de-ballasting in order to start or stop a ballast pump it was found that the operation should be stopped and that the BWTS stopped and re-started. In the case of side stream electrolysis, some manufacturer disinfectant dosage is 7-8 ppm whereas others apply 2-3 ppm.
- We wonder why some need 7 ppm to get USCG approval and the others can do it with just 3 ppm?
- There should be a function called "re-circulation" mode where before ballasting the pumps are operated sea to overboard before closing the overboard valve and opening the valve to the ballast tanks. Similarly, in de-ballasting there should be a "re-circulation" mode where the pump is running from sea to overboard and suction from sea is closed and the tanks opened. The reason for re-circulation mode is that ballast pump motors are very large motors that cannot be started and stopped frequently. In addition, frequent starting and stopping of ballast pumps creates harsh impact on valves, pipes, filters, fittings etc. It is a softer way to start and stop ballasting/de-ballasting by going into recirculation mode than by starting and stopping the ballast pumps.
- Operationally, we need much more flexibility during topping up of the ballast tanks. From 65% full to 100% full it takes a lot of starting, stopping, re-circulating, waiting, etc. which is also related with cargo operations. We would like the authorities to allow filling of ballast tanks to 95% full with the BWTS running at a slightly increased disinfectant dosage and the final filling from 95% to 100% without BWTS running. This is to allow topping up of the tanks without the starting, stopping and operational sensitivity of the system running. It goes without saying that during de-ballasting the water will be in compliance with the rule standard and the TRO recorded.
- Calibration of various sensors
- Mimic display is not user friendly
- Maintenance in operation of the 50 microns filters could prove costly and demanding due to the size and location on the lower platform of the pump room
- Buffer tank in the E/R should have a high level alarm for liquid level. At present it requires continuous monitoring.
- Systems do not notify when working out of parameter for effective treatment
- TRO chemical line dries up if not operated for long time; TRO no intake water, TRO unit alarm due to sea water quality with low salinity in port

Corrective action and contingency measures (83% Reported)

- To have salt water on the dedicated salt water tank at all times. This is to ensure stable salinity of sea water
- Flowmeter faulty low reading, turned off the power of flowmeters and after turned on the power again
- Ballast water exchange at sea is being carried out prior to every loading
- Understanding advisory received from maker and coordinating service engineers remotely
- Weekly check TRO system, prime chemical pump periodically if not in use
- Extensive correspondence with maker, claims and re-testing
- Defective parts supplied by makers under warranty
- Additional equipment for calibration or alternative sensor
- Electric overcurrent relay/breaker requested
- Check the flow rate of TRO sensor, check the sampling water line from the TRO sampling box, and check the manual valve and the solenoid in the sampling box

Systems logs regularly monitored (89% Reported)

- Crew's reluctance to operate the system
- A functionality report including all VGP parameters has been requested from vessel
- More common alarms are sensor fail, TRO no intake water, rectifier emergency stop (usually during starting, after reset no alarm)
- TRO over range, TRO dosage too high
- TRO values during ballast operation not increasing above 0.01ppm (set value is 7.5ppm) TRO during de-ballast operation 0.0ppm (set value less than 0.1ppm)
- Following "nuisance" alarms reported: filter differential pressure high during ballasting and neutralization dosing pump failure during de-ballasting

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (97% Reported)

- (55%) Satisfied with manual
- Exchange method is the primary in BWMP; nevertheless operation with the system has not revealed any major need, although the system is used rather frequently
- For PMS additional details (cleaning, TRO checking etc.) were added later on. No parts ordering was needed, however TRO and Neutralization Unit consumables are made
- Procedures for emergency/manual mode running of the BWTS system are not mentioned
- TRO sensor cabinet with spare reagents and maintenance routine was missing from the manual but added later

Spare parts availability/after sales service (86% Reported)

- (65%) Satisfied with spare parts
- Overall good, after some suppliers had a slow start to respond to issues
- Some of the sub-equipment manufacturers were unable to support directly due to licensing issues with BWTS manufacturer

Sampling

- Devices:
  - Drain valve
  - Portable container
  - Sample valve
  - Samples collected by technicians
  - Special sampling bag
- 100% In-line samples
- (92%) Sampled at discharge line, others in conjunction via manhole and via pump room
- (27%) Results tested satisfied, others are not tested yet
- Challenges:
  - Finding a specialized laboratory within 6 hours (max) distance from the port
  - Neutralization effectiveness in low temperatures
  - Lack of onboard equipment
  - Sampling cost variation
  - Crew familiarization-training for sampling

Number of BWMS maintenance events, issues and challenges (65% Reported)

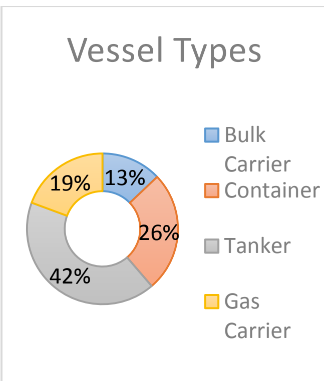
- After sales network hardly meet basic standards
- Chlorine ppm slow to build up to required 5.5 ppm leading to shut down. Frequent false alarms distracting officers on critical cargo operation. Frequent shutdown of ballast pumps overheats the motor starter
- Not monitored, too many to log, recorded in planned maintenance system

