White Paper November 2020

THE EXCELLENCE OF SIMPLICITY

Ballast Water Treatment Systems Performance Analysis and Review

Lessons learnt from the operation of the main Ballast Water Treatment System types. A detailed examination of real-life operational performance of key technologies including filters, electro-chlorination, UV and side-stream electrolysis.

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Executive summary

Not all Ballast Water Treatment Systems (BWTS) are made equal. BWTS is a crucial and necessary piece of equipment for globally trading commercial vessels. Complexity reigns supreme with an array of different solutions available on the market to shipowners.

ERMA FIRST, after 13 years of developing cutting edge BWTS solutions, has set the standard for effective ballast water treatment with superior operational readiness, build quality and ease of use.

Backed by extensive market data and scientific research, this document outlines in detail why the ERMA FIRST FIT BWTS is the most comprehensive solution currently available to shipowners and shipyards.

The review is based upon a comparison of the ERMA FIRST FIT BWTS with other prevalent BWT technologies. Focus is on process design and System Design Limitations for different technologies, as these impact compliance while considering the implications on CAPEX, OPEX and installation complexity.

An outline of the results:

- Filtration is key to compliance
- UV design limitations, a practical and operational constraint
- Side-stream EC systems deliver compliance at the cost of installation and operational complexity

Glossary

AI	Artificial Intelligence
IBWMC	International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004)
BWTS	Ballast Water Treatment System
D2 Standard	Stipulates the acceptable level of organisms that may be found within discharged ballast water
EC	Electro-chlorination. The process of producing hypochlorite by passing an electric current through seawater
EPA	Environmental Protection Agency (US)
IMO	International Maritime Organization
SDL	System Design Limitation
Side-stream system	Technology based on small portion of ballast water diverted for treatment and fed as concentrate into the ballast tanks
TRO	Total residual oxidants are the active substances produced by electro-chlorination ballast water treatment systems
Turbidity	A measure of concentration of suspended solids in water which is determined by the amount of light scattered by these solids
USCG	United States Coast Guard
VGP	Vessel General Permit
UVI	Ultra-violet intensity
UVT	Ultra-violet transmitance

Introduction

It is widely agreed that effective management of ships' ballast water and sediments can be achieved by using equipment-based solutions. Today, there are numerous available solutions and implementations that have been developed over the last 15 years. Considering the variety of available land-based water treatment technologies, it is not a surprise that a number of these have been packaged and transferred to the marine environment - albeit with varying degrees of success. According to the Clarksons Research October 2020 BWTS report, 46% of ships have installed electro-chlorination and 24% UV BWTS respectively.

The inherent flexibility of ERMA FIRST FIT BWTS, based on electro-chlorination technology, allows efficient installation and operation on all types of vessels such as LNG Tankers , Crude Oil & Product Tankers, Bulk Carriers, Container Ships, Vehicle Carriers and LPG Tankers trading globally as well as onboard smaller coastal vessels and superyachts. The key to ERMA FIRST's success is the operational flexibility that our Ballast Water Treatment System delivers to shipowners. This flexibility allows unrestricted trading under any given conditions regardless of the water's salinity, temperature and turbidity levels.

Filtration means compliance

The case for and importance of filtration in ballast water treatment (BWT) is well understood. Today, systems utilising filtration are the established majority while filter-less systems are the questionable minority. A key regulated water parameter is the count of organisms sized above 50 μm. These organisms are resistant to disinfectants (Chlorine, Chlorine Dioxide etc) and UV radiation. Removal of the larger than 50 μm organisms can only be accomplished by particle separation devices such as cyclonic separators, membranes and mechanical filters. The implementation of a filtration stage in BWT is therefore necessary.

By reducing the solids content in any type of water treatment, the burden on the treatment system is reduced considerably. A filter benefits all processes by removing solids and hard-to-treat larger organisms from ballast water. In electro-chlorination technology, filtration is the only way to achieve optimal use of power during operation.

