ISSN 2250-1967

MARINE ENGINEERS REVIEW INDIA

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

Volume : 16 Issue : 6 May 2022 ₹ 90/-

PAGE 9

RAMS - Centered System Engineering and Operations of Modern Multi-Megawatt Capacity Marine Power System - Part F2

PAGE 19

Green Method of Stemming the Tide of Invasive Marine and Freshwater Organisms by Natural Filtration of Shipping Ballast Water

PAGE 27

The Triple Zero Positive Appliance: Exhaust Gas Thermo Electric Generator (TEG) for Green Environment

A Dive into Sub-Sea Power Systems

The Institute of Marine Engineers (India)

IMEI HOUSE, Plot No.94, Sector-19, Nerul, Navi Mumbai.

Tel: +91 – 9967875995/ 9773363542 / 9594204403/ 022-27711663
Email: training@imare.in. Website: www.imare.in

REGISTRATION OPEN FOR Following DGS APPROVED COURSES (Online)

- Basic Training for Ships using Fuels covered within IGF code Course Id – 5311 (OFFLINE)– (4 Days) - Commencing on 17th May 2022 / 13th June 2022
- Assessment, Examination and Certification of Seafarers Course Id – 1062 (OFFLINE) – (12 Days) - Commencing on 18th July 2022
- Advanced Training for Ships using Fuels covered within IGF code Course Id – 5312 (OFFLINE) – (5 Days) - Commencing on May / June 2022
- MEO Cl. I (FG) : 2- months course (OFFLINE) 2nd May 2022 / 1st July 2022/ 1st Sep 2022 / 1st Nov 2022 (followed by Simulator course) Discount on combined bookings of Class I with Simulator
- MEO CLASS III (NCV_CEO) Upto 3000kW – STCW 2010: 2 month course (OFFLINE) – 1st July 2022/ 1st Nov 2022
- MEO Cl. III (NCV_SEO) Part-A - STCW 2010: 2-month course (OFFLINE) – 1st July 2022
- MEO Cl. III (NCV_SEO) Part-B - STCW 2010: 4-month course (OFFLINE) – 1st Sep 2022
- MEO Cl. IV (NCV) - STCW 2010 -4 months course (OFFLINE)– 2nd May 2022 / 1st Nov. 2022
- MEO CL. II (FG): 4-month Course (OFFLINE) - 1st June 2022 /1st July 2022/ 1st Aug 2022/ 1st Sep 2022/ 1st Oct 2022/ 1st Nov 2022/ 1st Dec 2022 (Discount on combined bookings of Class II Courses with Simulator)
- REFRESHER & UPDATING TRAINING (RUT - 4 Days) COURSE FOR REVALIDATION OF COC FOR ALL ENGINEERS and ETOs (OFFLINE)- Course Id – 1118 – 23rd May 2022
- ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (3 DAYS) COURSE FOR MEO CLASS I (OFFLINE) - 3rd May 2022
- ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (5 DAYS) COURSE FOR MEO CLASS II (OFFLINE) -3rd May 2022 / 6th June 2022
- ENGINE ROOM SIMULATOR OPERATIONAL LEVEL (3 DAYS) COURSE (OFFLINE) – 10th May 2022 / 13th June 2022
- MEO Cl. IV(FG) non mandatory course (2months duration) – On request
- 2 weeks Induction course for Naval candidates – on request

NOTE
For Payment:
Visit www.imare.in
Use the option "Buy Online" to pay the course fee

Payment can be done through the ICICI Bank (IFSC Code: - ICIC0000151) on A/C No.015101031872 in the name of "The Institute of Marine Engineers (India)" only after confirming the availability of seats.

Please make the payment from saving bank account only not from NRI / NRE account

For enquiries contact on training@imare.in

For Registration of Competency Courses: https://forms.gle/DBvLuEarFpbk3aqX9

For Registration of Modular (RUT/ERS) Courses: https://forms.gle/DSmcvmMJkZAvLDvo9

Documents – Mail your documents on documents@imare.in after putting all documents in one pdf file

Features:
Experienced Faculty, Individual Attention

WE CARE

ENGAGING | EMPOWERING | INSPIRING

Setting the standard

ANGLO-EASTERN

EDITORIAL

Knowing is not enough; we must apply.
Willing is not enough; we must do.

- Johann Wolfgang von Goethe

We are witnessing two wars... but the battlefields could be shifting.

The UR war is witnessing new dimensions. Cyber espionage is the mode and malware is the war weapon. The weapons used are spear-phishing, water holing, zero-day exploits etc. Search for these, you might find some have been used on you by the hackers. These might become perpetual threats that could make conventional wars redundant.

And there is another war... we call it the Drag the Degree Down War. The latest IPCC Reports forecast that even if the Nationally Determined Contributions are achieved (by all the Countries as agreed upon), we will still be warming over 1.5°C in this Century. It also warns that even a brief breach of this level in the next two decades might cause irreversible damages to the planet.

As the Earth Day and the Zero-Shadow Days pass by and power cuts loom across the country, some introspection would help.

What are the challenges for India?

The coal powered plants without Carbon Capture & Storage (CCS) are a major concern. We have almost 10% of the global plants producing >200Gw and another 30Gw are expected to be added and spew smoke in the coming times. Ships' coal carriage and railway rake numbers for the solid fuel have increased through the pandemic periods.

India knows that coal cannot be abandoned in its developmental plans and is also aware of its net-zero commitment for 2070. CCS included, India must ginger up and give traction to renewable energy technologies. Solar, tidal and wind... the applications must go deeper into the ocean depths also, which might hold cooler options.

The world knows that one war has to end, and the other has to be won. India knows that both the wars will have repercussions in the subcontinent and it needs to do more to ward off the weather and ware wars. Of course, India needs the will to do it.

In this issue...

We come to the concluding part (F2) in the Power Management Series. Here, Dr. Veda takes us deep under for a trip through the Subsea Electric Grid Systems (SEGS). While tapping the ocean energies, the SEGS architecture helps in transmitting power ashore. He also highlights the significance of SEGS for enhanced oil recoveries from offshore facilities. The description of SEGS components, wet electronics and the mechanism of pressure compensation keep up the interest. The concluding discussions on offshore power transmission leave us looking at future frontiers to be crossed in the power management domains. While I await your feedback, I must say that this has been an engaging and enlightening series.

From sub-sea ambience, we rise to the surface but still stay in the seas looking at filtering the waters for ballast usage. Dr. Prince *et al.*, present an innovative option of filtering the sea water (through ground wells located near to the coast) and lift it as clean, fresh water (FW) for use as ballast. The proposed option is reliant on sub surface filtration from shore based wells. A number of well designs are presented (FW generation mechanisms). A couple of designs require some arrangement intervention after which clear water can be obtained. The method appears simple, yet its effectiveness for generating large volumes (global ballast shifts range around 7-10 billion tons) remains to be proven. Also shorelines might not be conducive for well intake filtration etc. The idea is tempting, of course.

Adding another tinge of innovation are Hare Ram Hare *et al.*, proposing a waste heat energy capture from the exhaust gases. But in this instance, it is in the form of a Thermoelectric Generator.

Under Lube Matters, Sanjiv Wazir discusses additives that control deposits.

In Heritage Hourglass, Dennard highlights the Maratha King Shivaji's maritime interest.

And, May the guns go quiet and

May the mutations turn harmless...

Also with the May issue, May I request all the readers to register in our JMS, flip through our flipbook and do a favour with your feedback to make it better.

Dr Rajoo Balaji
Honorary Editor
editormer@imare.in

MARINE ENGINEERS REVIEW INDIA

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

Administration Office
IMEI House
Plot No. 94, Sector - 19, Nerul,
Navi Mumbai 400 706.
Tel. : +91 22 2770 16 64
Fax : +91 22 2771 16 63
E-mail : editormer@imare.in
Website : www.imare.in

Printed, Published and Edited by:
Dr Rajoo Balaji on behalf of The Institute of Marine Engineers (India). Published from 1012 Maker Chambers V, 221 Nariman Point, Mumbai - 400 021, an printed from Corporate Prints, Shop No.1, Three Star Co-op. Hsg. Society, V.P Road, Pendse Nagar, Dombivli (E) - 421 201. District – Thane

Print Version: **Mr Gaurav Kulkarni**

Typesetting & Web designed by:
Kryon publishing (P) Ltd.,
www.kryonpublishing.com

In This Issue

ARTICLES

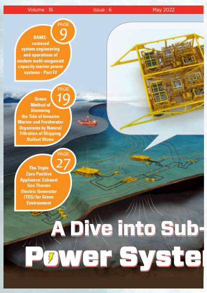
09 RAMS-Centered System Engineering and Operations of Modern Multi-Megawatt Capacity Marine Power Systems - Part F2
– Dr. N. Vedachalam

19 Green Method of Stemming the Tide of Invasive Marine and Freshwater Organisms by Natural Filtration of Shipping Ballast Water
– Jebarathnam Prince Prakash Jeba Kumar, Shunmugavel Ragumaran, Ganesan Nandagopal, Vijaya Ravichandran, Ramana Murthy Mallavarapu, Thomas M. Missimer

27 The Triple Zero Positive Appliance: Exhaust Gas Thermo Electric Generator (Teg) for Green Environment
– Hare Ram Hare, P. Ravichandra, Shrikrishna S Prabhu, Utkarsh Jaiswal, Naman Aggarwal, Chum Bikomiyo Deori

COLUMNS

32 Technical Notes
35 Shipping Matters
38 Branch News/Press Release
47 Heritage Hourglass
49 In the Wake



Cover Image: *Ormen Lange hydrocarbon field located in 1000m water depths and 120km from shore requires ~50MW capacity subsea compression systems*

The Ormen Lange field is located 120 km from the West Coast of Norway at a depth ranging from 800-1100m. The subsea gas compression system is currently being evaluated as an alternative to topside compression on a floater. Subsea compression on Ormen Lange would represent a major technological advancement for subsea processing systems, as both the required step-out distance for power (120 km), the total installed power (exceeding 50 MW), and the system throughput (some 60 Mcm/d) are an order of magnitude larger than existing subsea processing systems in operation to date.

Cover Insert: *World's first subsea compression system deployed at 260m water depth in the Asgard hydrocarbon field in the Norwegian Continental Shelf*

The system has compressor trains of 24MW capacity installed at a water depth of 260m which is ~40km from the shore, in a shared subsea structure with a total weight of 5100 metric tons, a footprint of more than 3300 sq.m and height of 17m above the seabed.

Cover Credits: ***https://onepetro.org/OTCONF/proceedings-abstract/16OTC/2-16OTC/D021S024R006/85767***

The Institute of Marine Engineers (India)
is Pleased to Announce

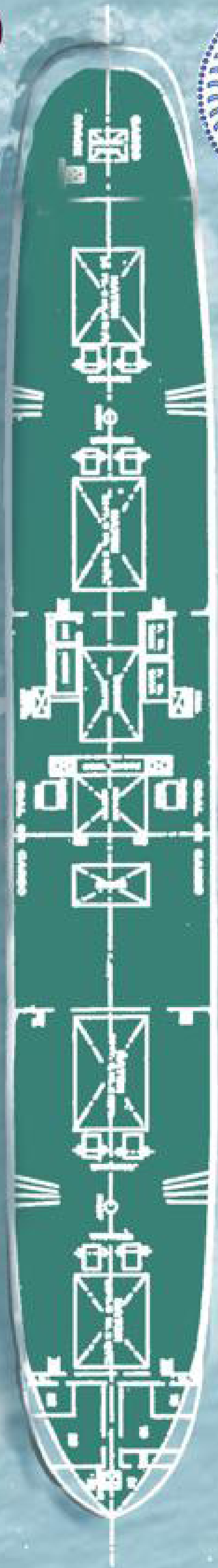
INMARCO 2022

Evolving Maritime World for Greener & Sustainable Future

QUADRENNIAL INTERNATIONAL MARITIME CONFERENCE & EXHIBITION

NOV' 2022 IN MUMBAI

Date and Venue to be announced shortly



THE INSTITUTE OF MARINE ENGINEERS (INDIA)
(MUMBAI BRANCH & NAVI MUMBAI AND GUJARAT CHAPTERS)

ABOUT THE CONFERENCE:

Since its inception in 1982, INMARCO has always witnessed an overwhelming response from the Maritime sector which in turn has propmted the Institute to organise this conference and exhibition quadrennially.

Papers are invited from Engineers, Manufacturers, Designers, Shipbuilders, Operators, Students, Educators, Researchers, Recyclers, Adjudicators, Salvors, etc. The topics of paper presentations will be announced shortly in the upcoming Brochure.

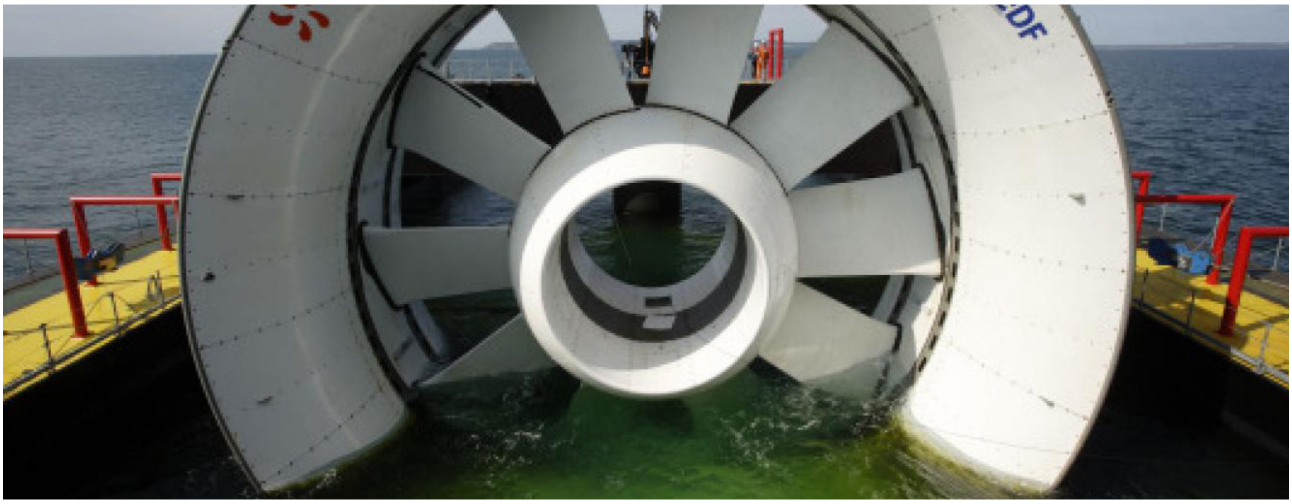
CONTACT :

Ms Aditi Thakur

info@inmarco.in

+91 84520 26684

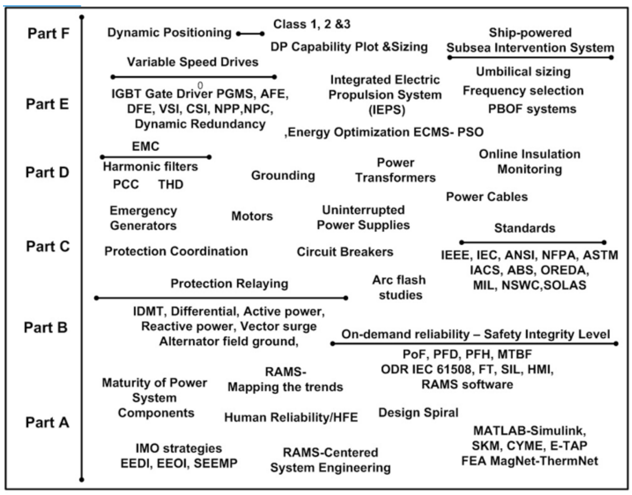
RAMS-CENTERED SYSTEM ENGINEERING AND OPERATIONS OF MODERN MULTI-MEGAWATT CAPACITY MARINE POWER SYSTEMS - PART F2



N. Vedachalam
National Institute of Ocean Technology, Ministry of Earth Sciences, Chennai, India

Abstract: Reliability, Availability, Maintainability, Safety (RAMS), operational efficiency and environmental performance are the key requirements for multi-megawatt marine power systems.The details presented in the previous five issues could be used for safety and reliability-centered system engineering and maintenance planning of multi-megawatt marine power systems This final part (published as two sections/ this is the second part F2) discusses the importance of RAMS in the strategic marine sector including subsea renewable power grids, subsea boosting stations and subsea power transmission systems. The strategic importance of wet electronics is also explained.

Index terms:Grid, Reliability, Subsea boosting, Transmission



Strategic Marine Developments

Operations in demanding offshore/subsea environments, increased regulatory requirements, spiralling maintenance costs, higher customer expectations, enhanced Health Safety and Environment (HSE) requirements have led marine organisations to proactively manage their offshore assets and optimise their lifetime value.

The objective is to identify a tradeoff between the cost and the effectiveness, in terms of performance, reliability and safety, and to ensure that the risk to human, equipment and the environment are within the acceptable level. Compared to the qualitative methods, Reliability, Availability, Maintainability and Safety (RAMS) assessment based on probabilistic methods is a robust and proven methodology that provides quantitative results that support asset owners in improving reliability and gaining visibility on the assets that are most critical for safe operations.

RAMS studies also helps to identify technology gaps, plan technology qualification programs (TQP), integrating reliability and safety requirements during the design/ system engineering and operational phases to arrive at a tradeoff between the system capital expenditure, operating expenditure, redundancy requirements and system modularity.

Subsea Renewable Power Grids

Among many ocean energy technologies under development, tidal farms have been proposed as environment-friendly. Tidal energy has the advantage of predictability over other non-conventional energy sources and has reduced carbon emissions. Tidal energy sites across the globe with significant potential include the English Channel, Gulf of Mexico, Bay of Fundy and Amazon.

The international tidal energy policies now form the key component of most governments' sustainable energy policies. In this decade, multiple energy-efficient turbine technologies are analysed, and the recent successful qualification of commercial-scale marine current turbines (MCT) including MCECS-Sea flow, grid-connected 1.2MW Seagen, floating 2MW Seagen-F, 1.5MW Seagen-U, EMEC 1 MW and the 0.5MW Open hydro turbine for Paimpol-Brehat and its subsea grid (**Figure.1**) are confidence boosters to establish tidal farms [1].

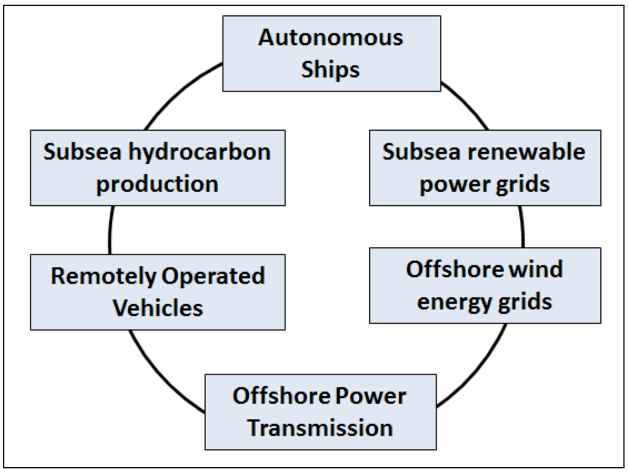


Figure.1. Strategic developments in the marine sector

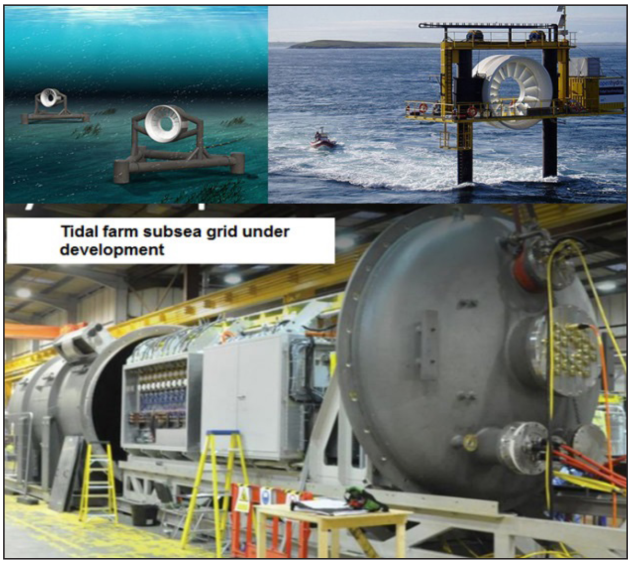


Figure.2. Open hydro turbine under installation & SEGS under development

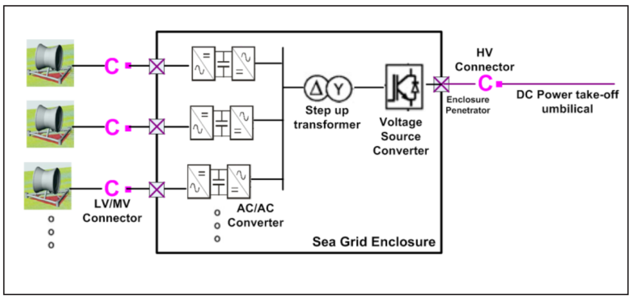


Figure.3. Architecture of SEGS with DC take-off

Electrical power transmission from the turbines to the shore is an integral aspect of any tidal energy project. For transmitting the turbine generated power to the shore power network, laying dedicated power cables from each turbine is not an economical and reliable solution.

This requires establishment of optimally-located enclosurised Subsea Electric Grid System (SEGS) that receives power from the multiple turbines, transforms to the required power levels and transmits it to the shore network using a single power take-off umbilical (**Figure.2**)

The SEGS poses challenge in effective marinisation of power and control systems, taking care of reliability and maintenance considerations. SEGS breakdowns lead to power production losses from the entire tidal farm, and system retrieval for repair and maintenance is very costly and time consuming.

The recovery of the system to the top side sometimes costs more than the cost of the system itself, as this involves the mobilisation and demobilisation of the required marine spread. Hence the SEGS internal systems need to be highly reliable [2].

The marine and electrical configuration of the Direct Current (DC) power takeoff topology is shown in **Figure.3**. This topology is followed in offshore wind energy generation networks involving long shore transmission distances. Long umbilical draw reactive current, which results in the under utilisation of the turbine and umbilical capacity and hence DC transmission is preferred for long takeoff umbilical.

The turbine output is controlled using the AC-AC converter which in-turn interfaced with a power transformer used for stepping up the voltage. The stepped up AC is converted to DC using a Voltage Source Converter (VSC) and transmitted to the shore network through umbilical.