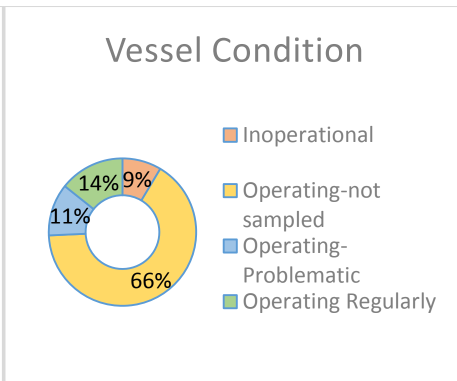
Consumable replenishment, issues, and challenges (38% Reported)

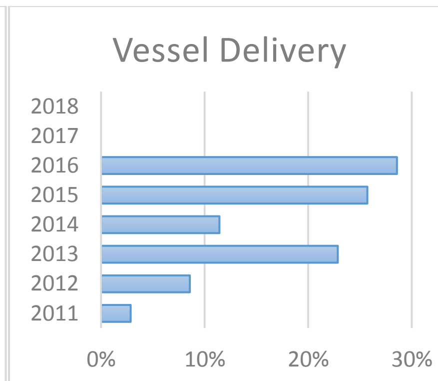
- TRO sensor agent kit needs replacement every 3 months, sufficient spares needed
- TRO sensor reagents take too long to be delivered
- After sales quality is low
- Need to develop vendors to supply spares and consumables
- Reagent limited lifetime, limited supply network

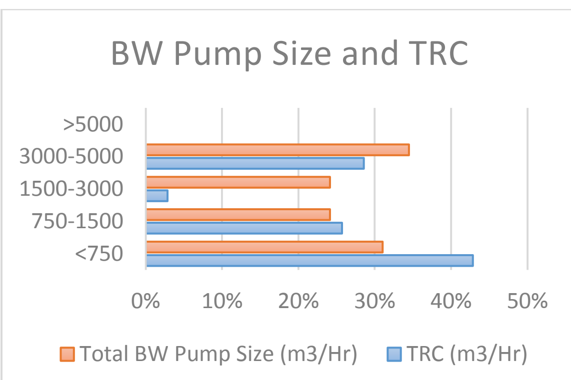
A5 Filtration + UV Treatment

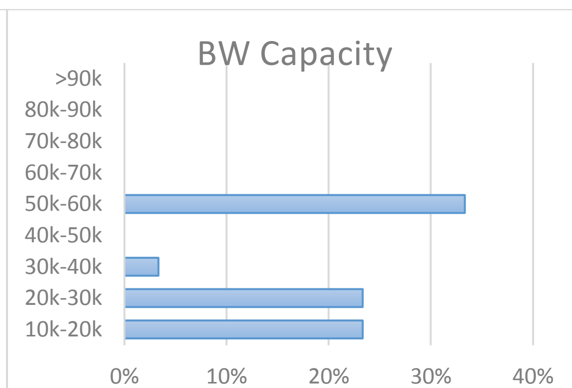
Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	**16%**
Filtration + Electro-Catalysis + Neutralization	8%
In-line EC + Neutralization	5%
Filtration + Chemical Addition Chlorination	4%
Filtration + Oxidation	1%











Installation work

- (58%) Installed in E/R, others installed in P/R, open deck (safe), and E/R 2nd Deck
- (100%) Installed in dry dock
- Challenges:
  - E/R area needs more space
  - Location of panels
  - TRO sampled waters
  - Bypass arrangements
  - Oversized filters
  - Components maintenance footprint

- Protection strainers upstream of sensitive components
- Shipyard and maker’s cooperation

Commissioning

- (52%) Commissioned at quayside, (48%) at quayside and onboard during voyage
- Commissioned in 1-2 days; or first vessels 4-5 weeks, next vessels 2-3 weeks
- (33%) Shipboard crew involvement
- Challenges:
  - Lack of similar experience from owner side, thus unable to pay attention to important matters and details, during the first commissioning tests
  - Yards were reluctant to operate the system for the whole trials at NB stage
  - Limited extent of onboard operation and safety/control tests, unless otherwise requested by the buyers at shipyard in NB stage
  - Language barrier
  - Improper commission and testing of logged parameters
  - No sampling and testing at delivery of the system
  - Crew adaptability as it was a new experience
  - Parameters adjustment: concern regarding integrity of parameters, it’s hard for ship staff to managed due to lack of experience on parameter setting adjustments in the future
  - None, also carried out at the NB site