Sea water contains various sized microorganisms and particles (consisting of both organic and inorganic material) that will most certainly have a detrimental effect on the lifetime of the electrodes. Unfiltered sea water will undoubtedly cause mechanical wear on the electrode surface. Market wide used TRO sensors will certainly face problems during TRO sampling procedure in the presence of large solids within the flow. From sensor filter clogging, to reduced accuracy of photo-metric measurement, unfiltered sea water does cause problems in the operation of these instruments during ballasting and de-ballasting.

It is no coincidence that those companies that initially developed BWT systems without filtration have now changed course and modified their processes to include filters as standard. A recent publication from a ballast water sampling and analysis lab, reports that during compliance testing 21% of the installations did not meet the D-2 performance standard of the Convention. All failures were found in the largest size class of organisms (≥50 μm). It is likely that those tests would have been successful if a filter had been installed.

Regulation D-2 : Ballast Water Performance Standard

The D2 Standard specifies that treated and discharged ballast water must have:

- Fewer than ten viable organisms greater than or equal to 50 micrometers in minimum dimension per cubic metre
- Fewer than 10 viable organisms less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometers in minimum dimension per millilitre.

In addition, a ballast water discharge of indicator microbes, as a health standard, shall not exceed the following specified concentrations:

- Toxicogenic Vibrio cholerae (O1 and O139) with less than one colony-forming unit (cfu) per 100 millilitres or less than 1 cfu per 1 gram (wet weight) zooplankton samples
- Escherichia coli less than 250 cfu per 100 millilitres
- Intestinal Enterococci less than 100 cfu per 100 millilitres

20 μm vs 40 μm filtration

UV treatment systems use advanced lamp technology to irradiate the water and the particles within. The irradiated organisms need to be on a direct line of sight to the energy emitting lamps. Suspended solids in water, and particles that cast a shadow, interfere with the light energy transmission and impact the exposure of organisms to UV light.

Particles do not need to be large to adversely impact UV treatment efficiency. Even chemicals dissolved in water interfere with the light path by increasing light scatter and thus decreasing UV transmittance. This vulnerability of UV to poor water quality is to some degree addressed by the adoption by several makers of fine ballast water filtration down to 20-25μm.

The use of a fine filtration grade introduces other challenges such as pressure drop, more frequent back washing and filter clogging. This translates to significant performance penalties in waters with high concentration of suspended solids, such as the Yangtze and Mississippi rivers.

ERMA FIRST after extensive testing recognised that filters with 40μm retention capacity provide the optimum balance between fine filtration and backflushing cycles. ERMA FIRST is the only BWTS manufacturer in the world that offers three (3) different types of 40μm filtration, proven to have the most effective operation on board a vessel.

UV - Design limitations

1. Flow reduction and power ramp-up

Challenges are experienced when a ship operates in shallow waters and estuaries with large tidal movements, such as Tilbury and the Humber. Large particles are retained by filtration, but a sizable volume of material comprising of fine silt still passes through the filters. To address the poor water quality and turbidity induced challenges (water with low UVT), UV system designers employ two main strategies to manage the UV dose: **flow reduction** and **power ramp-up** either independently or concurrently.

The **flow reduction** strategy simply means that installing a UV system matching a 1500m³/hr ballast pump will be restricted to the treatment of 750m³/hr or 300m³/hr in poor quality water areas (low UVT). There are few cases where the flow reduction is not easily feasible due to the existing ballast network configuration and design.

To counteract the effects of turbidity and reduced UVT in poor quality waters requires a **power ramp-up** to achieve a higher UV intensity (UVI) and deliver the necessary UV Dose (UVD), see Figure 1. UVD is the product of UVI × exposure time. Therefore, flow reduction aims at increasing the UVD through increased exposure time in the reactor while power ramp-up means a higher UVI.