The failure rate of a typical 5MW capacity VSC (detailed in Part D of the series) is about 8000 FIT. Reliability analysis is carried out for the SEGS based on GRIF-FTA and the results are presented. From the FTA simulation results, the PoF of the SEGS subsystem/components in 5 years are summarised in **Table.1**. The MTBF of the SEGS with varying number of connected turbines are shown in **Table.2**.

Table. 1. PoF of the SEGS subsystems [3]

System	PoF in 5 Yrs
Turbine AC-AC converters	31.1 %
Voltage Source converter	31.98 %
Cooling system	21.06 %
Step up transformer	2.34 %
Penetrators	4.4 %
Connectors	10.5 %
Take off umbilical and terminations	9.9 %

The FTA is carried out by incorporating redundancies in the power electronics system, cooling pump and in the IGBT sections (N+2) of the converters and the results are summarised in **Table.2**. It is identified that the MTBF of an SEGS with 10 turbines could be increased 2.7 times by incorporating redundant cooling pump and N+ 2 IGBT dynamic redundancies in all the machine side and in the grid (DC take-off) side converters.

Based on the survey conducted on 331 giant fields, it is estimated that offshore fields are depleting at the rate of 9.7% per year

The FTA is also performed for the SEGS with multiple turbine inputs with AC power take-off. It is identified that the MTBF for a 10 turbine input is 2.7 years. By incorporating redundant cooling pump and N+ 2 IGBT dynamic redundancies in all the machine side converters, the MTBF for a AC take-off system could be increased to 8.5 years, a 3-fold improvement. The identified results shall serve as inputs for identifying an optimum architecture based on modularity, redundancy and maintenance planning in harsh marine conditions.

Subsea Hydrocarbon Production Boosting

Offshore hydrocarbon fields hosts ~14% and ~36% of global technically recoverable reserve (TRR) of oil and natural gas. Presently, more than a quarter of global oil and natural gas supply is produced offshore, mostly in the Middle East, North Sea, Brazil, Gulf of Mexico and Caspian Sea.

In future, >75% of the global deep-water hydrocarbon production are expected from the Libra and Lapa fields in the Santos and Campos basins in Brazil, discoveries in West Africa, Stones and Julia fields in the Gulf of Mexico and Ormen Lange field in the Norwegian Continental Shelf. The fields are found to have massive hydrocarbon resources at depths 8000 m below the sea floor in water depths >2000 m.

Based on the survey conducted on 331 giant fields, it is estimated that offshore fields are depleting at the rate of 9.7% per year. Higher production capabilities built into offshore installations in order to repay expensive investments result in higher decline rates.

Table.2. MTBF of DC take-off SEGS with redundancies

Number of turbines	MTBF of SEGS with-out subsystem redundancy	MTBF with redundancy	
		Cooling Pump	Cooling pump and N+2 IGBT redundancy in converter
1	5.3 Years	6.7 Years	8.0 Years
2	4.6 Years	5.6 Years	7.4 Years
3	4.1 Years	4.8 Years	7.0 Years
5	3.3 Years	3.8 Years	6.3 Years
7	2.6 Years	3.1 years	5.8 Years
10	1.9 Years	2.5 Years	5.1 Years

The Enhanced Oil Recovery (EOR) is a process of boosting the declining production by injecting water in the vicinity of the production well using platform-based systems. Platform-based systems require dedicated flow lines from the surface platform and higher energy to overcome the pipeline flow friction.

The seabed-located water pumps that can take the sea water inlet and inject it into the reservoir for production support, require comparatively lesser infrastructure and energy, compared to platform-based alternatives.

Tyrihans is an operational field in the North Sea since 2009 with subsea water injection pumps of 6 MW capacities and 35 km step out distance. In the near future, subsea compression and pumping is proposed for the Asgard and Ormen Lange fields. The Asgard field requires a power of 16 MW at 25 km step out, Ormen Lange field requires 50 MW at 120 km step out, and long tiebacks for arctic fields are proposed in the future.

These fields require Long step-out All-Subsea Stations (LASS) with subsea processing systems installed in sea floor in deep waters with long tieback umbilical from the ship / platform / shore facility. The LASS processes involve subsea motors, valves and other systems to be operated at varying power and voltage levels, and this requires establishing subsea power stations local to the well head.

The subsea power stations have to receive power from the shore, using long step-out electro-optic umbilical, carry out voltage step-down using transformers, safe distribution using circuit breaker systems and power conversions using VSD in the order of tens of megawatts. Subsea breakdowns lead to huge production losses and recovery of the system to the top side costs more than the cost of the system [4].

Applying latest technological developments in power electronic control, circuit breaking techniques and insulation reporting systems could help in attaining higher reliability and operational safety**.** Subsea production processes are critical from the Health Safety and Environment (HSE) perspective and require safe and reliable process and emergency shutdown. Power supply for the valve control and actuator systems has to be highly reliable.

Moreover, a subsea system which is to be started after a prolonged stoppage has to be energised only after getting the status of the subsea electrical condition (black-start process). Based on the well head pressure and top side flow requirements, subsea production pumps

> ***Applying latest technological developments in power electronic control, circuit breaking techniques and insulation reporting systems could help in attaining higher reliability and operational safety***

and compressors need to be operated at variable speeds during the operational life [5].

A reliable power sting is the lynch-pin for a LASS booster station. A typical power string comprises of the Umbilical Termination Assembly (UTA), step-down transformer in pressure-balanced oil-filled (PBOF) containments, circuit breaker in pressure-rated enclosures, PBOF rectifier transformer, multi-megawatt water-cooled variable speed drives (VSD) in pressure-rated enclosures (**Figure.4**) and PBOF subsea motors with active magnetic bearings (AMB) for driving the subsea injection pumps and gas compressors.

The subsea Uninterrupted Power Supply (UPS) in pressure-rated enclosures serve critical loads such as AMB and process control valves. The Subsea Control Module (SCM) dispatches control to all the subsea systems that is received from the shore-based master control station [6].

The subsea interconnections include medium voltage(A and B), low voltage (C and D) and fibre optics (D) that are realised through a combination of dry mate and wet mate connectors depending on the modularity that is decided by deployment and maintenance. Normally work-

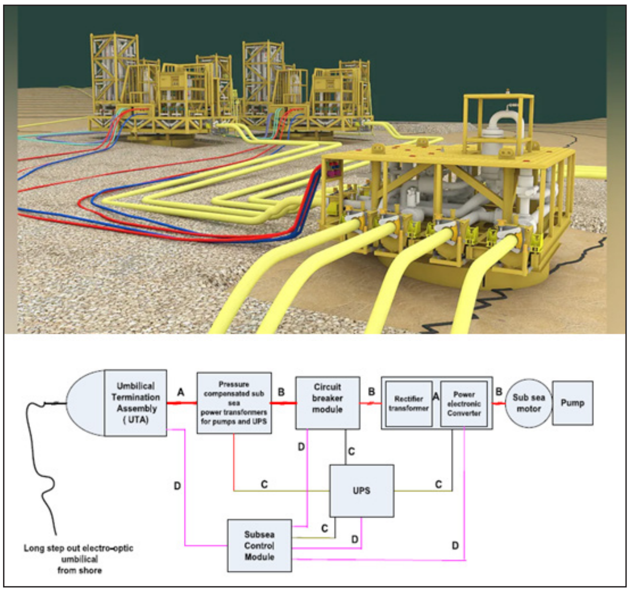


Figure.4. LASS processing station with boosting systems

class remotely operated vehicles (ROV) shall be used for interconnecting process lines and wet-mate power connectors (in ROV panels) after deploying the modular LASS subsystems.

Based on these component/subsystem failure rates, reliability modelling is done using GRIF-FTA for the SCM functionality involving UTA, redundant subsea UPS modules, SCM, electrical and optical interface harness (**Figure.5**). The SCM serves as communication interface between the shore control station and process safety-critical subsea systems. The failure rate for the SCM is 5300 FIT based on OREDA database. It is found that the PoF of the SCM functionality in 5 years is 66.77%, an MTBF is 4.5 years.

The FIT for the subsea pump motor VSD components for a temperature range (10-40ºC) are calculated using FIDES and IEEE failure models. Based on the failure rates, the FTA are also performed by incorporating redundancies in the LASS VSD subsystems for a temperature range of 10-40ºC, including machine bridge and active front end inverter controller, inverter IGBT redundancies and cooling pump and the results are plotted in **Figure.6**. It could be seen that lower ambient temperatures is highly advantageous for reliable operation.

Reliability modelling is done using FTA for the LASS based on the subsystem failure rates, including the subsea centrifugal pump failure rate computed as 9780 FIT from MMS database [7]. From extended simulations, the

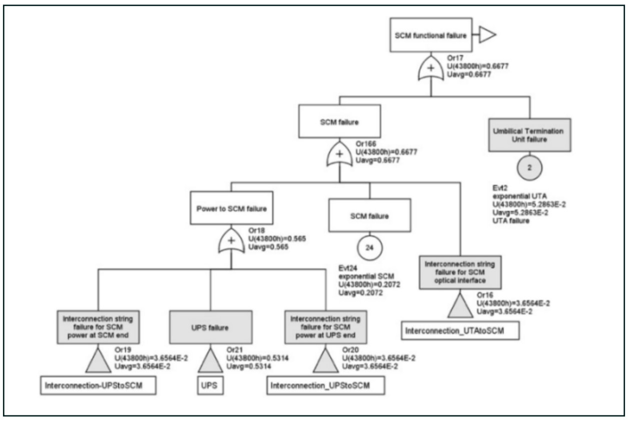


Figure.5. FTA for shore station to subsea system communication

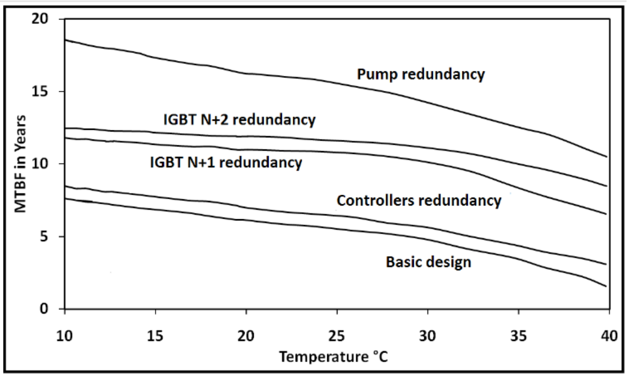


Figure.6. AFE-VSD performance at various ambient temperatures

As electrical and electronic control systems components cannot be exposed to direct seawater, they are kept inside nitrogen-filled pressure-rated metallic enclosures

number of redundant pumps required in a water injection LASS for achieving the required MTBF are summarised in **Table.3**.

Advantage of wet electronics

As electrical and electronic control systems components cannot be exposed to direct seawater, they are kept inside nitrogen-filled pressure-rated metallic enclosures. These systems produce heat due to winding and IGBT switching losses while in operation, and these results in the rise of the ambient temperature inside the dry enclosure. To maintain the internal temperature within safe limits, the heat produced has to be evacuated from the inside of the enclosure.

It is very crucial to maintain the temperature within the recommended limits (thermal management) as the internal ambient temperature is a deciding factor for the reliability and life of the internal systems. The failure rates of the VSD subsystems at various operating temperatures are computed based on FIDES and IEEE models (based on the physics of failure) and summarised in **Table.4**.

Thermal management studies involve building a thermal model and carrying out simulations to identify the thermal distribution inside the enclosure. Different cooling strategies adopted in the subsea industry include natural nitrogen convention, forced nitrogen convention, natural oil convention, forced oil and water cooling.

Figure.7 shows a nitrogen filled enclosure with forced water cooling for the high heat flux power electronics systems. The IGBT and VSD output sine filters are typical high heat flux components in subsea power conversion VSD. A pump is used for circulating the coolant water through jacketed components and the absorbed heat is dissipated in a shell and tube heat exchanger located external to the enclosure.

Nitrogen is also circulated using cooling fans inside the enclosure. The cooling system design is based on external sea water temperature, enclosure mechanical dimensions, nature of internal loads, quantity of heat to be dissipated, heat density of the loads, enclosure internal ambient temperature needs, cooling method, heat dissipation surface area availability and system MTBF requirements [8].

Thermal management studies involve building a thermal model and carrying out simulations to identify the thermal distribution inside the enclosure

Pressure compensation is a technique in which the metallic enclosure is filled with dielectric oil and the enclosure's internal oil pressure is maintained in equilibrium with the external seawater pressure by the use of hydraulic pressure compensators [9]. By means of pressure compensation, the enclosure thickness can be made independent of the water depth. However, a minimal thickness has to be ensured for structural integrity while handling.

Table.3. Redundancy requirements for LASS subsea pumps

Redundancies	Pumps essential (continues operation)	
	1	2
0	2 yrs	1.6 yrs
1	3 yrs	2 yrs
2	3.8 yrs	2.8 yrs
3	4.5 yrs	3.3 yrs

Share of LASSsubsystems to pumping operation failure :

UTA & Interconnections – 28%; Seals – 8 % ; Pump – 14% Transformers, Motors and Circuit breakers -7 %;

Control and communication electronics – 28%;

Power electronics- 14%.

Table.4. FIT of VSD components with ambient temperatures

Component/ Subsystem	FIT at			
	10°C	20°C	30°C	40°C
Discrete Components				
Al. elec. capacitors	0.2	0.3	0.8	1
Ceramic capacitors	1	1.2	2	3.2
Diodes	0.2	0.4	1	1.5
IC chips < 24 pin	0.3	0.5	0.9	2.9
Transistors	0.3	0.5	0.8	2.5
IGBT	0.5	0.6	1.5	65
Rectifier diode	30	120	160	225
Sine reactor	30	85	105	125
DC bus capacitor	25	50	75	100
Packaged Systems				
AC-DC SMPS 40W	65	116	230	329
IGBT Gate Driver	18	95	180	450
Microcomputer	800	1200	2000	4400

Pressure compensation is a technique in which the metallic enclosure is filled with dielectric oil and the enclosure's internal oil pressure is maintained in equilibrium with the external seawater pressure by the use of hydraulic pressure compensators

As cooling is implemented by the direct immersion of the electronic components in an oil medium, the temperature rise in the hot spots can be reduced significantly. Oil medium can handle heat flux density of up to 100W/m^2-k, compared to nitrogen which has a limit of up to 20W/m^2-k. As the ambient temperature in a deep-water environment is close to 2°C, PBOF offers a significant advantage in increasing the reliability of the electronic systems.

Further, as the enclosure thickness is comparatively lower, the thermal impedance between the internal oil and sea water is less, compared to its thick-walled counterparts. This ensures efficient heat transfer between the internal systems and sea water.

As the flooded fluid is an electrically insulating material, clearances between the electrical systems (such as bus bars) can be reduced considerably, resulting in a compact system compared to a nitrogen-filled system. Vibration dampening is also more effective in an oil-filled environment, compared to a nitrogen environment.

The major challenge lies in using electronic components in a dielectric PBOF environment, where the hydrostatic pressure experienced by the components is equal to the external seawater pressure. As an example, when a standard electrolytic 470µF, 50V capacitor (with a surface area of 3cm^2) is exposed to an ambient hydrostatic pressure of 300bar (the pressure at 3000m water depth), it experiences a buckling force of 900kg, which can result in implosion and damages.

This is now presently managed by categorising the components into pressure-tolerant and pressure-dependent. The pressure-dependent systems can be cased inside small volume pressure-rated enclosures and connected to the other systems through a pressure-rated feed-through.

Discrete components, including resistors, capacitors, transistors, optical devices and cables, oscillators and assemblies, such as gate drivers and amplifier circuits, are studied for behaviour under pressure. US Naval Research Laboratory and SINTEF of Norway were the forerunners in the study the behaviour electronic components and circuit breakers under hyperbaric conditions [10].

It is reported that that bulk carbon resistors showed a reduction in the values of up to 30%, while film resistors were pressure-tolerant. SINTEF studied the effects of exposing IGBT to high hydrostatic pressures, and it is indicated that filling the SF_6 gas-filled spaces with a dielectric fluid can render them pressure-tolerant.

As electrolytic capacitors are found to collapse with pressure, they experimented with film capacitors and found them to be suitable for application in operation in high hydrostatic pressure environments. Kubota et al., identified that ceramic capacitors are immune to pressure and canact as potential alternatives to the electrolytic capacitors.

Pittini and Hernes also studied the IGBT gate driver electronics board for pressure tolerance and found that optical components are unaffected because of short-term exposure to hydrostatic pressure [11].

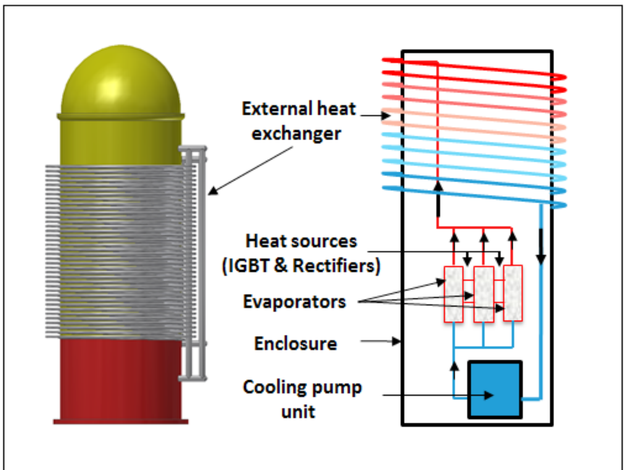


Figure.7. Forced water cooling in a subsea VSD

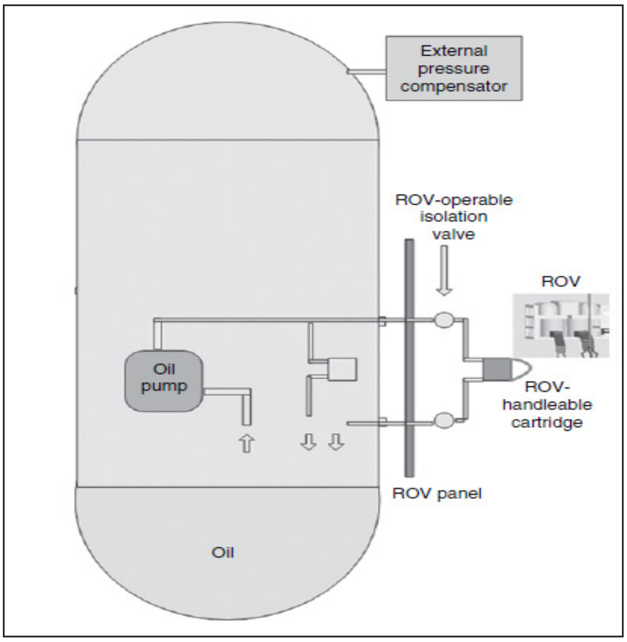


Figure.8. Failure of electronics components with temperature

Kampmann et al., compared the performances of 20MHz quartz-based oscillator with aceramic base, and micro-electro-mechanical system (MEMS)-based oscillator in a plastic package used for ROV manipulator embedded electronics. They observed that their oscillator output voltage amplitude fell to 60% and 80%, respectively, when subjected to a hydrostatic pressure of 600bar. However, no change in output frequency was observed.

The rendering shown in **Figure.8** indicates that in-situ conditioning of oil inside the PBOF enclosures could be done using ROV-operable PBOF zeolite-based molecular sieve cartridges. The enclosed internal pump could be used for pumping the oil through the cartridge at the required flow rate.

As the cartridge can be of PBOF, it can be used external to the enclosure, so that it can be replaced with the aid of a ROV and a wet-mate hydraulic connector interface. It is beyond doubt that with increasing activities in deeper waters, it is time for the global community to accelerate efforts in the development of pressure-tolerant electronics that are suitable for long-term reliable operation.

It is beyond doubt that with increasing activities in deeper waters, it is time for the global community to accelerate efforts in the development of pressure-tolerant electronics that are suitable for long-term reliable operation

Offshore Power Transmission

Electric power transmission to remote LASS hydrocarbon production fields and power transfer from offshore renewable power (wind and tidal) grids are realised using long step out electro-optic umbilical. The complexity of the power transmission increases with the length of umbilical.

The power transmission topology, voltage and frequency is decided based on the real power to be transmitted, cable reactive power consumption, load reactive power demands, cable size based on the cable current, allowable cable power losses and allowable voltage fluctuation at the receiving end.

Three topologies for offshore power transmission is shown in **Figure.9**. In topology (**Figure. 9 top)** is limited to 70MVA and 500kms, power transmission is done at the standard industrial frequency (50Hz/60Hz) with the transmission voltage depending on the step-out distance and the transmitted power.

The topology with low frequency AC (LFAC) transmission at 16 2/3 Hz (**Figure.9 middle**), is normally used in rolling stock applications is also applicable for step out up to 500kms and higher power levels. The reactive power requirements and the voltage drop in 16 2/3 Hz topology could be comparatively lower than those in 50Hz/60Hz topology.

The PoF of the subsea transmission system for both the topologies in a period of 5 years is 32 %, with a MTBF of 13 years. The topology with 16 2/3 Hz transmission (LFAC) requires extra cost, for a shore-based frequency converter and additional power transformer [6].

The Direct Current (DC) transmission topology (**Figure.9 bottom**) is applicable for higher power levels and very long step outs, usually >500kms. There is practically no reactive power demand from the shore station. The PoF of subsea DC transmission system in a period of 5 years is 78.8 % with an MTBF of 3.2 Years. The presence of the DC-AC converter in the subsea side is the reason for the reduced MTBF.

Modelling and simulations are performed in MATLAB to analyse the voltage regulation in a subsea AC power transmission cable of 100 km step out, transmitting 15 MW at 50 Hz frequency (with 3rd harmonics component of 10% of fundamental) and a cable capacitance of 0.1 µF / km.