Crew training

- (61%) Training conducted onboard, (59%) onboard and onshore
- Training period range from 2 to 24 hours; some reported monthly
- Methods:
  - Operation and troubleshooting instructions by attending/commissioning engineer
  - Extended 3-4 days shore-based training at regular intervals at operators premises, at makers premises for core officers
  - Hands on (demo on actual running of the system “Ballasting/De-ballasting & By-Pass mode), reviewing functions for real time operation
  - Video showing change of filter and UV lamp
  - Performance test
  - Seminar and onboard training, sea trials, maker's Instructions/on site by superintendent
  - Use of ballasting mode, i.e. transfer of ballast inside a random ballast tank through BWTS
- (80%) Reported Challenges:
  - Adaptability of crew, no past experience
  - Crew changes, therefore continuous training is necessary
  - Different type and makers of BWTS among the fleet
  - At NB stage (production progress in rush), it is difficult for engineers to concentrate
  - Training on sampling
  - Training for keeping records/monitoring for PSC and VGP
  - Arrangement of seminars at manning agent’s premises, lack of crew experience on similar equipment (for better understanding), limited real-life experience by the maker, managing electronic components

- Availability of qualified trainer and sufficient training period required from the maker to provide brief and detailed training to ship staff

Hardware failure (58% Reported)

- Burning of UV lamps
- Frequent cleaning of UV lamps required, frequent UV lamp failures, DP high, UV cycle over
- UV intensity meter sensor failure
- Backflush filter pressure switch broken
- Control panel hard disk failure
- Flowmeter cartridge (LCD failure)
- Reactors flooding due to defective seals, valves not operating due to scale developed
- Some minor components (plastic switches etc.) defective

Software failure (22% Reported)

- GPS Communication failure
- Flowmeter cartridge (LCD failure)
- Software requires update. Control panel malfunction with old software

Human error (38% Reported)

- Broken lamps due to waterfall effects
- Misuse of manually operated valves

Health and safety issues

- Nil

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate (22% Reported)

- About 3-4% depending on vessel trim and list
- Reduces the pumping capacity of ballast pumps
- Impact due to dirty UV lamps

Other issues and challenges (64% Reported)

- Calibration of various sensors
- Unable to use ballast/de-ballast by gravity method
- Software update difficult due to high cost and inconvenient port calls, not covered by makers' warranty
- Reduced flow rate
- Additional manpower required to operate manually operated valves
- Several damages (corrosion, holes etc.) on the associated pipes, not necessarily related to the function of the system
- UV low dosage
- Short circuits due to broken lamps

- Water leakage from sleeves

Corrective action and contingency measures (74% Reported)

- Service engineer modified the program
- Additional equipment for calibration or alternative sensor
- Upgraded, improved parts to be retrofitted as per maker's recommendations
- Enhance reliability of the system
- Makers service engineer to update the software and replace any defective hardware
- A strict planned maintenance scheme and testing has been applied
- Agreement for 5 year service, testing, calibration attendance by maker's service engineer
- Acknowledged the alarm (does not affect the integrity of operation) in software
- Familiarization of valve arrangement, constant communication with the operator of BWMS and person handling the valves with portable radio
- Plan ahead the operation especially during ballasting/de-ballasting in order to avoid delay during cargo operation
- Must have at least two personnel in attendance during operation (BWMS operator and manual valve operator)

Systems logs regularly monitored (68% Reported)

- (22%) System logs satisfied
- System installed on our vessels are certified. Pending is the type approval from USCG. Upon receiving USCG type approval, a software upgrade will be provided by maker to meet VGP requirements
- System is not in use until rectification of the system; vessel's primary means of ballast management is exchange method
- Frequent failure of UV lamps
- Logs are regularly monitored; however proper/detailed monitoring is very difficult due to complicated procedure required by makers of equipment (requires specialized tools and complicated calculations to be done by crew)
- GPS communication failure
- Incorrect output of the alarm and status log files
- Crew's reluctance to operate the system
- Intermittent loss of position monitoring by the system during operation "a common alarm of GPS position monitoring system"

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (100% Reported)

- Available onboard. Considered very useful for the familiarization of the operator and for troubleshooting

Spare parts availability/after sales service (100% Reported)

- Availability is good
- Troubleshooting required for software malfunctions were very time consuming; multiple correspondences with makers for over 1 year; potential high cost of service.

Sampling

- Devices:
  - Refitted the end connector and isolating valve
  - Drain cock
  - Portable container
  - Sampling valve installed at discharge line of the system, as near to the point of discharging as practicable, during ballast water discharging
  - Special drain device included on discharge line. Water sample in sealed container was collected and handed to shore laboratory for microbes testing
- (93%) Collected in-line, others in-tank
- (74%) Sampled in discharge, others via manhole, via sound pipe, at the lowest platform of E/R portside and starboard side
- (32%) Results are compliant, others not tested yet

Number of BWMS maintenance events, issues and challenges (77% Reported)