"Challenges are faced when a ship operates in shallow waters and estuaries with large tidal movements"

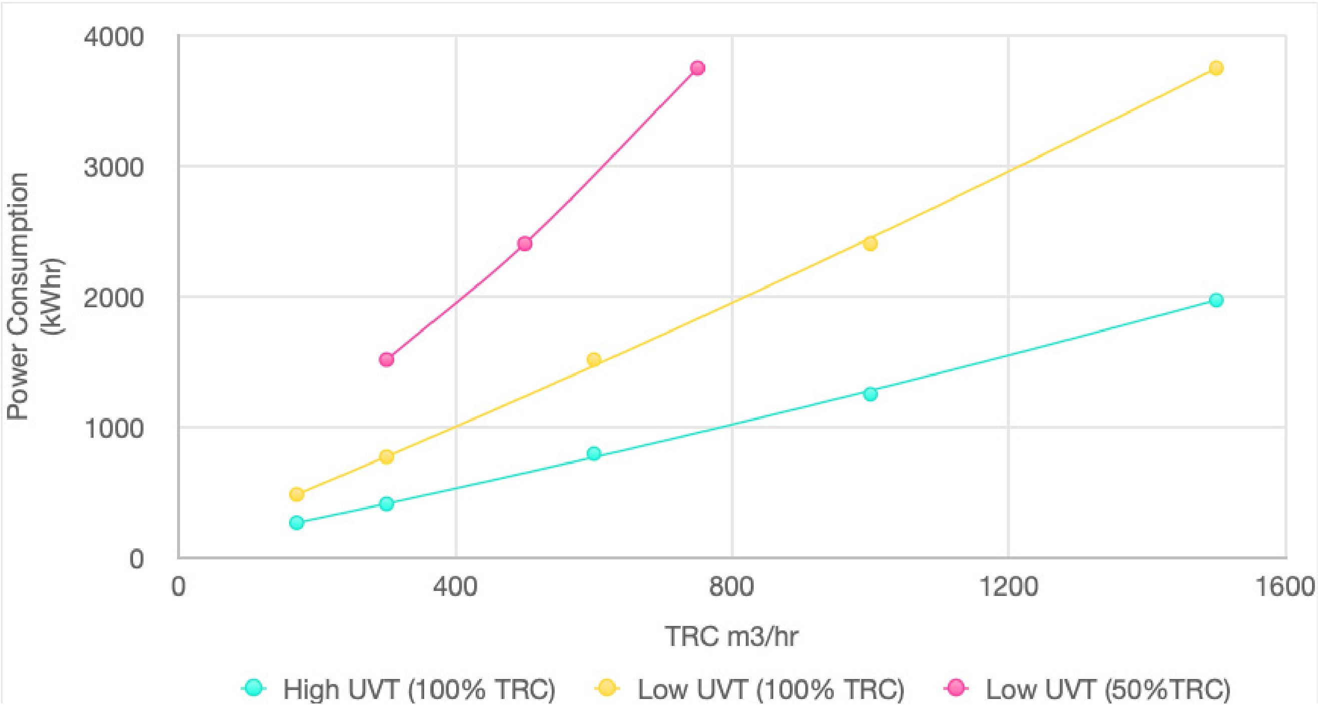
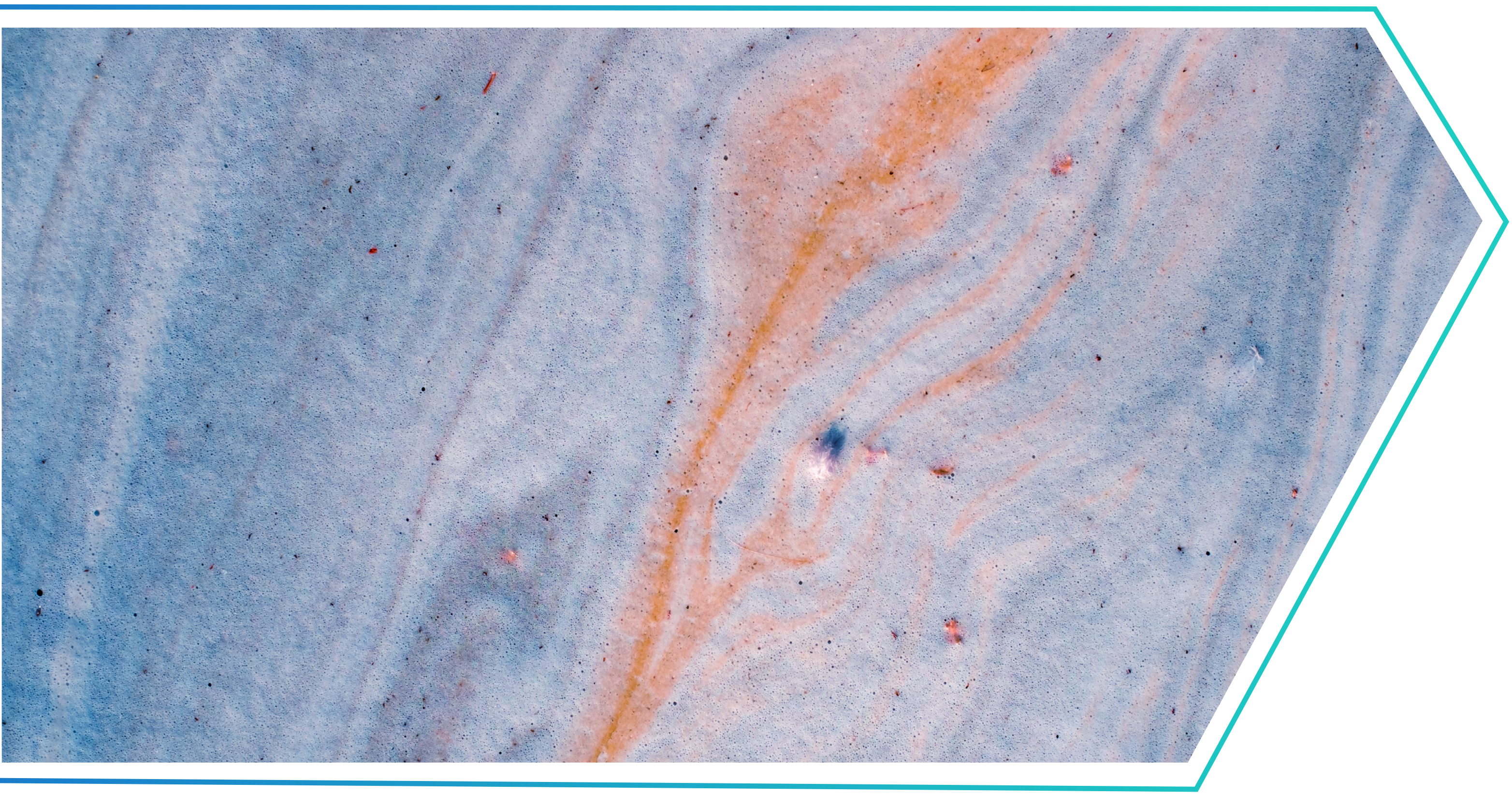