From the results plotted in **Figure.10**, it is understood that, at lower power factors (lower active power load), the receiving end (subsea side) voltage will be higher than the transmission end voltage. This is called Ferranti effect. The power transmission network could be relieved

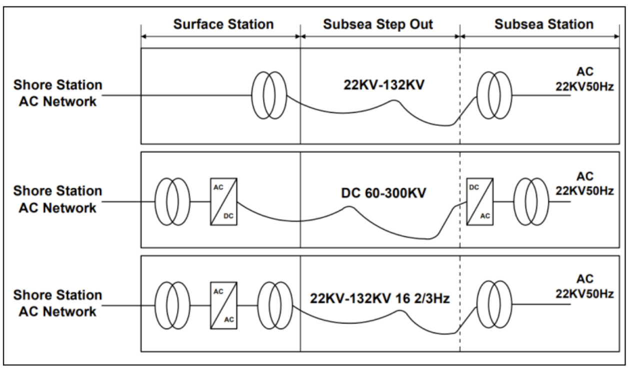


Figure.9. Subsea transmission topologies

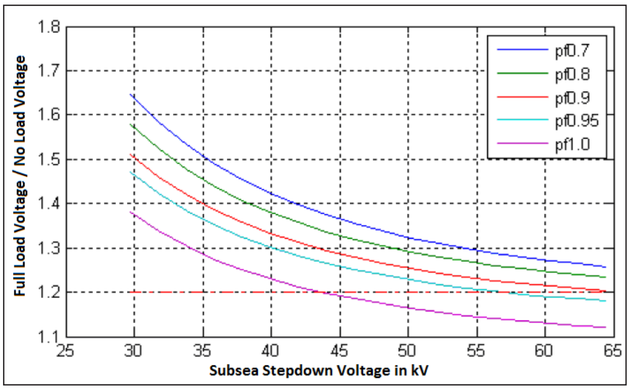


Figure.10. Voltage regulation in a long step out umbilical

from the reactive power demand, by using shore-based static reactive power (VAR) compensators.

The power transmission network could be relieved from the reactive power demand, by using shore-based static reactive power (VAR) compensators

Simulations have been performed to analyse the current variation in a subsea transmission cable for different voltages and loading patterns (power factor). It can be seen that at no-load, the total current is a function of cable reactive current (**Figure.11**).

Marine cable laying turntables and cable carousels are used to lay seafloor electric power cables (**Figure.12**). When the cable is laid, it has to be dispensed in the opposite rotation to take the twist out of the cable. The laid cables are buried in the seafloor and to backfill it totally with seabed material for protection against impact from trawling activities, anchors, heavy dropped objects, and ocean currents (**Figure.12**).

Safe and efficient trenching operations call for ROVs that can adapt to the seabed conditions (hard or soft silt) and bury cables and umbilicals to their required depth. Recent cable trenching systems have enough power to create a trench, provide simultaneous backfilling, and propel the trenching machine.

The electro-thermal modelling and simulations are to be carried out for subsea power cable based on finite element analysis approach to determine the cable ampacity when operated in water and buried in the seabed under the relevant ambient environmental conditions.

It is reported that, compared to the ampacity in air at 30 ºC, the ampacities in air, water with no flow condition and seabed buried conditions with a thermal conductivity of 0.8 W/m-k could be 1.37 times, 1.57 times and 1.5 times, respectively, at an ambient temperature of 5 ºC; and the same could be 1.13 and 1.36 and 1.31 times, respectively, at 20 ºC (**Figure.12**) [12].

Conclusion

RAMS studies based on field-failure data shall be of immense help in identifying a tradeoff between the capital investments, operating expenditure, redundancy requirements, system modularity and maintainability, as well as meet the stringent regulatory requirements.

By probabilistic reliability modelling and simulations using field-failure data, it is identified that, with redundant subsystems, the mean time between failure of a subsea enclosurised grid system processing the power generated by ten tidal turbines with alternating current and direct current take-off could be 8.5 years and 5.years, respectively.

Based on the present technological maturity, the subsea control module handling critical operations in a long step out all-subsea hydrocarbon boosting station could have a mean time to fail period of about 5 years.

The importance of using wet electronics in strategic applications is evident from the reliability analysis results that indicate the failure rate of a multi-megawatt variable speed drive could be reduced by half. The importance of voltage and current regulation in long step-out umbilical and the ampacity of buried seafloor cables are also discussed.

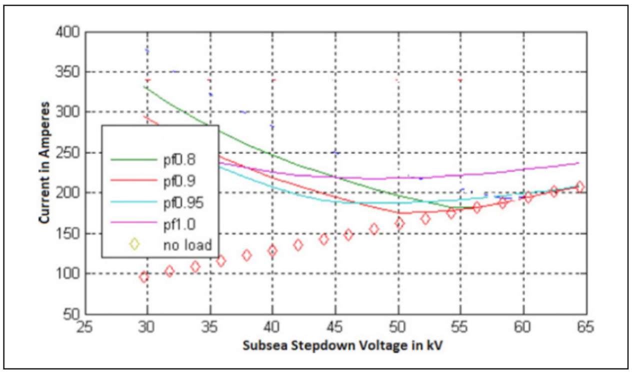


Figure.11. Current variation in a long step out umbilical

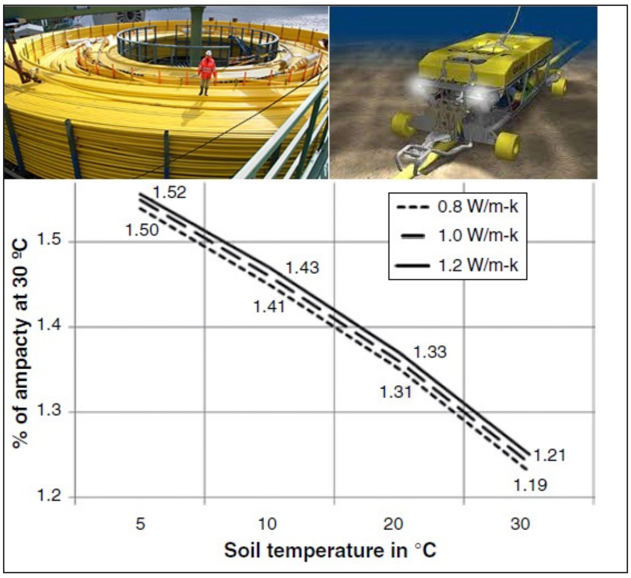


Figure.12. Laying of offshore umbilical using carousal, trencher ROV and ampacity of seafloor buried cables

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support extended by the Ministry of Earth Sciences, Government of India, in encouraging this work.

REFERENCES AND FURTHER READING

1. H.Chen at al, Attraction, Challenge and Current status of marine current energy,2018, Vol.6, IEEE Access, 10.1109/ACCESS.2018.2795708.

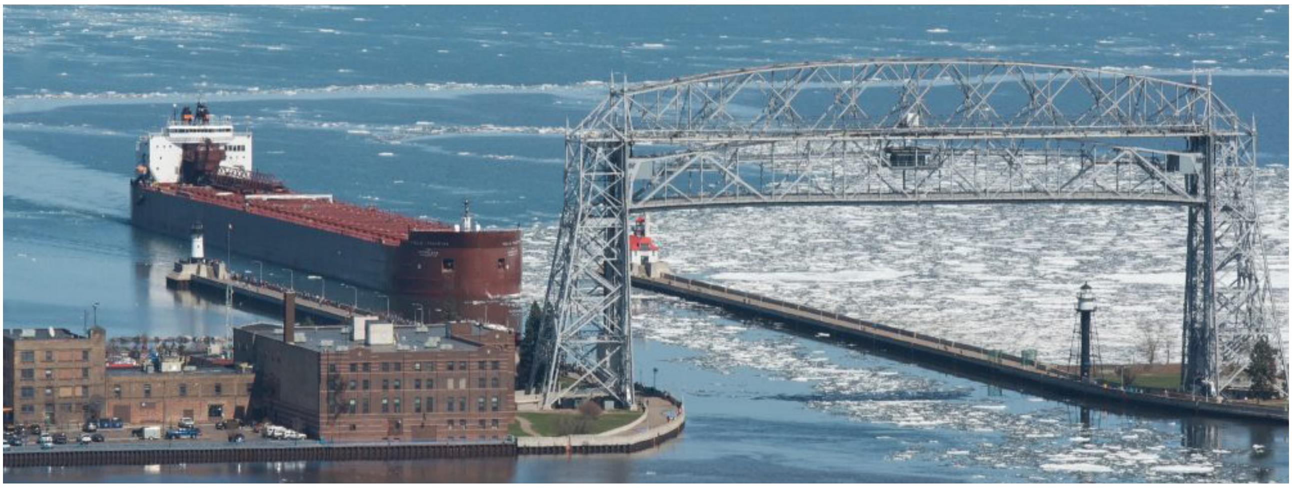
2. The Paimpol-Bréhat Tidal Turbine Farm, https://www.gepowerconversion.com/inspire/paimpol-br%C3%A9hat-tidal-turbine-farm-world-first-made-france.
3. N. Vedachalam and Bang-Andreasen, H., 2013, Challenges in realizing reliable subsea electric power grid for tidal energy farms, Marine Technology Society Journal, Vol.47, Issue 4, pp:80-93..
4. N. Vedachalam, S. Srinivasalu, R. Ramesh, A. Aarthi, G.A. Ramadass, M.A. Atmanand, 2015, Review and reliability modeling of maturing subsea hydrocarbon boosting systems, Elsevier- Journal of Natural Gas Science and Engineering, Vol 25, PP: 284-296.
5. N. Vedachalam, S. Muthukrishna Babu, G.A. Ramadass, M.A. Atmanand, 2014, Review of maturing multi-megawatt power electronic converter technologies and reliability modeling in the light of subsea applications, Elsevier- Applied Ocean Research, Vol.46, pp:28-39.
6. N. Vedachalam, 2013, Review of challenges in reliable electric power delivery to remote deep water enhanced oil recovery systems, Elsevier-Applied Ocean Research, Vol.43, pp: 53-67.
7. Enhanced Oil Recovery: An update review, 2010, Energies 2010, 3(9), 1529-1575; https://doi.org/10.3390/en3091529.
8. N. Vedachalam, 2014, A review of thermal and humidity management needs and feasible solutions for next generation subsea electric systems, Underwater Technology Journal, Vol.32, Issue 2, pp:129-143.
9. Mehnert TH. (1972). Handbook of fluid-filled, depth/pressure compensated systems for deep ocean applications. Deep Ocean Technology Program. Annapolis, Maryland: Naval Ship Research and Development Center, 292pp.
10. Pittini R and Hernes. M (2011). Pressure tolerant power electronics for deep and ultra deep water. OTC 21467. Offshore Technology Conference, 2–5 May, Houston, Texas.
11. Pittini R, Hernes M and Ljokelsoyk K. (2012). An IGBT gate driver for operation in a high pressure hydrostatic environments. Journal of Power and Energy Engineering 26:1500–1508.
12. Vedachalam, N., Umapathy, A., Ramadass, G.A. and Atmanand, M.A., 2017. Analysis of the influence of ambient conditions on the ampacity of Kevlar-armoured subsea power cables, Underwater Technology, 34 (2).

ABOUT THE AUTHOR

Dr. N. Vedachalam is currently Scientist G in Deep Sea Technologies division of National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, India. He is the technical lead for India's first indigenously developed deep-water manned scientific submarine MATSYA 6000. He holds a Bachelor's degree in Electrical and Electronics engineering from Coimbatore Institute of Technology (1995) and Ph D in Techno-economics of marine gas hydrates from College of Engineering - Anna University, India. His 27 years of experience include industrial power, process, offshore and subsea domains at Aditya Birla group, General Electric & Alstom Power Conversion in France. Technical exposure includes development of multi-megawatt subsea power and control systems for Ormen Lange subsea compression pilot; Ocean Thermal Energy Conversion and wave energy systems; subsea renewable power grids; unmanned and manned underwater vehicles; ocean observation technologies and industrial systems. His research interests include energy, subsea robotics and reliability. He has more than 100 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea processing. He is a recipient of the national meritorious invention award in 2019 for the development and usage of underwater robotic vehicles. He is a member of Indian Naval Research Board, member of Bureau of Indian Standards and was the Secretary of IEEE OES - India Chapter.

Email: veda1973@gmail.com

GREEN METHOD OF STEMMING THE TIDE OF INVASIVE MARINE AND FRESHWATER ORGANISMS BY NATURAL FILTRATION OF SHIPPING BALLAST WATER



Jebarathnam Prince Prakash Jeba Kumar, Shunmugavel Ragumaran, Ganesan Nandagopal, Vijaya Ravichandran, Ramana Murthy Mallavarapu, Thomas M. Missimer

Abstract

Marine and freshwater pollution caused by transport of invasive species in shipping ballast water is a major global problem and will increase in magnitude as shipping of commodities increases in the future. An economical method to preclude biological organisms in the seawater used for ballast is to exclude them at the source port. Integrated natural filtration using onshore wells or seabed gallery systems has been thoroughly investigated for use as pretreatment for seawater desalination systems and has proven to be environmentally acceptable and economic. Thus, the use of this proven filtration technology to another issue, ballast water treatment, is an innovative method of providing marine organism free seawater by non-destructive means in port-based facilities. This method is ecosystem-friendly in that no chemicals or destructive processes are used. Design and construction of well or seabed gallery intake systems for production of ballast seawater are feasible in virtually all global port facilities.

Keywords: Ballast water. Invasive species. Environmental impacts. Subsurface intake systems

Introduction

Seawater used for ballast typically contains numerous macroscopic and microscopic organisms, which are discharged into the oceans worldwide. Thus, ballast water disposal is believed to be a primary vector for the spread ofaquatic invasive species globally (Carlton 1985, 1999; Endresen et al. 2004; Takahashi et al. 2008; Tsolaki and Diamadopoulos 2010; Seebens et al. 2016; Carney et al. 2017; Seebens et al. 2017). Marine ship traffic is a critical part of the global economy by providing international delivery of goods and commodities. Each year between 3 and 5 billion metric tons of seawater are utilised as ballast water in shipping (Tsolaki and Diamadopoulos 2010). Global maritime traffic has been projected to increase 20-fold by 2050 to account for 80% of world trade, which could lead to a sharp rise in invasive species by 90% around the world if not controlled (Sardain et al. 2019).

The magnitude and diversity of marine organisms delivered in ballast water throughout the world include about 10,000 species transported between different biogeographic regions (Carlton 1999; Hewitt et al. 2009). Historical study of ship ballast water (freshwater) entering the North American Great Lakes revealed an average of 17 active species with varying densities of 10,000 to 8 billion individuals per vessel (Howarth 1981). Records of ballast water-mediated introductions and their threat to marine biodiversity, coastal economies, local cultures and livelihoods, and human health are well-documented by various studies (Sardain et al. 2019; Shimokawa 2012; Anil et al. 2002). Since the ballast water- transported species are alien to the new environment, they often cause harmful effects to the native biological community, thereby impacting economic and sociological conditions and establishing themselves as invasive species (ISs). In addition, there are also documented health effects based on the transport of disease-causing microorganisms, such as *Vibrio cholerae* (Takahashi et al. 2008).

The multiple impacts of ISs are recognised as major environmental threats to the marine and certain freshwater environments, causing predation and competition for food with native organisms and eutrophication in areas where discharge of ballast water containing dead organisms occurs (Halpern et al. 2008). Since the adoption of the Convention on Biological Diversity Strategic Plan for 2011-2020 by the International Union for Conservation of Nature (IUCN), there is traction on trying to achieve the realistic Aichi Target 9 of identifying invasive species and their pathways into nonnative environments. Priority invasive species in ballast water need to be controlled or eradicated, and measures must be implemented to manage pathways to prevent their introduction (Castro et al. 2018; Krishnamurthy et al. 2018; Mapari et al. 2018). Therefore, establishment of effective and economic technological methods to limit the invasive species menace is necessary.

The purpose of this research is to evaluate the use of subsurface intake systems as a source of filtered seawater or freshwater to eliminate the marco- and microorganisms from ballast water at ports where it is uploaded. This natural filtration technology using wells or galleries has been demonstrated to be cost-effective in the improvement of water quality (pretreatment) in seawater reverse osmosis desalination facilities. The use of well-developed engineering applications in one field to another problem is considered to be an innovation, and thus, the focus of this research is the application of this well-developed technology to treatment of ballast water.

Strategies for Control of Ballast Water Biological Contamination Control

There are three fundamental strategies that can be implemented to control the presence of invasive species in ship ballast water. First, the control measures can be implemented at the source where ballast seawater is pumped into the ship. Second, the ballast water can be treated within the ship before being discharged to the environment. Third, a combination of providing "clean" ballast at the source where it is pumped into the ship with later treatment to assure that no macroscopic species, ichthyoplankton, bacteria, or viruses can enter the environment during discharge.

Physical and chemical treatment methods (destructive)

The International Maritime Organization (IMO) is the United Nations (UN) specialist agency that is responsible for the safety and security of shipping and prevention of marine and atmospheric pollution by ships. It sets the standards for maritime transport that promulgates recommended control measures included in the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004). Because shipping is genuinely an international activity, the IMO sets technical standards and requirements regarding the regulatory control and management of ship ballast water and invasive species which are adopted by member states of the UN (IMO 2008a; IMO 2008b; IMO 2012). Many techniques that satisfy the IMO criteria are used to minimize or prevent the introduction of non-indigenous species into ballast water and to remove invasive species before discharge but be approved by the GESAMP-BWWG (IMO 2008b; IMO 2012; Tsolaki and Diamadopoulos 2010). The binding agreement established in 2004 mandated two management standards that should be applied as a choice of ballast water management. These standards are (1) standard D-1 on ballast water exchange that requires vessels to exchange their ballast water uploaded in coastal areas for ballast water from the open ocean "whenever possible 200 nautical miles from the nearest land and in the water at least 200 m in depth (Regulation B-4)" and (2) standard D-2 on ballast water performance that establishes water quality standards for ballast water treatment systems (BWTSs) (Gerhard et al. 2019).

Coarse filtration techniques are commonly used as an environmentally friendly method for ballast water treatment. Many multilevel filtration techniques do not have a significant effect on reducing microscopic planktonic organism concentrations in seawater pumped into the ship after debarking of cargo (Cangelosi et al. 2001; Cangelosi et al. 2014). The US Coast Guard does not specifically require some type of filtration in the treatment process but is commonly used in many treatment processes. Modern technology based, large-scale seawater filtration systems, like traveling water screens, used in coastal power plant intakes can effectively filter floatable debris and fish to reduce impingement and entrainment, but these coarse screens fail to screen ichthyoplankton, which consists of microscopic plankton, eggs, and larva of various fishes, prawns, and benthic organisms (Alimah and Parapak 2008; Jebakumar et al. 2018). Other techniques like mechanical separation and treatment include the use of ultraviolet radiation, heat treatmen, electric pulse applications, and chemical treatment were also adopted (Anil et al. 2002; Endresen et al. 2004; Tsolaki and Diamadopoulos 2010). These destructive methods eliminate most of the planktonic forms along with potential invasive species but leave behind contaminated seawater containing biodebris and changes of some dissolved organic carbon into assimilable organic carbon. In addition, excess oxidants and their chemical byproducts may be discharged into the marine environment, and larger debris generated would require disposal at a landfill or would have to be incinerated. Scientific documentation of invasive species worldwide indicates that insufficient mitigation efforts are being made to curtail spread of invasive species (Seebens et al. 2017). Hence, ballasting with seawater devoid of significant concentrations of life forms from the port is essential to minimise impacts from ISs.

Use of natural subsurface filtration systems at ballast water intake locations

Over the past 40 years, seawater desalination has become an integral part of water supply strategies in many parts of the world, and the reverse osmosis process is the leading technology in terms of efficiency and cost (Ghaffour et al. 2013; Amy et al. 2017). Unfortunately, seawater contains an abundance of organic materials and compounds that collectively cause biofouling of the primary membranes, despite extensive pretreatment of the raw water (Flemming 1997; Vrouwenvelder et al. 1998). In recent years, considerable research has been conducted on the use of subsurface intakes to remove organic macroscopic debris, algae, and bacteria. These natural filtration-based intakes also remove significant parts of the smaller-sized organic matter, including transparent exopolymer particles and the biopolymer fraction of natural organic matter (Missimer 2009; Missimer et al. 2013; Rachman et al. 2014; Dehwah et al. 2015; Dehwah and Missimer 2016; Dehwah and Missimer 2017). This technology uses either shallow wells located adjacent to the shoreline or some type of gallery intake and has been used successfully to remove organic materials from the raw seawater that allows seawater reverse osmosis desalination plants to operate more economically with addition of chemicals (e.g., chlorine) and less cleaning of the membranes (Missimer et al. 2015). This technology could also be used to pretreatment ship's ballast to remove invasive species.

Use of combined subsurface filtration for ballast source with treatment before discharge

Subsurface intake systems remove all of the macroscopic forms of carbon but only some percentage of the bacteria (Dehwah and Missimer 2016, 2017). The bacteria that are not removed may be only the very small-sized genera known as ultramicrobacteria (Cavicchioli and Ostrowski 2003). Therefore, if potential pathogens are suspected of occupying the source ballast water, then disinfection of the water could be performed prior to final discharge only if necessary. The need to disinfect the ballast water could be eliminated by monitoring of the subsurface source water bacteria prior to using it for ballast. If no pathogenic bacteria or viruses are found, then there would be no reason to disinfect the source water. If deep water well intakes are used, it would be highly unlikely that the source water would contain any pathogens.

Assessment of the technical feasibility and effectiveness of subsurface filtration for ballast water treatment

There are two aspects concerning the feasible use of subsurface intake technology to obtain "clean" ballast water. First, the issue concerning whether the geology near a port facility will allow the development of a well system or some type of gallery intake system. The presence of some type of aquifer is necessary for well development with yields sufficient to meet the ballast water demands. If a productive aquifer is not located near the port facility or the aquifer transmissivity is too low, then a seabed gallery or beach galley could be constructed instead of wells. Second, the intake type developed must provide a reliable supply of seawater that will effectively prevent the movement of invasive biological forms from the source water to the discharge location.

Well intakes where the geology is favorable

A number of different well designs are available for use where there are permeable sediments at shallow deeps near a port location. Three designs are shown in **Figure. 1**, with the most common one being the conventional vertical well (**Figure. 1a**). A slant well can be used, as shown in **(Figure. 2b)**, but this design necessitates the use of specialised well drilling equipment that may not be present in some areas of the world. However, this design allows the well to be constructed at some distance from tidal seawater. Another well type is the Ranney well which also is a specialized type of well but can yield large quantities of seawater up to 50,000 m3/day/well (**Figure. 1c**) (Missimer et al. 2013). Two key issues in the design of these intake wells are that they must be hydraulically connected to the sea and are located away from any sources of groundwater contamination that could provide water quality issues at the point of ballast water discharge. Detailed design methods for well systems located near the shoreline are described in Missimer (2009), Maliva and Missimer (2015), and Williams (2015).

A review of major port locations where large oil tanker ships take on ballast water is provided by Endresen et al. (2004) (**Figure. 2**). Based on these shipping port locations, most of them have acceptable geology nearby that would allow successful development of well intake systems.