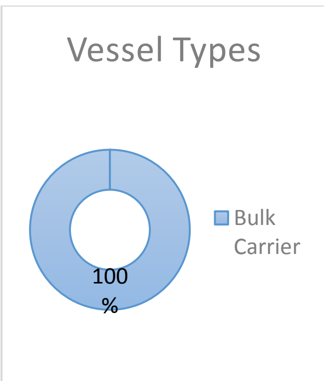
- Run a manual backwash cycle in order to maintain the good condition of the differential pressure sensor as well as a manual wipe cycle if the chambers are full of water and have not been operated recently
- All air actuated valves UV filters are operated to ensure sound condition and avoid sticking, which happens when they remain idle for some period of time
- Turn the wiper cleaning in manual mode and run wipers running cycle to clean the quartz sleeves
- Perform a 6-hour operational test of the BWTS (3 hrs. ballasting and 3 hrs. de-ballasting)
- After sales network can hardly meet basic standards due to limited availability of service engineers to provide administrative support especially when vessel trading in remote areas
- There were no shore services carried out since vessel delivery
- After about 1.5 years after installation, failure occurred on system's control panel. Software needed updating by maker
- Filter cleaning / UV lamp replacement

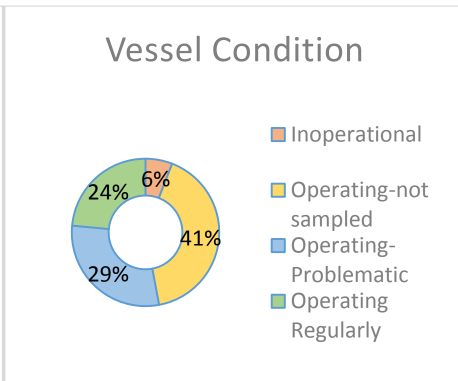
Consumable replenishment, issues, and challenges (61% Reported)

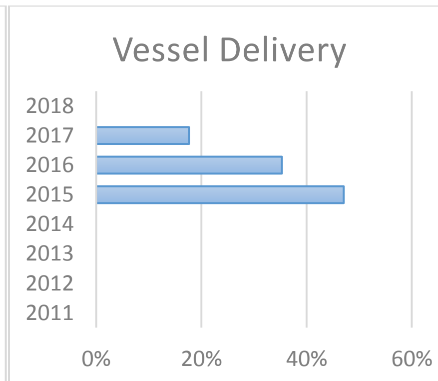
- Frequent failure of UV lamps, frequent replacement of UV lamps required
- Spare parts are expensive, UV lamps are the most expensive parts
- The most vulnerable parts seem to be the UV sensors, the purge units and the lamp wipers
- After sales quality

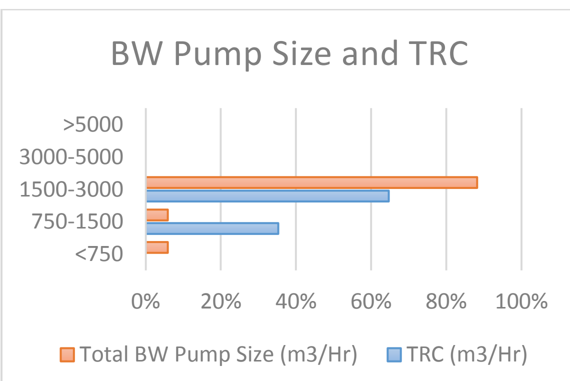
A6 Filtration + Electro-Catalysis + Neutralization

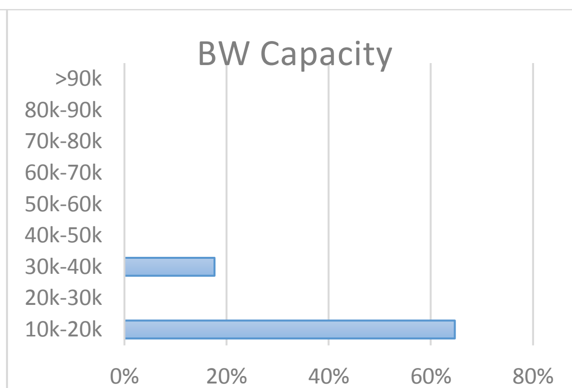
Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	**8%**
In-line EC + Neutralization	5%
Filtration + Chemical Addition Chlorination	4%
Filtration + Oxidation	1%











Installation work

- (100%) Installed in E/R and in dry dock
- Challenges: Language barrier

Commissioning

- (100%) Commissioned at quayside
- Commissioned on average about one week
- Maker's / dock personnel explained operation, valve alignments, ABD control panel to use and operate in remote/local mode
- (7%) Shipboard crew involvement
- Challenges:

    - Setting/adjusting parameters
    - Lack of experience in control and monitoring parameters of BWTS

Crew training

- (100%) Training conducted onboard
- Training time ranges from 1 to 40 hours
- Methods:
    - Actual operation of BWMS during ballasting and de-ballasting operation, hands on
    - Discussion regarding operation, parameter settings
    - Maker’s service engineer
    - Crew test results were reviewed for all the staff
- Challenges:
    - Limited technical and operational details in the instruction manual
    - Anticipation of new system technology, and the concept of its operation

