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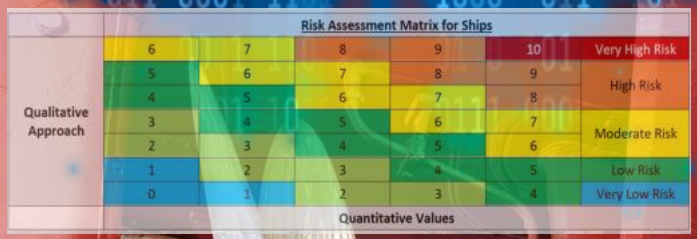

Regarding Risk Management on Research Vessels

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EDITORIAL

Live each season as it passes; breathe the air, drink the drink, taste the fruit, and resign yourself to the influences of each.
- Henry David Thoreau

The Glasgow COP26 was another chase for 1.5°C. Typical of such Conferences, there were droppings of keywords, but the commitments appeared only a little further than lip reverence. 'Phasing out' and 'phasing down' are bound to become fancy words in the coming confluences. Goals for coal elimination and corpus by the developed Nations to finance the developing ones were couple of unsmiling discussion points.

India's stand was rather pragmatic, pushing the deadline to 2070 for Net Zero status. The One Sun, One World, One Grid model (OSOWOG) and concerted focus on enhancing renewable energy sector could be a reality if the leadership and decision making are as efficient.

In the global context, relevant to maritime sector (being one of the hard-to-abate sectors), a promise to partially decarbonise was extended. Nations assured that at least 6 shipping routes will have 'Green Shipping Corridors' by mid 2020s. Since this does not apply to all ships plying in the routes, the target-deliverables appear hazy.

Though the COP26 was not as climacteric for the climate concerns, yet a prediction from this point is imperative: The coming decades will see greater thrust on electrification, energy efficiency, fist-loosening on fossil fuel/coal dependence, renewable energy exploitation, amongst other measures.

Another feeling emerging is the acceptance to the idea that containing the rise to 1.5°C is a difficult proposition in the given scenario. But efforts must go on and there is evidence to support. The seasonal flooding of cities and lands and fog-hazy air the globe is experiencing could become permanent satellite images for the future if the efforts are not influential enough.

If our labours do not attain fruition, the coming generations (maybe the current ones also) will still be able to breathe the air, eat the fruit and resign themselves to the nature but there might be no seasons to relish.

In this issue...

Mitigation of losses is an inherent preventive strategy in modern systems. Business and engineering solutions are spun out assessing at least a threshold level of risks of failure. With technology sophistication increasing day by day, the vulnerability of systems also increases exponentially. Shipboard systems are very much in the reckoning. Dr. Rajasekhar *et al.,* discuss few aspects of risk analysis and management with exemplar approaches. Though a deeper understanding is warranted in determining impact etc., the article projects one effective illustration of stern tube seal damage risk, which will connect well with an interested reader.

Following this, we gently dive deeper with Probabilistic Risk Assessment (PRA). In Part B of this Power Management series, Dr. Veda explains the PRA and the fault analysis. The approach to risk management through the ALARP/ALARA format is an interesting format which could be well applied to other systems demanding reliability. A seamless protection, based on strong theory underpinning the hardware functions is certain to enhance the user (engineers) confidence during operations.

We continue taking risk (as the theme) with an essay on cyber security. In the pandemic pressed year which went by, statistics indicate almost 90% of companies in industrial sector were subject to cyber-attacks. Notably, more than half of the industrial sector is unaware of the dangers. Ca. Mihir Chandra presents a collection of the obvious dangers and much deliberated regular information. This will be an easy read and a reminder of the changes happening on the security front.

Under Technical Notes, Agaram Ramanujan is back with a collision damage study and out flow analysis considering a tanker.

Under Spanner in the Works column, Shankar Ram narrates a Bond like escape from a PCTC and leaves few questions hanging for the sailing engineers to muse upon.

And we may tap feet with Taylor Swift to her Back to December rune and tune...

I'd go back to December, turn around and make it alright,
I'd go back to December, turn around and change my own mind,
I go back to December all the time...All the time.

This possibly could be one December we wish not to come back to but to make it all right, let us move ahead, putting away the pandemic perils... and welcome the New Year just coming around...

Hope you enjoy this December issue...

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In This Issue

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COLUMNS

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Engineering solution for fishing nets' entanglement.

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RISK ANALYSIS AND MANAGEMENT: AN EFFICIENT APPROACH FOR PERFORMANCE ENHANCEMENT OF RESEARCH SHIPS

D. Rajasekhar, D. Narendrakumar, Ananthakrishna, P. S. Deepaksankar, Pratik Bose

ABSTRACT

Establishment of various technologies are encouraged in order to meet the goals of maritime operations and oceanic research in terms of utilisation, efficiency and reliability. Incessant efforts are put up for various innovations and simultaneously the need for risk analysis for systems installed on board vessels has become an important aspect to monitor. Research vessels of India are the salient floating platforms for various oceanographic explorations undertaking various scientific research and technology demonstrations. There is huge need to operate these vessels with minimal interruptions to gain operational time to meet various Scientific Mission Requirement [SMR]. In this study, research vessels have been considered to provide an insight on various aspect of risk analysis and management to enhance the system performance by introducing appropriate modifications to the system designs.

Keywords: Research Vessel, Scientific Mission Requirements [SMR], Risk Analysis and Management

1. INTRODUCTION

Research vessels of India has been a crucial ocean observing platform for various technical innovations and has been successful in obtaining all the goals thus benefitting the scientific community to a large extent. Innovations implemented has been traditionally based on experiential learning and incremental novelties. With the continuous development in the maritime sector and research vessels, the concept of "artificial intelligence and unmanned vehicle" are used. Moreover, the environmental awareness technologies and sophisticated navigational and communication equipment installed on board the vessels have been providing a broader horizon of technical feasibility for the development to Green Smart efficient ships. Integration of advanced scientific equipment with the ship fleet operations is a methodological tool to approach the complexity.

In spite of increasing accuracy and highly precision equipment, contemporary technologies need to be controlled and monitored as remote operations increase the attack surface and makes them more vulnerable to threats and technical glitches. Interruptions in the operational need of a research ships may affect a planned scientific cruise which may incur huge cost and loss of precious oceanic survey time. Ever since India has boosted up oceanographic research, marine survey and technological demonstration in various environmentally challenging areas, the importance of risk assessment and management of the equipment on board has become increasingly important.

National Institute of Ocean Technology [NIOT] is a Research and Development organisation under the Ministry of Earth Sciences [MoES], Government of India. NIOT/MoES is having a fleet of Research Vessels: Oceanographic Research Vessel [ORV] Sagar Nidhi & Sagar Manjusha, Coastal research Vessel [CRV] Sagar Tara and Sagar Anveshika as shown in **Figure 1**. These vessels are effectively utilised for various Oceanographic research and coastal monitoring study viz, deployment of Tsunami Buoys, atmospheric study and data collection for weather forecasting, deployment of ROV/AUV, monitoring of marine pollution levels, swathe bathymetry survey, etc., which are of national importance.

Figure 1: Operational Fleet of NIOT

2. RISK ANALYSIS AND MANAGEMENT

Development in modern technologies have led to shipboard machineries and equipment fitted with complex integration of various system wherein, huge amount of data and information are exchanged for operation, control or any other physical process. But this exchange of information through networked system is more susceptible to cyber-attacks. In order to address the issue, risk analysis is the effective tool which encompasses for assessing and examining to avoid or mitigate the risk to an acceptable level.

Risk analysis is a multi-layered process which identifies the source of risk factors, as well as probability of occurrence and severity of the consequences. It is imperative to identify the factors for elaborating the strategies for risk diminishing and improvement of safety during the scientific cruise at deep sea by adopting measures for prevention, control and reducing the risk factor. Systematic assessment of maritime risk management is essential for improving on the risk factors. It represents a complex set of interdependent and intersecting features which will balance the impending challenges. Determining risk is the process of estimating the extent to which an entity is threatened by potential or unforeseen circumstances which is a function of adverse impacts based on the event and likelihood of occurrence.

2.1 Need for Risk Analysis and Evaluation of Assets

The present study intends to provide an insight about the evaluation of risk factors for a ship as highlighted below, by exploiting the vulnerability that may result in an undesirable consequence. The main objective of the study is to model a dynamic overview of occurrence in a semi-quantitative approach by assigning the risk factor and modify the system design to mitigate impending eventualities.

Risk analysis is a multi-layered process which identifies the source of risk factors, as well as probability of occurrence and severity of the consequences

In the analysis, ECDIS has been assigned with highest value of vulnerability as it has to be updated with anti-malware and anti-virus with time

Risk factor = function [Impact, Likelihood of Occurrence]

The scope of this study includes the mandatory navigational and communication equipment for Integrated Bridge System to analyse from potential threats of cybersecurity risk. The study will include the criticality on the basis of confidentiality, integrity or availability. The essential navigation and communication equipment with application is mentioned in **Table 1** for further analysis.

Based on various Information Security Risk Assessment listed on National Institute of Standards and Technology Special Edition [NIST SP800-30], some threats are identified and considered for the study as listed below.

- **Communication interception attacks:** Taking advantage of communication systems that are either unencrypted or weakly encrypted.
- **Wireless jamming attacks:** Interfere with wireless communications to prevent communications from reaching intended recipients.
- **Attacks using unauthorised, ports, protocols and services:** Ingress or egress that are not authorised for use by organisations.

In this analysis, based on the likelihood of threat & vulnerability, the occurrence value is calculated pertaining to the navigational and communication equipment installed on board and its values are marked as low probability (1), medium probability (2) and high probability (3). Similarly, the level of vulnerability is also assigned for each of the navigation and communication equipment installed on board the vessels and the values can be defined as low (1), medium (2) and high (3) as shown in **Table 2.** In the analysis, ECDIS has been assigned with highest value of vulnerability as it has to be updated with anti-malware and anti-virus with time.

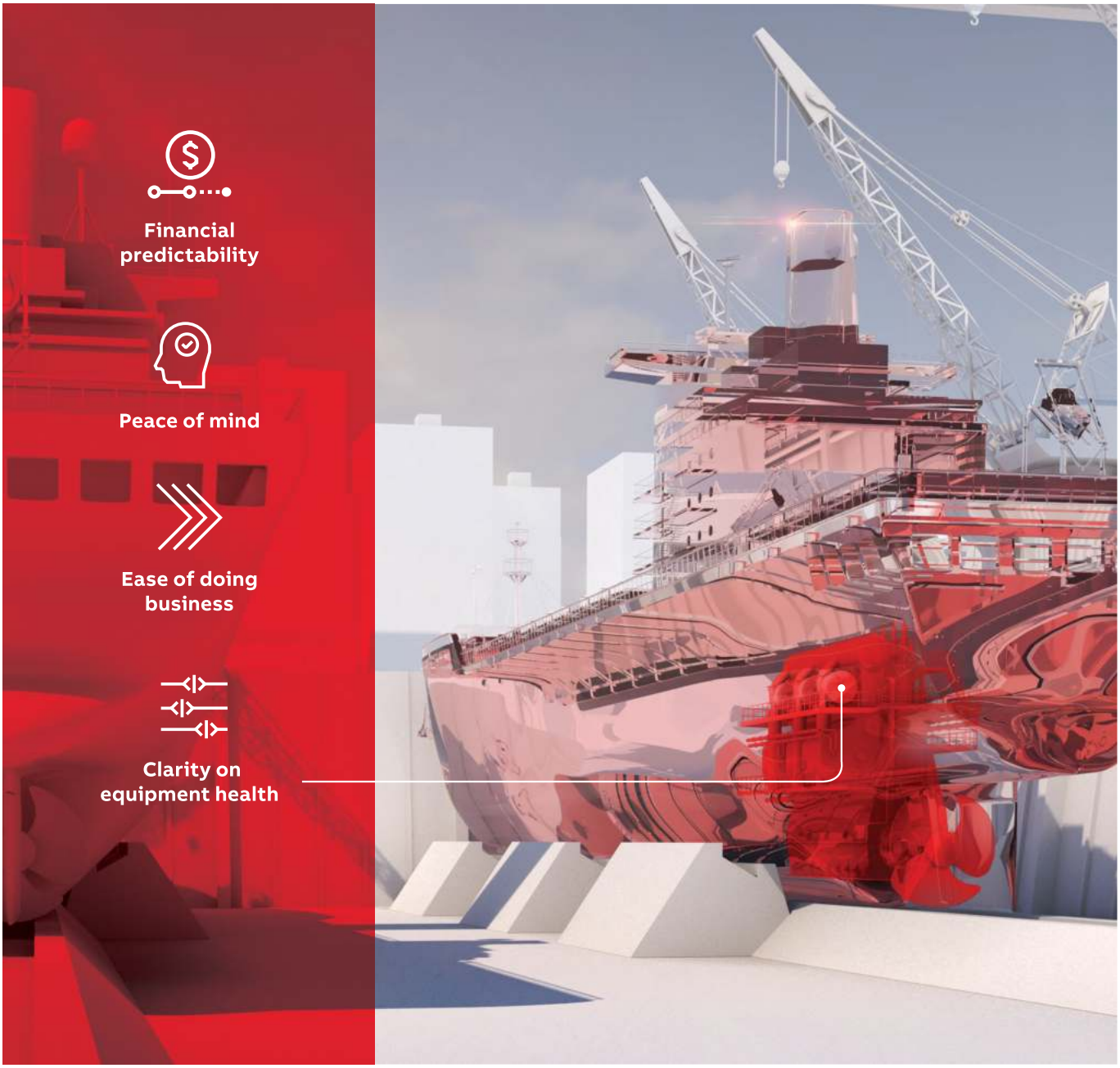

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Table 1: Equipment and its function for Integrated Bridge System

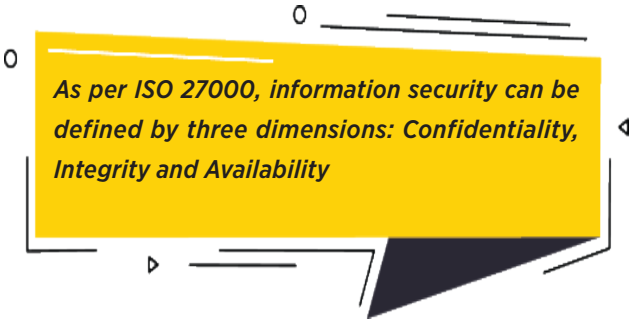
Equipment	ECDIS	Radar	Alarm Monitoring System [AMS]	AIS	GNSS	GDMSS Station	Navtex Receiver	VHF	Manual Steering Control
Functions	1. Planning of cruise track prior departure 2. Alter cruise track while underway. 3. Automatic determination and plotting of ship's position and route keeping. 4. Maintain track of traffic	1. Detect floating targets and analyse traffic situation 2. Track traffic	1. Monitor and evaluate on act of alarms for various system.	1. Transmits ship's position & decide on collision avoidance measures	1. Read Position on display 2. Plot Position	1. Distress Weather Safety 2. Alerting of shore-based communication and rescue authorities	1.Determine weather Conditions 2. Consider navigation warnings 3. Delivery of navigational and meteorological warnings and forecasts	1. External communications	1. Steering 2. Adjust Positioning and ship's heading

Table 2: Likelihood of Threat

System	Integrated Bridge System								
Assets	**ECDIS**	**Radar**	**Alarm Monitoring System [AMS]**	**AIS**	**GNSS**	**GDMSS Station**	**Navtex Receiver**	**VHF**	**Manual Steering Control**
Threat Scenario	Adversary remotely takes control of **ECDIS**	Adversary remotely takes control of **Radar**	**AMS** is not responding as a result of interception	Adversary intercepted **AIS**	Adversary intercepted **GNSS**	Adversary intercepted **GMDSS**	Adversary intercepted **Navtex**	Adversary intercepted **VHF**	Adversary remotely takes control of **steering control**
Likelihood of threat [1 to 3]	3	2	2	2	2	1	1	1	2
Level of vulnerability [1 to 3]	3	1	1	2	1	1	1	1	1
Likelihood of occurrence	9	2	2	4	2	1	1	1	2

Moreover, the likelihood of occurrence for any system is determined by the probability that the threats exploit vulnerabilities in the probable situations. The likelihood of occurrence is calculated by the product of Likelihood of threat and Level of vulnerability for the navigational equipment as shown in **Table 2**.

As per ISO 27000, information security can be defined by three dimensions: Confidentiality, Integrity and Availability.



2.2 Determination of Impact Value

The impact value can be evaluated as the aggregated value for confidentiality, integrity or availability of the equipment by which the system is integrated. However, null value for confidentiality has been assumed. In this study, the impact value for the bridge equipment has been evaluated as appended in **Table 3**.

2.3 Determination of Risk Factor

Based on the impact value and likelihood of occurrence, individual value of risk for the equipment is evaluated. In this analysis, the evaluation for the values is determined based on the circumstance and with consultation with the personnel on board. The risk level of the equipment and integrated bridge system are calculated as the product

Table 3: Determination of Impact Value

System	Integrated Bridge System								
Equipment impact value on each dimension	ECDIS	Radar	Alarm Monitoring System [AMS]	AIS	GNSS	GDMSS Station	Navtex Receiver	VHF	Manual Steering Control
Integrity	10	10	10	8	10	6	5	6	10
Avail-ability	6	8	7	5	6	5	3	6	10
Impact Value	16	18	17	13	16	11	8	12	20

Table 4: Determination of Risk Factor

System	Integrated Bridge System								
Equipment impact value on each dimension	ECDIS	Radar	Alarm Monitoring System [AMS]	AIS	GNSS	GDMSS Station	Navtex Receiver	VHF	Manual Steering Control
Likelihood of occurrence	9	2	2	4	2	1	1	1	2
Impact Value	16	18	17	13	16	11	8	12	20
Risk Factor of equip-ment	144	36	34	52	32	11	8	12	40
Risk factor for system	369								

Table 5: Assessment of Risk Analysis

System	Integrated Bridge System								
Risk Value	ECDIS	Radar	Alarm Monitoring System [AMS]	AIS	GNSS	GDMSS Station	Navtex Receiver	VHF	Manual Steering Control
Risk of Equipment	80	20	18.89	28.89	17.78	6.11	4.45	6.67	22.22
System Risk	22.78								

of impact value (2 to 20) and likelihood of occurrence (1 to 9) as indicated in the **Table 4**.