Measurements of the organic matter transport in well intake systems have been conducted at several locations around the world (Missimer 2009; Missimer et al. 2013; Rachman et al. 2014; Dehwah et al. 2015; Dehwah et al. 2016; Dehwah and Missimer 2016; Dehwah and Missimer 2017). Select data on the removal of combined algae and cyanobacteria and marine bacteria from these investigations are summarised in **Table 1**, and additional data are provided in the reference papers. In most cases, well intakes remove 100% of the algae (and ichthyoplankton) from the seawater when comparing the concentration in the raw seawater to that measured in the well discharge. Since the cyanobacteria are relatively small in size compared with the major algae, they can be used as a proxy for other pathogens of similar size in freshwater systems. There is also effective removal of marine bacteria with an efficiency range from 84.0 to 99.8%. The removal percentage increases with the seawater flow path length from the seabed to the well locations (Dehwah et al. 2016; Dehwah and Missimer 2016). Therefore, well intake systems are quite effective in the removal of biological organisms as small as marine bacteria. It is believed that the bacteria that pass through well filtration (and reverse osmosis membranes) are the ultramicrobacteria, which have a cell volume of <0.1 ftm^3. (Cavicchioli and Ostrowski 2003). These oligotrophic marine bacteria constitute a large percentage of the

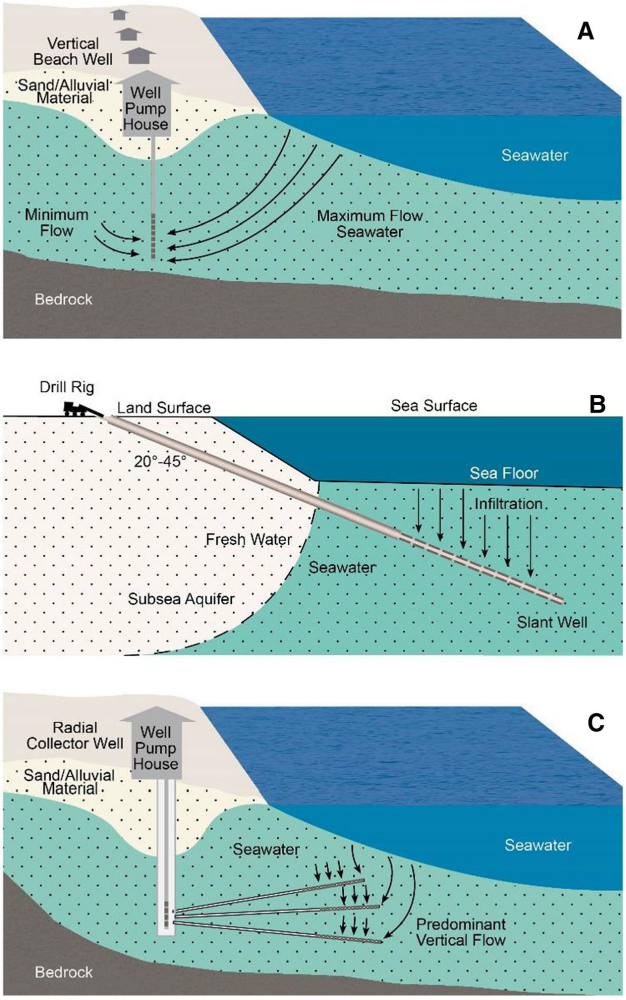


Fig. 1 Well, intake designs for obtaining ballast water. **a)** Conventional vertical well located near tidal water (or a beach). **b)** Angle well that can be constructed at some distance from the shoreline. **c)** Ranney well that would need to be constructed on the beach.

bacteria in the sea. In addition, they may be resistant to chlorination. The sampling and analytical methods used in the referenced investigations are included in the cited references.

Engineering and cost aspects of well filtration systems

There is an extensive amount of literature on use of wells to provide filtered water to desalination plants, some of which have high capacity. The largest capacity using wells for a seawater reverse osmosis water treatment plant is currently about 160,000 m^3/d at Sur Oman, and the largest capacity seawater gallery has a yield of 103,000 m^3/d that is located at Fukuoka, Japan (Missimer et al. 2013). However, it is not difficult to build these facilities at much higher capacity.

The estimated capital cost for the construction of treatment facilities using well filtration can be estimated based on existing desalination plant costs. A series of cost curves for the investment costs for SWRO desalination plants were developed by Ghaffour et al. (2013), which included intake costs. Based on a wellfield capacity of 100,000 m^3/d capacity, the investment cost would range between \$50 and \$200/m^3. This is directly applicable to systems used to develop ballast water and is based on the aquifer characteristics at the specific port site. Also, as the capacity increase, the cost tends to decline.

Because of the small size of the bacteria discharged from seawater wells, the removal of target classes of marine organisms of concern in ballast water is achieved. Based on the range of sizes of the groups considered within the D-2 standard under the IMO (2012) standards, all of these classes would be removed with no pathogenic bacteria remaining in the filtered water (**Table 2**). The size

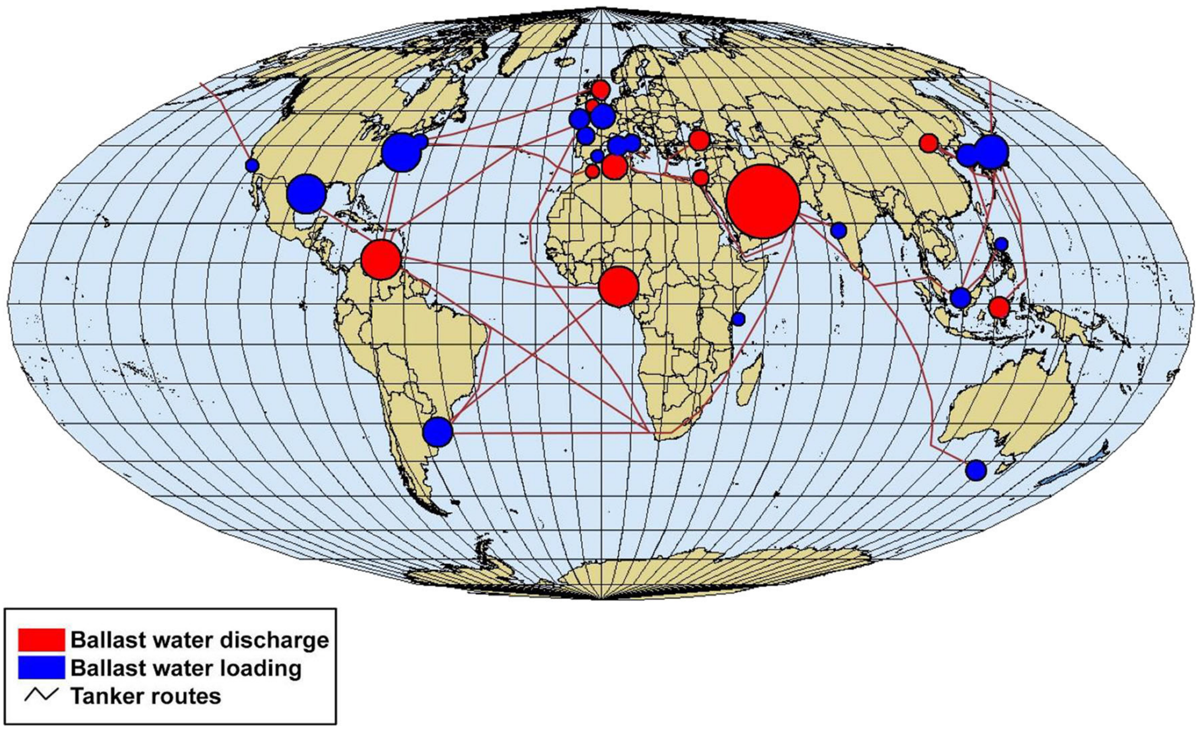


Fig. 2 Locations of oil tanker shipping ports where ballast water is loaded and discharged (modified from Endresen et al. 2004).

of microorganisms being discharged from well systems is commonly under 1 µm in diameter and likely occurs in the ultramicrobacteria size of 0.02 to 0.1 µm range.

Table 1. Representative effectiveness of combined algae and cyanobacteria and marine bacteria removal by well intake systems ([1]Dehwah and Missimer 2016; [2]Dehwah et al. 2016; [3]Rachman et al. 2014)

Location	Algae		Bacteria	
	Original number	Percent removed	Original number	Percent removed
1North Obhor, S.A.	Number/mL	(%)	Cfu/mL	(%)
Well 1	129,738	100	520,350	98.9
Well 2	129,738	100	520,350	97.5
Well 3	129,738	100	520,350	98.4
Well 4	129,738	100	520,350	97.9
1Coniche, Jeddah, S.A.				
Well 1	89,033	100	254,450	91.8
Well 2	89.033	100	254,450	90.3
Well 3	89,033	100	254,450	90.0
Well 4	89,033	100	254,450	80.5
1South Jeddah, S.A.				
Well 1	49,923	98.3	216,400	94.5
Well 2	49,923	99.5	216,400	89.0
Well 3	49,923	98.4	216,400	84.4
Well 4	49,923	99.8	216,400	84.6
2North Obhor, S.A. #2				
14 wells	129,738	100	520,350-1,356,600	97 avg.
3Sur, Oman				
Well SR1b	194,310	100	702,609	99.3
Well SR2b	194,310	100	702,609	99.8
Well SR3b	194,310	100	702,609	99.6
Well SR4b	194,310	100	702,609	99.3
Well SR5b	194,310	100	702,609	99.6

In addition, the organic chemistry of the discharge water from wells and seabed galleries is lower than the IMO standard D2 (**Table 3**).

The filtered water could be delivered to the ships with installed infrastructure at the port or could be conveyed under the seabed via pipelines to anchorage points. A design concept for the delivery of the filtered water is shown in **Figure. 3**.

Well filtration systems are environmental friendly in that they occur in locations near beaches and can be installed in a manner to make them part of the onshore coastal infrastructure. For example, numerous water supply wells are used at many resort island environments without causing environmental impacts (Missimer et al. 2013; Rachman et al. 2014). In addition, well systems occurring immediately adjacent to tidal water cannot cause saltwater intrusion into freshwater aquifers because no freshwater occurs between tidal water and the wells. Two water volume scenarios have been suggested for port treatment facilities which are (1) a treatment capacity of 2000 m^3/h, onsite storage of 25,000 m^3, and a residence time of 24 h and (2) 20,000 m^3/h, onsite storage of 25.000 m^3, and a residence time of 24 h (National Academies Press 1996).

These installed capacities can be met on the low side by a well system based on existing systems used by SWRO desalination intakes (Sur, Oman well system, installed capacity of 160.000 m^3/d) and on the high side by a seabed gallery system which has essentially unlimited capacity (Dehwah and Missimer 2017).

Seabed gallery intakes where the geology for well intakes is unfavorable

In some port locations, the geology of the adjacent shoreline or beneath the port may be unfavorable for the successful development of a well intake system. In these areas, a seabed gallery could be developed to

Table 2. IMO/USCG ballast water performance standard D2 sets the limits of active organisms as shown

Microorganism category	Control limit
Viable/living organisms, size > 50 pm	<10 viable/living cells/m^3
Viable/living cells, size 10–50 pm	<10 viable/living cells/mL
Toxicogenic Vibrio cholerae	< 1 colony-forming unit/100 mL
Escherichia coli	< 250 colony-forming units/100 mL
Intestinal enterococci	< 100 colony-forming units/100 mL

Table 3. Suspended solids and organic concentration standard under IMO/USCG ballast water performance standard D2

	Salinity		
	Marine 28-36 PSU	Brackish 10-20 PSU	Fresh < 1 PSU
Dissolved organic carbon (DOC)	> 1 mg/L	> 5 mg/L	> 5 mg/L
Particulate organic carbon (POC)	> 1 mg/L	> 5 mg/L	> 5 mg/L
Total suspended solids (TSS)	> 1 mg/L	> 50 mg/L	> 50 mg/L

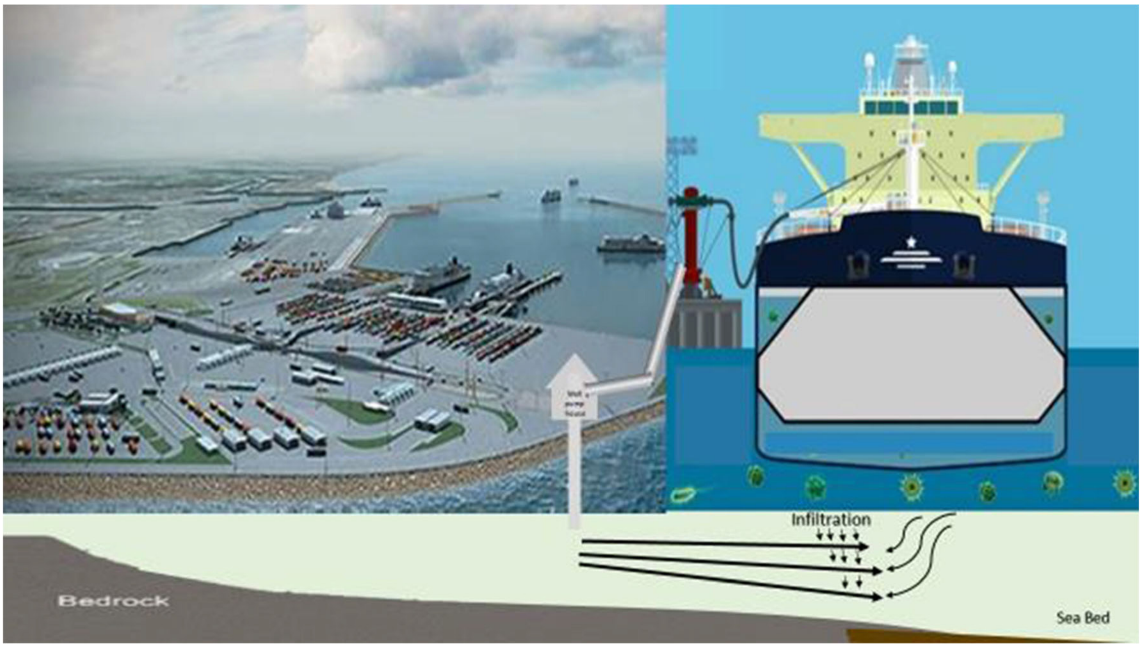


Fig. 3 Schematic diagram of the use of well filtration systems on seabed infiltration galleries to supply ship ballast water. Note that pipelines and storage tanks would be installed adjacent to the docking facilities.

obtain seawater free of algae and a high percentage of marine bacteria. Since the flow pathway through a seabed gallery system is generally less than a well system, the removal of bacteria is not as effective in terms of overall percentage (Dehwah and Missimer 2017). Experimental work conducted by Dehwah and Missimer (2017) verified that 100% of the algae are removed in the filter and up to 84% of the marine bacteria are removed. They also found that the initial removal percentage of bacteria could be as low as 50%, but increased as the filter matured, which could take up to several months of operation. This finding was similar to that found in a large-scale operating seabed filter in Fukouka, Japan, where the silt density index of the filtered seawater improved significantly over 12 years of operation (**Figure. 4**; Hanamo et al. 2006; Shimokawa 2012). The design criteria for seabed gallery systems are discussed in detail by Missimer et al. (2015). This type of intake can be constructed near the shoreline or offshore depending on localised conditions, such as the sedimentation rate.

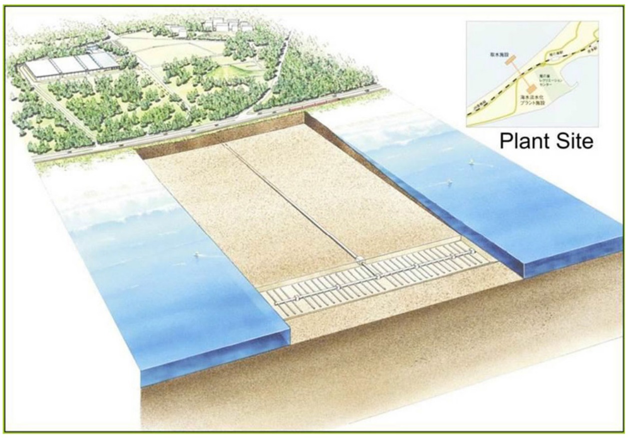


Fig. 4 Seabed filter design of the 103,000 m3/day seabed gallery system used as a seawater intake for the Fukuoka, Japan desalination plant (from Hanamo et al. 2006). The system has been operating for more than a decade with no issues such as clogging.

Discussion

In science and engineering, technology that has been developed and applied for another purpose can be used to solve other environmental or engineering problems which is considered to be an advancement and an innovation. An example of this concept is the development of advanced oxidation technology to treat industrial wastewater for reuse in manufacturing facilities (Rojas et al. 2010). The process facilitated reuse of water and caused a reduction in the overall water consumption. This technology has been applied in recent years to the removal of trace concentrations of emerging contaminants (Tufail et al. 2020).

Natural filtration technology using wells or seabed gallery systems was successfully developed and tested for pretreatment of seawater in the desalination process. This same technology can be applied to filter seawater through wells (aquifer treatment), or seabed galleys can be used to provide high- quality seawater to be used as ballast in ships at most port facilities. This filtered water is essentially free from harmful marine or freshwater organisms. There are, however, some infrastructure issues at large ports that must be considered in design of ballast water supply systems. The engineering design will require an initial assessment of the water volumes required and the support water storage and pipelines required for delivery of water to the ships. Individual well yields are based on site-specific aquifer hydraulic properties, and the number of wells and their location would have to be coordinated with the other infrastructure. Some port locations (e.g., Port of Miami) would have no issue with development of very high yield wells which could

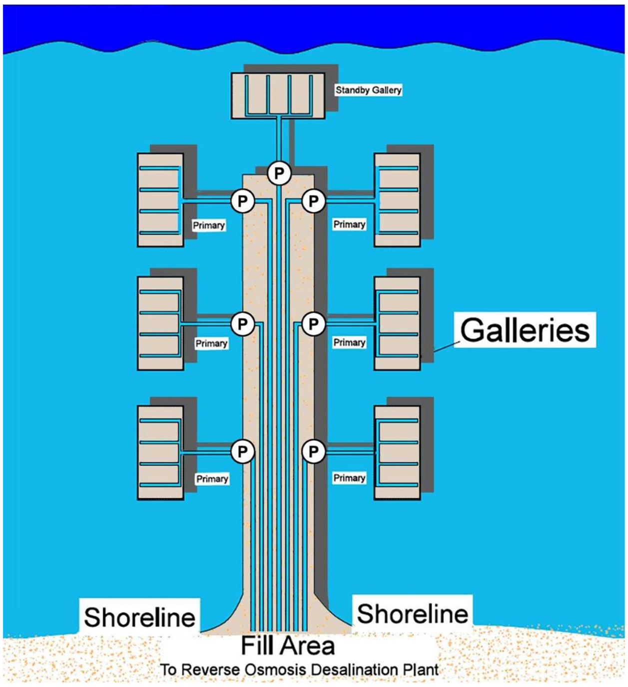


Fig 5. Example of a seaport gallery system that could be installed adjacent to the docks of a port facility (from Missimer et al. 2015).

preclude the need for tank storage, because of the very high transmissivity of the underlying Biscayne aquifer.

There will be locations where well yields are insufficient to meet the needs of the overall ballast water requirements. At these locations, a seabed filter system would be the best design solution because systems can be designed to meet any potential water volume required (Missimer et al. 2015). An example of a very large-scale seabed gallery system is shown in **Figure. 5**. This was initially designed to supply a high-capacity seawater reverse osmosis desalination plant, but could be easily modified to operate in a port facility, perhaps directly adjacent to docks and beneath ships. The top of the filters would have to be periodically cleaned using a mini dredge to remove 10 to 20 cm of sediment. The cleaning time would be dependent on the turbidity of the water at the facility. This issue would be evaluated during the design of the system.

As shown in the data from operating well intake systems, all of the algae (including marcoscopic ichthyoplankton) are removed in the filtration process. However, not all of the marine bacteria are removed, which may not be problematical because most of them are very small and not pathogenic. If this is an issue, some chlorination could be used in the storage tanks at the ports to remove any remaining bacteria. Proper environmental investigations should be conducted before disinfection is considered.

Conclusions

Transport of invasive species in ballast water (3 to 5 billion tons per year) used in shipping from one location to another has caused considerable environmental harm over the past century. It is proposed that the seawater pumped onto ships as ballast should be pretreated using a natural subsurface filtration process, a technology initially developed to improve seawater desalination plant performance. Two environmentally friendly filtration methods, wells or galleries, can be used to provide "clean" seawater, devoid of both macroscopic (algae and ichthyoplankton) and microscopic living marine organisms. Both methods provide the necessary pretreatment without the use of chemicals (i.e., chlorine) and/or expensive post-treatment of the ballast water before discharge. This technology has been thoroghly researched in desalination applications in terms of effectiveness for removal of particulate matter, algae, and bacteria. It has direct application to balast water treatment.

References

1. Alimah S, Parapak B, (2008). Study of intake technology for the condenser coolant and desalination plant of NPP. J Pengembangan Energi Nuklir 10(1):11–19.
2. Amy G, Ghaffour N, Li Z, Francis L, Linares RV, Missimer TM, Lattemann S, (2017). Membrane-based seawater desalination: present and future prospects. Desalination 401:16–21.
3. Anil AC, Venkat K, Sawant SS, Dileepkumar M, Dhargalkar VK, Ramaiah N, Harkantra SN, Ansari ZA (2002) Marine bioinvasion: concern for ecology and shipping. Curr Sci 83(3):214–217.
4. Cangelosi AA, Knight IT, Balcer M, Wright D, Dawson R, Blatchley C, Reid D, Mays N, Taverna J, (2001). Great lakes ballast technology demonstration project biological effectiveness test program (includes MV Regal Princess trials) Proc., IMO 1st Inter Ballast Water Treatment R&D Symposium, London, UK, March 26–30, 2001 88–94.
5. Cangelosi AA, Aliff M, Allinger L, Balcer M, Beesley K, Fanberg L, Hagedorn S, Mangan T, Marksteiner A, Mays N, Polkinghorne C, Prihoda K, Reavie E, Regan D, Ruzycki E, Saillard H, Schaefer H, Schwerdt T, Stoolmiller M, TenEyck M, (2014). Land-based performance evaluation in ambient and augmented Duluth-superior harbor water of eight commercially available ballast water treatment system filter units. Great Ships Initiative, Northeast-Midwest Institute, Washington.
6. Carlton JT, (1985). Trans-oceanic and interoceanic dispersal of coastal marine organisms - the biology of ballast water. Oceanogr Mar Biol 23:313–371.
7. Carlton JT, (1999). The scale and ecological consequences of biological invasions in the world's oceans. In: Sandlund OT, Schei PJ, Viken A (eds) Invasive species and biodiversity management. Kluwer Academic Publishers, Dordecht, pp: 195–212.
8. Carney KJ, Minton MS, Holzer KK, Miller AW, McCann LD, Ruiz GM, (2017). Evaluation the combined effects of ballast water management and trade dynamics on transfers of marine organisms by ship. PLoS One 12(3):e0172468. https://doi.org/10.1371/journal.pone. 01722488.
9. Castro MCT, Hall-Spencer JM, Poggian CF, Fileman TW, (2018). Ten years of Brazilian ballast water management. J Sea Res 133:36–42.