Hardware failure (12% Reported)

- Bypass found broken, guarantee claim raised

Software failure

- Nil

Human error

- Nil

Health and safety issues

- Nil

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate (12% Reported)

- Due to clogging filter elements in muddy/ cloudy waters

Other issues and challenges (12% Reported)

- EUT failure
- Incorrect installation since delivery (e.g. naturalization unit)

Corrective action and contingency measures (41% Reported)

- Manual adjustments
- Clean filter elements regularly
- Back-up battery supply run automatically during black out
- Failure of remote control in ECR system can be operated in manual mode
- Fabricated temporary valve disc. Replaced with spare from guarantee claim

- Replaced EUT power unit
- Emergency switch button for BWTS malfunction

Systems logs regularly monitored (59% Reported)

- (70%) Monitoring system is in good working condition
- Valve alarm and is fixed by wiring terminal loose connection
- TRO status shows "No intake water"
- Ballast TRO adjusts overtime
- System usually used as "Bypass" mode
- Only automatic logs are saved by the system. No hard copy records nor printer installed

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (70% Reported)

- (92%) Equipped with manual
- The part number for filter O-rings is not available in the manual

Spare parts availability/after sales service (53% Reported)

- (60%) Satisfied with spare parts
- Replaced spare parts: e.g. double electric solenoid valve, electromagnetic coils, relay, sodium thiosulfate ($Na_2S_2O_3$)
- Minimum availability since delivery

Sampling

- Devices: sampling container (plastic)
- (76%) In-line sampling, a few also in-tank
- (88%) Sampled in discharge line, others via manhole, via air pipe and via sounding pipe
- (78%) Samples tested found satisfactory
- Challenges: Incorrect installation of neutralization units

Number of BWMS maintenance events, issues and challenges (88% Reported)

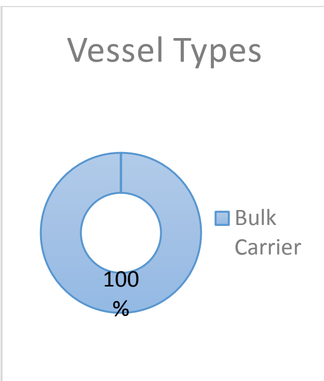
- No extractor for filters provided, fabricated extracting tool to facilitate manual cleaning
- After sales network hardly meets basic standards, no service engineers available
- Filter element needs frequent cleaning, easily clogged in cloudy waters
- Degree of contamination is heavily soiled

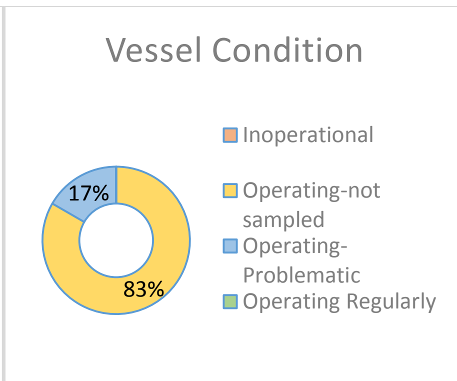
Consumable replenishment, issues, and challenges (88% Reported)

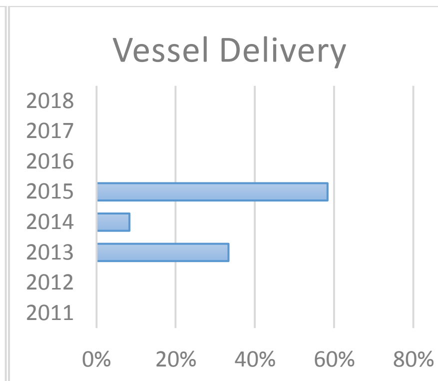
- No spare O-rings for filters available fabricated replacement from splicing kit
- TRO reagent must be replaced every 3 months to prevent discoloration
- Sodium Thiosulfate - Regular daily as per actual level observed
- Insufficient consumables were available onboard the vessel, e.g. Chlorobenzoic acid, total residual oxidant buffer, total residual oxidant indicator, DPD powder for total residual oxidant meter