Figure 1 UV BWTS typical power consumption for 12hrs of ballasting and 12hrs of de-ballasting operation. UV BWTS modes: High UVT in IMO mode, Low UVT in IMO mode (power ramp-up), Low UVT in USCG mode (power ramp-up and 50% flow reduction)



2. No back up plan for low UVT waters

What is abundantly clear is that Filter UV systems cannot operate in challenging waters without imposing constraints on ship cargo operations. Such UV BWTS, cannot apply a backup plan to manipulate the water quality to meet its SDLs. This means that if the targeted UVI is not met following the maximum allowed flow reduction - or the UVT mentioned in system Type Approval is not met - then the system control cannot accommodate such a challenge and will shut-down.

Electro-chlorination systems do not have this major disadvantage. These systems can increase the uptake water salinity by adding sea water or increasing the water temperature with a heater in the case of side-stream electrolysis BWTS. ERMA FIRST FIT BWTS achieves the former with the use of intelligent controls and without the need of heating, since it can work down to –2 ºC of electrolyte feed temperature.

3. De-ballasting limitations

It is a common practice for Bulk Carriers to use different ballasting and de-ballasting rates. This is caused by cargo terminal loading and unloading rates. It is frequently the case that de-ballasting needs to be conducted twice as fast as ballasting. A good example is Australia where de-ballasting must take place in less than 18hrs for a Capesize Bulk Carrier (> 50,000m3 of ballast water). This feature is accommodated by ERMA FIRST FIT BWTS as there is no treatment at deballasting, allowing for 100% operational flexibility.

In the case of a UV system, treatment is required at discharge. This imposes a massive challenge, further compounded by the operational limitations in ports with challenging water quality and forced flow rate reduction. This means that in case the ship operator chooses UV technology, then the size of the system must be able to cover both the ballasting and de-ballasting rate which results to a much higher CAPEX.

ERMA FIRST FIT BWTS provides ship managers and operators with unmatched practical flexibility and allows ships to operate unimpeded globally. There is no need to slow down cargo operations, no need to undertake ballast water exchange and no need for treatment at discharge.

Case study: UV BWTS restrictions to tramp trade

In the tramp trade, a ship's itinerary can be dynamically changed without warning to accommodate new chartering arrangements.

Consider the scenario that a ship fitted with a UV BWTS has been discharging cargo in Panama and ballasting for the next port of call in Mexico. Whilst the ship is on its way to Mexico for the next cargo, it is called to divert to the US instead. The ship in Panama, following the ballast water management plan, would ballast using the IMO mode of the BWTS. The call to divert to the USA is a problem as the ballast water on board has not been treated in accordance with the maker's instructions and system type approval certificate.

In order for the ship to discharge ballast in the US, it will have to undertake a ballast exchange operation and re-ballast while operating the BWTS in USCG mode. Having received the instruction to divert to the US, a ship fitted with an ERMA FIRST FIT BWTS will have no issue. Unlike the case of UV treatment, the ballast water on board will be compliant irrespective of departure port as ERMA FIRST uses reliable electro-chlorination treatment that delivers compliance globally for operations in both IMO and USCG regulated ports.

In a second scenario, a ship is operating in the estuary of New Brunswick on the US east coast, an area with low quality waters. Brackish waters with low UVT will impose serious challenges for a vessel hoping to complete ballasting at a normal rate, as there will be a critical flow-reduction in order to achieve treatment.

In the same situation, a ship utilising ERMA FIRST technology will not be impacted by the brackish low UVT water because the system is able to operate in all water qualities. In situ electro-chlorination provides a sustainable and low power demand ballast water treatment. For a better illustration of these scenarios please refer to ERMA FIRST YouTube channel.

"Filter UV systems cannot operate in challenging waters without imposing constraints on ship cargo operations"

OPEX considerations

1. Power consumption

While UV treatment of ballast water takes place at both uptake and discharge, the simultaneous use of flow throttling and power ramp-up imposes severe constraints to the practical use of UV technology in challenging ballast water situations. The power consumption of UV systems versus the ERMA FIRST FIT BWTS is shown in Figure 2 below. It is very apparent that the power consumption of UV systems, in nearly all ballasting conditions, is significantly higher than the consumption of ERMA FIRST FIT BWTS in the same flow range. In addition, UV technology shall consume equal power consumption on de-ballasting, ERMA FIRST FIT BWTS technology shall only consume 1,5kW during de-ballasting.