10. Cavicchioli R, Ostrowski M, (2003). Ultramicrobacteria. In: Encyclopedia of life sciences. Macmillian Publishers Ltd, Neture Publishing Company, London.
11. Dehwah AHA, Missimer TM, (2016). Subsurface intake systems: green choice for improving feed water quality at SWRO desalination plants, Jeddah. Saudi Arabia Water Res 88:216–224 Dehwah AHA, Missimer TM (2017) Seabed galley intakes: investigation of the water pretreatment effectiveness of the active layer using a long-term column experiment. Water Res 121:95–108 Dehwah AHA, Li S, Al-Mashharawi S, Winters H, Missimer TM (2015) Changes in feedwater organic matter concentrations based on intake type and pretreatment processes at SWRO facilities, Red Sea, Saudi Arabia. Desalination 360:19–27.
12. Dehwah AHA, Al-Mashharawi S, Ng KC, Missimer TM, (2016). Aquifer treatment of sea water to remove natural organic matter before desalination. Groundwater 55(3):316-326 Endresen 0, Behrens HL, Bryestad S, Andersen AB, Skjong R (2004) Challenges in global ballast water management. Mar Pollut Bull 48: 615–623.
13. Flemming H-C, (1997). Reverse osmosis membrane biofouling. Exp Therm Fluid Sci. 14:382–391.
14. Gerhard WA, Lundgreen G, Drillet G, Baumler R, Holbech H, Gunsch CK, (2019). Installation and use of ballast water treatment systems - Implications for compliance and enforcement. Ocean & Coastal Management 181. https://doi.org/10.1016/j.ocecoaman.2019.104907.
15. Ghaffour N, Missimer TM, Amy G, (2013). Technical review and evaluation of the economics of desalination: current and future challenges for better water supply stability. Desalination 309:197–207.
16. Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R, (2008). A global map of human impact on marine ecosystems. Science 319(5865):948–952.
17. Hanamo T, Tsuge H, Goto T, (2006). Innovations perform well in first year of operation. Desalination Water Treat 16(1):31–37
18. Hewitt CL, Gollasch S, Minchin D, (2009). The vessel as a vector—bio- fouling, ballast water and sediments. In: Rilov G, Crooks JA (eds) Biological invasions in marine ecosystems: ecological, management, and geographic perspectives. Springer-Verlag, Berlin, pp 117–131.
19. Howarth RS, (1981). The presence and implication of foreign organisms in ship ballast waters discharged into the Great Lakes. In: Casson DM, Burt AJ, Joyner AJ, Heinermann P (eds) Bio-Environmental Services LTD. The Water Pollution Control, Directorate Environmental Protection Service Environment Canada, Georgetown, pp 1–97.
20. International Maritime Organization (IMO) (2004). International convention for the control and management of ships' ballast water and sediments. International Maritime Organization, London International Maritime Organization (IMO) (2008a) Guidelines for approval of ballast water management systems (G8). Resolution MEPC174(58).
21. International Maritime Organization (IMO) (2008b). Procedure for approval of ballast water management systems the make use of active substances (G9). Resolution MEPC169(57).
22. International Maritime Organization (IMO) (2012). Methodology for information gathering and conduct ofwork of the GESAMO-BWWG, BWM.2/Circ13/Rev. 1.
23. Jebakumar JPP, Nandhagopal G, RajanBabu B, Ragumaran S, Ravichandran V, (2018). Impact of coastal power plant cooling system on planktonic diversity of a polluted creek system. Mar Pollut Bull 133:378–391.
24. Krishnamurthy V, Sawant S, Anil AC, (2018). Ballast water risk assessment: the Indian experience. ASEAN J Sci Technol Dev 35(1-2): 25–30.
25. Maliva RG, Missimer TM, (2015). Well intake systems: design and limitations. Chapter 8. In: Missimer TM, Jones B, Maliva RG (eds) Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Systems: Innovations and Environmental Impacts. Springer International Publishing, Cham, pp. 147–162.
26. Mapari KE, Krishnamurthy V, Anil AC, (2018). Role of reporting in compliance monitoring and enforcement of ballast water management. ASEAN J Sci Technol Dev 35(1-2):49–52
27. Missimer TM, (2009). Water supply development, aquifer storage, and concentrate disposal for membrane water treatment facilities, 2nd. Schlumberger, Sugar Land.
28. Missimer TM, Ghaffour N, Dehwah AHA, Rachman R, Maliva RG, Amy G, (2013). Subsurface intakes for sweater reverse osmosis facilities: capacity, water quality improvement, and economics. Desalination 322:37–51.
29. Missimer TM, Dehwah AHA, Lujan L, Mantilla D, Al-Mashharawi S, (2015). Feasibility and design of seabed galley intake systems along the Red Sea coast of Saudi Arabia with discussion of design criteria and methods, Chapter 11. In: Missimer TM, Jones B, Maliva RG (eds) Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Facilities: Innovations and Environmental Impacts. Springer International Publishing, Cham, pp 215–250.
30. National Academies Press (1996). Stemming the tide: controlling introductions of nonindigenoue species by ship's ballast water. The National Academies Press, Washington.
21. Rachman RM, Li S, Missimer TM, (2014). SWRO feed water quality improvement using subsurface intakes in Oman, Spain, Turks and Caicos, and Saudi Arabia. Desalination 315:88–100.
32. Rojas MR, Perez F, Whitley D, Arnold RG, Saez AE, (2010). Modeling of advanced oxidation of trace contaminants by hydrogen peroxide photolyis and Fenton's reaction. Ind Eng Chem Res 49(22): 11331–11343.
33. Sardain A, Sardain E, Leung B, (2019). Global forecasts of shipping traffic and biological invasions to 2050. Nature Sustainability 2:274–282. https://doi.org/10.1038/s41893-019-0245-y.
34. Seebens H, Schwartz N, Schupp PJ, Blasius B, (2016). Predicting the spread of marine species introduced by marine shipping. Proc Natl Acad Sci 113:5646–5651.
35. Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pysek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grapow L, Dawson W, Dullinger S, Fuentes N, Jager H, Kartesz J, Kenis M, Kreft H, Kuhn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Stajerova K, Tokarska-Guzik B, van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F, (2017). No saturation in the accumulation of alien species worldwide. Nat Commun 8:14435.
36. Shimokawa A, (2012). Fukuoka district desalination system with some unique methods. Proceedings of the International Desalination Workshop on Intakes and Outfalls. National Centre of Excellance in Desalination. Adelaide, Australia, May 16–17, 2012.
37. Takahashi CK, Lourenco NGGS, Lopes TF, Rall VLM, Lopes CAM, (2008). Ballast water: a review of the impact on the world public health. J Venom Anim Toxins incl Trop Dis 14(3):393–408. https:// doi.org/10.1590/S1678-91992008000300002.
38. Tsolaki E, Diamadopoulos E, (2010). Technologies for ballast water treatment: a review. J Chem Technol Biotechnol 85:19–32.
39. Tufail A, Price WE, Hai FI, (2020). Acritical review on advanced oxidation of trace organic contaminants: a voyage from individual to integrated processes. Chemosphere:260. https://doi.org/10.1016zj.chemosphere,2020.127460.
40. Vrouwenvelder HS, van Passen JAM, Folmer HC, Hofman JAMH, Nederlof M, van der Kooij MD, (1998). Biofouling of membranes for drinking water production. Desalination 118(1-3):157–166.
41. Williams DE (2015) Slant well intake systems: design and construction. Chapter 13. In: Missimer TM, Jones B, Maliva RG (eds) Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Systems: Innovations and Environmental Impacts. Springer International Publishing, Cham, pp. 275–320.

Author's email: tmissimer@fgcu.edu;
prince.niot@gov.in

This paper is a reprint of the first publication in Environmental Science and Pollution Research (2021) 28:5116-5125.
https://doi.org/10.1007/s11356-020-10839-4.

THE TRIPLE ZERO POSITIVE APPLIANCE: EXHAUST GAS THERMO ELECTRIC GENERATOR (*TEG*) FOR GREEN ENVIRONMENT

Hare Ram Hare, P. Ravichandra, Shrikrishna S Prabhu, Utkarsh Jaiswal, Naman Aggarwal, Chum Bikomiyo Deori

ABSTRACT

Exhaust/Flue gases from the main engine on board ship possess significant thermal energy. The energy, if recovered, can be utilised to generate substantial amount of power. Heat recovery by using a heat exchanger results in additional pressure drop and is not preferred.

An alternate way is to analyse a vertically fitted ***Thermoelectric generator (TEG)*** *in the exhaust pathway of a vessel for power generation. TEG's work on the principle of* ***Seebeck effect*** *in which due to temperature gradient between two electrically conductive metals / alloys/ semiconductors, flow of electrons take place which generate electricity. The TEGs in conjunction with the main can be used at immediate machinery exhaust (Incinerators, boilers etc.) which will act as if two generators are acting in series* ***(Thury system of connection)*** *and additional output can be expected. The output power can be used to power low energy requirement applications such as electric control panels of a machinery, panels in engine control room (ECR) which will make it* ***self-sustaining*** *at running hours, various sensors which require micro/ milli amperes of current and many other devices. The energy can also be stored in batteries for battery powered operations. This in turn will reduce the o/p demand of the generator by significant extent thus saving fuel for running the generator. This* ***one-time investment*** *in the installation of this system of electricity generation has* ***minimal maintenance****,* ***zero emissions,*** *which makes it environment friendly.*

Keywords: Thermoelectric generator, Seebeck effect, Thury system

1. INTRODUCTION

Rising need for sustainable use of resources have forced the organisations to opt for various **renewable**, **non-polluting** and **efficient sources of energy**. Harnessing the waste energy from the effluents emitted by the machinery and utilising it for running system accessories, subsystems which would reduce the load on the power generating consoles, leading to savings on fuel and capital. With this aim, **TEG's (Thermoelectric generator)** were adopted in various industrial sectors like power plants, automobiles etc. These are one of the few methods to harness waste energy into productive ones. On-board ship, energy is lost in the form of exhaust heat. Recent study shows that the ship's exhaust has capability to generate **6.2 MW** of energy which is pretty large. Thus, the use of TEG's can help in reviving some part of this waste energy and can be utilised for reduction in consumption of fuels and subsequently emissions.

2. TEG: The Core

Thermoelectric Generator (TEG), a stationary device with no moving parts generates electricity on the principle of **Seebeck effect (Figure 1)**. The principle on which TEG's work was discovered by **Thomas Johann Seebeck**, a German physicist which states that an emf is generated between two electrically conducting metals/ alloys/ semiconductors when there is temperature difference/ gradient between the two (**Figure 2)**. When there is a temperature difference, the charge carriers (electrons/ holes/ positive particles) in the metal at the hot side flow

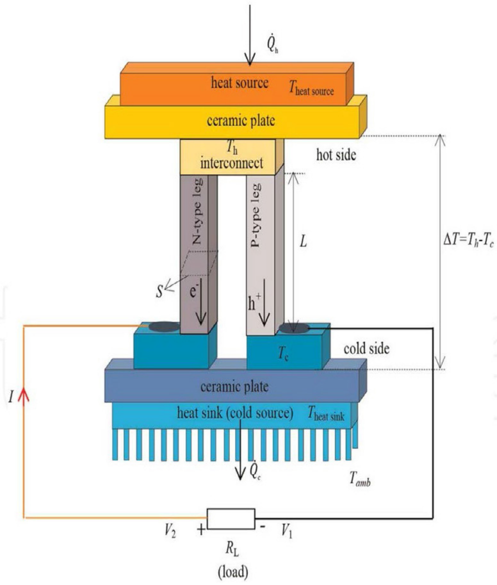


Figure 1. Seebeck Effect

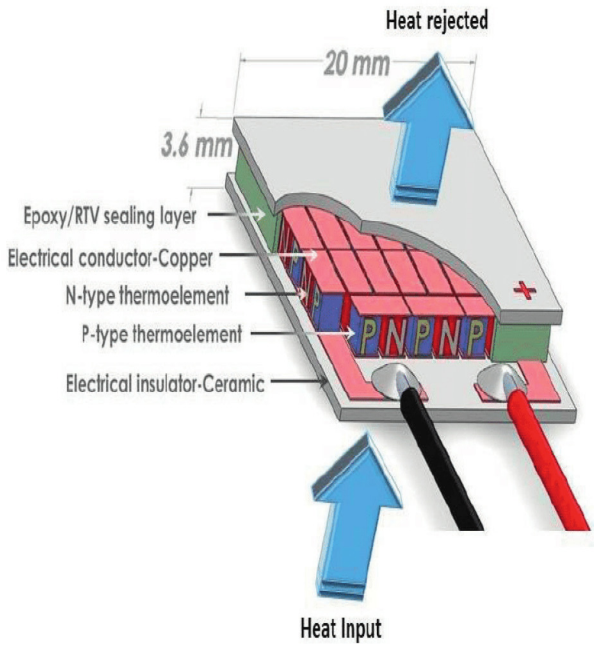


Figure 2. TEG Single Unit

towards the cold side metal which generates a potential difference and hence the current. TEG generates **DC electricity** and a single TEG has a capacity of about **1W to 125W**.

2.1 Materials used in manufacturing TEGs

- Semi-Conductors like Bismuth telluride (Bi_2Te_3), lead telluride (PbTe), and silicon germanium (SiGe).
- Metals like stainless steel, copper compounded with semiconductor for high temperature applications.

The efficiency of the TEG is about **10%-20%** and is directly proportional to the Temperature Gradient (. The electrical and thermal conductivities are usually high or low in a material as the energy is transferred through electrons. Recent developments in the field of ceramics have seen materials that can possess high electrical conductivity and low thermal conductivity which would keep the temperature gradient as high as possible and favour an increase in efficiency.

3. EGTEG: The Solution

In the exhaust funnel of the ships, TEG modules can be installed vertically which would allow the exhaust to flow without any interruption (horizontal arrangement would lead to back pressure formation in the funnel). There are no fins in the hollow vertical chamber. The temperature of flue gases in combined exhaust funnel is about 200°C- 250°C after passing through turbochargers and exhaust gas economisers. The individual exhaust of auxiliary machinery such as incinerator is about 800°C-900°C which is again an ideal location for TEG installation.

Figure 3 gives a brief idea of TEG installation across exhaust funnel covering total diameter of the funnel. TEG units are coupled together to form a module and these modules are supplied with good amount of cooling fluid (mostly water) to maintain the temperature gradient as high as possible for efficient TEG operation. Cooling system of the module can be connected with normal fresh

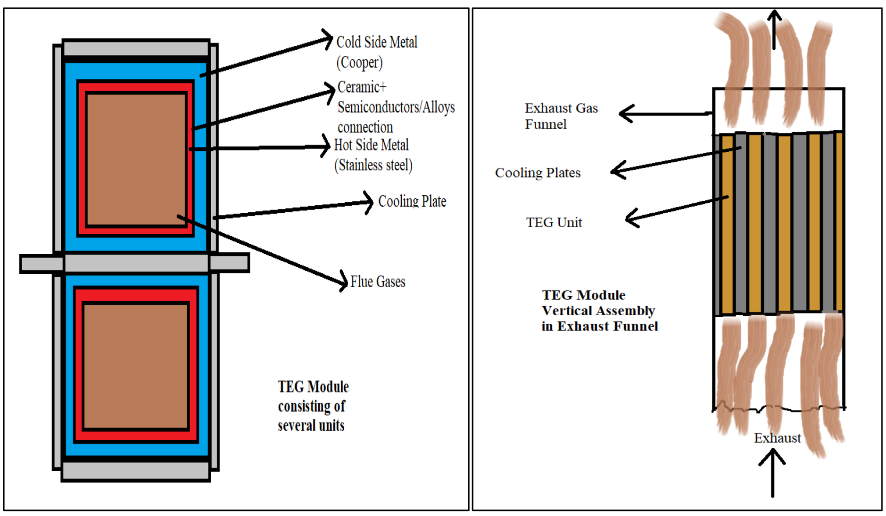


Figure 3. EGTEG cross sectional and longitudinal view

water-cooling lines which cool the auxiliary machineries. The approximate temperature gradient created is about:

$$(\Delta T) = T_{hot\ side} - T_{cold\ side} \longrightarrow 250^\circ C - (30\text{-}40)^\circ C \sim= 210^\circ C$$

This system is subjected to high temperatures and hence the semiconductors cannot be directly exposed to the flue gases as they might be damaged. Thus, the TEG unit is made up of Stainless steel and copper compounded together with the internal unit. Stainless steel and copper are used as steel has very good thermal conductivity and copper has very good electrical conductivity. Semiconductor unit is sandwiched between these two plates with a ceramic liner on both sides of semiconductor which acts as thermal refractor and promotes working temperature range of the semiconductors.

For much better output, TEGs of much higher tolerance towards elevated temperatures and heat can be used at individual machinery exhausts. For instance, at incinerator exhaust funnel where flue gas temperature ranges between 800°C-900°C or at boiler uptake. The material of TEG needed for such cases is about to enter in production stage and is said to be improvised version of steel with its lattice consisting of semiconductor structures with low thermal conductivity but enough for semiconductor to function properly, resulting in high temperature gradient and more efficiency hence the power.

Such two major modules (Main and Auxiliary (Incinerator)) can be coupled together for more power output using "THURY SYSTEM OF CONNECTION OF SERIES GENERATOR". This complete system acts as if generators are connected in series (**Figure 5**). In this case the opposite nodes/ semiconductor plates of a module with respect to the module to be connected are coupled. This leads to generation of more current with constant voltage. This will be very effective for power generation. Also, the generated DC current by the unit after converting into AC can be used to run AC devices and panels. The conversion system (**Figure 6**) consists of an inverter made up of IGBT / SCR which converts DC to AC.

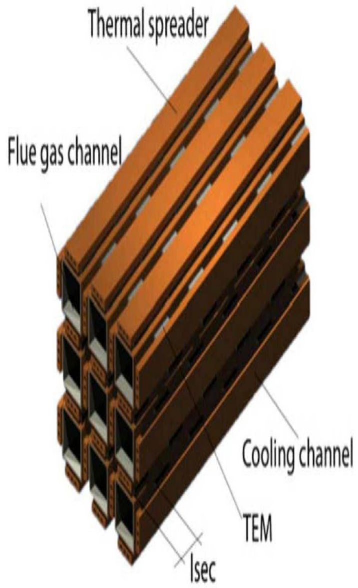


Figure 4. Actual TEG Module

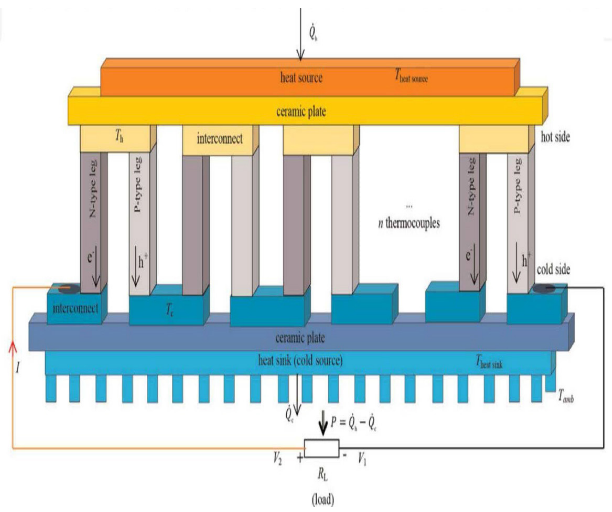


Figure 5. Module Formation. This will be similar for interconnection

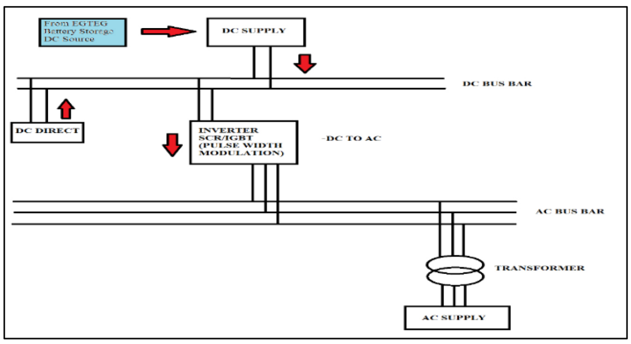


Figure 6. System for DC to AC

4. Operational Design and Specifications

Table 1 shows the design specifications of the EGTEG module for the exhaust funnel of 1500mm diameter. For different values of diameter of exhaust funnel, the module can be altered. The number of units, the dimensions of the cells etc., can be varied to suit. The installation of any system in a flowing chamber causes formation of backpressure in the chamber and this is not being exempted in this system. The standard set by various organisations state that when the engine is operating at its MCR, the back pressure in the exhaust funnel should not exceed **0.035bar** after the turbocharger unit. Exceeding this amount of backpressure may lead to frequent surging of turbocharger, damage to its components and ultimately failure. The governing factors for the back pressure consists of gas velocity and the diameter of the pipe/ free area available for flow and is related by the following equation (1).

$$\textit{Gas velocity } \alpha \ 1/(\textit{Diameter of exhaust funnel})^4 \quad (1)$$

As a countermeasure for this issue, the design of the EGTEG consists of nozzle type arrangements (**Figure 7**) at

Table 1. Design Specifications

Parameter	Measurements	Units
Exhaust gas velocity	35-50	m/s
Exhaust gas pipe diameter (assumed)	1500	mm
Module Parameters:		
Length of the module- L	800	cm
Cross sectional side (available in funnel) (square)-A	106.066	cm
Actual module side (square)- A*	100.00	cm
C/s Area available with appendages*- a	11249.99	cm^2
C/s Area for module/ total area of operation-a*	10000	cm^2
TEG Cell Parameters:		
Square TEG side	6.4	cm
Surface area available for heat transfer	40.96	cm^2
TEG Single Unit Parameters:		
Side length (2 cells per unit) -Square	12.8	cm
Cooling walls thickness w.r.t. enclosed TEG unit-t	2	cm
Total side length including cooling walls (both sides)	16.8	cm
Total Calculations:		
TEG units across c/s of square	25 units	-
TEG units across length (800cm)	125 units	-

**Appendages include the holding bars, angle bars, girders to hold the EGTEG in the exhaust funnel*

the exhaust entry point of the module. This arrangement helps in reducing the obstruction to the flow caused by the end points of the module (at the entry of exhaust). The direction of nozzle type arrangement is such that the convergent end is in the direction of the flow. This helps in creating a low-pressure region at the starting point facilitating the exhaust to flow in same direction, rather than creating back pressure at the entry point of the module. Also, this arrangement favours rapid flow of exhaust over the coarse surface of TEG units leading to efficient heat extraction.