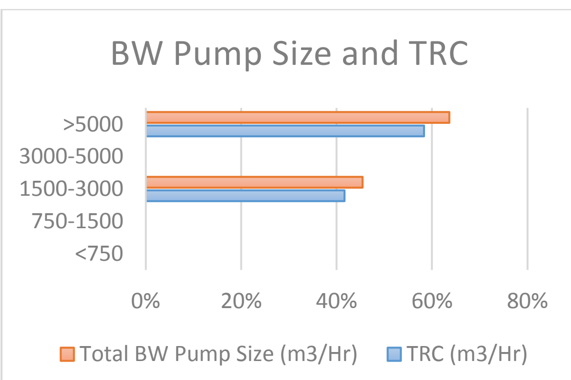
A7 In-line EC + Neutralization

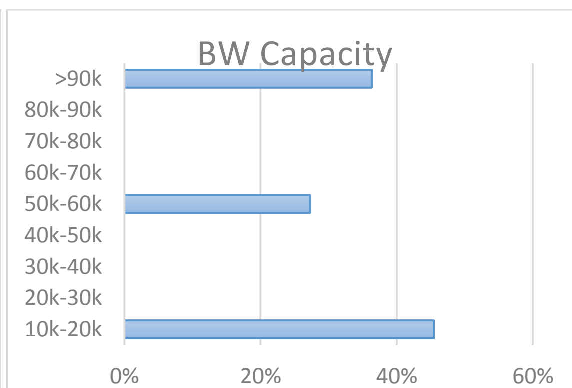
Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	8%
In-line EC + Neutralization	**5%**
Filtration + Chemical Addition Chlorination	4%
Filtration + Oxidation	1%











Installation work

- (63%) Installed in E/R
- Others installed in pump room for main line and E/R for aft peak line, E/R 2nd Deck
- (100%) Installed in dry dock
- (63%) Reported Challenges:
  - Lack of space in E/R area
  - Location of panels
  - TRO sampled waters
  - Bypass arrangements
  - Components maintenance footprint

- Start/Stop locations of system are on same position with ballast pumps control
- Alarm and safe guards for excess flow rate control

Commissioning

- (36%) Commissioned at quayside, (64%) Commissioned onboard sea trials
- Commissioned in 2-4 days
- (0%) Shipboard crew involvement
- (64%) Reported Challenges:
  - Yards are reluctant to operate the system throughout the trials during NB stage
  - Limited extent of onboard operation and safety/control tests, unless otherwise requested by the buyers at NB stage
  - Improper commission and testing of logged parameters; no sampling and testing at delivery of the system
  - Language barrier

Crew training

- (100%) Training conducted onboard
- 25+ hours of training
- Method:
  - Training videos
  - Operation and troubleshooting instructions by attending/commissioning engineer
  - Extended 3-4 days shore-based training at makers premises for core officers
  - Shore-based training at regular intervals at operators premises
- (64%) Reported Challenges:
  - Crew changes; for crew continuous training is required
  - At NB stage (production progress in rush), it is difficult for engineers to concentrate
  - Training on sampling , keeping records/monitoring for PSC and VGP
  - Different type and makers of BWTP along the fleet

Hardware failure (54% Reported)

- Leakage in the module; rectifier module failure
- Leaking and defective gas detector unit alarm always active in BWMS; defective power rectifier unit

Software failure

- Nil

Human error

- Nil

Health and safety issues

- Nil

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate (9% Reported)

- Occasionally a reduction of 20% on the ballast rate is noticed

Other issues and challenges (64% Reported)

- Calibration of various sensors
- Defective gas detector unit leaking
- Warning messaging ESJ Module failure indicated during ballasting
- CPC cabinet, wrong type of alarm speaker as per makers manual
- TRO (maintenance and operation)

Corrective action and contingency measures (100% Reported)

- PRU replaced
- Additional equipment for calibration or alternative sensor
- Replacement of complete sensing unit, suitable alarm speaker
- Reliable rectifier sub suppliers; extended guaranty for rectifier units

Systems logs regularly monitored (64% Reported)

- System logs regularly
- Crew's reluctance to operate the system

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (64% Reported)

- Reported satisfactory

Spare parts availability/after sales service (64% Reported)

- Reported satisfactory

Sampling

- Device: sampling valve
- (100%) Sampled in-line sampling through discharge line
- (18%) Results tested found satisfactory, (82%) Not tested yet
- Challenges:
  - Lack of onboard equipment; limited lab network; sampling cost variation
  - Crew familiarization-training for sampling

Number of BWMS maintenance events, issues and challenges (9% Reported)

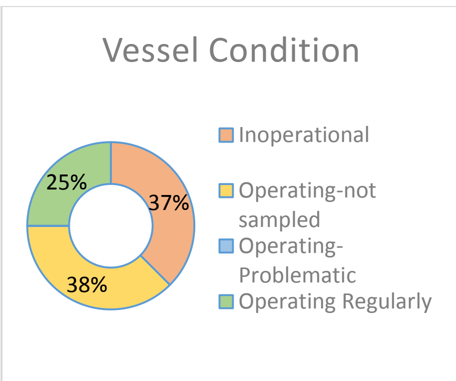
- TRO (maintenance and operation)

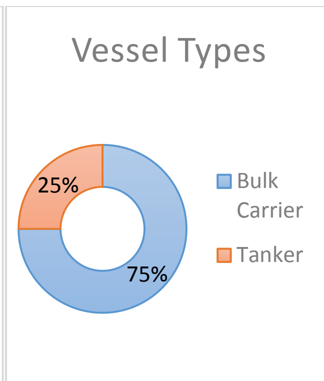
Consumable replenishment, issues, and challenges (64% Reported)