Equipment risk = [∑ Equipment risk / 180]* 100; with 180 being the maximum value of risk for an equipment.

System risk = [Equipment risk / 1620]* 100; with 1620 being the maximum system risk value.

Based on the assessment scale of risk levels elaborated in NIST SP800-30 R1 as shown in **Table 6**, it has been observed that value for ECDIS has a very risk value and thus it needs to be addressed to minimise to an acceptable level as shown in **Table 5**. However, overall risk factor of the integrated bridge system is on the verge of lower side (considering the value range).

Table 6: Assessment Scale – Level of Risk

Qualitative Values	Semi-Quantitative Values	Description	
Very High	96–100	10	Very High risk
High	80–95	8	High risk
Moderate	21–79	5	Moderate risk
Low	5–20	2	Low risk
Very low	0–4	0	Very low risk

Figure 2, 3: Testing setup for computational vulnerability scanning of ECDIS, Integrated Bridge System on board Sagar Nidhi

2.4 Risk Management and Mitigation Controls implemented on board

Risk Management and mitigation controls deals with the reduction of risk levels to an acceptable level as per the prevailing standard. It is important to reduce the probability of threats exploiting vulnerability and its impact. Technical solutions are implemented on board NIOT Research Ships to improve the safety of ship and personnel on board, to enhance the reliability and improve the performance of the system. To reduce the level of venerability,

- ECDIS is patched, scanning of vulnerability and anti-virus installed on board the ships as shown in **Figure 2**
- Regular intervention of OEM for navigational and communication equipment and various systems are ensured and thorough inspections are carried out to upgrade for any information security warnings related to interceptions
- Remedial patches are applied by OEM against vulnerabilities, probable threats and unforeseen eventualities
- Safety management system and simulation course are updated to train and practice the thorough operational safety procedures
- The default passcode has been changed and control mechanism has been enforced

Risk Management and mitigation controls deals with the reduction of risk levels to an acceptable level as per the prevailing standard

Based on thorough research, mitigation plan has been implemented on board NIOT Research Ships **(Figure 3)**. Related to this, the new level of vulnerability can be defined as: 1 (low) for ECDIS and AIS and impact value has been reduced to 12 for ECDIS.

Similarly, following the standard calculation with the updated value of vulnerability, **Table 7** illustrates the new values of assessment for risk analysis.

It can be inferred that the risk analysis for both equipment and system has a low value and it is within the acceptable limit as per the prevailing standard. Constant effort and incessant follow up is ensured for NIOT research ships to reduce the risk factor to obsolete the probable risk to enhance the operational time.

3. CONDITION BASED MACHINE RISK ANALYSIS – A SUCCESSFUL APPROACH

Machine Risk Analysis is one of the optimum tools to analyse the innovation, quality and reliability. It is extremely important to understand the basic design and construction of a research ships to effectively utilise the ship time in sea for various survey of multi-disciplinary nature. Coastal survey and oceanic research demand propulsion plant capable of operating in severe environment as well. The most challenging part of whole system design is to cater scientific mission requirements in extreme environment. This highlights the need of identification of vulnerability and risk reduction in marine propulsion equipment specification.

Sagar Tara and Sagar Anveshika are the Coastal Research Vessel owned by MoES, equipped with state-of-the-art scientific equipment and advanced navigational system which are deployed and extensively utilised for various scientific programmes along the entire coast of India which are of national importance viz., Monitoring of marine pollution levels, bathymetry survey of the Exclusive Economic Zone of India (EEZ), atmospheric study and data collection for weather forecasting, etc. This operational region is bound to have abundant floating dunnage, fishing nets, discarded ropes and other debris at all times and frequent entanglement in propeller is one of the major operational challenges as shown in **Figure 4**. Moreover, these research areas are shallow water regions, dumped with ghost nets (as abandoned fishing nets are called), torn lines, ropes, discarded plastic fish traps and other marine

Table 7: Assessment of Risk Analysis

System	Integrated Bridge System								
Risk Value	**ECDIS**	**Radar**	**Alarm Monitoring System [AMS]**	**AIS**	**GNSS**	**GDMSS Station**	**Navtex Receiver**	**VHF**	**Manual Steering Control**
Risk of Equipment	20	20	18.89	14.44	17.78	6.11	4.44	6.67	20
System Risk	14.25								

Figure 4: Fishing nets entangled in Propeller

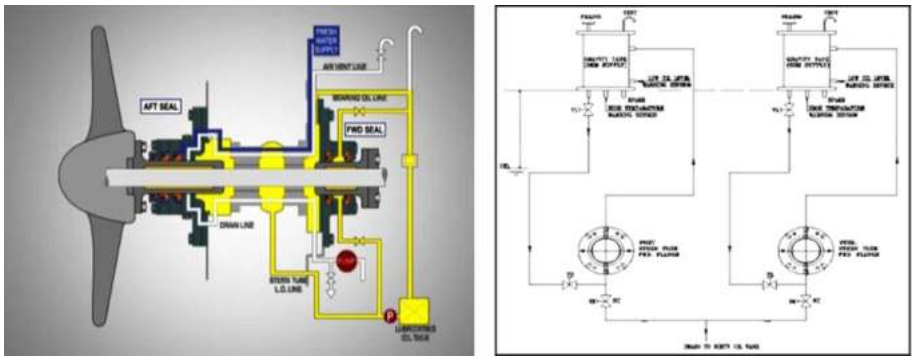


Figure 5: Shafting & Stern Tube Arrangement

debris. The shallow waters are important hunting grounds for small-scale fishermen.

Sealing arrangement between stern tube and the propeller shaft plays an important role to increase the reliability of the system under wonted and arduous condition of the shallow waters. The forward seal prevents stern tube oil entering into the vessel and the aft seal prevents stern tube oil from emanating out into the sea water and also prevents sea water entering into stern tube as shown in **Figure 5**.

Financial intervention is high on the list of consideration for stern tube arrangement and system analysis plays a pivotal role for judging the investment decision by assessing its costs and benefits. The forward and aft shaft seal is at a most risk in the system as shown in the probabilistic assessment in **Figure 6**. Through a damaged aft seal, stern tube oil will continuously emanate out in to sea and might cause water to enter the stern tube. As the water content in the oil increases, the load carrying capacity of the oil is reduced until the point at which the bearing can no longer function hydro dynamically and ultimately it fails. This can involve dry docking the ship and incur huge cost and loss of essential ship timing. The major factors involve dry docking which incurs huge cost is highlighted below.

- Dry docking fees and repair cost
- Cost for Classification agency / statutory survey
- Cost of necessary spares
- Damage repair cost

Thus, putting the appropriate action in place in a timely manner is a way of mitigating extra costs. Thus, to avoid the entanglement of fishing nets and ropes in propeller shaft, an exhaustive research was carried out pertaining to the existing arrangement of rope guards and designs of new rope cutters. L-Shaped 8 no's stainless-steel cutters are lap welded to the rope guard periphery with equidistance

Figure 6: Failure distribution of Shafting arrangement

during her mandatory dry dock as shown in the **Figure 7** to provide efficient cutting capability of nets and adequate strength. Adequate horizontal and vertical clearance between propeller hub, blade and cutter tip are maintained.

The arrangements for rope cutters proposed have been submitted to OEM prior fitment and the same had been approved without any further modification. This engineering solution has resulted in the minimisation of ship-time lost since there was no need to procure spares and saving of cost and operational time involved towards it as appended in the **Table 8**.

4. CONCLUSION

The proposed study on risk analysis presents a perspective to identify the selected foundational issues for research

Table 8: Innovative Solution for Safe Shallow Water Operation

Innovative System Design	Cost Savings (in INR)	Ship time gained
Design and fabrication of Net Cutters	20 Lakhs	22 days

Figure 7: Modified arrangement of rope cutters to get through ropes / fishing nets

ships to operate without any technical issue. A diversified gamut of oceanographic research and coastal study providing a wealth of data in such diverse and inter related fields can be undertaken successfully only by a thorough risk assessment and factors which influence their severity. Identifying new measures and implementing modification in the system design can enhance the reliability of the system. By leveraging the outcome of the assessment and applying a systematic structured approach, appropriate baseline mitigation plan has been identified and implemented which has enhanced the operational time of the research ships thus benefitting the scientific community to a great extent.

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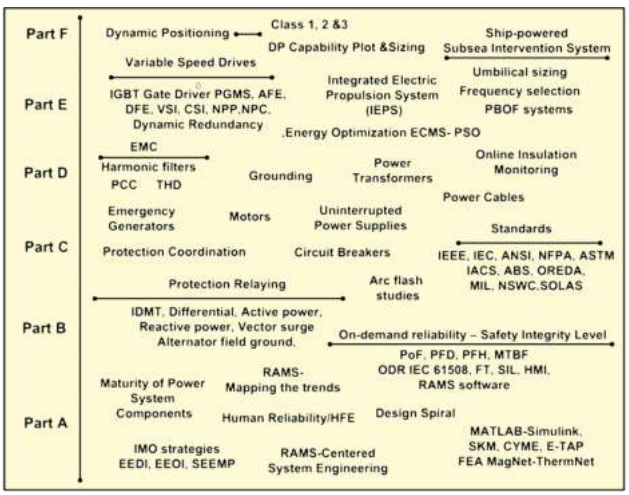
RAMS-CENTERED SYSTEM ENGINEERING AND OPERATIONS OF MODERN MULTI-MEGAWATT CAPACITY MARINE POWER SYSTEMS (PART B)

N. Vedachalam

ABSTRACT

This article in six parts (this is the second, Part B) discusses the importance, trends and integrated approach to RAMS-centred system engineering, key design and operational considerations for low- and medium-voltage marine power systems, including alternator protection, effective protection coordination, integrity requirements of relaying, emergency diesel generators and uninterrupted power supplies, significance of grounding, condition monitoring of power transformer, cables, motors, harmonics filters and the methodologies for realising fault-tolerant voltage source inverter based variable speed drives and dynamic positioning systems.

Part A (first part) of the series was published in the November 2021 issue.



Index terms: Alternator, Cables, Grounding, Harmonics, Medium Voltage, Motors, Protection Coordination, RAMS.

Integrated approach for RAMS estimation

Functional Reliability

Probabilistic Risk Assessment (PRA) is a comprehensive, structured and logical analysis used for identifying and assessing risks in complex technological systems. It is intended to cost-effectively improve their safety and performance [1]. The Fault Tree Analysis (FTA) which is a used in this article series is a PRA tool used to evaluate the combination of failures that can lead to the top event of interest.

An illustration for FTA shown in **Figure 1** made using TOTAL-GRIF reliability modelling and simulation software, comprises of basic events A, B and C (represented as circled Event 1, 2 and 3), OR operand B+C, and the AND operand A.(B+C) as the top event. The relationships for calculating the Probability of Failure (PoF) in OR and AND operations are shown in equations 1 and 2.

In **Figure 2**, the 2/3 voting gate (represented as KOutN1), the relationship for calculating the PoF in a redundant system is shown in equation 3. The voting gate in the FTA (**Figure 2**) indicates that if 2 components out of 3 fail at the same time, then the total system will be unavailable.

Probabilistic Risk Assessment (PRA) is a comprehensive, structured and logical analysis used for identifying and assessing risks in complex technological systems

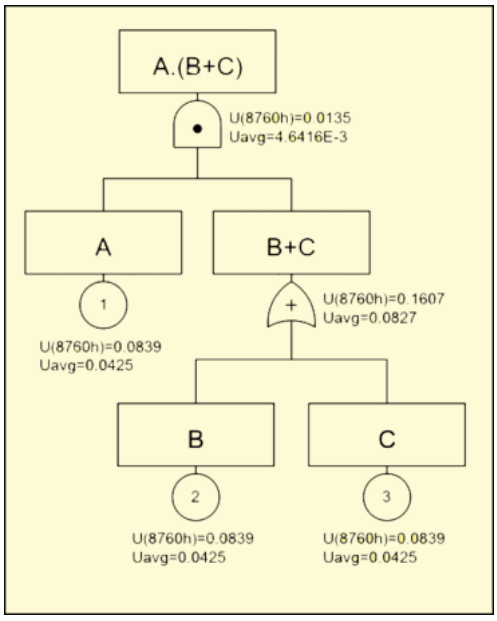


Figure 1 Methodology of FTA with AND & OR operands

When modelling the failure trees (FT), the failure/degradation patterns can be programmed for the individual components/events, which could be exponential, linear, power law, Weibull shaped, constant failure rate, non-homogenous Poisson process, etc. When simulating the FT for calculating the PoF, Weibull shape factor (also called Weibull slope) represented as β, provide information on the failure mechanism in which different slopes lead to different kind of failure predictions (**Table 1**).

As β gets steeper, failure times become more predictable, example, turbine vane wear out. When β>1, a periodic or scheduled inspection could be cost-effective in reducing breakdowns, which encourages reliability centred maintenance (RCM) approach for increasing the availability. If the failure rate is constant, then the component failures follow an exponential distribution.

$$P(A\ OR\ B) = P_A + P_B - P_A.P_B \quad (1)$$

$$P(A\ AND\ B) = P_A.P_B \quad (2)$$

$$R\ (2oo3)\ \text{system} = -2\ Pa\ Pb\ Pc + Pa\ Pb + Pa\ Pc + Pb\ Pc \quad (3)$$

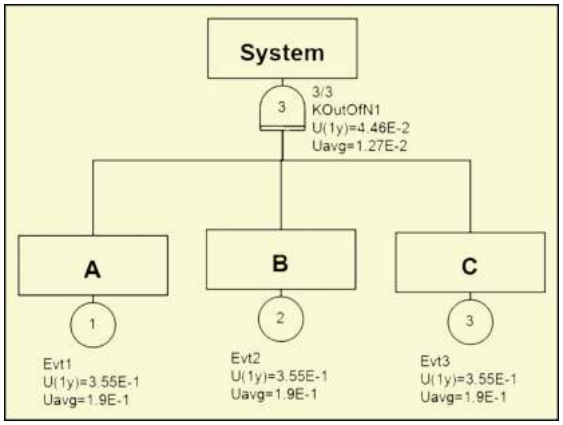


Figure 2 Methodology of FTA with multiple redundancies

Table 1. Failure patters based on Weibull slope

β	Failure pattern
<1	Infant mortality failures
=1	Due to design deficiencies/unexpected failures
>1	Represent wear-out failures like bearing cage failure
1.8-3	Failure over longer spans

Based on the calculated value of the top event failure rate, Mean Time To Fail (MTTF) is calculated as,

$$MTTF = 1/\lambda \quad (4)$$

The availability of the system in % is calculated as,

$$\%\ Availability = MTTF/(MTTF+MTTR) \quad (5)$$

Where MTTR is the Mean Time To Repair

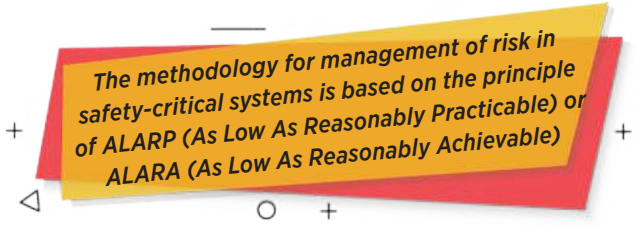
The availability of a system could be increased by increasing the MTTF (through redundancies) and by reducing the MTTR through improved restoration mechanisms.

On-demand Reliability

The methodology for management of risk in safety-critical systems is based on the principle of ALARP (As Low As Reasonably Practicable) or ALARA (As Low As Reasonably Achievable) (**Figure 3**). For a risk to be ALARP, it must be possible to demonstrate that the resources and time involved in reducing the risk further would be grossly disproportionate to the benefit. Hence the principle of ALARP is based on the scientific judgment on the trade-off between the risk, cost and performance (**Figure 4**).

Electrical protection and emergency support systems need to perform their intended function on demand, and hence managing their integrity over the operational period is critical. IEC 61508/11 standard is essentially a framework for implementing instrumented safety systems, using the principles of the safety life cycle and Safety Integrity Level (SIL) concepts. If a demand occurs after a time, the probability that the system has already failed is the Probability of Failure on Demand (PFD).

It is also defined as the ratio between the tolerable frequency of the accident to the frequency of the accident with no protection. The SIL defines the degree of safety protection required by the process and consecutively, the on-demand reliability (ODR) of the system necessary to achieve the function. SIL has four levels, 1 to 4, with the higher number meaning the safer the system.



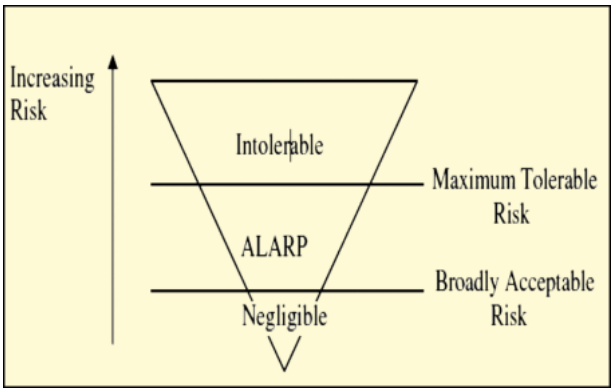


Figure 3 Principle of risk reduction based on ALARP (carrot diagram)

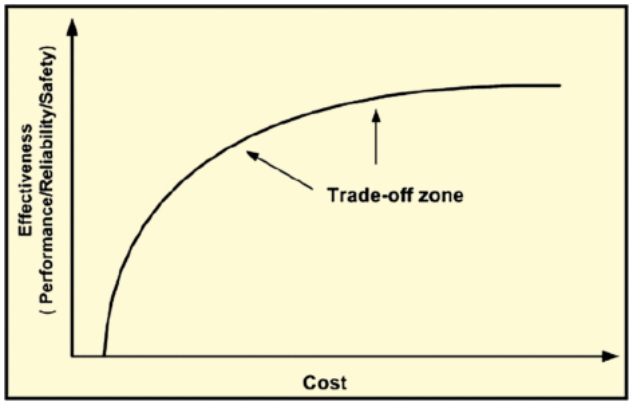


Figure 4 Performance-Cost trade-off

Table 2 describes various SIL with corresponding PFD for low and high demand systems [2].

Based on IEC 61508 Health, Safety and Environment (HSE) guidelines, SIL requirements are computed taking into consideration the risk consequence, alternative safety instrumented function (SIF) in place, human occupancy and the demand rate for the SIF. As an example, the system SIL requirements for various unsafe scenarios are summarised in **Table 3**.