5. Fuel Saving Calculations

As per estimated calculation for **MAN B&W 175D**, 2000kW power output of the generator, about **650 litres** of fuel per day will be saved on running the generator & Monthly savings will be **19500 litres** of fuel.

6. Strengths of EGTE

- **AC** systems can also be operated by AC power generated from the inverter
- For running hours, exhaust emitting machineries e.g.: incinerator, boilers can be made electrically **self-sustaining**
- Burning of less fuel in generator will thus **reduce emissions**
- Furthermore, utilisation of waste energy is achieved other than economisers and turbochargers
- The system is relatively **cheap**, requires **very less/ annual maintenance** since it has no moving parts and thus adding **no extra load** on ship's crew
- EGTEG doesn't generate any system emissions **(zero emissions)** and hence **environment friendly** which is the need of hour
- EGTEG total costing will be **totally refunded** by the savings made on fuel expenses within few years and yield some amount of **profit** in the subsequent periods

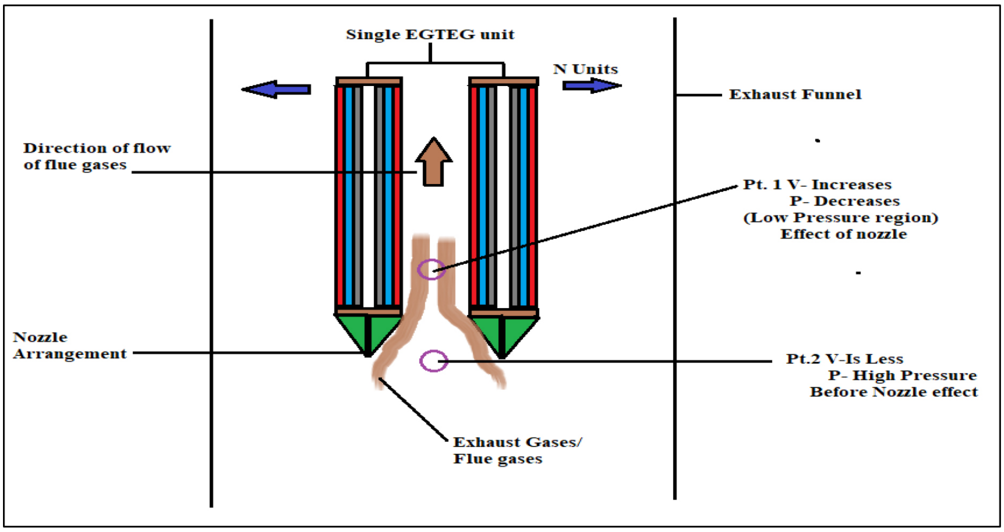


Figure 7. Nozzle arrangement as countermeasure

- **Most** of the small requirements of power to electric panels, sensors etc. can be met by the power generated by this system

7. Restrictions and Challenges for EGTEG

- EGTEG installation is complex as coupling it with sub systems and power storage units demand heavy cabling and connection work.
- The system can only be operated when there is ample flow and temperature of flue gas. It needs to be backed up by regular power solutions available on ship for better redundancy.

8. Conclusion

EGTEG utilisation could be one of the revolutionary measures in the shipping world as it serves the purpose of **GREEN ENVIRONMENT.**

References

[1] TEG: Harvesting and Principles: Diana Enescu.
[2] Waste Heat Recovery Systems: N.R. KRISTIANSEN, G.J. SYNDER, H.K. NIELSEN &L. ROSENDAHL 1. —Technical Department, TeamTec AS, 4902 Tvedestrand, Norway. 2.—Materials Science, California Institute of Technology, Pasadena, CA 91125, USA. 3.—Faculty of Engineering and Science, University of Agder, 4898 Grimstad, Norway. 4.—Department of Energy Technology, Aalborg University, 9220 Aalborg, Denmark: Published: 2012.
[3] MAN B&W: Waste heat recovery system: Reduction of emissions: https://mandieselturbo.com/docs/librariesprovider6/technical-papers/waste-heat-recovery- system.pdf.
[4] Electrical Machines: B.L Thereja: DC machines: Generator in series.
[5] https://espressomilkcooler.com/teg-cascade-800c-hot-side-thermoelectric-power- modules/- Teg dimensions.
[6] https://www.marineinsight.com/main-engine/exhaust-gas-system-of-main-engine-on-ship/ . - Exhaust system details.
[7] https://www.man-es.com/marine/products/four-stroke-engines - Generator details.
[8] https://www.man-es.com/marine/products/two-stroke-engines - Engine details.
[9] GHG and Energy Efficiency in the Shipping Industry- IMO.

About the Authors

Hare Ram Hare is a Marine Engineer and is currently attached to the School of Marine Engineering and Technology, Indian Maritime University, Mumbai Port Campus as Assistant Professor.

Email: hareram@imu.ac.in

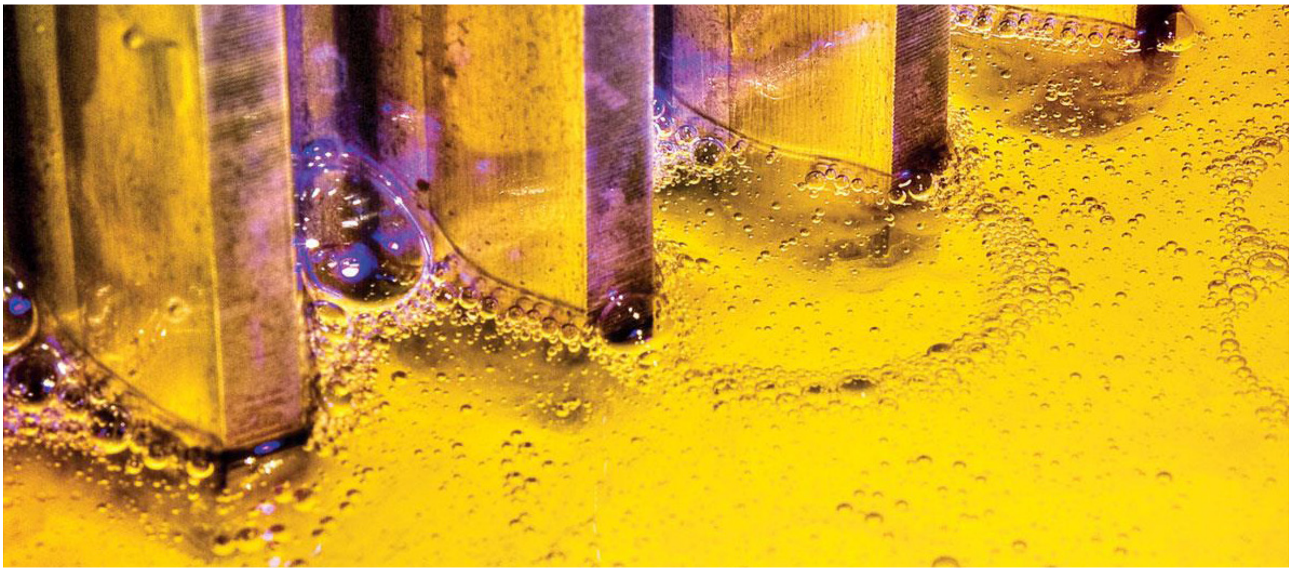
P. Ravichandra is currently attached to the School of Marine Engineering, Indian maritime University, Mumbai Port Campus as Assistant Professor.

Shrikrishna S Prabhu, Utkarsh Jaiswal, Naman Aggarwal and Chum Bikomiyo Deori are Final Year students pursuing B.Tech. in Marine Engineering.

TECHNICAL NOTES

LUBE MATTERS # 11

DEPOSIT CONTROL ADDITIVES



Sanjiv Wazir

Introduction

To effectively meet today's demanding lubrication needs, base oils (mineral or synthetic) usually need the help of chemicals known as additives. Additives improve the lubricating performance of the base oils, either by imparting new properties, boosting existing properties, or eliminating undesirable properties of the base oil.

Modern lubricants are a blend of a base oil (or a mixture of base oils), and a performance improving package of additives. Such a package may include additives extending oil life (e.g., antioxidants); protect equipment surfaces (e.g., anti-rusting, anti-corrosion); extend lubricant performance range (e.g., pour point depressant, viscosity index improvers), and multi-functional additives (e.g., Zinc dialkyl dithiophosphates - ZDDP).

Additives can make up 2-30 percent of a finished lubricant.

Autoxidation of hydrocarbons (1)

Virtually all lubricants are exposed to atmospheric oxygen. Base oils consist of hydrocarbons with (C20–C70) carbon atoms. At high temperature, these hydrocarbons are oxidised to form solid deposit forming materials. The rate of oxidation is influenced by the amount of oxygen, presence of nitrogen oxides (NO, NO2), temperature, presence of catalysts (wear metal ions) and the types of hydrocarbons present.

The self-accelerating oxidation of hydrocarbons is called autoxidation. It consists of four distinct stages: initiation, propagation, chain-branching and termination. Unless this cycle is interrupted it will proceed until the lubricant is completely degraded.

Initiation: Oxidation is initiated by the attack of oxygen molecules or nitrogen oxides (NOx) on the RH molecules (R refers to a long chain alkyl substituent). This results in the formation of alkyl (R*) radical.

Propagation: Once an alkyl radical has formed, this reacts irreversibly with oxygen to form alkyl peroxy (ROO*) radical. The peroxy radicals start abstracting hydrogen from another hydrocarbon resulting in formation of hydrogen peroxide (ROOH) and another alkyl radical (R*) which can again react with oxygen and so on.

Chain branching: At low temperatures, peroxides may cleave homolytically or in the presence of metal ions to alkoxy (RO*) and/or peroxy radicals. As a result of hydro-peroxide accumulation and subsequent cleavage, the concentration of reactive free radicals initiating new chains increase. (Above 120 °C cleavage of hydro-peroxides plays the major role in degradation). The free radicals react with lubricant hydrocarbons forming a variety of additional radicals and oxygen containing compounds, such as alcohols, aldehydes, ketones, and carboxylic acids.

Aldehydes and ketones are highly reactive and form polymers in the presence of acids (such as sulphuric and nitric acids formed during fuel combustion by the reaction of sulphur and nitrogen oxides, and water). These lead to formation of deposits.Carboxylic acids attack iron, copper, and lead in the equipment to form metal carboxylates providing metal ions that further accelerate the rate of oxidation.

Termination: As the reaction proceeds, autoxidation is followed by an auto-retardation stage resulting in a standstill before the hydrocarbon is completely consumed (1).

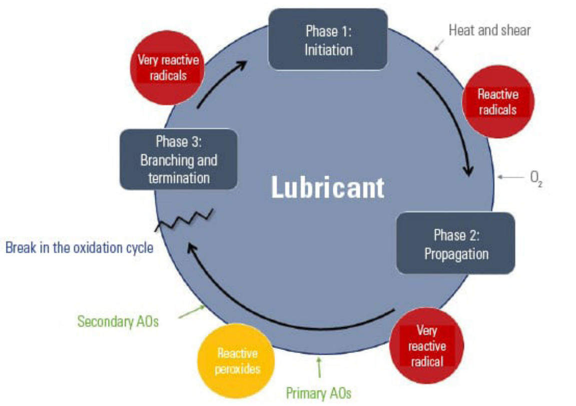


Figure 1. Oxidation Cycle (3)

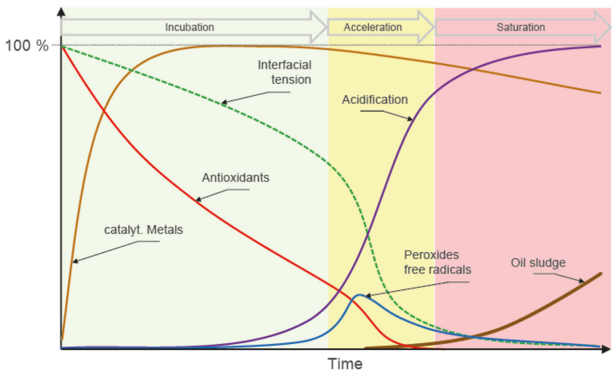


Figure 2. Typical progression of oil oxidation over time (6)

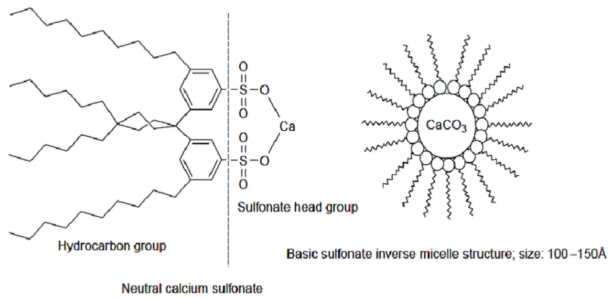


Figure 3. Micellar structure of neutral and inverse micelle structure of over based detergent (5)

Antioxidants (2)

Three types of antioxidants have proven successful in controlling oxidative degradation of lubricants

-hydro-peroxide decomposers

-free radical scavengers

-synergistic mixtures of the two

These break the peroxide and radical chains to form harmless compounds. Some additive compounds, such as dithiophosphoric acid derivatives (e.g., ZDDP) are extremely effective oxidation inhibitors, as they act as both peroxide decomposers and radical scavengers. In addition, they have antiwear properties.

Metal deactivators are another class of oxidation inhibitors that work by forming compounds with metal ions, thus taking them out of the oxidation chain reactions. These inhibitors are mainly used in fuels.

Detergents (2)

Detergent and Dispersant additives are essential in lubricants to prevent harmful carbon and sludge deposits. These additives are somewhat like the familiar household detergents. The household detergents are water soluble while the lubricant detergent and dispersants are oil soluble.

Detergents are alkaline metal salts of organic acids. The detergent molecule is made up of two parts as illustrated in **Figure. 3.** The hydrocarbon group which enables the detergent to be fully soluble in the base oil. The other part is the polar head containing a metal cation that attaches to contaminants. Detergents suspend sludge & oxidation products, in the bulk lubricant. In addition, they can neutralise acidic products from combustion and oxidation, thus controlling corrosion and deposit build-up.

Detergents are made by reacting precise amounts of an organic acid (e.g., alkylbenezene sulphonic acids, carboxylic acids, alkylphenols, etc.) with a metal (e.g., sodium, magnesium, calcium, barium, etc.), forming metal-sulphonates, -carbonates, -phenates, -salicylates, etc.

When the metal is present in stoichiometric amount, the detergent is called "neutral". When it is present in excess, they are called "basic or over based". The base number (BN) of the detergent indicates its acid neutralising ability.

Engine oil formulations (particularly those used in marine applications) contain high levels of detergents.

Dispersants (2)

Dispersants work by suspending oil-insoluble *dirt* present in the oil, within the bulk liquid lubricant. In lubrication parlance *dirt* describes undesirable contaminants that result from the oxidative degradation of the lubricant, chemical reaction of acids (e.g., carboxylic acids) with metal surfaces, decomposition of thermally unstable additives (e.g., EP additives). In diesel engines, soot from combustion is the major component of carbon, and lacquer deposits, and sludge, that occur on combustion space components. Resins (oil insoluble products) are formed by the reaction of partly combusted fuel components with NOx or oxygen.

In diesel engines, soot from combustion is the major component of carbon, and lacquer deposits, and sludge, that occur on combustion space components

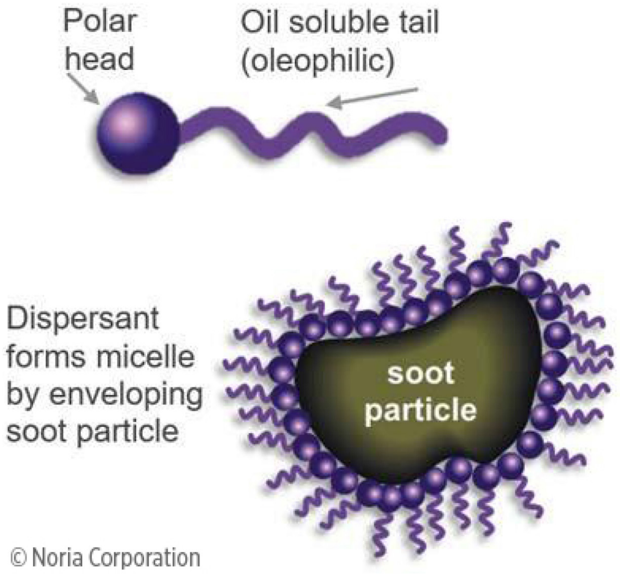


Figure 4. Dispersants & their action (4)

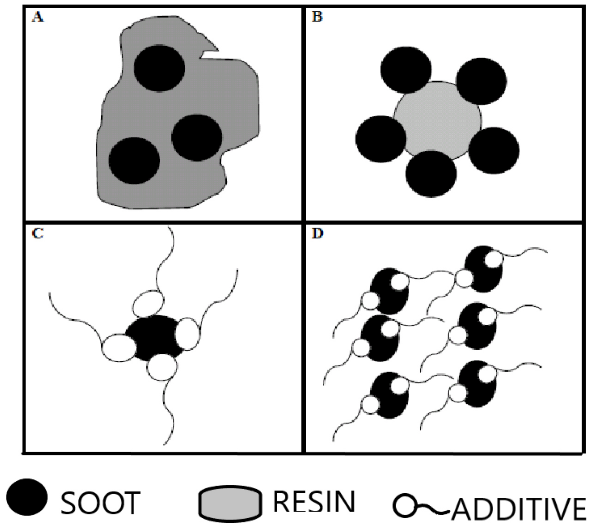
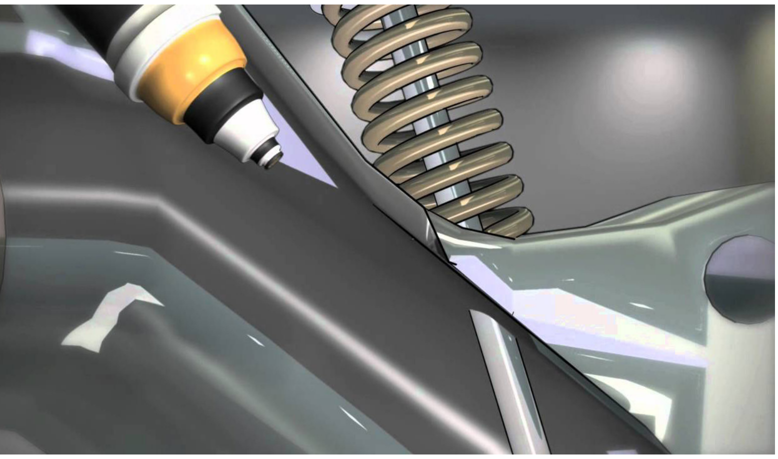


Figure 5. Mechanism of soot-resin-additive interaction (3)

Deposits are rich in soot. Lacquers are rich in resins. Sludge forms when soot combines with other oxygenated compounds, and water. Local piston temperatures and ash from lubricant additives greatly impact the composition of carbonaceous deposits.

Dispersant molecular structure, like that of detergents, consists of a polar head and a hydrocarbon tail (**Figure. 4**). The most used polar heads are derived from alcohols and amines. Thus, dispersants are non-metallic or ash-less cleaning agents. The size and nature of the polar head determines dispersancy. The hydrocarbon tail contains 70 to 200 or more carbon atoms to ensure good oil solubility. Since most of the *dirt* components, including both resin and soot are polar in nature, dispersants supress interaction between them by associating with them and keeping them apart, preventing agglomeration, and at the same time remaining suspended in the bulk lubricant due to its oleophilic tail (**Figure. 5**).

Dispersants are major components of additive packages used in engine oils (petrol, diesel & natural gas). They are also used in automatic transmission fluids, power transmission fluids, gear oils, etc.



Conclusions

Oxidation is a major cause of oil thickening and formation of deposits, lacquers, and sludge. Antioxidants minimise the formation of such compounds. Antioxidants enable lubricants to work longer and at higher temperatures. They are used in almost all kinds of lubricants.

Detergents and dispersants play a vital role in the formulation of engine oils. Nowadays, transportation (including marine), construction & agricultural vehicles would not exist without oils containing additive packages that include large proportions of detergents and dispersants. They also play a vital role in tractor fluids, automatic transmissions, gears oils and hydraulic fluids.

References

1. Oxidative degradation & stabilisation of mineral oil-based lubricants. M.Rasberger, Chemistry & Technology of Lubricants, Ed. R.M. Mortimer, Blackie Academic (1997).
2. Additives and Additive Chemistry, Syed Rizvi, Fuels & Lubricants Handbook, Ed. George E Totten, ASTM Intl. 2003.
3. All about Lubricant additives, Anthony Grossi, Nye Corporation, POWERMAG,08/2016.
4. Lubricant Additives, A practical guide; Machinery Lubrication (04/2017), Noria Corporation.
5. Researchgate.net upload by Hamdy S Abdel-Hameed.
6. Antioxidants: Elixirs of life for modern lubricants, OILCHECKER, Winter 2020.

About the Author

Sanjiv Wazir is a Technical Adviser with LUKOIL Marine Lubricants. He is a mechanical engineer from IIT-Bombay. He is a marine engineer and a member of the Institute of Marine Engineers. He is a Certified Lubrication Specialist from the Society of Tribologists & Lubrication Engineers (STLE), USA and is a member of the Tribological Society of India. He has contributed to MER on marine lubrication developments in the past, and on oil contamination issues under "Lube Matters," earlier.

Email: sanjiv@lukoil.com

CLASS ACTION/INDUSTRY MOVES

Compilation : Rashmi Tiwari

INDIAN REGISTER OF SHIPPING (IRS) LEADS PUSH FOR IMPROVED INLAND WATERWAY SAFETY THROUGH INTEGRATED IV RULES

IRS is continuing its drive to improve inland vessel safety throughout India, having played an integral role in the drafting of the Inland Vessels Act 2021. The Inland Vessels Act 2021 will help integrated vessel movement throughout waterways and establish uniformity in law and standardised provisions. The **IV Act 2021 addresses safety and pollution control norms** and makes provisions for the use of new and special category vessels. It also specifies retrieval of wreck and salvage norms.