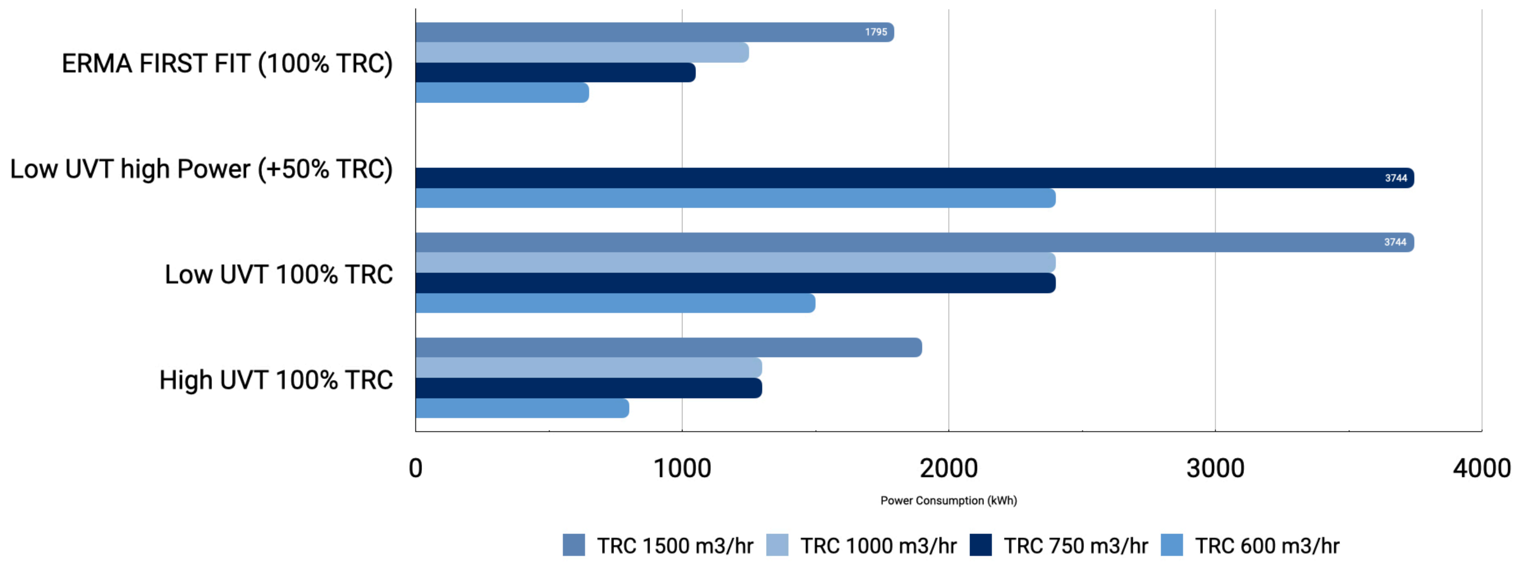


Figure 2: Power consumption comparison between ERMA FIRST FIT and UV BWTS for typical flow rates.UV BWTS modes: High UVT in IMO mode, Low UVT in IMO mode (power ramp-up), Low UVT in USCG mode (power ramp-up and 50% flow reduction)

Annual power consumption figures for UV systems calculated for 10 ballasting operations is shown on Table 1 assuming a power generation cost of 0.09 $/kWh.

Table 1 Annual power consumption OPEX for 10 ballast/de-ballast operations

OPEX (USD)				
TRC (m³/hr)	600	750	1000	1500
High UVT(100% TRC)	713	1123	1252	1771
Low UVT(100% TRC)	1360	1980	2160	3369
Low UVT high Power (50% TRC)	2160	3369	-	-
ERMA FIRST FIT (100% TRC)	566	905	1132	1615

It, therefore, becomes self-evident that these strategies contribute to an already significant power OPEX. The extreme flow cutbacks impact ballasting and cargo operations, which can result in hidden OPEX due to delays and extended stays at cargo terminals. Besides, there are ships whose diesel generators will be challenged to supply the required energy.

Moreover, the current lack of data related to water UVT in ports and a subsequent lack of correlation with the targeted UVI - does not allow the vessel to effectively plan its loading/unloading operations in advance.

2. Consumables

To increase the likelihood of organisms being exposed to UV light and receive the required UVD, UV systems employ multiple lamps. The typical number of lamps for systems using medium pressure UV lamps is shown in Table 2. The number and power of each lamp is variable and depends on the reactor design, but typical lamp powers are in the range of 3-9kW.