In **Table 3**, parameters C, F, P and W represent the consequence of the incident (ranging from A to F), availability of alternate protection system (1 or 0), human presence (1 for occasional and 2 for continuous) and demand frequency (ranging from 5 to 9) is taken as 1-3 years, pertinent to power system fault frequency. It can be seen that for specific values of F, P and W, based on the consequence, the SIL requirements varies from 2 to 4.

In order to maintain the safety critical system in the desired SIL, it is required to identify the Proof Test Interval (PTI). Every time a proof test is carried out, the safety function is proven to work, and so the PFD is reset to zero. In **Figure 5**, Tp is PTI. The average PFD is given by,

$$PFD_{avg} = \frac{1}{T_P}\int_0^{T_P} 1 - e^{\lambda_{DU}t}dt \qquad (6)$$

Where T_p is the PTI, λ_{DU} is the failure rate of the safety system,.For $\lambda_{DU}\ T_p$<<1 , this simplifies to

$$PFD_{acg} = \tfrac{1}{2}\lambda_{DU}T_P \qquad (7)$$

Table 2. SIL & PFD for a low and high demand systems [2]

SIL	Low demand	High demand (PFH)
1	10^{-1} to 10^{-2}	10^{-5} to 10^{-6}
2	10^{-2} to 10^{-3}	10^{-6} to 10^{-7}
3	10^{-3} to 10^{-4}	10^{-7} to 10^{-8}
4	10^{-4} to 10^{-5}	10^{-8} to 10^{-9}

Table 3. SIL Requirement for various unsafe scenarios

Event/Accident	C	F	P	W	Sum	SIL
One death	D					2
Multiple deaths	F	0	2	8	10	4
Environmental damage	E					3

Table 4. SIL/ PFD for a low and high demand systems

SIL	Hardware failure tolerance
1	0 (simplex low or high demand)
2	0 (but low demand only)
3	1 (1oo2, 2oo3)
4	2 (1oo3, 2oo4)

Based on the recommendations of the IEC 61508/11 standards, the hardware redundancy requirements (allowed failure tolerance) for various levels of SIL are summarised in **Table 4**.

The methodology followed for computing the PoF, ODR and the PTI for time-critical protection systems based on the IEC 61508/11 HSE standards is shown in **Figure 6**. The methodology is adopted in process industries, marine and subsea production systems, including assessment of ODR of natural disaster warning systems [3] [4], deep water manned submersibles [5], deep water enhanced hydrocarbon recovery systems [6] and vessel dynamic positioning systems [7]. The commercially available software for the RAMS studies include TOTAL-GRIF, Reliass, Isograph, BQR, SHARPE, MATLAB, Mathworks, Weibull, SoHar, ALD, Relyence, Itemsoft etc.

Protection relaying for MV power generation system

Power system protection coordination (PC) is the choice and arrangement of the protective devices to ensure adequate protection of all zones of the marine power system. The ratings and settings of the protection devices

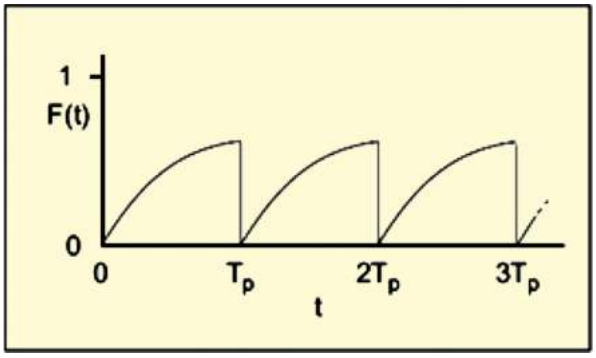


Figure 5 Principle of PTI and SIL management

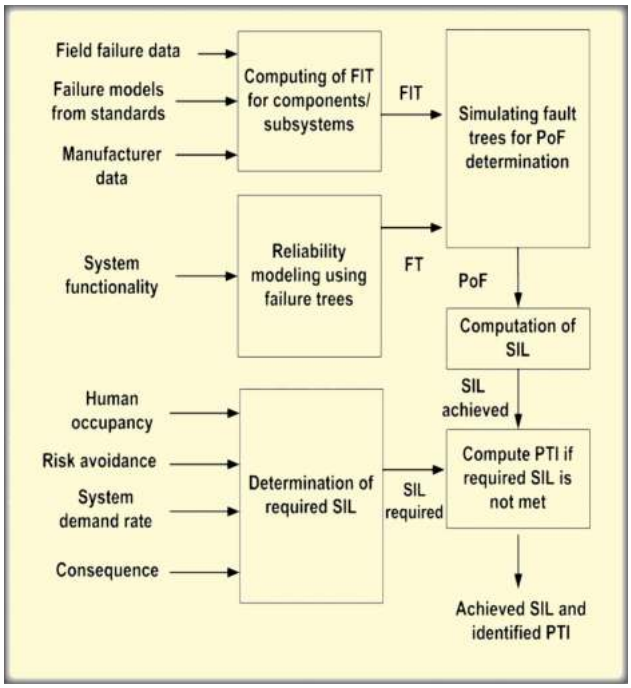


Figure 6 Functional and on-demand reliability assessment methodology

should ensure that the faulty section is discriminated and isolated within the shortest possible time, ensuring safety to the operating personnel, reduce equipment damages, and increasing the power system availability.

PC studies are done based on the power system single line diagrams (SLD) and the subsystem short circuit time-current curves. The standards defined by IEC [8] and American National Standards Institute (ANSI) [9] for the protection relays used for MV alternator, circuit breaker, transformers and motors are shown in **Table 5** and **Table 6**, respectively. The location of the relays in a typical multi megawatt MV marine power system is represented in **Figure 1**.

Power system protection coordination (PC) is the choice and arrangement of the protective devices to ensure adequate protection of all zones of the marine power system.

Table 5. IEC standards for protection systems [8]

Standard	Description
IEC61892	Electrical installations in offshore units
IEC 60909	Short-circuit currents in 3 phase ac systems
IEC60947	Low voltage switchgear and control gear.
IEC60255	Electrical relays
IEC60269	Low voltage fuses
IEC62020	Residual current monitors
IEC61378	Converter transformers
IEC 255-3	High voltage system protection characteristics

Table 6. ANSI code for protection relays [9]

Code	Device
50/51	Phase over current
50BF	Circuit breaker failure
59	Phase to Phase Overvoltage
59N	Neutral Voltage displacement relay
32	Directional active power (anti-motoring)
40	Directional reactive power (loss of field)
26	Transformer temperature, gas, buckholtz
27	Under voltage
87T	Transformer differential protection relay
46	Negative sequence/Unbalance
87G	Alternator differential current
64F	Alternator field ground
81H,L	Under frequency and Over frequency
38	Over temperature
81R	Rate of Change of Frequency (ROCOF)
66, 48	Motor starts per hour, Locked rotor
78PS	Alternator pole slip

Protection of the power system from over-currents arising out of short circuits is important for human and equipment safety. In a typical power system shown in **Figure 7**, the asymmetrical short circuit current arising due to superposition of direct current (DC) component on the symmetrical short circuit current is,

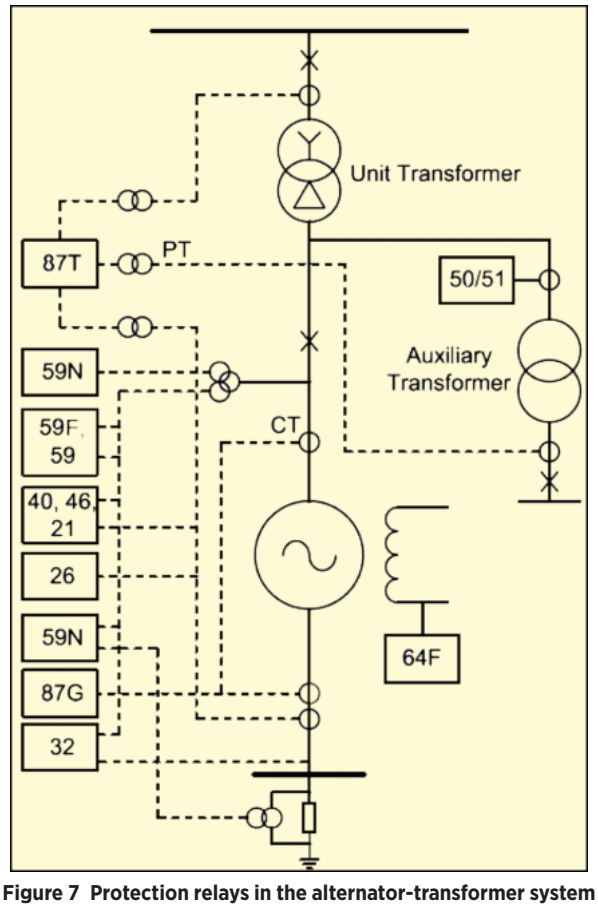


Figure 7 Protection relays in the alternator-transformer system

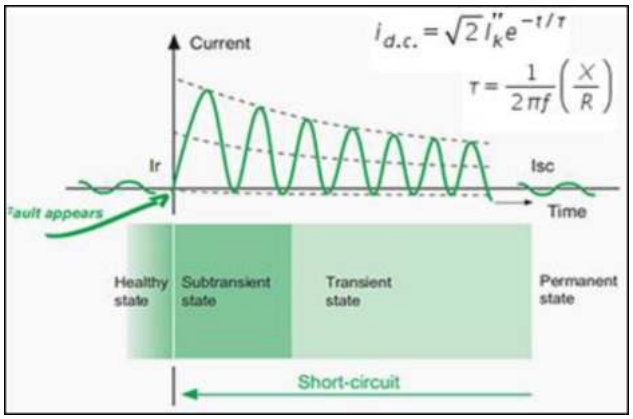


Figure 8 Short circuit current in a typical power systems

$$Isc = Ir/Xsc \quad (8)$$

Where Xsc is the short circuit reactance and Ir is the rated current of the power generating source.

The initial value of the DC component is dependent on the exact time within a cycle at which the fault occurs and the value of the current at that time. In extreme conditions, the initial DC offset will be √2 times the symmetrical root mean square (rms) value of the short circuit current. In the equation shown in **Figure 8**, Ik'' is the symmetrical short circuit current, T is the decay time constant (in secs), and t is the time of the fault occurrence, which could be up to 4 kA for a 10kV-15MVA synchronous alternator.

The sub-transient, transient and permanent short circuit reactance of a typical synchronous alternator is shown in **Table 7**. The accuracy class, accuracy limit factor and rated burden of current transformer (CT) and potential transformer (PT) should be given careful consideration during protection system engineering.

Table 7. Reactances for a typical synchronous alternator [8]

State	Sub-transient X''d	Transient X'd	Permanent Xd
Xsc	10–20%	15–25%	200–350%

Table 8. Characteristics of various IDMT relays [8][9]

Type of protection	Characteristic
Normal Inverse (Type A)	$\frac{0.14}{\left(I/I_P\right)^{0.02}-1}.T_P\,[s]$
Very Inverse (Type B)	$\frac{13.5}{\left(I/I_p\right)^{1}-1}.T_P\,[s]$
Extremely Inverse (Type C)	$\frac{80}{\left(I/I_P\right)^{2}-1}.T_P\,[s]$
Long Inverse (Type D)	$\frac{120}{\left(I/I_p\right)^{1}-1}.T_P\,[s]$

Phase overcorrect relays (ANSI 50/51) based on the inverse definite minimum time (IDMT) characteristics shown in **Table 8** is used for protecting alternators, transformers, motors and other loads.

Protection coordination for LV systems

As an illustration, the PC study carried for a typical LV system comprising of a utility bus, step-down transformer, cable, induction motor and protection devices including circuit breaker with in-built short circuit and overload protection, Programmable Logic Controller (PLC) based over-current protection system commanding the circuit breaker and protection fuse is shown in **Figure 9**. The IDMT characteristics of ABB PR221 circuit breaker, 25A aM fuse, PLC-based overload sensing, transformer inrush current and the 10 mm^2 power cable are shown in the PC graph.

The following are the inferences from PC graph (**Figure 9**):

- The protection devices are insensitive to the transformer inrush current (90A for 1s),
- The PLC-based relay provides protection in the overload region from 30A to 150A.
- In the 150-200A range, the circuit breaker is more responsive (~1s) than the fuse (~8s).
- In 200-250A range, both circuit breaker and fuse have equal response time (~1s) and for higher short circuit currents (say 300A), the fuse is more responsive (~1s)
- The cable that has the higher short circuit withstand capability (600A for 5s to 10kA for 200ms) and the induction motor are well protected.

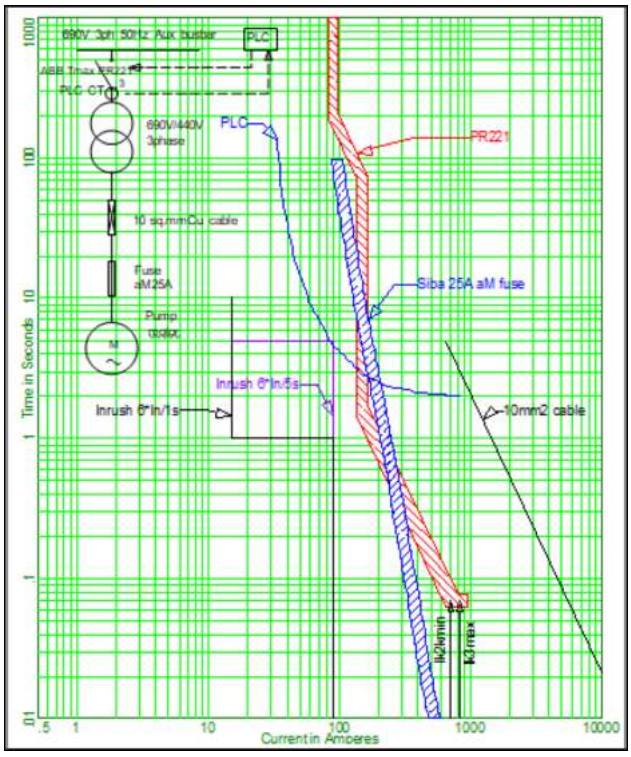


Figure 9 Protection Coordination in a typical LV system

The implementation of protection logic in a PLC with adjustable alarm and trip settings is shown in equation 9.

$$\text{Alarm}/\text{Trip time} = \left[\text{Time constant x } \text{Log}_e \frac{\left(I^2 - I_i^2\right)}{\left(I^2 - I_C^2\right)}\right] \quad (9)$$

Short circuit studies, protection coordination and arc-flash analysis are carried out using software like SKM, CYME, e-tap etc. The arc-flash analysis done using National Fire Protection Association (NFPA) 70E standards helps to identify the arc flash boundary and the coincident energy at a defined working distance in cal/cm^2 essential for defining the arc rated clothing. The NFPA recommends arc clothing whenever there is a possible exposure to an electric arc flash above threshold incident energy level of 1.2 cal/cm^2.

The transformer differential relay (87F) protects the power transformer from internal faults by instantaneously comparing the primary current and secondary currents. The circuit breaker failure monitoring relay (50BF) monitors the electrical circuits that are used to close and most importantly open (trip) a critical circuit breaker during a fault.

When the circuit breaker fails to open at the desired time, 50BF sends a tripping order to the upstream circuit breakers. The neutral voltage displacement relay (59N) protects the transformer against earth fault in the delta side winding, in which three PTs are connected in broken delta configuration so that the vector sum of the voltages is measured. During a ground fault, due to the zero-sequence current flow, the voltage at the broken delta becomes 3Vo or three times the phase-to-ground voltage.

The directional active power relay (32 in **Table 6**) that operates with the inputs from PT and CT calculates the direction of power flow and protects the diesel generator sets and turbine from damages caused by reverse power. The protection is important in steam turbines because if the turbine fails and a reverse active power flow occur, a reduction of the steam flow reduces the cooling effect on the turbine blades leading to overheating. The directional reactive power relay (40 in **Table 6**) offers protection to the mains-synchronised alternator stator during loss of excitation and preventing it from drawing reactive power from the mains.

When alternator phase currents are equal and displaced by exactly 120°, only positive-sequence current exist. A current or voltage unbalance causes negative and zero-sequence components which results in increased heating of the alternator stator. The flux produced cuts the rotor at twice the rotational velocity, thereby inducing double frequency currents in the field system and in the rotor body. The negative sequence relay (46 in **Table 6**) protects the synchronous alternator and induction motor from unbalanced loading.

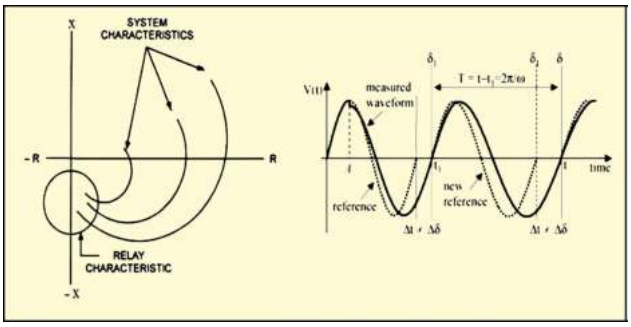


Figure 10a Detection principle of reverse power relay and Figure 10b Alternator vector surge relay [10]

The alternator field ground relay (64F in **Table 6**) detects the grounds in the alternator field winding, as these ground faults should be detected and removed immediately, as a second fault could cause extensive damage to the field winding. When the excitation is lost, the equivalent generator impedance traces a curve from the first quadrant of R-X diagram into a region of the fourth quadrant (**Figure 10a**).

When an alternator pole slips and falls out-of-step with the power system, the generator and system voltages sweep past one another at a slip frequency, producing a pulsating current, which can be greater than a three-phase fault at the generator terminals which could be detected using alternator pole slipping relays (78PS in **Table 6**). The recent voltage jump/vector surge relay isolates the alternator rapidly from the mains within a cycle (**Figure 10b**) during momentary overloads [10].

Reliable circuit breaking

In the power distribution network, the ODR of the circuit breaker and protection relays are very critical, as failure-to-trip during a fault cannot be tolerated from human, vessel and environmental safety perspectives. As the likely demand for the protection relays and the circuit breakers in the marine power systems is normally ≥1 per year, the protection system should comply in IEC 61508 SIL high demand category.