For more information, visit: http://www.irclass.org

DNV AWARDS FIRST DATA INFRASTRUCTURE TYPE APPROVAL

DNV has awarded Kongsberg Digital's Vessel Insight and its end-to-end **data infrastructure and cybersecurity**, its D-INF(P) and Cyber secure SP1 certifications. With these certifications, Vessel Insight is believed to be the first solution to meet the D-INF(P) end-to-end requirements. In addition to D-INF(P), DNV has approved the infrastructure with additional cyber security requirements and achieved Cyber secure Essential (SP1) approval.

For more information, visit: https://www.cleanshippinginternational.com/dnv-awards-first-data-infrastructure-type-approval/?utm_source=email&utm_medium=2022-05-04-newsletter&gmc=IkPI0xSANd&gm=8907&gml=xlY5S90DqL&gmv=0

DNV AND PARTNERS LAUNCH SAFEMATE PROJECT

At the Nor-Shipping trade fair, DNV, Kongsberg Maritime, Kongsberg Seatex, Bastø Fosen and NTNU announced the launch of the new SAFE Maritime Autonomous Technology (SAFEMATE) project. The RCN funded project will work on improving and assessing the **safety and efficiency of autonomous navigation systems** and deploy a pilot on an operational ferry, the Bastø VI. The promise of automating more functions in shipping shows great potential, and interest continues to grow throughout the industry as more projects are developed.

For more information, visit: www.dnv.com/maritime

DNV AWARDS INO12™, A NEW 12MW FLOATING OFFSHORE CONCEPT, AIP AND BASIC DESIGN APPROVAL

DNV has awarded Inocean AS, a Norwegian subsidiary of Technip Energies, Approval in Principle (AiP) and Basic Design Approval for their new INO12TM **semisubmersible platform** concept. The certificates were presented during the Nor-Shipping trade fair at the DNV stand, by Geir Fuglerud, Director of Offshore Classification at DNV to Øystein D Nilsen, Managing Director of Inocean AS. The INO12TM floating offshore wind concept has been designed to accommodate a 12MW wind turbine, with a life span of 25 years without dry docking. The concept emerged initially from internal research at Inocean and was further refined in the WINDMOOR research project, 4-year project funded by the Research Council of Norway and the offshore wind industry.

For more information, visit: www.dnv.com/maritime

CLASSNK SETS FORTH CLASS NOTATIONS FOR ADVANCED INITIATIVES ON SAFETY AND LABOR

ClassNK released "Guidelines for Advanced Safety Measures", "Guidelines for Excellent Living and Working Environment", and "Guidelines for Installations for Infection Control". These guidelines outline the requirements for additional class notations for ships adopting measures and equipment related to improving safety as well as living and working environment on board. Guidelines for Advanced Safety Measures stipulate requirements for the class notation "Advanced Safety (a-SAFE)", indicating that the ship is adopting advanced safety measures. They include Radar Based System which displays additional information on waves and so on, Collision Risk Indication System including Obstacle Zone by Target (OZT) etc. Extended Reality Display System for superimposing the navigation information, Forward Underwater Obstacle Detection System, and Berthing Support System.

For more information, visit: www.classnk.com

MoU SIGNED FOR ZERO-EMISSION VLCCs

Lloyd's Register, Samsung Heavy Industries (SHI) and MISC via its subsidiary, AET, have signed a Memorandum of Understanding (MoU) for the development and construction of two very large crude carriers (VLCCs) which can be operated on zero-emission fuel. The three companies, all founding members of The Castor Initiative, are taking the lead to encourage the use of **green ammonia as propulsion fuel**, with the first of these dual-fuel tankers entering into service in late 2025 and the second in early 2026. The Castor Initiative, a multinational coalition committed to make zero-emission in shipping a reality, includes MISC Berhad (MISC), Lloyd's Register (LR), Samsung Heavy Industries (SHI), MAN Energy Solutions (MAN), the Maritime and Port Authority of Singapore (MPA), Yara International ASA (Yara) and Jurong Port (JP).

For more information, visit: https://www.cleanshippinginternational.com/mou-signed-for-zero-emission-vlccs/?utm_source=email&utm_medium=2022-05-04-newsletter&gmc=IkPI0xSANd&gm=8907&gml=adPobEDxtL&gmv=0

DNV TO CLASS COMMISSIONING SERVICE OPERATION VESSELS PREPARED FOR HYDROGEN OPERATIONS

DNV signed a classification contract for two new Commissioning Service Operation Vessels (CSOVs), ordered by the Norwegian pure play offshore wind operator Edda Wind. The vessels will be built at Colombo Dockyard in Sri Lanka and are designed for service operations during the commissioning and operation of **offshore wind farms** and are prepared for **hydrogen operations**. They are scheduled to be delivered under the Norwegian Flag in January 2024 and July 2024. Advanced CSOVs that offer both next generation technology and comfortable accommodation are an important part of the value chain in a booming offshore wind segment that is expected to grow as the demand for renewable energy soars in the coming decade.

For more information, visit: www.dnv.com/maritime

HYBRID BIOMASS CARRIER TO BE POWERED BY ABB

The Roboship hybrid-electric vessel being developed by the e5 Lab consortium, comprising Asahi Tanker Co, Exeno Yamamizu Corporation, Mitsui OSK Lines and Mitsubishi Corporation, will be equipped with ABB's complete modularised electrical propulsion package. The compact DC distribution system will allow the vessel to draw on multiple energy sources, enhancing efficiency and future-proofing it for emission-free operations. The e5 Lab Roboship design is for a 70m long, 499gt biomass fuel carrier, powered by a standardised, electric propulsion system to attain zero emission operations in harbour. Built by Honda Heavy Industries, the hybrid vessel will, as well as potential zero-carbon operation, enable reduced noise and vibration, lower maintenance costs, and improved steering capabilities to simplify make pier docking and undocking operations.

For more information, visit: https://www.cleanshippinginternational.com/hybrid-biomass-carrier-to-be-powered-by-abb/?utm_source=email&utm_medium=2022-19-04-newsletter&gmc=04vz7Hi9Aw&gm=8906&gml=vM9CdCyGlr&gmv=0

PRESS RELEASE

TRANSTECH 2022

The 15th Edition of the All India Technical Seminar **TRANSTECH 2022**, was organised by TMI, in association with The Institute of Marine Engineers (India), Pune Branch and The Institution of Engineers (India), Pune Local Centre from 24th to 26th March 2022.

TRANSTECH provides a platform to students from maritime as well as other engineering colleges to present their technical papers and showcase their ideas/models on specified themes. Poster displays and Marine Quiz were new additions to the event this year. The main theme of the event was "**Future Trends in Shipping Industry**" and the 8 subthemes were: Blue Economy, Industry 4.0 in Maritime Sector, Alternative Propulsion Systems, New Techniques and Advancements in Fire Fighting, IMO's GHG Strategy: How to Meet 2030 and 2050 Goals, Innovative Solutions for Ship-Shore Data Link for Real Time Monitoring, Maritime Education & Training Framework for Autonomous Vessel Operations and Technological Advancements in Navigation, Communications and Search & Rescue in Maritime Industry.

Dr. Sanjeet Kanungo, Principal, TMI Pune, welcomed the gathering and emphasised on the relevance of themes and subthemes of Transtech 2022 for future trends in shipping.

Capt. M. Sairaj (Director, Synergy Navis Marine Pte Ltd, Pune) was the Chief Guest on the first day. He delivered the inaugural speech on 'The Innovative Smart Ship Solutions' which was well received by all. He released the 'Book of Proceedings' for Transtech '22 and the Institute's Annual 'Bulletin of Maritime Science & Technology'.

Mr. Chirag Bahri delivered a talk on "Pre-departure awareness for seafarers". He is the Director of Regions (India) at International Seafarers' Welfare & Assistance Network (ISWAN) and a TMI alumnus.

Mr. Praful Kalankar, Director, S. P. Auto Engineering, Pune shared his insights on "Total Quality Management."

Prof. Tanuja Sachin Khatavkar, Regional Coordinator (Pune), Virtual Labs Regional Centre, IIT Bombay" and "Prof. Pushpdeep Mishra, Senior Project Manager, Virtual Labs-IIT Bombay" shared their information on "Introduction to virtual labs" on the second day of the event.

Capt. Nikunj Parashar, CEO & Director, Sagar Defence, Pune was the guest speaker on the 3rd day. He delivered a talk on Remote Operation of vessels and his journey and involvement in the build-up of such vessels and establishment of his venture.

Dr. (Mrs.) Malini V. Shankar, IAS (Retd.), Vice Chancellor, Indian Maritime University was the chief guest on the 3rd and final day. She delivered a keynote address on "Challenges in Maritime Education and Training to Deal with Future Trends in Shipping." She inaugurated the newly installed state of the art Simulators for Navigation, Cargo Handling, Engine Room and Welding.

24 full length papers were received on the given subthemes from 5 institutes across the country and finally 12 papers were selected for presentation. Seven technical models were also there. A team of three judges selected deserving participants for the prizes. Top three prizes for technical papers were sponsored by The Institute of Marine Engineers (India), Pune branch and the remaining by Tolani Maritime Institute itself.

Transtech 2022 was held in hybrid mode. Marine quiz prizes were sponsored by Amazeng Nautical Association, Pune. Overall it was a very interesting, informative and successful webinar which benefitted students, faculty, guests and online viewers (YouTube etc.).

Prize winners at Transtech 2022 were:

Technical Papers Presentation:

First prize: A Sharma, C Mahajnab and C Yesudas of TMI Pune for their technical paper titled 'Hybrid Energy Regenerating System.'

Second prize: A Chauhan, R Dutta, R Mishra of GEIMS, Lonavala for their technical paper titled 'Smart fire extinguishing device (SFED).'

Third prize: A Ratha, E Anto, R Nair of IMU Vishakhapatnam for their technical paper titled 'Review Analysis on Advancements in NCSR Technologies'.

Technical Models:

All 7 models were from TMI Pune itself.

Bhavesh Kumar Sendh won the 1st prize for his technical model titled 'Safety and Efficiency Improving Technologies in Autonomous Ships'.

Bendre Shardulshantanu, Shaurya Sharma and Vipul Kumar Dubey won the 2nd prize for their technical model titled 'Thermoelectric Cooler- Waste Heat Recovery System on Ships'.

Aryadeep Bharadwaj, Arpit Raj and Harshvardhan Bhati won the 3rd prize for their technical model 'Green Energy Power Generation on Ship Using VAWT'.

Technical Poster Display:

Sandrana Nandini, Aditi Wadekar and Adarsh Ranjan of IMU Visakhapatnam won prize for the best technical poster.

Marine Quiz:

Kartik Thakur and Hriseeka Nayak of TMI Pune won the 1st prize. Ojasvi Saxena and Karan Maliya of GEIMS Lonavala won the 2nd prize. Shashikant Mishra and Sudeep Ray of HIMT College Chennai won the 3rd prize.

[News Write-up: Anirudh Kumar, Convener, Transtech 2022]

OBITUARY

N. SANKAR

(19.11.1945 – 17.04.2022)

Mr. N. Sankar obtained his B.Sc. Tech. in Chemical Engineering from the AC College of Technology, University of Madras, graduated in First Class with distinction. Thereafter he obtained his Master's Degree from the Illinois Institute of Technology, Chicago.

He was elected as an Honorary Fellow of the Institute of Marine Engineers (India) in March 2018. He contributed generously to the Maritime Community activities in Chennai, such as the National Maritime Day and the World Shipping Forum.

Over an eventful career spanning more than 50 years, Mr. Sankar was the Chairman of the Sanmar Group. Operating in core areas of Chemicals, Shipping, Metals and Engineering, the India based Group has operations in Egypt, USA and Mexico. The Group's Shipping arm (since September 1994), owns and operates 10 vessels, comprising Tankers and LPG Carriers.

Mr. Sankar served on the Board of NOCIL Limited, Mumbai, and the India Advisory Board of FLSmidth A/S, Denmark. He also served as the Honorary Consul General for Denmark in South India from 1989 to 2017, and was awarded the `Knight of the Order of the Dannebrog, First Class' by the Danish Government in recognition of his services.

Mr. Sankar has held office in several public bodies representing trade and industry, including

- ***President*** – Assocham (1991-92)
- ***Chairman*** – Indo-US Joint Business Council (1998-99)
- ***Chairman*** – Madras Chamber of Commerce and Industry (1986-87)
- ***President*** – Madras Management Association (1981-87), etc.

He also received many awards recognising his services to business and industry.

He was also involved with the management of a number of educational and charitable organisations. He was a Member of the Board of The CHILDS Trust. He was the Chairman of the Chennai Willingdon Corporate Foundation and Chennai Heritage, and a member of the Board of Governors of the Indian Institute of Management-Kozhikode.

Keenly interested in sports, he was Vice President of the All India Tennis Association, and President of the Tamil Nadu Cricket and Tennis Associations.

KOLKATA BRANCH

WEBINAR ON CII BY KOLKATA BRANCH

A webinar on the theme 'Improvement of Carbon Intensity Index (CII) for Ships' was hosted on 22 April 2022 by IME(I) Kolkata Branch, jointly with the Institution of Engineers (India) West Bengal State Centre, and the Association of Ex-cadets of DMET Kolkata.

After the opening addresses by Chairman, IEI WB State Centre, Chairman, IEI Marine Engineering Division Board, Chairman, IEI CATE, Vice President, IEI and President IEI, the speakers for the day were introduced by Mr. Gautam Sen, who is both Chairman IME(I) Kolkata Branch and Chairman Marine Engineering Division, IEI WB State Centre.

The first speaker, Mr. S. K. Sarkar, Secretary AECDMET and ex-Director (i/c) MERI / IMU Kolkata Campus, spoke on the topic 'Marine System Design to Curtail GHG Emissions'. He discussed various aspects of ship design aimed at energy efficiency, such as hull modification, hull lubrication, waste heat recovery systems, etc. He said existing ships also could have these features as retrofits to improve their CII.

The second speaker, Mr. Arun Kumar Singh, Faculty, Marine Engineering Department, IMU Kolkata, spoke on the topic 'Search for Carbon-free Energy'. He discussed various positives and negatives of zero emission fuels that are under consideration for future use to achieve the goal of 2050 and beyond leading to zero carbon emission.

The presentation also addressed the problems faced by ship owners in introducing new technologies due to inadequate returns from the business of transportation with respect to the investment involved. Ways had to be found, Mr Singh said, to get ship owners involved in the process of developing and utilising technologies leading to zero GHG emissions within the set time frame.

The last speaker, Mr. Amit Bhatnagar, Vice President IME(I), touched on the following aspects:

- Candidate fuels and technologies
- Comparison of fuel candidates
- Rules & regulations
- Study of present active ship fleet

Mr. Bhatnagar concluded by covering the takeaways from these studies. Apart from detailed information on a couple of fuels, there was a brief mention of about ten other fuels.

Mr. Sen summed up the session and also monitored the Q & A session. Hon. Secretary IEI WB State Centre then proposed a vote of thanks, thus concluding a very interesting webinar. The Webinar was attended by about 60 persons in virtual mode and was watched by many others via live streaming on YouTube.

MUMBAI BRANCH

NMD CELEBRATIONS: MARITIME AWARENESS RUN

India celebrates the National Maritime Day (NMD) on April 5 every year. The first anniversary of the day was held in 1964 in order to raise awareness about international trade and the economy. The day is commemorated to support the global economy and express gratitude towards the Indian Shipping Fraternity. Remembering the same, the National Maritime Day Celebrations (Central) Committee (NMDC) in Association with Institute of Marine Engineers of India IME(I) and Company of Masters Mariners of India (CMMI), organised a “Maritime Awareness Run” on April 3, 2022.

On the 59th NMD 2022, NMDC, under the aegis of Directorate General of Shipping, Ministry of Ports, Shipping and Waterways, Government of India, celebrated the Merchant Navy Week across the country between 30th March and 5th April, 2022.

The awareness run was held at Nerul, Navi Mumbai. The theme for the event was “Propelling Indian Maritime to Net-Zero”. There was an overwhelming response from the participants and the Registrations had to be closed as it reached over 500.The marathon started from IME(I) House / Fire Brigade, Nerul and ended at IME(I) House, Nerul, Navi Mumbai. The distance of the marathon was of 6 kms for Students and 3 kms for Senior citizens, ladies and general public.

NMDC organises one such event every year on the NMD to salute and cherish the courage of our seafarers. The participants started assembling from 6.30 am onwards and were given T- shirts (Courtesy: CMMI, NUSI, MUI and ANA) and the NUMBER BIBS were issued by the Awareness run Organizing committee to all the participants. The Marathon started at 7:30 am.

The facilities provided for a safe run included drinking water and rest room services by IME(I) and Food boxes organised by NMDC.

All Covid protocols were followed and guidelines were provided beforehand. An ambulance from Apollo Hospital, Navi Mumbai accompanied the participants with the medical staff for emergencies. Only those who were fully vaccinated were allowed to enrol and participate.

Being a Sunday Morning, a good warming up session was provided followed by Zumba exercises, prior to the start. Marshals and Wardens accompanied the participants for first aid and necessary attention. The participants were also provided with a MAP and circuit of Awareness Run. A goodie bag with Moov Energy Bar, Energal, and a Cap (Courtesy: INMARCO / IMEI) was distributed to all participants.

After the successful completion of the event, the winners in different categories were awarded with medals and certificates (courtesy: CMMI) and Gifts (courtesy: Amazeng Nautical Association).

IME(I) is thankful and grateful to the NMDC organising committee for entrusting them to arrange and organise the Maritime Awareness run in Navi Mumbai.

It is heartening to know that the NMDC officials and the Senior executives of the industry who participated in the Awareness run and visited IME(I) house much appreciated.

Media Partners: Sea and Job | Marex Media Pvt. Ltd. | Bhandarkar Publications

SEA AND JOB · BHANDARKAR PUBLICATIONS · MAREX Media Pvt Ltd

INAUGURATION OF MERCHANT NAVY WEEK

by His Excellency, Shri Bhagat Singh Koshyari, Governor of Maharashtra, on 31.03.2022 at 1100 hrs at Raj Bhavan

The delegation of the National Maritime Day Celebrations (Central) Committee headed by Shri Amitabh Kumar, Director General of Shipping and Chairman NMDC (Central) Committee visited His Excellency, Shri. Bhagat Singh Koshyari, Governor of Maharashtra to attend Flag Pining Ceremony at Raj Bhavan, Mumbai to commemorate the beginning of Merchant Navy Week starting from 31st March to 05th April, 2022. The delegation consisted of officers from the Directorate General of Shipping & Shipping Corporation of India and heads of the various Organisations and unions in maritime sector.

The NMDC (Central) Committee is composed of representatives of Ship owners, Seafarers, Port Trusts, Maritime State Governments, and Ministry of Shipping and is set up for organising and co-ordination of the various programs for celebrations of the National Maritime Day /Merchant Navy Flag Day. ***'Propelling Indian Maritime to Net Zero'*** is the theme for this year celebrations.

Shri. Amitabh Kumar informed that since 1964 we are celebrating 5th April every year as the National Maritime Day, since on this day in 1919 the first Indian Steamship "S.S. LOYALTY" of M/s. Scindia Steam, Navigation Co. Ltd., Mumbai, sailed into international waters on her maiden voyage from Mumbai to London (UK).

Merchant Navy Week will be celebrated this year to highlight the role and promote development of the Shipping Industry in all its aspects by diffusion of knowledge and information to the public and to recognise the services of seafarers and services of any other persons connected in promotion and development of national shipping and other allied matters by way of the following awards, scholarship and/ or any other manner.

He also gave detailed account of the merchant marine infrastructure in India and several recent developments and progress made in the maritime sector. He informed that various functions like webinar on the 'Covid Pandemic- Challenges & Opportunities' & 'Propelling Indian Maritime to Net Zero' were being organised on 1st and 2nd April respectively. The grand finale event was celebrated on 5th April, 2022. He felicitated the Hon'ble Governor of Maharashtra, pinned the first miniature flag on his wearing apparel and sought his blessings for starting the weeklong celebrations. Hon'ble Governor unveiled a collage depicting the Voyages of Mahatma Gandhiji during his life time.

While interacting with the delegates, the Hon'ble Governor touched upon the maritime history of India and stressed upon the importance of the merchant navy

to the economic development of India. He appreciated the yeomen services of the shipping industry during the challenging Covid times. He expressed that there is a need for further growth of maritime education in India and maintenance of safety and security of the seafarers at sea. He gave his best wishes and greetings to NMDC (Central) Committee, all the stakeholders of maritime industry and seafarers for celebration of the Merchant Navy week.

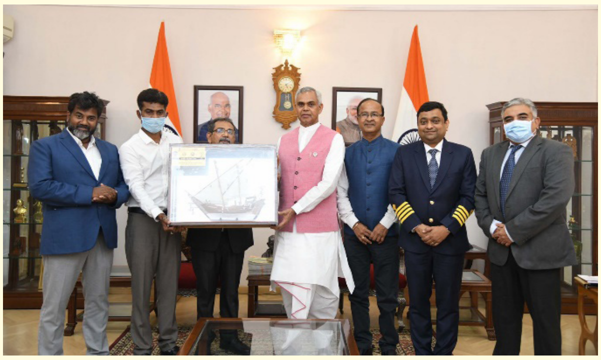
NMDC WEEK CELEBRATION REPORT

As a part of the NMD celebrations, a seminar was organised on the theme ***"COVID Pandemic- Challenges and Opportunities"*** at **SCI Auditorium, Nariman Point, Mumbai** on **1st April 2022**. Capt. M.P. Bhasin, Managing Director at MSC Crewing Services; Mr. Amar Singh Thakur, General Secretary, The Maritime Union Of India; Mr. Abdulgani Serang, General Secretary-cum–Treasurer, NUSI; Capt. Anshul Rajvanshi, Managing Director, Synergy Maritime Recruitment Services Pvt. Ltd.; Mr. Sanjay Kumar Bariar, Additional Director General of Shipping; Mr. PK Gangopadhay, Director (Personnel & Administration), SCI; and Dr. Sanjay Bhavnani, Director & Chief Operating Officer, MMS Maritime India were present and actively participated in the seminar.

A panel discussion on the theme **Propelling Indian Maritime Towards Net Zero** was discussed at **IRS, Powai, Mumbai** on **2nd** April 2022. The discussion was graced by Mr. Indra N Bose, Advisor at The Great Eastern Shipping Co. Ltd; Mr. Vijay Arora, MD, Indian Register of Shipping; Mr. A Sukumanran, Principal Officer cum Joint Director General of Shipping (Tech), MMD Chennai; Mr. CPK Kashyab, President - Operations, Sanmar Shipping; Mr. Umesh Grover, Secretary General, CFS Association of India; Mr. Dasgupta, Dr. P. K. Raut, IRS, DDG, Mr. S.M. Rai and Mr. Sanjeev Mehra, Hon. Secretary, IME(I) Mumbai Branch.