Table 2 Typical lamp counts for medium pressure UV systems

Lamp Counts					
UV System 1		UV System 2		UV System 3	
TRC m^3/hr	No.Lamps (pieces)	TRC m^3/hr	No.Lamps (pieces)	TRC m^3/hr	No.Lamps (pieces)
170	6	135	8	125	6
300	10	340	8	300	12
600	20	750	18	500	12
1000	16	1000	24	750	18
1500	25	1500	36	1000	18

A lamp is a replaceable item and although its rated life can be 2000 or even 5000 hours, this is normally based upon continuous 24/7 operation and assumes that the lamps are rarely switched off. However, as with all electrical and electronic systems, it is fair to assume that the ship operating environment and frequent on/off power switching can have a detrimental effect on the service life of lamps and lamp drivers. UV lamps are also very sensitive to calcium deposits and can easily break in case of negligence during maintenance or replacement activities. UV lamps contain toxic chemicals such as mercury and must be disposed as a hazardous waste in certified port reception facilities.

UVI is a critical operational parameter. It is subject to monitoring and the readings are used for flow and power control in a UV reactor. However, only a single lamp is monitored using the relevant UVI sensor. That means the system UVI is managed based upon the readings obtained from a single lamp. UV lamps are typically replaced when the UVI is at approximately 70% of the 'as new' lamp intensity. In order to maintain the UVI for the full range of values in a multi-lamp reactor, all lamps will have to be replaced at once when the UVI reading drops below 70% UVI when compared to a new lamp. This raises concerns on how a system could determine if all lamps are emitting at the same intensity since UV system is based on the monitoring of a single lamp. It is questionable how can compliance be consistent, if intensity of single lamp is a system design limitation.

ERMA FIRST FIT BWTS has been designed for marine applications by industry experts. The main reactor is robust, suitable for the engine room , pump room and deck applications with the biggest life time expectancy in the market. Our guarantee policy proves that.

Full flow vs side-stream BWTS installation

When choosing a BWTS, there are many factors to consider. Amongst the most important are the installation simplicity and flexibility permissible by the technology. There is a notion in the market that side-stream BWT systems are great candidates when installation and flexibility become major decision factors. However, that is not the case.

Side-stream systems rely on a small percentage of water entering the ballast line to be channeled into the treatment system. The hypochlorite used to treat the water is created in the side-stream and then introduced to the full volume of ballast water. Side-stream systems have limitations of salinity (>15 PSU avg) and sea water temperature (4-18ºC) therefore conditioning of the water is imperative.

Installing the various components of a side-stream system requires considerably more space in different areas and complicates the design outcome. Installation is more demanding due to the number of extra components: bulky electro-pack unit, Total Residual Oxidant (TRO) injection pumps, degas tanks, heat exchangers and mixers.

The heat exchangers and mixers are delivered on skids that become a challenge when being retrofitted on vessels with limited available space and smaller capacity pumps. Extensive new piping installation is required (piping with high spec materials that resist the high concentration TRO corrosive effects) and ventilation pipes, blowers and permanent gas detectors for the high hydrogen production are also to be installed.

> *"Side-stream BWT systems: extensive modification works will normally result in longer installation periods and higher installation cost."*

The inherent flexibility of ERMA FIRST FIT BWTS is derived from the system's modular design. This facilitates the easy identification of ideal installation solutions, especially for retrofitting (reduced number of components, cables and pipes). Minimum modifications in piping are required in retrofit cases where most of the existing piping remains intact.

The system's major components are installed on the main ballast line and simply become part of it. The ERMA FIRST electrolytic cell becomes part of the ballast line due to its geometry. This results in an optimal use of the available installation space. The full flow configuration of ERMA FIRST FIT BWTS removes the need for the conveyance of electrolysis products through bulkheads and cofferdams and all associated installation costs for such piping are eliminated.

> *"The ERMA FIRST FIT BWTS design allows for a straightforward installation, minimising the costs and time required for the system to be commissioned."*

The ERMA FIRST advantage

The ERMA FIRST FIT BWTS is a filter full-flow configuration. It comprises of a filter stage followed by full flow electro-chlorination. Sea water is used in the disinfection stage to generate the requisite amount of disinfectant through the electrolysis of the filtered ballast water. The ERMA FIRST FIT BWTS system employs special anodes that allow a broad environmental envelope of operation, while offering flexible solutions for both safe area and hazardous zone installation.