The present generation advanced microcontroller/CPLD-based multifunction relays with network enabled capabilities help to achieve higher ODR compared to stand-alone relays. The method of increasing the ODR for an over current protection function using the upstream protection block as redundancy is described in **Figure 11a**.

The primary protection block comprises an over current relay (50/51 in **Table 6**), CB and CT. The breaker failure monitoring relay (50BF in **Table 6**), upstream circuit breaker (CB_U) and CT constitute the redundant block. During an over current condition due to faults in the downstream network, the primary protection block isolates the faulty section. When the primary block fails-to-trip, the 50BF issues command to the CB_U and trips the entire section.

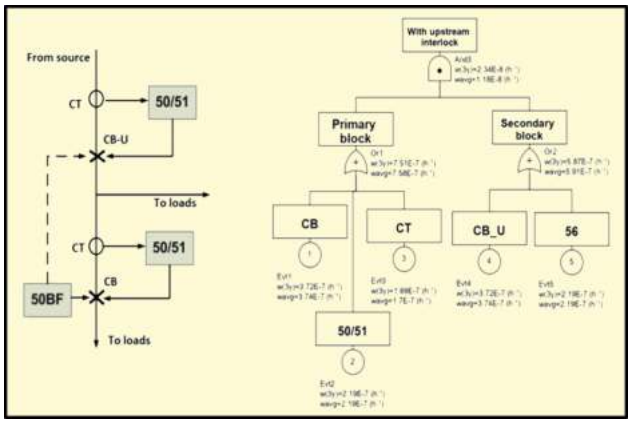


Figure 11a. Configuration with primary and upstream interlock
Figure 11b. PFH for normal and upstream interlock

Based on the IEEE data base and published literature, the failure rates of CB, 50/51/50BF relay and CT, defined in terms of failures per billion hours are 376, 220 and 170 FIT, respectively [11][12]. The ODR analysis is performed by modeling and simulating TOTAL GRIF FTA software and the probability of failure per hour (PFH) for the two configurations (**Figure 11b**) are calculated.

The primary block has a PFH of 7.5 x 10^{-7} complying with SIL2 and configuration with upstream interlock complies with SIL3. The ODR SIL results shall be used for calibration/maintenance interval that is required to maintain the integrity of the system over current protection function.

Conclusions

The reliability of the propulsion, protection and life support power systems in an Integrated Electric Power System needs careful evaluation during the design and operational phases, as the ramifications of non-operation or mal-function could be catastrophic. Hence, safety-centered system engineering with a reasonable reliability,safety and efficiency trade-offis essential for multi-megawatt vessel power systems.

The advancements in protective relaying, its application in subsystem protection and the configuration requirements for meeting various levels of IEC 61508 safety integrity level is analysed using reliability analysis software with field failure data as inputs. The approach towards ensuring seamless power system protection coordination and fault discrimination using the current-time characteristic curves and methods for increasing the on-demand reliability using redundant systems for circuit breaking are described.

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Dr. N. Vedachalam is currently a Senior Scientist with NIOT, Chennai. His 26 years of experience includes industrial power, process, offshore, and subsea domains at Aditya Birla Group and GE Power Conversion & Alstom-Converteam in France. His technical exposure includes development of multi-megawatt power and control systems for deep-water enhanced hydrocarbon recovery systems of Ormen Lange subsea compression pilot with GE; Ocean renewable energy systems including ocean thermal energy conversion, wave energy systems & remotely operated vehicles with NIOT; subsea grids for tidal energy farms for Paimpol Brehat, France and industrial power generation, utilisation and boiler control systems in process industries. He has more than 90 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea process. He is a recipient of the National Meritorious Invention Award in 2019 for the development and usage of underwater robotic vehicles. He is presently a Member of Bureau of Indian Standards and was the Secretary of IEEE Ocean Engineering Society- India Chapter and Executive Member of Marine Technology Society-India Section. He is a regular contributor to MER.

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ENHANCING CYBER SECURITY AWARENESS

Mihir Chandra

ABSTRACT

Cyber security involves stakeholders, policies, processes and technologies to protect cyber assets of any industry. It is optimised to levels that help shipping personnel define, balance resources required with usability/manageability and the amount of risk offset. The aim of this paper is to develop understanding and awareness of key aspects of cyber security such as identify threats, identify vulnerabilities, assess risk exposure, develop protection & detection measures & establish contingency plans. Furthermore, guidelines to be established for operators to assess their ship's operations & to put in place necessary procedures and actions to maintain the security of cyber systems for marine industry. The integration of technology in shipping operations is being enabled by the integration of Information Technology and the Operation Technology on board ships. This has enhanced the threats of unauthorised access or malicious interventions to ship's systems and networks. The measures to guard against cyber threats should include, (i) quantification and type of risks to security, environment and commerce if no cyber security measures are in place, (ii) due protection to IT and OT infrastructure and its networked equipment, (iii) management of access(iv) protecting data related with its sensitivity. With emerging technologies, there is a direct applicability of trends like Artificial Intelligence to enhance security and fraud prevention. Extending the use of Security Analytics for understanding and detecting risk level of vulnerabilities, improving the performance of own security policy by removal of unnecessary data, feature extraction and selection, data cut off, parallel processing, machine learning and deep learning algorithms – are some examples for the use of advanced technologies for improving Cybersecurity.

Keywords: IT-Information Technology; OT-Operation Technology; parallel processing; deep learning

1. INTRODUCTION

On an average, hackers attack 2244 times a day (University of Maryland).

Digital era has given many pluses but one of the major negatives hitting the netizens hard is cyber-attack. And Ships, when exposed to interference from one of the many electronic navigation devices, such as the Global Positioning System face risks. As the crash rate increases to 70%, or if bugged with viruses in cargo work/ in sensitive and seamless documentation, and /or in the propulsion units of engine room or in machines, any or all can cause serious trouble to the ship owners. And on the roll are now the Autonomous ships and block chain technology for activities of marine logistics, insurance, digital documentation and support systems so that last mile connectivity is ensured and encrypted.

In cyber security terms, threat has risk potential (e.g., a person or thing that is likely to cause damage) to exploit a vulnerability (a flaw, feature or user error) that may result in some form of negative impact (National cyber security centre UK, NCSC). Recently cyber-attack has hit 'COSCO' Shipping in USA-the internet and their email system is disturbed.

The integration of technology in shipping operations is being greatly enabled by the networking of Information Technology (IT) and the Operation Technology (OT) on-board ships over the worldwide web and Internet of things (IOT) has become a norm. Hence the threats of unauthorised access or malicious attacks to ships systems and networks get greatly heightened.

There could also be risks arising from the inadvertent introduction of malware from say removable media by untrained or unaware personnel and compromising the systems and data.

It becomes imperative that ship-owners and operators regularly assess their operations and develop resilient approaches to safeguard the security of cyber systems on board their ships.

56% of IT decision makers believe phishing attacks are their top security threats. 32% of the breaches involved phishing. So phishing awareness and education are some of the best ways to decrease risk.

Who might be attacking you?

Geo political trade interests (recent ransomware attack on 'Colonial pipeline company' of USA was forced to shut down on 7 May 2021- the attack alleged to be originated from Russia), Ship-manning agencies, Chartering and shipbrokers' agencies and cross-border intel-agencies, who may be interested in gaining an economic advantage for the host companies or flag-states. They are Hackers who find interfering with computer systems, an enjoyable challenge. Hacktivists who wish to attack companies for political or ideological motives. Employees, or those who have legitimate access, either by accidental or deliberate misuse.

2. OBJECTIVE

To find out the factors for awareness and mitigation drive of cyber risk, threat, vulnerabilities in hindsight, at hand and as a foresight to be prepared for treading in uncharted terrains of new possibilities in shipping industry.

2.1 Discussions

The cyber risks usually are specific not only to the company and the ship depending on the technology usage, but also its area of operation and the trade they are in. The challenge here becomes manifold due to the fact that no historic data or evidence can be relied upon to get any definitive information on the imminent incident or its impact, unlike the traditional areas of concern on safety or maritime security. The threats could emanate from internal sources like disgruntled employee or outsiders like criminals, opportunists, terrorists or just activists.

There are mainly two types of cyber-attacks– untargeted and targeted. Untargeted attacks happen by taking advantage of the openness of the internet without bothering so much about who the victim is. While targeted attacks are when organisations are singled out for a specific interest and can be more dangerous.

2.1.1 Untargeted Attacks: In un-targeted attacks, attackers indiscriminately target as many devices, services or users as possible. They do not care about who the victim is as there will be a number of machines or services with vulnerabilities. Following are few techniques by which internet becomes slave to attackers:

- Phishing–sending emails to large numbers of people asking for sensitive information (such as bank details) or encouraging them to visit a fake website
- Water holing–setting up a fake website or compromising a legitimate one in order to exploit visiting users
- 'Ransomware'–which could include disseminating disk encrypting extortion malware
- 'Scanning'-attacking wide swathes of the Internet at random

For ships, untargeted attacks are one where a company or ship's system and data are one of the many potential targets.

2.1.2 Targeted Attacks: Indigeneity which is engineered and applied in targeted attacks are more sophisticated as they are very specific and so they are more dangerous than non-targeted attacks. For ships, targeted attacks are like the system or data being intended targets.

Targeted attacks may include:

- Spear-phishing - sending emails to targeted individuals that could contain an attachment with malicious software, or a link that downloads malicious software
- Deploying a botnet - to deliver a DDOS (Distributed Denial of Service) attack
- Subverting the supply chain - to subvert equipment or software for the organisation
- Vishing-voice phishing by adversarial AI-communication system
- Water ingress alarm system
- Ballast water system
- Gas liquefaction
- ODMCS-GPS interdependency-compatibility
- Various documents –E-bill of lading, E-logs, E-oil record books (forthcoming MEPC resolutions for MARPOL-to be enforced)

❖ *Passenger Services:*

- Property management system
- Medical records
- Passenger embarkation access control
- User authentication and authorisation system

- Passenger or seafarer boarding with own device [BYOD]
- Passenger Wi-Fi /-LAN internet access
- Entertainment system
- Communication

❖ *Administrative and crew welfare system:*

- Certificates in digital format, Seamen-identity document, for example
- Quarantine digital reports

❖ *Other vulnerable activities related to shore-side:*

- Berthing /Un-berthing activities
- VTS-Pseudo VTS
- Port related documentation-FAL Convention
- C and F agencies
- Port access control
- Tanker and Gas terminals—safety, security, pollution related access, operation, spoofing.

Regardless of whether an attack is targeted or un-targeted, or the attacker is using commodity or bespoke tools, cyber-attacks have a number of stages in common. Some of these will meet their goal whilst others may be blocked.

2.1.3 Stages of an attack: The attacker is effectively probing your defences for weaknesses, which if exploitable, will take them closer to their ultimate goal. So following stages are worth as a learning –lesson.

A number of attack models[13] describe the stages of a cyber-attack. A simplified model is taken that describes the four main stages present in most cyber-attacks:

- Survey - investigating and analysing available information about the target in order to identify potential vulnerabilities
- Delivery - getting to the point in a system where a vulnerability can be exploited
- Breach-exploiting the vulnerability/vulnerabilities to gain some form of unauthorised access
- Affect-carrying out activities within a system that achieve the attacker's goal
- Pivot-targeting the weakest file and after making access to disturb the system

When assessing vulnerability and impacts, the three areas that should be measured are: Confidentiality, Integrity and Availability. The measures to guard against cyber threats include:

(a) assessment of risks to safety, security, environment and commerce if no cyber security measures are in place

(b) due protection to IT and OT infrastructure and its connected and networked equipment

(c) managing access, and

(d) protecting the data depending on its sensitivity

3. LITERATURE SURVEY

Marine Security professionals have additional resources to defend vulnerable networks and data from cyber attackers to combine the strength of artificial intelligence (AI) with cybersecurity. The use of AI yields automated processes including continuous risk assessments, autonomous incident response, configuration monitoring, and automatic remediation and integration of security solutions and data.

There is a significant reduction in response time to cyber-attacks. According to a report published by *'Capgemini'*, about 42% of the companies which did study had observed a rise in security incidents through time-sensitive applications. However, the use of Artificial Intelligence in addressing areas of cybersecurity can be a considerable threat to ships, apart from being potential solutions[11] (as if double-edged sword).

Study from Varonis[9] suggests that 21% of files are not protected and so it suggests for a paradigm shift in cost versus security processes.

- Digital ship newsletter and 'g captain' article of 11th March 2020 has shown through Digital container shipping association's publication named as DCSA cyber security implementation guide, the best practices –manageable task based approach towards meeting IMO resolution[1] MSC.428(98) implementation schedule for January 2021.
- An article by H.A. Boyes[10] suggests that 37% of data breaches were attributed to malicious and criminal acts. The remainder were split between system glitches (29%) and human factors (error/negligence) at 35%.
- Incidents of vessels[10] 'Royal Majesty' highlights the GPS/Autopilot problems, whereas vessel ANNABELLA' suggests of loading software glitches.
- Indian news agencies have reported on 10th March 2021 about Data theft of about 3 Lac or more people from Australia from Facebook account by a firm.
- International Maritime Organisation had instructed that by January 2021 all member states to take measures to mitigate cyber threats. Member States have been advised to adopt policies in safety and security related endeavours to create a sort of preventive mechanism of cyber security.
- In 2017, on June 27, AP Moller-Maersk[8] confirmed that the group was hit as part of global cyber-attack named 'PETYA', affecting multiple sites and select business units. The cost to company for recovery was about 200 to 300 million USD.
- Press trust of India reported that at Jawaharlal Nehru port trust Shewa, Panvel, Maharashtra APM MAERSK faced disruption in operation due to cyber- attack.

- Antwerp Port faced cyber -attacks with respect to containerised cargo getting stolen during 2011-2013 by organised cyber- crime by breach to IT system.
- A survey by IHS fair play in 2017 shows that out of 300 industry responders 65 had been attacked through cyber space. Malware apparently found to be of main attack nature.
- In July 2013 a test was done by research scholars of University of Texas, Austin, for GPS spoofing to a sailing yacht and it was achieved successfully by creating false civil GPS signal.
- July 2015, South Korea reported of GPS jamming which paralysed all navigation and auxiliary systems on board. It was intentional interference of Geo-political nature.
- A report by Hugh McDowell[7] in 'Quantitative assessment' shows that the risk of cyber-attack is excluded from Insurance cover by 'Institute cyber-attack exclusion clause' [CL380], 10 November 2013. Though P&I CLUB has pooling facility with limit of 30 million USD per ship, provided attack is not an act of war or terrorism.

From a literature survey, it is observed that a specific network architecture should be in place for assessing the systems as it is the demand of the day[4]. With threat perceptions looming larger by every passing day and soon autonomous ships will be plying across waters. Their function will depend mostly on Information communication technology, ICT, high integration of systems and their connectivity with shore system and internet.

A contingency plan to be ready to Identify, Detect, Respond, Recover processes[12] for cyber-attacks. According to 'Gartner', global information security market is predicted to be about $170.4 billion in 2022.

4. CONCLUSION

Shipping industry is unique and complex wherein different stakes are existing for different vendors having long life periods, systems, and vessels which are almost different to each other in network topology. The industry has plenty of case studies on damages, loss of life and claims of cargo losses in past. An analysis shows human element as the reason for the failures and resulted error chain dynamics. But in the current scenario, the human element need not be present (near the machinery) and acts can be remote to do intentional, unintentional, targeted or untargeted attacks.

STCW, ISM, ISPS codes did deal with filling the gaps of KSA by having KPIs. Now the need is to train the manpower of industry with essential security tools, paradigm realignment with cutting edge technologies.

CIA triad model may be used for finding the potential breach of data—particularly as the 5G technology has entered.

'Bring your own device' [BYOD] may be economical and facilitating to work on board ships but vital data segregation must have a safe protocol. So a cyber security management plan must be established with cyber-security policy of the company enshrined.

With the shipping industry's increasing reliance on technology and remote monitoring, maritime cyber security is no longer optional, but is business-critical. It is imperative that companies are ready to tackle the cyber challenge and remain resilient. Whilst the risk is real, a company can only be resilient to get back to business if their cyber-preparedness is swift and up to date and it needs investment to pay dividend.

Artificial intelligence, though is double edged sword; is still a need of the hour in this industry to aid the human element as one integrated system. Also, sound cyber capability in shipping may be ratcheted up by installing appropriate systems, by training and by putting resources in place to effectively hone the skills and knowledge of operators. The solution has to be human centred.

Artificial intelligence and cyber security solutions can be put into effective use (e.g., by employing the 'White hat hackers' system of Artificial intelligence to counter Adversarial intelligence's neural networks and also to raise the cyber defences). It is also proposed to have tough international digital legislation. And lastly, the most important of all is to impart cyber related education to users since Human beings are the weakest link in the length of this 'Ship

Operation Chain cable' and needless to add, that a shackle length of cable must be as strong as every link of chain.

The bottom line remains that cybersecurity skill-gap shall remain an issue for the industry. Awareness and alertness, if used adroitly the attacks may be neutralised appropriately and effectively.

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LUBE MATTERS 6: READING THE UOA REPORT

Sanjiv Wazir

Introduction

Much time, effort, and resources are spent on collecting the used oil samples, sending them to the lab, testing and analysing the results. The UOA report can tell a lot about our lubricant, equipment, and operating conditions. Understanding how to read the UOA report is important to get the most out of it.

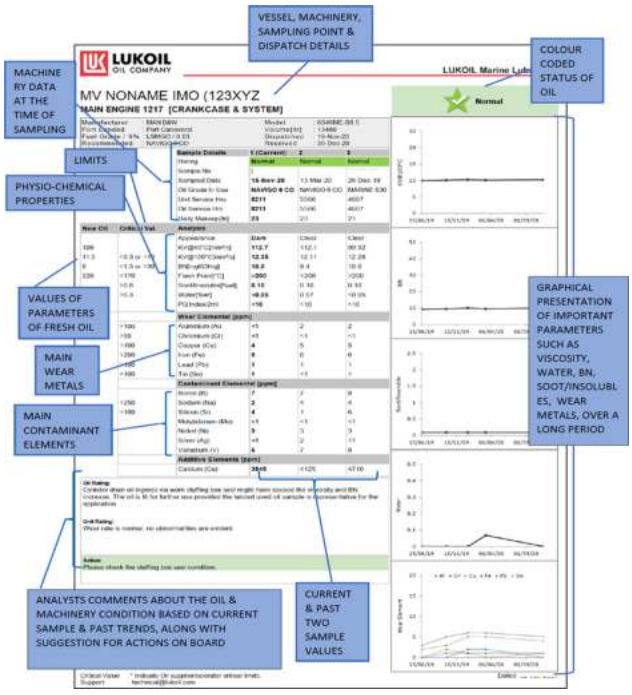

Figure 1 Example of LUKOIL UOA Report (1)

How to go about reading the report?