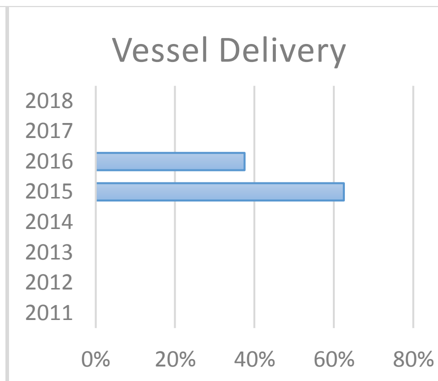
- Reagent limited lifetime and limited supply network

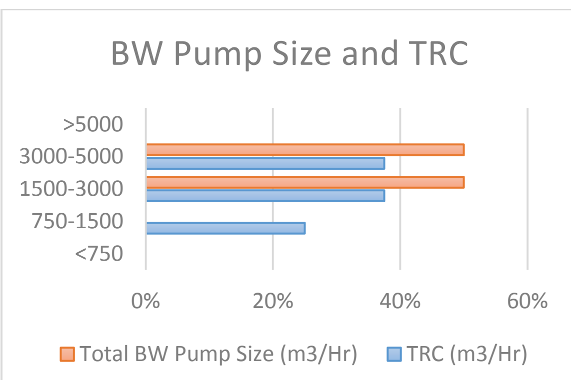
A8 FILTRATION + CHEMICAL ADDITION CHLORINATION

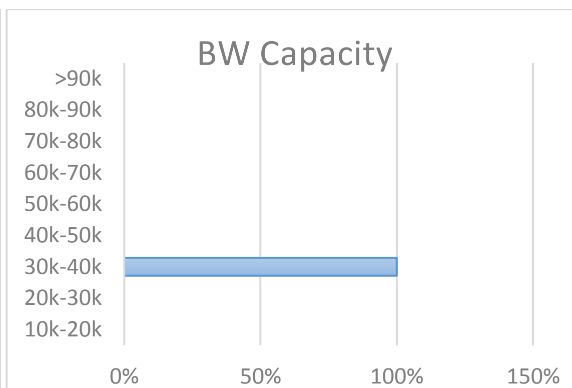
Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	8%
In-line EC + Neutralization	5%
Filtration + Chemical Addition Chlorination	**4%**
Filtration + Oxidation	1%











Installation work

- (87%) Installed in E/R, E/R 2nd Deck and in Open deck (safe)
- (100%) All installed in dry dock

Commissioning

- (100%) Commissioned at quayside, some in conjunction with onboard during voyage
- (37%) Shipboard crew involvement
- Challenges: setting/adjustment parameters

Crew training

- (75%) Training onboard; others also during sea trials
- Training hours range from 3 to 8 hours
- Training methods: Hands on, during actual operation and site office lecture, theory and practice onboard by maker's service engineer
- (62%) Challenges: material, instructor, place

Hardware failure (37% Reported)

- (37%) Reported no hardware failure
- O_2 + O_3 sensors calibration failure
- TRO analyzers dirty due to chemicals remaining inside after use

Software failure (75% Reported)

- (37%) Reported no software failure
- PLC failure in BWTS room
- Failure to produce O_3 in auto mode

Human error (37% Reported)

- None

Health and safety issues (37% Reported)

- None

Impact on ballast tanks coating of piping (50% Reported)

- (37%) Reported no impact
- Impact of chemical on all system, valves, gaskets etc.

Reduction in ballast rate (37% Reported)

- None

Other issues and challenges (75% Reported)

- Service technician attended onboard recently and replaced/overhauled damaged part, upgraded software installed, test run satisfied
- Mishandling issues at first stage
- Ozone sensors are out of order
- TRO unit alarm due to sea water quality with low salinity in port

Corrective action and contingency measures (75% Reported)

- Proper operating procedures required by all involved parties
- Raised guaranty claim report and waiting to rectify
- All parts replaced by maker service technicians, software upgraded
- Always have salt water on the dedicated salt water tank to ensure stable salinity level
- Ozone sensors have to be replaced

Systems logs regularly monitored (87% Reported)

- (33%) Reported regular monitoring
- Full auto log function. All BWMS activities recorded
- TRO over range; TRO dosage too high

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering (100% Reported)

- (75%) Satisfied of the manual onboard
- Manual is huge but not vessel specific. Troubleshooting procedures are very scant and always require maker's assistance

Spare parts availability/after sales service (75% Reported)

- No extensive network of chemicals (disinfectant agent – neutralizing agent)
- One provider for reagents required for TRO supervision units
- Vessel's staff is not aware of spare parts availability

Sampling

- Devices: TRO analyzer, TRO unit
- (75%) Sampled in-line through discharge line
- (33%) Samples tested found satisfactory
- (67%) Not tested

Number of BWMS maintenance events, issues and challenges (62% Reported)