PINNING OF FIRST NAVY DAY FLAG TO HON'BLE GOVERNOR OF GUJARAT, SHRI. ACHARYA DEVVRAT

On the occasion of **59th National Maritime Day celebration,** Capt. Santoshkumar S Darokar Principal Officer (I/c), MMD Kandla has pinned First Merchant Navy Day Flag to **Hon'ble Governor of Gujarat, Shri. Acharya Devvrat** on **30th March 2022** at Raj Bhavan, Gandhinagar, Gujarat.



On this occasion, representatives from MMD Jamnagar, Gujarat Maritime Board, Gujarat Chamber of Commerce and Sailing Vessel Association were present. Model of the vessel, SS Loyalty, other mementos like Voyages of M K Gandhi and coffee table book of Samudra Manthan were also presented to Hon'ble Governor of Gujarat.

59TH NATIONAL MARITIME DAY

On the occasion of the **59th National Maritime Day**, the **NMDC** organised an award ceremony on **5th April 2022**, with the theme **"Propelling Indian Maritime to Net-Zero."** The event was graced by many prominent dignitaries of the Shipping Industry.

The Institute of Marine Engineers (India)

DELHI BRANCH

INVITES ALL MARINERS

for

Annual Function

On Saturday, 28th May, 2022

at

HOTEL RADISSON BLUE PLAZA

NH-8, Mahipalpur, New Delhi,

Time : 07:30 PM Onwards

Dress Code: Smart Casual

DRINKS, DINNER & DANCE

ENTRY PASSES AVAILABLE AT:

Gurgaon: Capt Berry +91-9811123936,

Delhi: A Sharma +91-7350002721, Capt Lal +91-9810091794,

Ramanujam, +91-9871418768,

Noida: Vicky Malhotra: +91-9811046949, Rajesh +91-8527966888

Ghaziabad: Chirag Bahri +91- 9997117220

PASSES:

@ INR 2000/- Per head (May 1- May 24, '22)

@ INR 3000/- Per head (May 25- May 28, '22)

Basic Training for Ships using Fuels covered within IGF

For booking of a course please follow the below procedure after confirming the availability of a seat. Mail can be sent on training@imare.in or contact on +91 22 - 27711663 / 27701664

- Course ID- 5311
- Course Duration: 4 days
- Course Timings: 0900hrs to 1630 hours (with lunch and tea breaks)

BOOKING PROCEDURE

For booking
please follow the below

STEPS:

STEP1: For Registration:
https://forms.gle/DSmcvmMJkZAvLDvo9

STEP 2: Upload the documents: Create a *single folder* with your Name + the Course name. Scan each of your documents and place them inside the folder and then email on **documents@imare.in**
For example: Folder Name Abhinav Class I. Files are CDC.pdf (Front page, last page), Passport.pdf, INDos.pdf, 4 Basic Safety Courses.pdf. Only your photo can be a .jpg file.

STEP 3: Pay the course Fee:
Visit **www.imare.in** Use the option **"Buy Online" (/buy-online.aspx)** then choose the course you want to pay the course fee.

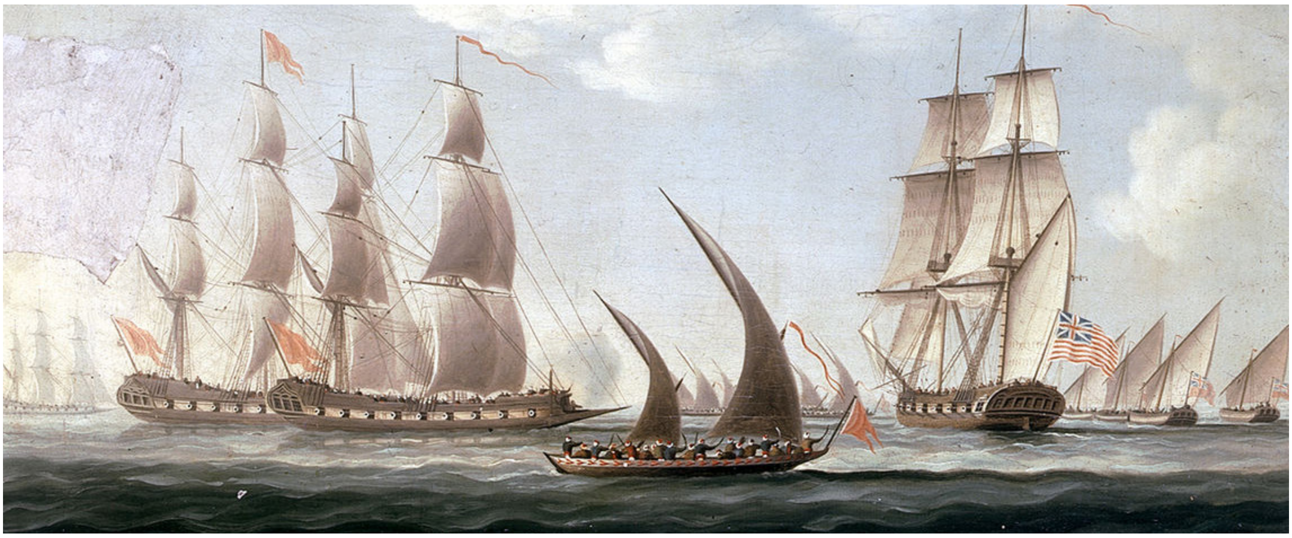
STEP 4: Send an email to **training@imare.in** and **accounts@imare.in**. Kindly mention that you have completed all steps i.e., Step 1, 2 & 3. After completing all the steps, share your details and transaction details.

STEP 5: On completion of all 4 above steps, you will receive confirmation from training department.

UNLESS YOU COMPLETE THE ABOVE 4 STEPS YOUR BOOKING WILL NOT BE CONFIRMED.

Note: In Case of Cancellation 25% of the Course fee will be deducted.

Heritage Hourglass : THE KING WHO RAISED A NAVY



Dennard H D'Souza

Traditional Indian polities were land-bound and largely confined themselves within the terrestrial frontiers of the Indian Sub-continent. Seldom did any Indian ruler ever consider the sea as an extension of his territorial domain. It must be noted that some rulers did have fleets patrolling the coast which were mandated to repulse seaward aggression and indulge in full-fledged battles, occasionally. But under Shivaji, the concept of a navy took a rather radical turn from the traditional modus operandi of indigenous navies.

According to Ramachandra Pant Amatya - who was the finance minister forming part of the elite coterie of Shivaji's *Ashta Pradhans* - the Maratha *Armaar* was established with the intention of acquiring dominion over the seas.[1] Such a concept of territorial waters was not conceived by the Indian princes here before, although some rulers assumed high-sounding titles like *Samudradhipati* (Lord of the seas) which rarely reflected their dominion on the seas.

By the time of the Mughals, the safety of the sea lanes was outsourced to the Europeans, who had already held the Arabian Sea to ransom. Whatever naval fleet the mighty Mughal state possessed was dwarfed in comparison to the sophisticated and numerously large fleets of the Europeans. The infirmities of the Mughal naval establishment would in the future prove to be the Achilles heel of the Mughal Empire. An empire that had already begun crumbling under the despotic rule of Aurangzeb. It is at this interstices period that Shivaji raised an armed flotilla which was small in comparison to the leviathan armadas of the European intruders but bagged great achievement through the strategic use of its agility.

The Maratha navy took form in the din of clashing swords of the Bijapur and Mughal sultanate. In the chaos that ensued after the fall of the Bidar fort –An important garrison of the Bijapur sultanate – Shivaji saw an opportunity in the power vacuum and descended into North Konkan and captured the port city of Kalyan and the neighboring town of Bhiwandi from the Bijapur Sultan. Kalyan was already a well-fortified city and a functional Ship-building hub inhabited by resident shipwrights even before it was acquired by Shivaji.[1] It was from Kalyan that the keel for the first ship to join Shivaji's navy was set afloat in 1659.[2]

After the capture of the North Konkan, Shivaji set his eyes onto the South. In a series of victories, he captured the district of Kolaba (Modern day Raigad district) with all its Important forts. By 1663 the important trading ports of Rajapur and Dabhol came under his territorial domain. Dabhol and Rajapur were reputed to have traded in pricey merchandise with the ports of the Red Sea and Hormuz.[3]

Having control of such ports would have enhanced the revenue of the Maratha state and exercised considerable influence on the transoceanic trade between India and West Asia. It seems Shivaji had taken a deep interest in the maritime economy of his state and a navy would have been essential to maintain the stability of trade especially when there were aggressive competitors like the Europeans. The East India Company records show that Shivaji had established trade relations with the ports of West Asia and he even sent several ships to these ports annually which, were mostly laden with salt and rice.

Besides maintaining order on the Konkan coast, the Maratha navy waged a few naval expeditions outside its domain, the most outstanding of which was the sacking of Basrur. The city of Basrur in the seventeenth century was a prosperous port town on the Kanara coast perched on the southern banks of the Panchagangavali. The town of Basrur was originally in possession of the Portuguese before it was acquired by the Bednore Nayaka, Shivappa in 1652.

However, the port town once again fell into the hand of the Portuguese after a series of intrigues, deaths, and succession battles in the Nayaka's family. Basrur was for the Portuguese the granary of the Estado da India from where food was rationed throughout the Portuguese enclaves in India.[4]

At the same time, when Shivaji was planning his raid on Basrur, the Portuguese were involved in their own strife, concerning the Islands of Bombay which was then part of the Portuguese domain in India - before it was handed over reluctantly to the British. The Islands of Bombay became a bone of contention between the Portuguese Viceroy Mello de Castro and the British, who had since long coveted the seven islands.

The Portuguese viceroy refused to obey orders to transfer the islands of Bombay to the British which were promised in dowry to Catherine of Braganza upon her marriage to Charles II of England. Sensing opportunity in this ensuing chaos, Shivaji raided Basrur on 14 February 1665 with a fleet of three big ships and eighty-five small frigates.[5] The troop sailed from Maland[6]- a port to the north of Malwan, with Shivaji himself leading the expedition from the front, a rare feat for Kings of the Medieval period.

Even before the expedition could be undertaken, Shivaji had the Kanara Coast recced by his trusted aides. This shows that the Maratha navy had achieved a considerable degree of sophistication in the art of Naval warfare even at such a nascent stage of evolution.

The Maratha navy in size and number of their ships was modest in comparison to the European fleet, which was unlike anything seen before in the waters of the Konkan. In distinction to their European counterparts who depended largely on ammunition for warfare, the Maratha navy used the topography of the Konkan in consonance with their agile crafts. This tactical use of geography and agility at sea proved to be of great utility for the guerilla form of warfare that was the hallmark of Shivaji's career on land.

According to contemporary chronicles, Shivaji's naval fleet consisted of 400-500 ships, big and small, known as "Gurab, Tarande, Galbat, Mubar, Sihad, Pagar, Machva, Tirkati ana Pal. The men who manned his naval flotilla belong mostly to traditional coastal communities who were raised in the briny air of the Arabian sea. Most of these men belonged to Koli and Bhandari classes.

The Kolis were traditionally involved in the fishing trade. They built and manned their own boats at sea and their knowledge of the coastal geomorphology was fairly foolproof. The bhandaris were held in high regards for the capability to climb steep trees. As toddy tappers, the Bhandaris were capable of swinging between two palm trees.

Seeing this talent already at hand, Shivaji employed the services of both these classes. He made the Kolis to man his ships while he appointed the Bhandaris to serve at the mast. Darya Sarang and Mainak Bhandari were some of the leading stars of the Maratha Navy.

Truly in the history of indigenous warfare, the Marathas were the first to make optimum use of its navy to acquire sovereignty at sea. Shivaji was the only indigenous ruler to have foresight which was rare among the medieval princes of India.

Endnotes

1. https://archive.org/details/Adnyapatra1/mode/1up
2. MacDougall, Philip. Naval Resistance to Britain's Growing Power in India, 1660-1800: The Saffron Banner and the Tiger of Mysore. United Kingdom: Boydell Press, 2014.
3. Apte, Bhalchandra Krishna. A History of the Maratha Navy and Merchantships. India: State Board for Literature and Culture, 1973.
4. Subrahmanyam, Sanjay. "The Portuguese, the Port of Basrur, and the Rice Trade, 1600-50." The Indian Economic & Social History Review 21, no. 4 (December 1984): 433–62. https://doi.org/10.1177/001946468402100403.
5. Sarkar, Jadunath. Shivaji and His Times. India: Alpha Editions, 2019.
6. Pagdi, Setumadhava Rao. Shivaji. India: National Book Trust, 1990.
7. Ibid
8. Shejwalkar, T. S. "SIVAJI'S RAID ON BASRUR." Bulletin of the Deccan College Research Institute 4, no. 2 (1942): 135–46. http://www.jstor.org/stable/42929309.

About the Author

Dennard H Dsouza works at the Maritime History Society as a Senior Research Associate. He has a master's degree in Ancient Indian Culture History and Archaeology from Saint Xavier's College, Mumbai. Currently his work entails documentation and research of India's Naval and Cultural legacy on the Trans Indian Ocean Routes. His other interest areas are in the study of ancient polities of the East and intermingling of Cultures, Religion and Art as a result of trans regional movement. He also keenly observes current global trends and the application of history to augment policy.

Email: dennardhdofficial@gmail.com

IN THE WAKE

Rajoo Balaji

Corona Chronicles

Are the Shanghai shivers for real?

If not, India must be nearing zero at the IPL (Indian Pandemic Losses, I mean).

A Fair Warfare

The political arena sees a number of name changes. Any Party comes to power, it goes about naming and renaming streets, programmes/policies with personalities (many may not be known beyond the Party's corridors). The warring factions and supporting countries also do this. Check this out...

In the US of A, now anything Russian is an anathema...

Items that have been swept off the shelves: Russian Salad/Caviar/Vodka/beer. Moscow Mule is now Ukraine Mule.

So was it during the WW I & II: Sauerkraut became Liberty Cabbage; Hamburgers became Liberty Steaks; Frankfurters became Hot Dogs (of course). The French Fries also underwent an appellation agony... as Freedom Fries. Yes, all these in America.

We in India can be renaming Mysore Pak as Mysore Mittai; Cheeni can become Gannameeta (sweet from sugarcane).

Russia for US can be Ughrussia and Ukraine: Bombrain.

Tech Talks:

Heard of a horizontal ship becoming vertical and partly stays out of water?

Yes. The Floating Instrument Platform (FLIP) [research vessel] has been doing just that for years now (first build 1962?).

FLIP has no self-propelling power but is usually towed. From about 3+ metre draft, she flips vertical to 90+ metre draft (in about 30 minutes). Interesting info: the FLIP Structure has duplicated toilets; two doors... horizontal & vertical (ceilings become walls, remember?), two sets of lights etc.

How does it flip? Playing with about 700 tonnes of ballast.

What do they use it for?

(Source: https://gcaptain.com/the-flip-scripps-institute-of-oceanography/)

Ocean research (study sound wave pattern changes due to ocean thermal gradients and sloping sea floors etc.).

Why is it in news?

There is a contemplation that it has outlived its use as a stable ocean research platform (but some believe, it will still continue to contribute). But there is one use: Education & Training on the Laboratory at Sea. So To FLIP or not to FLIP is not a question worth thinking about.

Rather we may work on a FLIP with the pressing of a button (yes, like we flip in the MS Windows).

About May

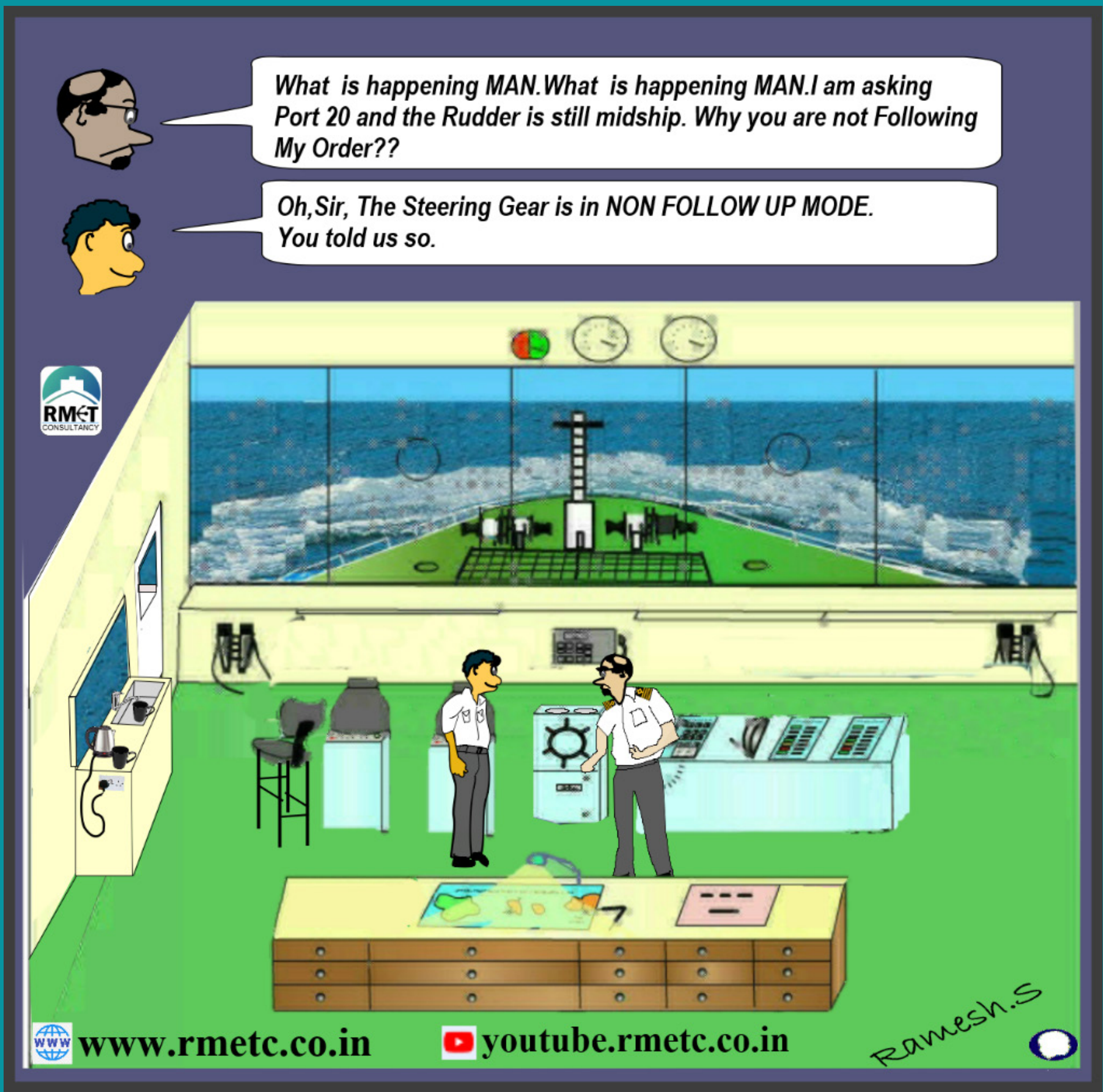
May we keep the days in May for a healthy way...

1 May: World Laughter Day (Laugh and the world laughs with you...)

12 May: International Nurses Day (Go Vaccine or Go Virus... Don't we need them always?)

31 May: World No-Tobacco Day ('exit to eCigarettes' too must be the motto)

THE END VIEW

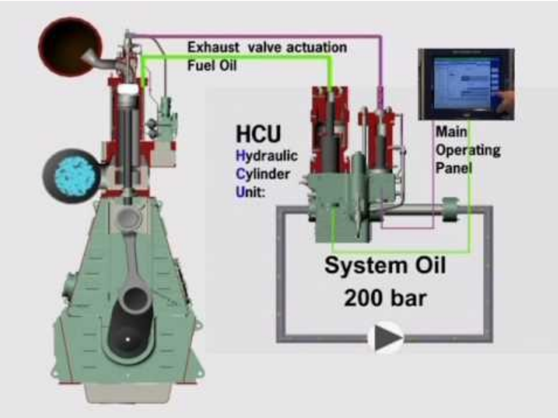


Idea, Words & Drawing: **Ramesh Subramanian**

MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

Electronic Engine Familiarisation Course (ME-Type Engine) Delivered online with Cloud access to ME Engine Simulator



This 3 days course is designed for all Ship's Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. This course consists of technical lessons and practical instructions on the design, principles, operating procedures and maintenance activities for the safe, efficient and optimal performance of the engine system.

Course Aims and Objectives:

The course aims to provide practical understanding of the principles, design, operation and maintenance of the ME Engine System, enabling participants to safely and efficiently operate the engine and perform fault-finding in the control system.

Coverage / Program Focus:

This course deals with the following training areas:

- **Introduction to ME Engine**
- **Hydraulic Power Supply (HPS)**
- **Hydraulic Cylinder Unit (HCU)**
- **Engine Control System (ECS)**
- **Main Operating Panel (MOP)**
- **Standard Operation**

Entry Requirement / Target Group:

Entry is open to all Ship's Engineers and Electro Technical Officers with basic knowledge of diesel engines.

DATE & TIMING : 17th to 19th **May'22**; 14th to 16th **June'22**; 19th to 21st **July'22**; 16th to 18th **Aug'22**; 20th to 22nd **Sep'22** **8:00 am - 4:00 pm IST**

VENUE : Web Platform / Zoom**. APPLICATION LINK:** https://forms.gle/e4As7kCucR5xoJBm9

REGISTRATION & PAYMENT : Rs. 15,000/- /- per participant – inclusive of taxes.
For IME(I) Members 13,500/- per participant - inclusive of taxes.
Payment to be made to: https://imare.in/buy-online.aspx
(Under Category - Value added Courses) *10% discount available for IME(I) members*

FOR MORE INFORMATION : **@IME(I)** - **email:** training@imare.in, Ms. Anukampa
(M). 9819325273, **(T)** 022 27701664 / 27711663 / 2771 1664.
@ MASSA Maritime Academy Chennai - **email:** mmachennai@massa.in.net
Ms. Saraswathi, **(T)** 8807025336 / 7200055336 .

After registration and payment, please email the details of the receipt to: ***training@imare.in***

Published on 5th of every month
and Posted on 5th & 6th of every month at
Mumbai Patrika Channel Sorting Office, G.P.O., Mumbai - 400 001.
'Licence to post without prepayment'

"Reg. No. MCS/090/2018-20"
RNI No. MAHENG/2006/19917
W.P.P. Licence No.:
MR/Tech/WPP-336/ South/2018-20

IME(I) House, Nerul, Navi Mumbai