Step 1. Check that the information supplied by the vessel, with the sample, is correct.

MV NONAME IMO (123XYZ

MAIN ENGINE 1217 [CRANKCASE & SYSTEM]

Manufacturer	: MAN B&W	Model	: 6S46ME-B8.5
Port Landed	: Port Canaveral	Volume[ltr]	: 13480
Fuel Grade / S%	: LSMGO / 0.03	Dispatched	: 19-Nov-20
Recommended	: NAVIGO 6 CO	Received	: 30-Dec-20

Sample Details	1 (Current)	2	3
Rating	Normal	Normal	Normal
Sample No	;		
Sampled Date	15-Nov-20	13-Mar-20	28-Dec-19
Oil Grade In Use	NAVIGO 6 CO	NAVIGO 6 CO	MARINE S30
Unit Service Hrs	8211	5566	4607
Oil Service Hrs	8211	5566	4607
Daily Makeup[ltr]	23	23	21

Figure 2 Confirm Vessel supplied Information is correct. (1)

- Vessel Name & IMO no.
- Machinery no. Machinery make & model no. (for engine samples- Fuel type & S%).
- Recommended lubricant, lubricant in use. If different, why?
- Sump volume, sampling location
- Average daily top-up. High top-up volume will tend to normalise any condition.
- Dates of sampling, dispatch, receipt at lab, and report date. (In the above example > 10 days from dispatch to receipt at lab)
- Did something happen during interim period between sampling & receipt of UOA report?

Step 2. Take a quick glance at the status (usually) at the top right corner

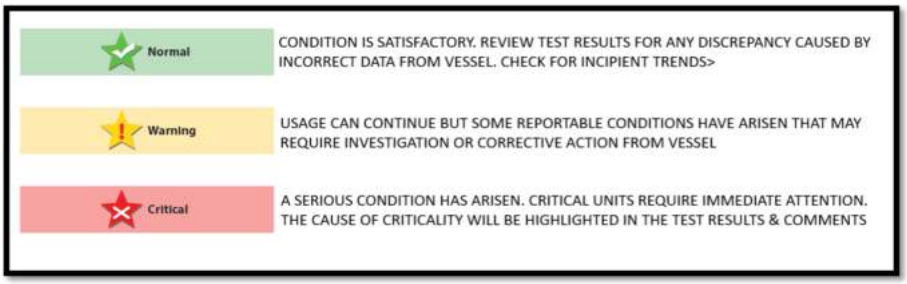

Figure 3 What does the Oil Status Signify? (1)

Step 3. Review the Laboratory analysts' comments about the oil condition, machinery condition, etc.

For a moment, skip the test numbers and jump to the comments section to see which conditions the lab considers to be of primary importance. This provides an overview of the machine & lubricant condition.

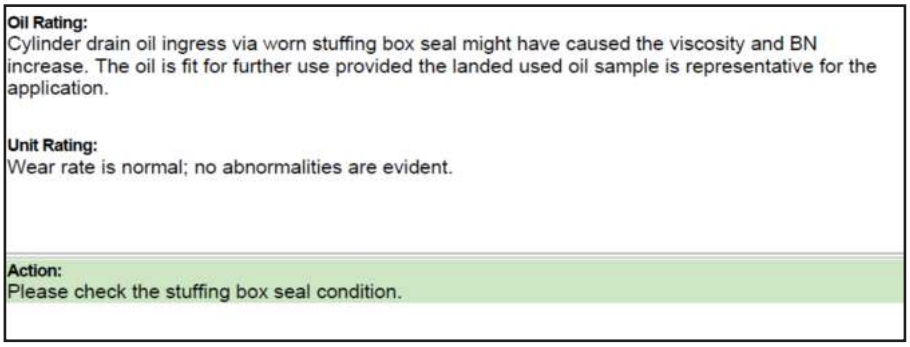

Figure 4 Example of Analysts' comments (1)

Step 4. Now dig into the elemental analysis

Rising Iron values should be compared with PQ to get an idea of the kind of wear process taking place. Rise in Fe accompanied with rising Cr or Ni, may point at wear of specific steel components. Rising levels of Tin, Lead, Copper would indicate bearings requiring attention. Rise in Silicon level could be indicative of ingress of air-borne dust, whereas rising sodium could be from seawater or cooling water (treated with Na-based chemicals). The ships engineers have access to material composition of various components in the OEM manuals, drawings etc. Hence, they are often in a better position to decipher the sources of unusual metal values in elemental analysis. **(Figure 5)**

	Wear Elements [ppm]			
>100*	Aluminium (Al)	**2**	3	2
>50*	Chromium (Cr)	**<1**	1	1
>50*	Copper (Cu)	**2**	2	2
>150*	Iron (Fe)	**11**	13	13
>50*	Lead (Pb)	**1**	1	1
>30*	Tin (Sn)	**<1**	<1	<1

Figure 5 Example of Elemental Analysis (1)

The LUKOIL oil test report provides a generic guide to the possible sources of various elements on the last page of the report.

(The reader may refer to LUBE MATTERS # 3: ELEMENTAL ANALYSIS for more information on this topic)

Step 5. Check the Physio-Chemical properties of the sample.

- **Kinematic Viscosity & compare with KV of fresh recommended grade & oil-in-use grade.**

For successful lubrication, viscosity of the oil is its most important property. If it is too low, the oil film formed may be too thin to keep the rubbing surfaces apart. If it is too high, the oil flow may be impeded, especially in narrow passages. If the KV is not right, contamination may not be carried away, nor will heat be dissipated adequately **(Figure 6)**.

New Oil	Critical Val.	Analysis			
		Appearance	**Dark**	Dark	Dark
150.0	<75 or >187.5	KV@40°C[mm²/s]	**157.9**	173.2	170.1
14.0		KV@100°C[mm²/s]	**15.51**	16.76	16.63
	>0.3	Water[%wt]	**0.10**	0.11	0.10
30.0	<4	BN[mgKOH/g]	**24.3**	22.3	23.8
230	<170*	Flash Point[°C]	**>200**	>200	>200
	>2	Soot/Insoluble[%wt]	**0.60**	0.90	0.90
		PQ Index/2ml	**<10**	<10	<10

Figure 6 Example of Physio-Chemical (1)

- **Water content**

Water is one of the most common contaminants & also one of the most destructive to oil & machinery. Low levels of water may be from condensation. High levels indicate leakage or other gross ingress. Source of ingress should be urgently identified & rectified. Concomitant increase in Na & Mg levels would be indicative of contamination by sea water.

(The reader may refer to LUBRICATION ENEMY No. 2: WATER in the Jan2015 & Feb2015 editions of MER for more about water contamination)

- **Base Number (BN)**

In trunk piston engine crankcase oil, BN is expected to decline as it gets used up in neutralising the acids produced

during combustion. Rate of BN drop should be monitored & top-up rates maintained in line with OEM recommended SLOC.

In 2-stroke Engine system oil, rise in BN is usually indicative of ingress of waste cylinder oil through the stuffing box seals. Gradual rise in K. Viscosity & soot/ insoluble is likely. Increase in levels of elements associated with residual fuels like Vanadium & Nickel will further confirm this is the cause.

- **Acid Number (AN)**

Rise in AN is an indication of oxidative degradation of the lubricant. High acid levels can lead to corrosion of components. Tracking the trend of AN can be a guide to oil change.

For many grades of lubricants LUKOIL tests and reports "Oxidation" as a separate parameter. This test is based on FTIR.

(The reader may refer to LUBE MATTERS # 5: FTIR for more information on this topic)

- **Soot/insolubles**

In diesel engine oils, soot is the main component of insolubles & its rise is indicative of poor combustion. In other machinery, wear debris, dust and oil oxidation products are the main components. Look for clues in the elemental analysis.

- **Flash Point**

Change of lube flash point is typically a sign of fuel contamination. If it is HSD, then K. Viscosity will also dip. Ingress of a heavier fuel may cause K. Viscosity to rise.

- **Particle Count**

PC gives an indication of the overall cleanliness of the system oil which is especially important for hydraulic systems. LUKOIL carries out particle count for all hydraulic system samples.

(The reader may refer to LUBE MATTERS # 4: MEASURING OIL CLEANLINESS for more information on this topic).

Step 6. Study the trends! A single analysis report is like a 2-D image, often not sufficient to draw proper conclusions. Comparation with historical trends, adds perspective. LUKOIL UOA reports show the results of the latest & previous two results in tabular format. Additionally, long term trends of important parameters are presented in graphical form. Studying the trends makes it possible for us to place the current oil properties in context with the past & enables us to recognise when the oil parameters may turn "abnormal". For example, sharp improvement in the graphs of all parameters to near-new oil levels at a certain point in time may be an indicator of oil change having taken place at the time: or persistent high Na/Mg levels with low water content may mystify, until we note the water content graph indicating that there had been ingress of a large quantity of water in the past.

Step 7. My report is "Normal".

Over 90% of all used oil samples that we test are "NORMAL". Do not just file such reports.

- Used oil analysis is greatly influenced by the quality of the sample
- Information about operating conditions from the vessel are an important input for commenting on the result. E.g., a rise of 2-3 cSt in KV100 over 1000 running hours and the same increase over 50 running hours have different implications. If oil service hours have not been provided, the lab may not be able to comment upon this
- What may be normal for a machine operating in one area may not be so for a similar machine operating under different conditions. For example, water content of a sample from machinery operating in an arid area would be lower than for a sample from a similar machine operating in a humid area, & if it is not, may be something is amiss?
- Also trends in some parameters, which may still not have reached "abnormal" or "reportable" conditions, may be pointing to incipient trouble
- Hence studying the report in the context of your domain knowledge is important

Conclusion

A UOA report gives us a lot of data to think about.

If some information was missing or incorrect, convey it to the lab so they can amend the report accordingly.

If the lab has suggested some action, for example, partial sweetening of the oil charge, or checking and improving purifier efficacy, or topping -up with the right grade, etc, act on it.

Incipient problems will not go away on their own. Taking early action may save you from a lot of expense and downtime later.

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MODEL STUDY ON DAMAGE AND DAMAGE STABILITY OF TANKERS: COLLISION DAMAGE AND ACCIDENTAL OUTFLOW

Agaram Ramanujan

1. INTRODUCTION

In a recent statistical report of ITOPF (International Tanker Owners Pollution Federation), the causes for oil spill is listed with their percentages for all oil spills occurred after 1970 (**Table 1**).

Table 1 Causes for Oil Spill (ITOPF)

CAUSE	PERCENTAGE
ALLISION/COLLISION	30
GROUNDING	32
HULL FAILURE	13
EQUIPMENT FAILURE	4
FIRE/EXPLOSIN	11
OTHERS	7
UNKNOWN	3

Others specify heavy weather damage and human error. Unknown are incidents recorded without any known facts of their cause. From **Table 1**, it is noted that the maximum incidents of spill are caused by groundings followed by allision and collision. Allisions are the contact incidents involving a moving vessel and a stationary anchored vessel. Human error is partly attributed to collisions and allisions.

Following the EXON VALDEZ incident of 1989, IMO amended MARPOL ANNEX 1 to suit. Requirement of accidental outflow of oil following side damage in a tanker caused by a collision and this is elaborated in regulation 25, CH 4 of the present MARPOL Annex 1.

This paper attempts to explain how the collision damage is possible, the resultant damage stability and how the probability table is used to assess the mean probability quantum of accidental outflow of oil, by using a standard model of a loaded tanker.

2. Hypothetical case (incident) with damage calculations

Assume a loaded tanker of 150000 tons displacement proceeding at 15 knots due south in the English Channel during heavy fog with visibility less than 10 meters is passing a loaded container ship of 150000 tons proceeding eastward at 20 knots. Since the visibility was poor, both ships had reduced their speeds by half as a precautionary measure and even so a collision has occurred.

The collision damage is located on starboard side of the tanker amidships.

Let us verify if this damage as per the damage assumptions stated in Reg. 24 of CH 4 MARPOL ANNEX 1 which is quoted as under.

REG 24 Damage assumptions

For the purpose of calculating hypothetical oil outflow from oil tankers in accordance with Regulations 25 and 26, three dimensions of the extent of damage of a parallelepiped on the side and bottom of the ship are assumed as follows.

SIDE DAMAGE:

Longitudinal extent (l_c): $1/3L^{2/3}$ or 14.5mi whichever is less

Transverse extents (t_c): B/5 or 11.5m, whichever is less

Inboard from the ship's side at Right angles to the centreline at the level corresponding to–the assigned summer freeboard;

Vertical extent (v_c): From the baseline upward without limit.

The damage zone or total affected space consists of a parallelepiped of maximum dimension length 13.23m, transverse depth 8.8m and full height from baseline of say, 22m.

The bulbous bow of the container ship has pierced the tanker starboard side at about mid- ships and the damage on tanker is given as under:

The damage on tanker is the sheer damage of both the inner and outer side shell plating together with their frame stiffeners. On the container ship, the damage is restricted to the bow flare and the bulbous bow resulting in a reduction of length of the container ship and a corresponding caving in of the Bow flares to allow the bulbous bow to penetrate into the tanker to the assumed transverse distance. Using the total energy method or conservation of energy equation, we can apportion the energies absorbed by the respective damages.

Total energy available for damage
= [150000*(7.7162/4+10.2822/4)]/2 = 150000/2* (26.42+ 14.88)
= 3097500 KJ

The outer shell plating of the tanker as per the shell expansion is 30 mm thick and the inner side plating is 25 mm thick. The two sheared plates of the inner and outer shells are connected by the inner bottom plating which also shears and bends sufficiently to allow the bulbous bow to penetrate the inner shell plating and stop at 8.8 m distance transversely from the outer surface of the outer shell plating.

Tanker Shear damage energy of the outer, inner shell plating and inner bottom plating of 25 mm thickness is considered for an ultimate shear stress of 480 N per mm2.

The shear energy used is 480(22 +13.23) *2 *1000 *30 *30/1000
= 30439KNM OR 30439 KJ add extra 40 % for stiffener frames
= 42615 KJ

*Shear damage energy for the inner side plating for the same U shear stress
= 480*(13.23 +22) *2 *1000 *25*25/1000 = 21138 KJ and adding extra 40 % for stiffeners, we have the sheer energy for damage to inner side plating
= 29593KJ

*The shear damage energy for bottom plating
= (480*2055*25*2*25/1000)/1000 KJ. Add extra 30% for bending the bottom plating
= 1603 KJ.

The energy balance is as follows:
Available energy for damage= 1548750KJ from the container ship

Energy used for damage to outer shell of tanker= 42615KJ
Energy used for inner side plate damage of tanker= 29593KJ
Energy used for shearing and bending inner bottom plating = 1603KJ

Balance available energy = 1474939KJ. This balance energy is utilised as follows:

Container ship damage: soft nose, bulbous bow and caving in of the bow flares for the bow to enter 8.8m into the tanker. Movement of container ship 8.8m into the tanker.

The combined energy of the tanker ahead motion (1548750KJ) together with whatever energy left from the container ship is used for onward locked motion of tanker and container ship in the resultant direction till they come to rest.

Peripheral deformation at all locations of contact

The ratio of computed damage energy to total energy available is or about 2.38%, which confirms that the assumptions made in Reg. 25 of MARPOL CH4 are realistic and practically possible.

The immediate effect of the damage by collision will be bodily sinkage of the tanker caused by loss of intact water plane area.

The next damage activity is outflow of the cargo oil, a quantity required to balance the hydrostatic pressure within the damaged cargo tank and the new draft in seawater.

Applying the hydrostatic balance between the hydrostatic pressures inside and outside the damaged tank, the quantum of oil outflow can be determined.

3. TANKER MAIN DIMENSIONS AND DESCRIPTION

LENGTH (L) 250m LOA 258m BREADTH(B)=44m and DEPTH (D)=22m DRAUGHT(d) =20 m.

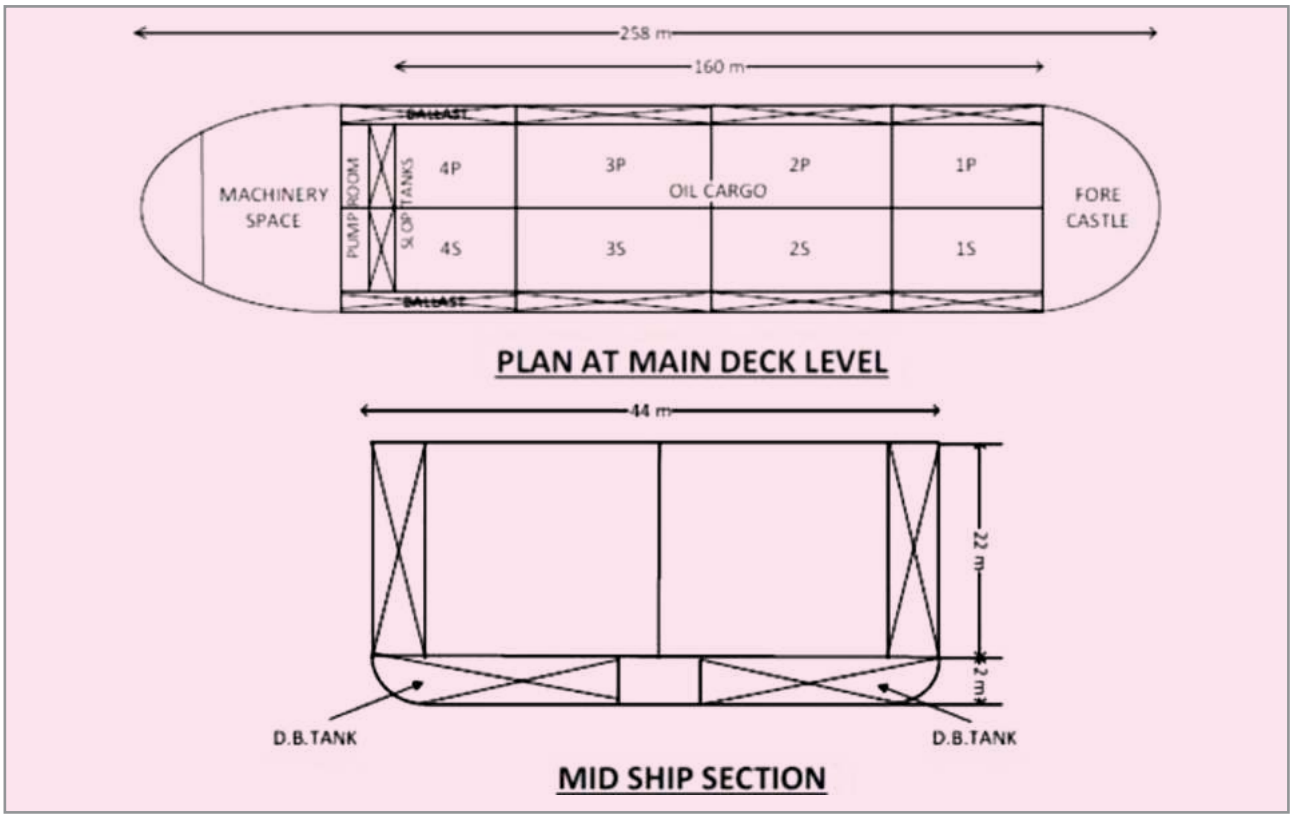

Figure 1 Plan view at Main Deck Level and Mid Ship Section

The Freeboard calculated using the freeboard formula is 3m. The plan view at main deck level and midship section is given in **Figure 1**.