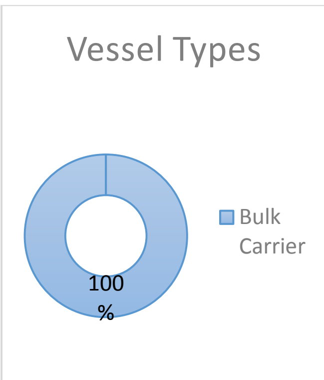
- Not in use since delivery due to system problem and waiting to rectify
- Poor after sales network

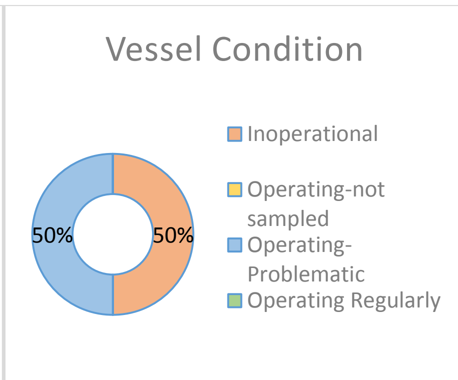
Consumable replenishment, issues, and challenges (75% Reported)

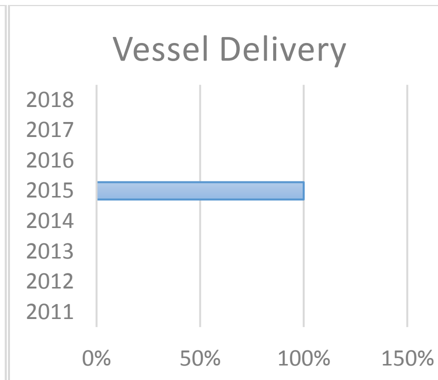
- After sales quality is low
- Maker should enrich the network of supplying the required agents since the system is chemical injection
- Proper handling is required for transferring and storing the chemicals

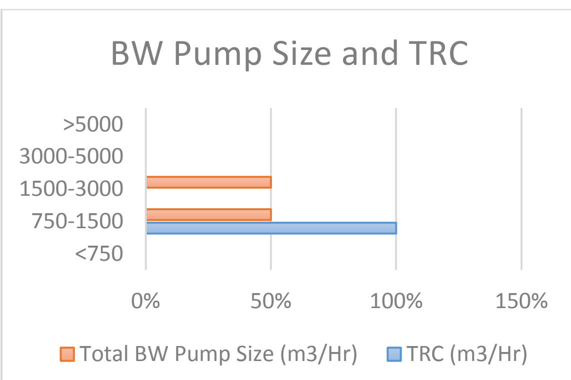
A9 Filtration + Oxidation

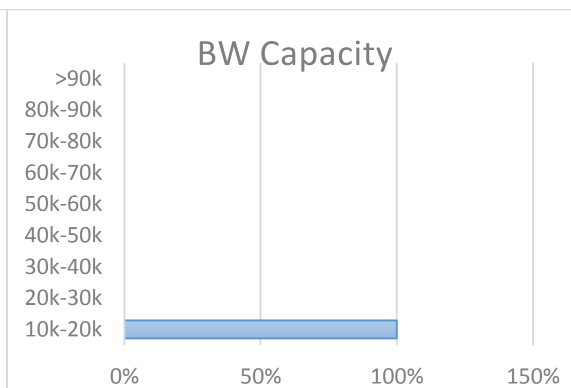
Filtration + In-line (Full Flow) EC + Neutralization	32%
Ozone Treatment + Neutralization	18%
Filtration + Side-Stream EC + Neutralization	17%
Filtration + UV Treatment	16%
Filtration + Electro-Catalysis + Neutralization	8%
In-line EC + Neutralization	5%
Filtration + Chemical Addition Chlorination	4%
Filtration + Oxidation	**1%**











Installation work

- E/R, E/R before overboard
- All installed in dry dock

Commissioning

- Commissioned at quayside
- Challenges: setting/adjusting parameters

Crew training

- Onboard, 3 hours
- Methods: hands on and in accordance with instruction manual

Hardware failure

- Nil

Software failure

- Nil

Human error

- Nil

Health and safety issues

- Nil

Impact on ballast tanks coating of piping

- Nil

Reduction in ballast rate

- Pumping rate limited

Other issues and challenges

- Clogging filter candles due to dirty ballast water

Corrective action and contingency measures

- As per manual
- In clogged filter candles, stop ballast pump concern and use the standby ballast pump
- Clean clogged filter candles

Systems logs regularly monitored

- Alarm observed at times - TRO status: no intake and low flow rate; generally equipment is in good operational condition
- Salinity value
- TRO value

Operation and maintenance manual completeness for troubleshooting, maintenance, parts ordering

- Available onboard

Spare parts availability/after sales service

- EUT power unit
- Sodium thiosulfate pentahydrate (4kgs/packet) – for neutralization unit

Sampling

- Device: bottle
- Inline through discharge line
- (50%) Samples tested found satisfactory

Number of BWMS maintenance events, issues and challenges

- Nil

Consumable replenishment, issues, and challenges

- After sales quality is low
- Residual oxidant indicator
- DD powder
- Chlorobenzoid acid
- Total residue oxidant buffer