The system is designed to deliver compliance for ships trading globally and has been uniquely tested and certified with three different 40μm basket filters. Each filter's performance has been proven in conjunction with the specially designed electro-chlorination cells. The achieved bio-efficacy meets and exceeds the dis-charge standards as defined by the IMO and USCG, making the system future proof.

Turbidity and low UVT do not present the same challenges to an electro-chlorination system as they do to a UV system. Power ramp-up and flow reduction practices are not used with the ERMA FIRST FIT BWTS, which performs just as well in turbid as in clear waters. The ship's operator does not need to select an IMO or USCG mode. Ship managers and charterers are therefore not required to factor a delay or protracted stay at a terminal due to slow cargo operations into their voyage planning. The ERMA FIRST FIT BWTS makes use of intelligent controls that allow safe and automatic operation in all situations.

ERMA FIRST has also evaluated the corrosivity with tests according to GESAMP recommendations and concluded that the untreated water shows a higher crevice corrosion rate than the samples in the treated ballast water. The higher corrosion rate in the untreated ballast water is probably due to the formation of a derby film on the surface which promotes crevice corrosion (microbial influenced corrosion). Moreover, Electrochemical Impedance Spectroscopy (EIS) measurement showed that the coating barrier properties are not influenced by the chlorine treatment of the ballast water in such low concentrations.

The ERMA FIRST FIT BWTS has been fully validated through testing and has no assigned operational limitations with respect to hold time, salinity or temperature of ballast water. Specially designed and constructed electrolysis cells allow effective treatment of water with temperature higher than -2°C (sea- water freezing point) and salinity ≥0.9PSU cell feed water conditions. Every aspect of the process has been researched in depth and best practices have been adopted with best-in-class design and the selection of highest quality components. The development of the critical treatment process has been implemented with due consideration to ship operator expectations and detailed evaluation of cargo operation practices on different ship types.

The dose of the disinfectant is designed to impart immediate treatment upon contact with marine organisms, but also allows for a residual amount (TRO). Whilst present in the tanks, this continues the treatment and suppresses any regrowth which ensures compliance at discharge without need of retreatment. The biological efficacy has been demonstrated in all salinity ranges.

> *“Reliable electro-chlorination treatment that delivers compliance globally for operations in both IMO and USCG regulated ports”*

Leveraging Artificial Intelligence

METIS CYBERTECHNOLOGY

ERMA FIRST FIT is the first BWTS with embedded Artificial Intelligence powered by METIS Cyber Technology platforms. It offers users real time remote BWMS operation monitoring. The unique machine-learning feature provides important information to the user and allows critical decisions to be made prior to any ballasting/de-ballasting operations. The system can also facilitate the preparation of Port State Control reporting documentation.

Conclusion

Electro-chlorination systems have set the standard for effective ballast water treatment. The market data clearly demonstrates the compatibility of electro-chlorination with the full range of vessels. Filter full flow electro-chlorination delivers unmatched operational flexibility compared to the hidden limitations and operational risks of other technologies.

ERMA FIRST provides the shipowner with a partner to support regulatory compliance through the lifetime of the installation along with equipment quality, timely deliveries and aftermarket technical support. ERMA FIRST FIT BWTS delivers superior operational readiness and availability through the power of simplicity.

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GLOBallast Publications

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About

ERMA FIRST founded in 2009 and headquartered in Piraeus, Greece. ERMA FIRST is an experienced manufacturer of ballast water management systems. **ERMA FIRST FIT BWTS** is an advanced modular system which can be installed on both newbuildings and as a retrofit. Covering an extensive capacity range from 50 to 3600m³/hr and holding IMO, USCG Type Approval, **ERMA FIRST FIT BWTS** is an ideal solution for all types of ships available for safe and hazardous zone installations.

ERMA FIRST is the winner of the Lloyd's List Technical Achievement Award (2013) and the Green4Sea Technology Award (2016). ERMA FIRST provides sales, technical support, maintenance and training services to its clients via a global network in 46 countries.

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