The cargo is loaded in 8 tanks as 4 longitudinal x 2 transversal. All tanks are of same capacity and their dimensions are length 40m, breadth 20m and depth 20m.

At full capacity of 98% (MARPOL requirement), the volume is 16000m^3 and with cargo of 0.9 sp. Gr; load is 112896 tons.

The tanker is double hulled with ballast loaded in the space between the inner and outer skins as well as the DB space. The DB space is transversely subdivided by a central duct keel at the bottom extending throughout the cargo space including the pump room. The ballast space is further divided transversely as per the cargo tanks arrangement, i.e., the transverse WT bulkheads of the cargo tanks also form the transverse bulkheads for the bulkheads at the sides and the bottom. The Forepeak and After peak tanks are also ballast tanks.

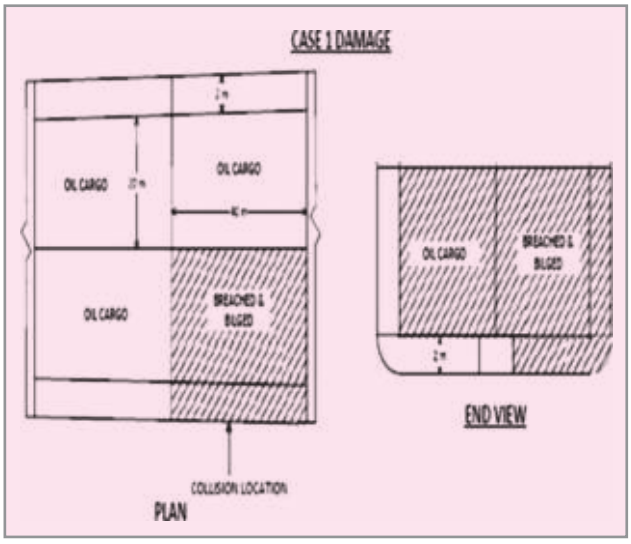

Figure 2 Case 1 Damage

CASE 1

4. INTACT STABILITY, DAMAGE STABILITY AND OIL OUTFLOW CALCULATIONS

Table 2 KB in loaded condition: 9.5 m Moment

Load particulars	Mass (tons)	KG (m)	MOMENT (TM)
LIGHT SHIP	34554	7	241878
Bunkers	2000	6.5	13000
CARGO	112896	12	1354752
Fresh water	200	11	2200
Lob oil	50	6	300
Unpumpable constants (ballast)	300	1	300
TOTAL	150000	KG = 10.75m	1612430

Table 3 Loaded water plane area of tanker

½ Ord	SM	Product for	1/2 ord 2	SM	Prod for 1st	1/2 ord 3	SM	Prod for 2nd
0 AP	1	area	0	1	0	moment	1	moment
5	4	20	25	4	256	125	4	500
10	2	20	100	2	512	1000	2	2000
22	4	88	484	4	1836	10648	4	42592
22	2	44	484	2	968	10648	2	21296
22	4	88	484	4	1836	10648	4	42592
22	2	44	484	2	968	10648	2	21296
22	4	88	484	4	1836	10648	4	42592
10	2	20	100	2	512	4096	2	2000
5	4	20	25	4	256	512	4	500
0	1	0	0	1	0	0	1	0
		432						175368

**Length 240 m Breadth (max): 44 m Area divided into 10 equal distances with 11 ordinates, common mean distance 24 m*

Table 4

Area of load water plane	2*25/3*432 = 7200 m^2
Second moment of LWP	2*24/3*1/3*1753 935296 m^4

INTACT STABILITY:

BM = 935296 m^4/150000*1.025 = 6.39m.
GM = KB + BM-KG = 8+6.39-10.75 = 3.64m.

Applying free surface correction for all cargo tanks we have

Free surface correction = (2*223*160/12) *(0.9/150000) = 1.7m Hence corrected initial GM = 3.64- 1.7= 1.94 m

Initial GM departure condition is 1.94m

In the damaged condition, due to bilging of the cargo tank and its adjoining ballast space, the sea water fills the available permeability in the space which is assumed 99 % as per MARPOL Annexe 1.

Second moment of intact LWP in damaged condition:

This is calculated using the parallel axis theorem for the residual intact water plane. In this case, the transverse axis of water plane shifts and this to be first found out.

Taking moments for the original area and the damaged area about the side opposite the damaged side we have,

(6912*22 – 40*22*33)/(6560 – 880) = (152064—29040) /5680 and it is 21.66 m from intact side.

Residual intact LWP second moment is given by

[935296 + 6912* 0.34^2] - [40*22^3/12+880*$(11.34)^2$] m^4 and that is 936095—35493—141935=**758667 m^4**

BM in damaged condition = 758667/150000*1.025 = 5.18m

Initial GM in damaged condition is 8+ 5.18-10.75 – 1.7= 0.73m, which is more than the minimum required GM in accordance with intact stability conditions

Bodily Sinkage: If d is the increase in draft due to bilging of both ballast and cargo tanks, it is obtained by equating the permeated sea water into the available spaces both in the cargo and adjoining ballast tanks against the intact water plane area.

Hence (7200—40*22) *d = 0.99{20*2*40 + 22*2*40 + 40*20*0.4} (1)

Where,

20*2*40 is the available volume in side ballast tank 22*2*40 is the available space in DB tank.

40*20*0.4 is the available space in the cargo tank with 98 % oil Hence

6320*d = 0.99(1600 + 1760 + 320)

or

d = 3680*99/6320 = 0.58 m or say 58cms Hence the new draft is 20 .58m

Applying the hydrostatic balance after the damage, with the following assumptions applicable.

The sea water and oil are not miscible
The weather is absolutely calm.
No currents exist
The inert gas pressure in damaged tank is zero

Let us assume that the collision is not so violent as stated above for the time being and this collision causes a damage of dimensions 13.3 m longitudinal length, vertical height 3m (VC) in both the inner and outer shell plating's referred to the base line.

Let "h" be the height of the oil in the damaged cargo tank. When damage to the cargo tank occurs, the permeable vacant space of 2 % is filled by the seawater. The oil column exposed to the sea (which is 1m in this case) and the volume of oil represented by this height,

(which is 800 m^3) escapes to the sea and is replaced by an equivalent volume of seawater to give the required hydrostatic balance.

This quantity also includes the height of seawater of 0.4m being required to fill the permeable empty space of 2 % of full volume of the tank.

The hydrostatic balance is given by

$$3.4*1.025 + h*0.9 = 20.58*1.025 \quad (1)$$

$$h = (20.58-3.4)*1.025/0.9 = 19.56$$

The total height of cargo tank and DB = 22m. Hence the excess height above 22m is the height in the vapour line leading to the masthead and this is 3.4 + 19.56-22 = 0.96 m.

Hence the oil volume retained in the tank is 18.6*40*20=14880 m^3, the oil outflow quantity is 15680-14880 = 800 m^3.

This also shows that the quantity of outflow is the volume of exposed oil volume of 1m height and area 800 m^2

This equation of hydrostatic balance can be written in general terms as:

$$H = (ND - V_C + PS) *1,025/0.9 \quad (2)$$

Where, ND = New draft in m
V_C = Vertical height of cut from base line
PS = Permeable space in cargo tank
1.025 = Relative density of sea water
0.9 = Relative density of oil. This can be different as applicable in each case

In the model considered, we can obtain the outflow quantity for different V_C'S ranging from 3m to 18m.

It will be noted that the longitudinal length and the transverse depth do not affect the outflow quantity.

Part of the oil head required to maintain the hydrostatic balance will extend into the vapour line of the tank and can be omitted since it is negligible when compared to the quantity in the tank.

Table 5 Outflow Table for Various V_c

V_c	OUTFLOW IN M^3
3M	800
6M	3200
9M	5600
12M	8000
15M	10400
18M	12800
22M	15680

The quantum of outflow volume is proportional to the height V_C of the cut in the inner shell plating.

The arithmetic mean or average between the worst and least conditions as arrived above, considering that in the worst condition all the oil is lost to the sea, is

$$(15680 + 800)/2 = 8240\ m^3$$

From the above hydrostatic balance condition, we learn that the quantum of outflow is not dependent on the opening dimensions, but on the height of the opening top from base line.

The mean probability outflow using the statistical parameters specified in Reg. 25, provides a more fine-tuned and realistic quantum of outflow.

HEEL CAUSED BY UNSYMMETRICAL BILGING:

The heeling moment is caused by virtual shift of the bilged volume of sea water from centre to the side and it is given by sum of the following moments due to virtual shift of volume. Considering the worst condition, we have, the total shift moment of affected buoyancy given by the sum of the following shift moments.

Replacement of sea water by oil
= 15680*0.125*11.34 = 22226.4 m^4
(The moment arm is increased by 0.34m due to shift of the transverse axis)
Permeable space in tank = 0.4 *40*20*11.34 = 3628.8 m^4
(same reason mentioned in 1)

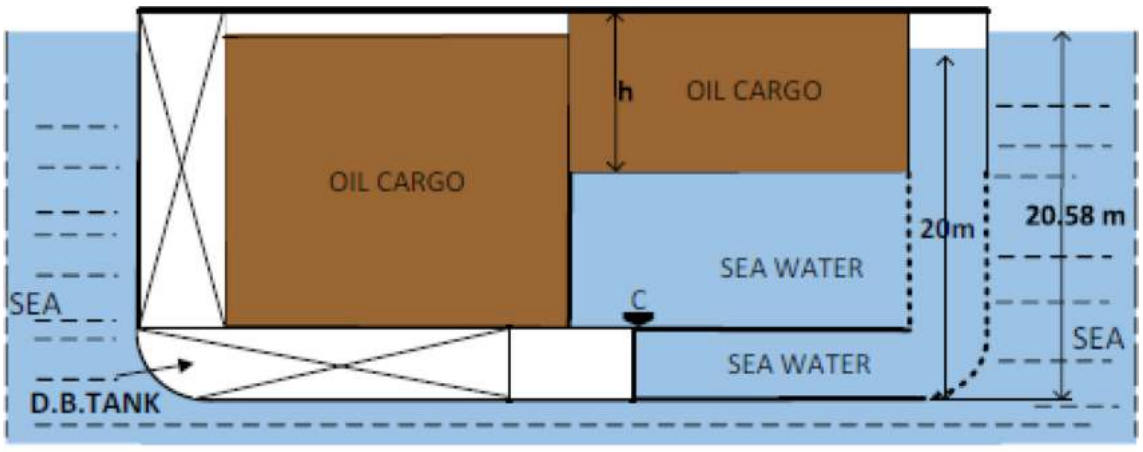

Figure 3 Bilged Condition – Mid Ship Section

3) DB tank = 21*40*2 *11.34 = 19051.2 m^4 (Same reason as in 1)

Side ballast tank = 2*20*40 *21.34 = 24144 m^4 (Same reason as in 1) Total moment = 69050.4 m^4

Heel angle is $\sin^{-1}\theta$ = (69050.4/150000) *(1.025/5.18) = 5.2 degrees and the initial GM in this Condition is 0.73m or 73cms.

The damaged stability condition is within the Reg. 26 requirement.

5. CALCULATIONS FOR PROBABILITY PARAMETERS FOR SIDE DAMAGE USING THEMETHODAND TABLES GIVEN IN CH4 REG 23

To provide adequate protection against oil pollution in the event of collision or stranding, the following shall be complied with:

For oil tankers of 5,000 tones deadweight (DWT) and above, the mean oil outflow parameter shall be as follows:

For oil tanker of less than 5,000 tones deadweight (DWT):

The length of each cargo tank shall not exceed 10m or one of the following values, whichever is greater:

Where no longitudinal bulkhead is provided inside the cargo tanks:

But not to exceed 0.2L

Where a centreline longitudinal bulkhead is provided inside the cargo tanks:

Where two or more longitudinal bulkheads are provided inside the cargo tanks:

For wing cargo tanks: 0.2L
For centre cargo tanks:
1 if = 0.2L .0.2L
2 if is <0.2
Where no centreline longitudinal bulkhead is provided
Where centreline longitudinal bulkhead is provided

If we assume a tank with dimensions to suit the minimum outflow requirement, the number of tanks will increase considerably combined with proportional increase in steel weight which will render the light ship so heavy that the economy of transportation objective is lost. Hence the graded size limitations suggested serves not only the strength but also the probabilistic mean accidental outflow requirement.

The mean outflow for side damage OMS shall be calculated as follows:

$$O_{MS} = C_3 \sum_{i}^{n} P_{S(i)} O_{S(i)} \quad (m^3)$$

where:

i = represents each cargo tank under consideration

n = total number of cargo tanks;

$P_{S(i)}$ = the probability of penetrating cargo tank i from side damage, calculated in accordance with paragraph 8.1 of this regulation;

$O_{S(i)}$ = the outflow, in m^3, from side damage to cargo tank i, which is assumed equal to the total volume in cargo tank i at 98% filling, unless it is proven through the application of the Guidelines referred to in regulation 19.5 that any significant cargo volume will be retained; and

The probability P_S of breaching a compartment from side damage shall be calculated as follows:

$P_S = P_{SL}\, P_{SV}\, P_{ST}$

P_{SL} = probability the damage will extend into the longitudinal zone bounded by X_a and X_f; $P_{SL} = 1\text{-}P_{SF}\text{–}P_{SA}$

P_{SV} = probability the damage will extend into the vertical zone bounded by Z_l and Z_u; and $P_{SV} = 1\text{-}P_{SU}\text{–}P_{SL}$

P_{ST} = probability the damage will extend transversely beyond the boundary defined by y.

$P_{ST} = 1\text{–}P_{SY}$

P_{Sa}, P_{Sf}, P_{Sl}, P_{Su} and P_{Sy} shall be determined by linear interpolation from the tables of probabilities for side damage provided in paragraph 8.3 of this regulation

where

P_{Sa} the probability the damage will lie entirely at of location X_a/L;

P_{Sf} the probability the damage will lie entirely forward o location X_f/L;

P_{Sl} the probability the damage will lie entirely below the tank;

P_{Su} the probability the damage will lie entirely above the tank; and P_{Sy} the probability the damage will lie entirely outboard of the tank.

Compartment boundaries X_a, X_f, Z_l, Z_u and y shall be developed as follows:

X_a the longitudinal distance from the aft terminal of L to the aft most point on the compartment being considered, in meters;

X_f the longitudinal distance from the aft terminal of L to the foremost point on the compartment being considered, in meters;

Z_l the vertical distance from the moulded baseline to the lowest point on the compartment being considered, in meters;

Z_u the vertical distance from the moulded baseline to the highest point on the Compartment being considered, in meters. Z_u is not to be taken greater than D_S; and y the minimum horizontal distance measured at right angles to the centreline between the compartment under consideration and the side shell, in meters.

P_{Sy} shall be calculated as follows:

P_{Sy} = $(24.96 - 199.6y/B_S)\,(y/B_S)$ for $y/B_S \le 0.05$

P_{Sy} = $0.749 + \{5 - 44.4(y/B_S - 0.05)\}\,(y/B_S - 0.05)$ for $0.05 < y/B_S < 0.1$

P_{Sy} = $0.888 + 0.56(y/B_S - 0.1)$ for $y/B_S \ge 0.1$

Table 6 Probabilities For Side Damage

X_a/L	P_{Sa}	X_f/L	P_{Sf}	Z_l/D_S	P_{Sl}	Z_u/D_S	P_{Su}
0.00	0.000	0.00	0.967	0.00	0.000	0.00	0.968
0.05	0.023	0.05	0.917	0.05	0.000	0.05	0.952
0.10	0.068	0.10	0.867	0.10	0.001	0.10	0.931
0.15	0.117	0.15	0.817	0.15	0.003	0.15	0.905
0.20	0.167	0.20	0.767	0.20	0.007	0.20	0.873
0.25	0.217	0.25	0.717	0.25	0.013	0.25	0.836
0.30	0.267	0.30	0.667	0.30	0.021	0.30	0.789
0.35	0.317	0.35	0.617	0.35	0.034	0.35	0.733
0.40	0.367	0.40	0.567	0.40	0.055	0.40	0.670
0.45	0.417	0.45	0.517	0.45	0.085	0.45	0.599
0.50	0.467	0.50	0.467	0.50	0.123	0.50	0.525
0.55	0.517	0.55	0.417	0.55	0.172	0.55	0.452
0.60	0.567	0.60	0.367	0.60	0.226	0.60	0.383
0.65	0.617	0.65	0.317	0.65	0.285	0.65	0.317
0.70	0.667	0.70	0.267	0.70	0.347	0.70	0.255
0.75	0.717	0.75	0.217	0.75	0.413	0.75	0.197
0.80	0.767	0.80	0.167	0.80	0.482	0.80	0.143
0.85	0.817	0.85	0.117	0.85	0.553	0.85	0.092
0.90	0.867	0.90	0.068	0.90	0.626	0.90	0.046
0.95	0.917	0.95	0.023	0.95	0.700	0.95	0.013
1.00	0.967	1.00	0.000	1.00	0.775	1.00	0.000

P_{Sy} shall not be taken greater than 1.

Using the above tables, values for the various parameters are selected and given in tabular format against selected location for each tank.

P_{SY} is common for all tanks and is 0.888 in this case

Using the above three equations for P_{SL}, P_{ST}, and P_{SV}, P_S for each tank is found and is given under:

TANK 1P = (1-0.767-0.167) *(1-0.873-0.007) *(1-0.888) =0.066*0.12*0.112 = .000887
TANK 2P = (1-0.667-0.267) *(1-0.789-0.021) *(1-0.888) =0.066*0.2*0.112=.0.001478
TANK 3P = (1-0.567-0.367) *(1-0.670-0.055) *0.112 = 0.066*0.275*0.112= 0.00203
TANK4P = (1-0.467-0.467) *(1-0.525-0.123) *0.112 =0.066*0.352*0.112= .0026

Table 6

	Location from stern bulkhead	Location from bottom of tank	PSf	PSa	PSu	PSl
TANK 1P	0.2	0.2	0.767	0.167	0.873	0.007
TANK 2P	0.3	0.3	0.667	0.267	0.789	0.021
TANK 3P	0.4	0.4	0.567	0.367	0.670	0.055
TANK 4P	0.5	0.5	0.467	0.467	0.525	0.123
TANK 1S	0.6	0.6	0.367	0.567	0.383	0.226
TANK 2S	0.7	0.7	0.267	0.667	0.347	0.255
TANK 3S	0.8	0.8	0.167	0.767	0.482	0.143
TANK 4S	0.9	0.9	0.068	0867	0.626	0.046

TANK 1S = (1-0.567-0.367) *(1-0383-0.226) *0.112 =0.166*.0.712*0.112=0.0132
TANK 2S = (1- 0.467-0.367) *(1- 0.367- .055) *0.112 =0.166*0.578*0.112= 0.0107
TANK 3S = (1- 0.167-0.767) *(1—0.482–0.143) *0.112 = 0.166*0.375*.112 = .00697
TANK 4S= (1-0.068-0.867) *(1-0.046—0.626.) *0.112 = 0.166*0.328*0.112 = 0.00609

The mean probability = sum of above probabilities = 0.051938. Hence the accidental mean outflow = 0.051938*15680 = 814.38 m^3, Which is well within the regulation requirements.

The probability conditions also assume that a collision can occur at only one location for the same incident. But however, this incident can cover two adjacent tank spaces, in which case, the transverse movement of the colliding vessel is restricted by the adequately strengthened transverse watertight bulkhead.

This requirement is explained in the case 2 collision incident using the relevant regulation section.

CASE 2

It is possible and probable that the container ship can hit the tanker dead on the common cargo tank and ballast tank WT bulkhead edge. If this happens, the physical resistance provided by the bulkhead will not allow the container ship bow to penetrate into the tanker as assumed in case 1, which is validated by the assumption stated in regulation 2.8.5 CH 4, which is quoted under:

Where the damage between adjacent trans verse water tight bulkheads is envisaged as specified in subparagraph 1.3 of this regulation, no main transverse bulkhead or a transverse bulkhead bounding side tanks or DB tanks shall be assumed damaged, unless the spacing of the adjacent bulkheads is less than the longitudinal extent of assumed damage specified in subparagraph 2.1 of this paragraph,

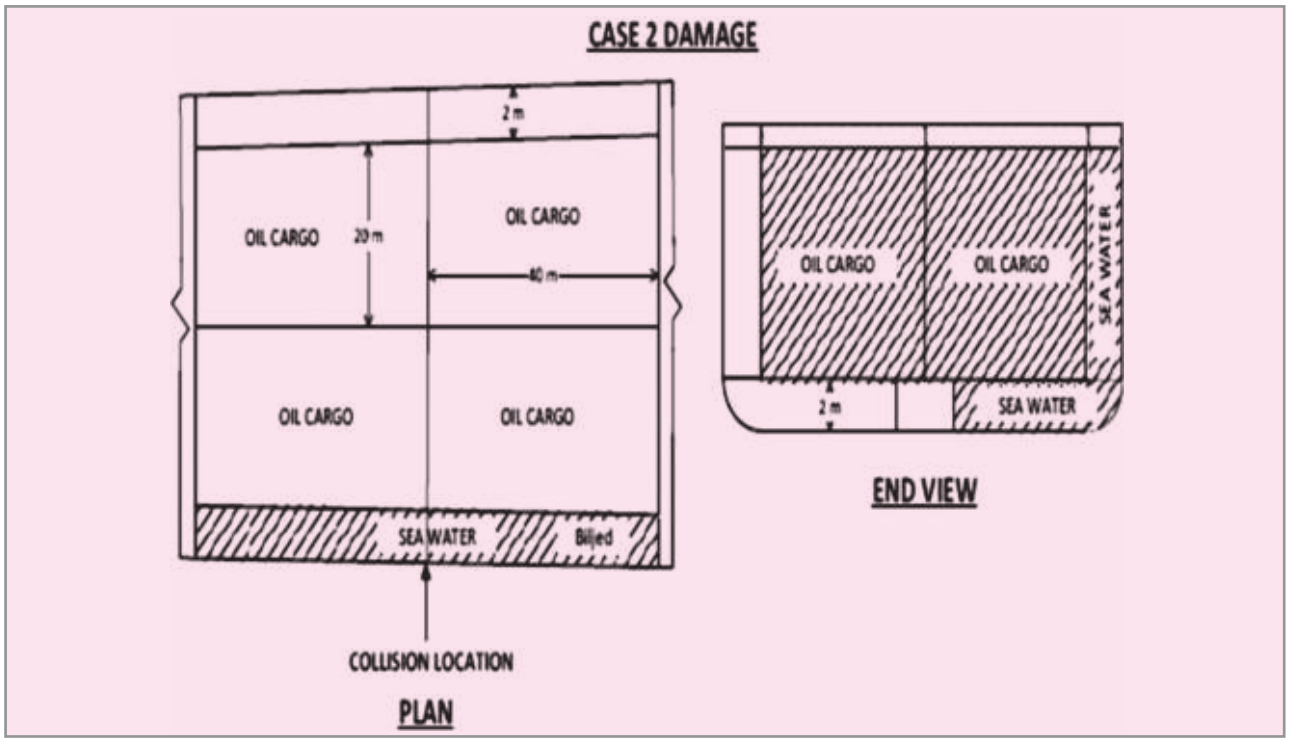

Figure 4

or there is a step or recess in a transverse bulkhead of more than 3.05m in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and after peak top shall not be regarded as a step for the purpose of this regulation.

Both conditions .5.1 and .5.2 are not applicable since the adjacent transverse bulkhead is 40m away which is more than 13.23m the assumed longitudinal length and there is no step in the ballast tank.

It is assumed that the outer shell plating has split to the extent of assumed length 13.23m extending to both sides of the continuous WT bulkhead which breaches and bilges both the adjacent ballast tanks. No penetration has occurred since the WT bulkhead being strong (as assumed) has prevented penetration. But being strong, it has penetrated the bulbous bow of the container ship, after the outer shell plate of the tanker has split from the tank bulkhead junction on both sides. Both ships get locked and move in the direction of the resultant residual force till they come to rest. This is how the collision energy is dissipated. This results in the ballast space of both adjacent cargo tanks to get bilged and flooded.

CASE 2 : ADJACENT BALLAST TANKS BILGED

New intact WP area and second moment.

The transverse axis of the WP shifts towards the intact side and this shift is found by moments of the concerned areas taken with reference to the intact side of the ship. Shift of axis = (**original WP area moment-lost area of ballast tanks moment**)

(Net area) = (7200*22—80*2*43)/(7200—160) = 0.478m towards intact side.

Intact WP second moment
= (935296 + 7200*0.4782) - (160/12 + 160*21.5222)
= 862816 m^4 Hence new BM = (862816/150000)* 1.025
= 5.9 m
New GM = 1.45m

BODILY SINKAGE:

Assume d is the increase in draft, then
(7200—160) *d = (2*80*20+ 2*80*22),
Hence d = 6720/7040 = 0.955 m

HEEL CAUSED BY BILGING:

The shift moment for bilged volume
= 11(2*20*80 + 2*22*80)
= 73920 m^4

Hence heel angle θ is tan θ
= (73820/150000)* (1.025/5.9)
=.0855 Or θ is 40 52'.

Grounding and stranding damage will be dealt with in another article.

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CHENNAI BRANCH

TECHNICAL SEMINAR

The Chennai Branch Conducted its first Technical seminar online on 25th November after the new Committees had taken charge. It was well attended by Marine Engineers from different parts of the country. President, IME(I), Mr. V. K. Jain graced the occasion.

Mr. Kannan, Hon. Secretary, commenced the proceedings with a warm welcome to all.

Mr. Sanjeev Vakil, Chairman, Chennai Branch took the opportunity to introduce the newly elected members of the EC Committee. Then President Mr. V. K. Jain spoke on the efforts and directions that IME(I) is expected to take in the next few years, actions taken so far to achieve the set objectives and promised some very exciting times in the future.

EC Member Mr. Ramesh Subramanian introduced the Guest speaker, Mr. Ramesh Rao who then made a powerful presentation, rendering full justice to the topic **RELIABILITY of OPERATIONS and RELIABILITY of PERFORMANCE.**

He highlighted that 'Preventive Maintenance', which is widely followed in the industry was in fact the LOWEST and most ineffective form of Asset Management. He elaborated that deviations in performances, which trigger us to carry out maintenance jobs, are in fact recognised only when the equipment has deteriorated substantially and is almost on the verge of catastrophic failure. He explained the 'journey of failure' and the classic PF curve.

He explained how traditional planned maintenance missed out on the opportunities and how failures could have been predicted much earlier by using advanced techniques such as Ultrasonic measurements, Thermal imagery, ECS, Vibrations, elemental analysis of Lub oil etc. He also underlined the limitation of human beings in diagnostics and justified the use of proactive and advanced techniques for enhanced Asset Management. He stressed on the importance of capturing the SIGNATURES of the machineries at the POINT of INSTALLATION (i.e., while building the ship).

The presentation was followed by a Q & A session, moderated by Mr. Suresh Shenoi, Vice Chairman.

Mr. Kannan, Hon Secretary, proposed the vote of thanks.

IME(I) Chennai Branch's Hon. Secretary Shri. S. Kannan was elected as Chairman of the Tamilnadu State Centre of The Institution of Engineers India (IEI). The Chairman and the Executive Committee members of IME(I) Chennai Branch is proud to say that in 100 years of The Institution of Engineers India, Tamilnadu State Centre, this is the first time a Marine Engineer has been at the helm and the chairman of the Institution.

The branch wishes Mr. S. Kannan good luck and in his tenure, The Institution of Engineers India, Tamilnadu State Centre is going to celebrate the centenary year in 2022. IEI Tamilnadu State Centre has also offered the auditorium for IME(I) technical meets/seminars. The branch sincerely hopes to use the resources of IME(I) & IEI Tamilnadu State Centre, Chennai branches in the interest of all engineers.

KOLKATA BRANCH

ONLINE SESSION ON MEDITATION

Often it is observed that seafarers go through mental stress owing to the lonely life they spend at sea. Further, the eruption of Covid-19 has added to the stress on personnel even on shore, due to the same isolation and issues related to work-from-home.

With this in mind, on 30th October 2021, the Kolkata Branch organised a web session on **'Meditation for Stress-free Mind and Inner Peace'.** Accomplished speaker **Swami Prem Anveshiji** was invited to talk on the subject.

Chairman of Kolkata Branch, Shri Gautam Sen, welcomed Swamiji and the attendees. Vice President, IME(I), Shri. Amit Bhatnagar, gave an introduction of Swamiji.

Swamiji explained in a lucid manner the reason for his own transformation to a monk from an engineer-cum-business tycoon. In his enlightening speech, dealing with many issues related to life, the speaker also explained how the ego of a person needed to be eliminated before one can really feel one with the creator. Swamiji then explained the benefits of doing pranayam regularly. He then demonstrated the fundamental steps of pranayam, and suggested that members practise them on a daily basis to feel the difference in their minds and bodies.

Chairman, Kolkata Branch, then proposed a vote of thanks, with special respect and appreciation to Swami Prem Anveshiji.

WEB SESSION ON HOVERCRAFT

A virtual seminar on the topic **'Technical Operations & Maintenance of Air Cushion Vessels'** was held on 6 November 2021 by IMEI Kolkata Branch. **Shri. M.G. Raju, PSC, Indian Coast Guard, Haldia**, delivered the lecture on the topic.

Shri. Gautam Sen, Chairman, IME(I) Kolkata Branch, welcomed the speaker and the attendees. He mentioned that this was the first time that a lecture was being conducted by the branch on this subject. Shri. Amit Bhatnagar, Vice President, IME(I), introduced the speaker and spoke of his various achievements.

Shri. Raju initially gave a brief description of the history, construction and communication system of hovercraft, which, he informed, was invented in the 1950s.

In his paper, Shri. Raju elaborated on the hull structure and various appendages, along with skirt and its connection methodology with the hull. He also discussed in detail about the main engine, lifting fan, and the different systems, such as transmission, steering, control and communication, maintenance aspects of hovercraft, and types of surveys carried out etc.

The webinar was attended by about a hundred attendees from across all branches of IME(I). The presentation was followed by a Q & A session.

Shri. Swapan Kumar Saha, GC Member, Kolkata Branch, gave a vote of thanks.

ADDRESS BY THE PRESIDENT ELECT

Outgoing President – Mr. Uday Purohit, Outgoing Vice President – Mr. Kushal Roy, Outgoing HGS Mr. Tarun Kumar, Members of the Governing Council (both incoming and outgoing), Editor MER – Dr. Rajoo Balaji, Past Presidents, distinguished Lifetime Achievement Award winners, past office bearers of the IME(I), incoming office bearers, Mr. K. Shankar, Mr. NMC Nair, Ladies and Gentlemen.

At the outset, my heartfelt thanks to everyone who considered me worthy enough to lead the Institute of Marine Engineers (India). The overwhelming faith and trust which has been reposed in me is indeed humbling. It is an honor to be accorded this privilege and it shall be my sincere and utmost endeavor to fulfil the expectations of me.

Earlier this year, when I filed my nomination, I could never imagine what would be in store for me over the next few months till the elections were completed. I was witness to offers of support, offers of garnering support (both open and muted), a wide range of ideas and suggestions for the future, volunteers to work with me if I got elected, so on and so forth. There is a deep underlying passion in our members to serve, which has to be but tapped. All these gave me a feeling of immense pride in our Institute.

I also realised that I have large shoes to fill. Those of the past office bearers and Past Presidents who have served the Institute with so much dedication since its inception. One amongst such illustrious Past Presidents was my late father Mr. P. C. Jain. I remember my father encouraging me to excel and outdo myself constantly, whether it was at work or elsewhere. He instilled in me the importance of having unlimited passion for whatever I did. He would surely have been extremely proud to be here amongst the audience today. To see his son become the President of the IME(I), a seat which he himself had occupied almost 3 decades ago and had passionately worked for during a large part of his life.

Coming to the road ahead. Times are turbulent, COVID threatens to disrupt world shipping, more so Indian shipping. Frontiers of technology are being pushed ahead on a daily basis. There are innumerable challenges, and with these challenges will come the opportunities for organisations like us to prove our worth.

During the election, I was advised by many to be focused and take up one issue.

However, after giving much thought to the issue, I arrived at the conclusion that it is imperative the Institute moves ahead on multiple fronts, if we are to remain relevant in this fast changing world of today. The multiple issues which I feel are required for taking the Institute to the next level, and which had translated into the creatives of my election campaign, at the risk of repetition, are reproduced.

1. **Members Welfare**. We have an extremely large Membership base, with an even larger base of potential members. Other professional organizations like the Institute of Chartered Accountants, The Institution of Engineers etc., all work for the benefit of their Members. They have in their Articles, enablers for a number of welfare schemes, such as: Insurance schemes – be it insurance for life, personal accident or motor vehicle. The provision of credit cards, loans for personal use, be it business or housing, are arranged at preferential rates, along with many other similar group benefits. It is time we evolved and looked towards such additional benefit of our Members.

2. **Student Members**. The student members of today are our Members of tomorrow. We must provide them with benefits and suitable training. Assisting them in improving their employability currently remains an untouchable topic for the IME(I), but vital for them. Setting up a Youth wing will go a long way in engraining IME(I) in their veins from an early age and for hand holding which they all seek. I propose to set up a separate team to look exclusively into Students affairs.

3. **Women Members**. Increasing the number of women marine engineers becoming our member, remains a priority. It is time we focus our attention at alleviating their problems. To formalize this I hope to have more Members looking into this and I seek the assistance of our existing Women Members to make this happen.

4. **Technology**. Technology remains at the forefront and we must keep pace with it. Be it useful apps, effective communication or effectively tapping social media sites – the IME(I) must keep pace with modern day developments. Using technology for administrative functions, the availability of information or the usage of technology for more advanced training methodologies – will need to be focused upon in the coming 2 years.

5. **Globalisation of IME(I)**. It is time the IME(I) went global. It is my earnest desire that we should look at opening Chapters abroad during this term, with the large membership that we have in countries like Singapore, UAE, Hong Kong, US and the UK. These are only a few of the issues that I intend to take up in the coming months. To make all these happen, along with some of the other ideas suggested to me – it is important that the Members across the globe chip in and assist. The IME(I) needs assistance of its extremely skilled and talented Members who are willing to contribute to its growth and I request Members to volunteer for areas of work and to join various sub-committees, so that they can be part of the said growth, in areas of their choice. With more hands on board along with the widespread experience of the incoming Governing Council Members, I am sure we will be able to make numerous initiatives happen and count. In order for this to happen, we will also need to change our thinking and embrace changes at every level. I am reminded of a favorite saying by Andre Gide ***– Man cannot discover new oceans till he has the courage to leave sight of the shore.***

Ladies and Gentlemen, the exciting part of our journey has just begun.

I hope that at the end of the two year term, we would have made substantial progress on most, if not all of these issues. I am indeed fortunate to have the very dedicated Cmde Bhupesh Tater alongside me as the Honorary General Secretary. Having worked with him at the Branch level – I can confidently say that he is extremely committed with superlative administrative skills, combined with a no-nonsense approach. All these are much required qualities to have, especially when working in a large and diverse organization such as ours.

As Vice President – Mr. Amit Bhatnagar brings to the table the considerable experience of being a Past Chairman of not only Visakhapatnam Branch, but the Chairman of the Kolkata Branch as well, a unique honor not held by many, as far as I can remember. The zeal to start Glomars, an International seminar in Visakhapatnam and then mobilize the Members in the Kolkata Branch to similarly start ISSCO during Covid times, are clear indicators of his mettle and commitment to the IME(I).

Dedication, team work and passion is what I ask for from the incoming Governing Council Members. The voluntary office that you have taken up provides you an opportunity to achieve more than plenty for our fraternity. I hope and pray that at the end of our 2 years in office, each one of us in our team can look back with pride and satisfaction at our achievements.

I wish all the very best to everyone.
Do take good care of yourselves and stay safe!
Thank you and Jai Hind!

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Registration & Payment :	Kindly enroll & make payment through https://linktr.ee/imei.m and after registration please drop email to mumbai@imare.in
Contact Person for any queries:	Kindly contact Ms. Nimisha Nayan- 9373394137 Ms. Neetha Nair - 9930977647 The Institute of Marine Engineers (India) – Mumbai Branch, 1012 Maker Chamber V, Nariman Point, Mumbai-400021

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A SURVIVAL STORY

Shankar Ram

My life's unforgettable incident took place in one of a PCTC vessel while I was the Chief Engineer. I remember this incident so vividly and every time I do, it sends chills up my spine. I wouldn't wish this for anyone.

It was the first time I was joining this company, leaving my earlier one just because I was promised that I will be put on a M.E type v/l (Cam-less engine) after taking the training course with them. I was trained with this company for about a week and I was sent to a vessel which was a Pure Car and Truck Carrier (PCTC) with a conventional engine. I was told that I will be doing a parallel voyage with the incumbent Chief Engineer till the next port where I was supposed to take charge. Then I travelled to Southampton from Chennai to join the ship. I reached Southampton, but my bags were missing. To add to the misery, all my Certificates were in my bag except for my Passport, CDC, COC and health book, which I had carried in my hand baggage. I reached the vessel without my baggage and requested the captain to sign me on. He refused to sign me on as Chief Engineer, citing the absence of STCW certificates. My argument went in vain and finally I was signed as superintendent which was to be until the next port. We were ready to set sail on 3rd Jan 2015 at 2000 hrs.

The Chief Engineer left me in the engine-room and went to his cabin to calculate fuel figures. I was left in ECR with 2nd engineer, electrical officer, 4th engineer, trainee electrical officer and a motor man. Initial start was given to the engine around 2015 hrs and we were on our way to Bremen. The vessel was under pilotage and there were two sharp bends that needed to be negotiated before reaching the Pilot drop point. When the vessel picked up the ramp for stowing, we did not feel anything abnormal. The starting and following movements were smooth.

When the vessel took the first bend, it rolled close to 10 deg. Starboard and slowly came back to upright position. In a car carrier this is considered quite normal and a 2 to 3 degrees' tilt to one side happens often with wind forces. We were almost at full ahead rpm when we took the second bend. This time the vessel went to 10 deg. Starboard and we were expecting it to come back to normal, slowly. But the roll increased to 12 degrees and then to 15 degrees. At this time, myself and the 2nd engineer went out through the ECR entrance door and we were holding on to the railing outside. The 4th engineer and Trainee electrical officer were taking rounds. They froze and held on to the railing near the staircase by the cylinder head platform.

The electrical officer and motor man had just reached the engine room exit located on the after portion of the highest (12th) deck to have the last glimpse of Southampton. The vessel went from 15 to about 45 degrees quickly and all alarms started sounding. Myself and the 2nd engineer were clinging on to the platform railings and the Trainee and 4th engineer were clinging on to the staircase railings. We were in a state of panic and couldn't think on next course of action.

At this juncture, the main engine ran for a few seconds and tripped off due to low L.O pressure. Both A/E's ran for about half a minute more and they too tripped, causing a total black out. It was pitch dark in the engine-room and we were stranded with alarms sounding to its glory. There might have been some announcements regarding the situation but we could not hear anything in E/R except the alarms. After a period of about 45 seconds, which appeared to be a very long delay, Emergency generator came on load and the emergency lights came on. We were still like statues, gripped with fear not knowing what to do. After a few minutes I realised that everything will be all right as long as there is no water ingress to the engine-room.

In a car carrier, the possibility of water entering through the entrances of the engine room are remote because of the structure, but this didn't mean that it was impossible. We were afraid of the water ingress as the vessel's tilt was slowly increasing. To reach the staircase where my 4th engineer and trainee electrical officer were clinging on to, I had to cross the cylinder head platform, which was located three steps below the ECR platform. I decided to climb down the steps and after reaching the platform I thought I could balance myself and walk slowly towards the staircase. After positioning myself securely (or so I thought), I let go of the railings. In an instant I lost my balance and was sliding down towards the Main Engine Fuel pump. I hit the Main Engine fuel pump control lever and my slide was stopped with a sharp pain in my ribs.

Seeing this, the 2nd engineer decided to squat on the platform and had started to slide down. He came crashing down on me, which was quite painful and to top it all, he was a big guy. We had no time to think about the pain and we started crawling towards the end of the platform, which can lead us to the staircase. We slid towards the staircase and on the way caught hold of everything we could to help with our balance. Some were steam lines, water lines etc., and at last we reached the bottom of the staircase. After taking few quick breaths and a break for a few minutes, we started climbing the stairs.

We were in the fourth deck of the vessel and needed to climb to the 12th deck to reach the aft entrance of the engine room. On a normal day, this would take only about a minute via the elevator or 10minutes if you walk slowly using the stair case, but on this day it took us about an hour. We had to rest at each of the staircase landings and finally reached the after portion with a lot of puffing and panting. My throat was dry and I was driven by fear and I thought that vessel would start to sink.

Outside on the deck, the evacuation process was going on with the help of a helicopter in the forward area and at port side bridge wing. In fact, now the vessel had stopped tilting and was resting on the sand banks with a 62-degree tilt to the Starboard side. This was something we got to know only after we were rescued and were at the Seafarers Club.

While we were struggling to get to the accommodation, and then on to the upper decks, the electrical officer and the motor man who had come up earlier sensed the danger. They picked up and donned the life jackets provided near the aft of the engine room entrance. In car carriers, usually the accommodation will be located in the forward portion of the ship and there will be a passage (covered or uncovered) connecting the Port and Starboard sides of the vessel. In this vessel, there were four such openings. While trying to cross one of the openings, the electrical officer slipped and fell towards the Starboard side railings on that deck. He was not aware of the fact that the vessel was resting on the sandbank. He saw a rescue boat approaching the vessel and flashed his torch light towards the boat and jumped into the water. The water was at 5 deg. C (he would not have realised this also). Fortunately, he was picked up by the rescue boat and was provided with warm clothes.

Meanwhile, me and my team of four came to a standstill when we approached the gaps in the corridor. I showed my team members how to cross the passage. I was lying on the floor and stretched out my hands to hold on to something so that I could pull myself up to cross the passage. My team followed what I did and made it to the other end of the corridor, reaching the accommodation. In the accommodation, we needed to go one deck above to reach the bridge space where the evacuation was taking place. My team members were tired and they informed me that they prefer being guided by rescuers and leaned against the corridor bulkhead and waited for the rescue team to arrive.

I wanted to take the passage with a short flight of steps with a door and make it to the upper deck. We knocked on the door and somebody from the other side informed us not to open it as there was an injured man lying against the door. So I took a circuitous route to reach the bridge wing leaving my team members. On the way I went to my cabin and grabbed whatever I could and headed to the evacuation place.

The helicopter could take about 5 people to safety in a single trip. I got on the helicopter on the 4th trip and landed safely in the area where other crew members were waiting ashore. The Captain initially refused to come off but was convinced and was forced to evacuate in the last trip. All 24 of the crew members were directed to the Seamen's club where help was rendered. The company immediately took action and accommodated all of us in the hotel for a couple of days. Since I had just joined, I was sent back home along with the other crew members and only 5 people were detained for questioning by authorities. I came back home and visited my family doctor who treated me for muscle strains and I was back to normal in a few days.

When I was back nursing my injuries at home, the vessel was taken over by a salvage party and they were trying to make the ship upright. The weather was not permitting and after a 10 days' effort, they succeeded in making the vessel float with a 15-degree list. To bring up support, the company recruited a new set of crew members of all ranks. They asked me if I wanted to join the same vessel again, for which I readily agreed without consulting

my family. Later at home, we had arguments and finally, half-heartedly I was given a send-off from home. We had a pre joining meeting in Mumbai office where the situation and condition of the vessel was explained. After reaching Southampton, we came to know that the vessel was floating with 15-degree Starboard tilt and only a few crew members were allowed to board the vessel.

Of the entire crew, only the 2nd officer and I were from part of the old crew. We brought the vessel to a manageable 4-degree tilt by ballasting and then it was towed to the berth. At the berth, we stayed for a couple of days to discharge the cargo and setup the main engine. After preparing the vessel for sailing, we sailed to Falmouth for underwater inspection and minor repairs. After a week stay, the vessel was ready for sailing and the earlier fixed route, which was Chennai - Sri Lanka – UAE - Med. Ports - U. K - Germany. This got cancelled and we were asked to take a trip to the east coast of U.S and back to U.K. We performed the voyage creditably with a hired Emergency generator on-board as the original one had broken down for want of a spare cylinder unit block, which was not readily available. On our return voyage, I signed off in the U.K after making the Emergency generator operational.

Presumed reasons for the occurrence of event:

There were 'n' number of reasons for this to happen. It was stated that skilful manoeuvring by pilot and captain saved the vessel. Maybe it was true but I have my doubts. In my opinion, the following could be the reasons for this very unfortunate, unforgettable incident.

Remote gauges for the ballast tanks were not showing correct readings. Vessel's D.B Fuel oil bunker tanks were empty needing ballasting of water ballast tanks. Ballasting operation was carried out by running the pump for a predetermined time based on the quantity of water to be pumped into the tanks (calculated and presumed that the quantity has been ballasted). This might have created slack tanks.

Further, loading plan was modified in last moment and some heavy cargoes were kept on the upper deck. Heavy cargoes were lashed with nylon belts, normally chains are used. Belts expiry dates were not maintained.

The vessel while negotiating the turn at full ahead speed, listed more than necessary, snapping of belts securing the heavy vehicles. This caused the cargo shift, the roll, the tilt and the settling on the sand dune. I found out when I joined the vessel again. I dared to find out what the reasons could be but more scared I remain, whenever I think of the escape.

*Chief Engineer **Shankar Ram** is an experienced Marine Engineer who teaches in between his sailing assignments.*

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IN THE WAKE

Rajoo Balaji

Corona Chronicles

While the pandemic wave abates (Do we have to skate the 3rd wave?), countries are opening up and providing palliative help also. Singapore has launched a vaccination programme (called SEAVAX) for non-Singaporean seafarers, which will run till June 22. The score till November is about 8000 and the island-state has allotted another 12000 [Moderna] jabs for the non-S seafarers (BTW, this is totally free).

The score of crew changes in Singapore since March 2020 is around 190000 (ticking towards 200000).

Few queries (looking at the stats):

1. Are these numbers enough (12000) for the crowd passing through?
2. The Moderna jabs... are they compatible with other ones? The earlier Reports say yes.

Bonus Booster: While medical world is contemplating on boosters, a mix & match could very well be on the cards for approval (So jab of Moderna in Singapore and a prick of Covaxin in Bharat will be cool).

Shipping Matters

COP26 saw a lot of emissions (I mean emissions of reports... reports). An interesting one is on bio-fouling released by IMO. The preliminary report contains analyses of a collection of results from many research studies tying up the biofouling with energy efficiency i.e., emissions (**See graph**). The factor to reckon is the **increased hull roughness**.

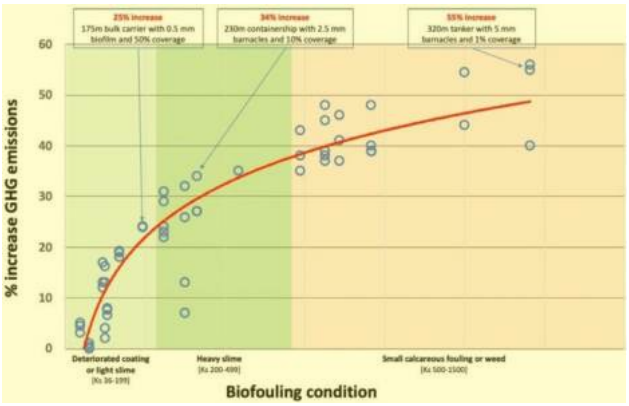
Some highlights:

1. Heavy slime (0.5mm thick) increases the resistance and emissions. Slime thickness, surface area, speed etc., determine severity.
2. Light hull growth (barnacles/tapeworms) can double these emissions.

The Report observes that the 'perceived impact of biofouling is likely to have been historically underestimated by the shipping community'.

While the second part of the Report is expected (circa Feb 2022), the prognosis could be that care with hull coating, propeller polishing and ultrasonic AF etc., will help while awaiting pointed advise on effective AF technology. The idea is that this could be an easy tool to adopt as a measure towards efforts on emission control.

Bottom line: Clean bottom, cleaner funnel.



Source: IMO>> Preliminary results: Impact of Ships' Biofouling on Greenhouse Gas Emissions

Tech Talks:

Sharing some interesting info from a DNV webinar on anchoring losses:

The reported losses have been on the rise in the last 3 years. The trends are negative and so it is matter of concern.

What are the major reasons/causes?

- At Anchorage: Bad weather; Operational errors (in anchoring procedures)
- At Sea: No proper securing; fastener failures
- At emergency situations to avoid collisions/grounding (trying to anchor etc.).

The three big villains are Bad Weather, Deep Waters and Strong Currents.

A survey result was almost split (Yes & No) on the question whether Master and crew were aware of the design limitations of the anchor use (particular aspect: environmental conditions).

Now to some more useful info picked up:

- Ships using anchor equipment not very often: Container ships; Car carriers
- Storms have become more frequent
- Staying at the anchorage might not be the safest choice (as believed to be)

There were good pointers on the Class Rules on limitations due to environmental conditions and couple of case studies (Those interested can check from the webinar recordings).

One line takeaways: Crew Competence (be aware of limitations); Have Action Plans (especially for bad weather).

About December

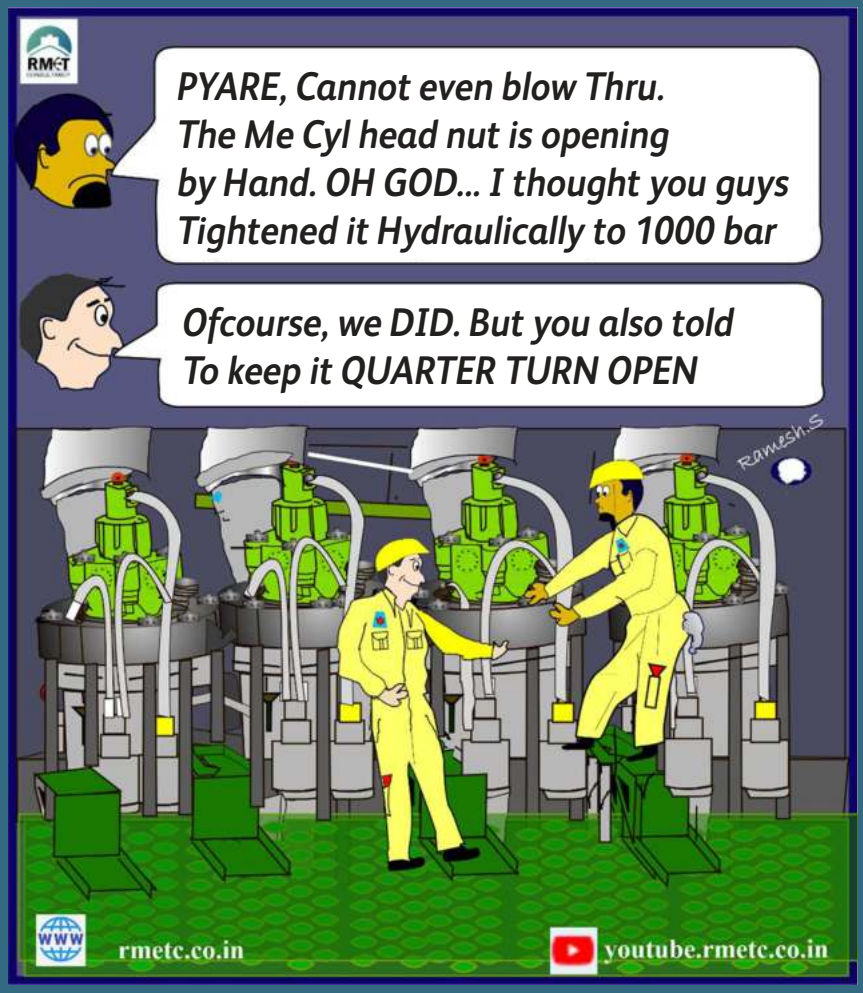
This December, let us choose something relevant to the times...

14/12: International Energy Day (Catchphrase for the coming year: Conserve and Consume).

23/12: Kisan Divas (Farmer's Day) (Haven't they gone home yet?)

We wish our entry into the 22nd year of the millennium bring blessings for good health and better health!

THE END VIEW

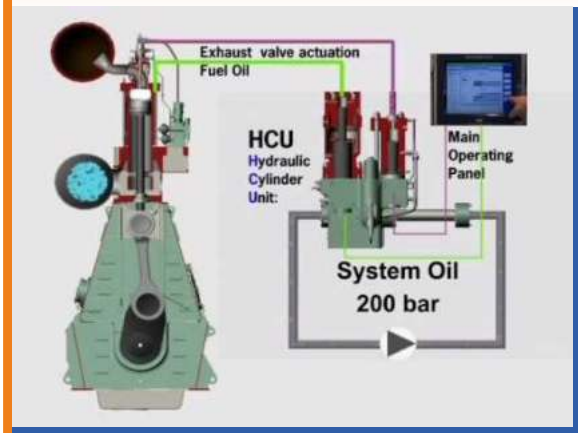


Idea, Words & Drawing: **Ramesh Subramanian**

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 : 14th to 16th **Dec.'21**, 18th to 20th **Jan.'22**, 15th to 17th **Feb.'22**, 15th to 17th **Mar.'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***

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