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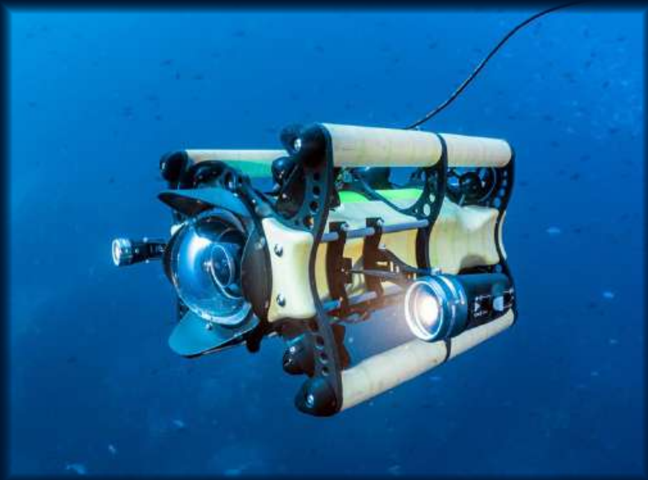

Robotics for Repairs

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EDITORIAL

The sea finds out everything you did wrong.
- Francis Stokes (yacht racing champion)

While some global guns have gone silent and the tariff turret turns slower, shipping continues to create waves. MEPC 83 did the amendments for multiple engine operational profile and the certification of tier change for NOx mitigation (matters for marine engineers).

India plans to expand its energy transportation by buying and building tankers. The big Fund for boosting and bolstering the maritime industry will live its purpose if part of the tonnage is realised in the Indian yards. The MoPSW has been talking to the Korean principals for enhancing the yard capacities. Another vertical getting traction is the training for building competencies in shipbuilding with Korean support. Ongoing efforts to energise a shipbuilding design and research centre in parallel will augur well as Indian yards start shaping the steel for commercial vessels.

The global climate is also favouring shipbuilding. The tariff tornadoes have hardly troubled the shipyards (Korea & Japan) and Chinese yards are perhaps an exception where some value erosion is seen. *The Economist* observes that the combined market value of the global shipyards (about 120 listed shipbuilders) have risen by 15% (value: >US$200 billion). To add to the argument, Hanwa Ocean has logged a quarterly revenue of US$2.2 billion (38% rise YoY). Given these sentiments, India's US$10 billion plan for building tanker tonnage sounds doable, here and soon. To ride this wave, India has to get its act together, make prospective builders/shipowners be aware of the Governmental support so they may internalise the intent. In parallel, the designers' woes and ancillary industries' supply chain chinks etc., are to be addressed as well. The time has come to build more merchant ships in our yards with quality. And hence, the seas may find them free of flaws and float-worthy.

In this issue

We start with a paper presented at WMTC 2024. Cmdt. Dr. Sudeeptho Ghosh describes the merits of employing robotic machines and techniques in ship hull maintenance in particular. Inspection and surveying, cleaning of the hull surfaces etc., are possible using robotic machines, declares the Author. There are mentions of a few studies in support and a number of nominal suggestions that IN should adopt, including a Cost Benefit Analysis. This is an easy read.

Following this is another article from the WMTC 2024 basket. Katie Earnshaw and Chirag Bahri bring in the perspective of how decarbonisation has impacted seafarers on board. Based on a study, they surmise that adoption of technologies for decarbonisation is having a negative impact relating to workload, stress, fatigue, mental health and fear of criminalisation. An intriguing observation from the survey results is that engineers (read: sailing marine engineers) are more impacted with meeting the demands for decarbonisation than their deck counterparts. The Authors propose a number of oft-repeated, via media solutions. In all, this is a very easily understandable read for all level of mariners and worth reflecting upon. I would invite your thoughts on this.

Then we move under ice. Dr. Vedachalam brings an educative piece on underwater inspections of the Polar ice. In his regular style, he traces the investigation history and the importance of ice studies. The discussion gets more technical on the types of drilling (mechanical, electro thermal etc.) and the mechanics, which include design talks, difficulties of drilling etc. It is all drill discussions and getting further into the cold-thickness. The robotics are to come in Part B.

The interesting takeaway: the ice cores and climate change estimations.

Under Students' Section, an AI integrated safety device is discussed. While exclusive innovation hubs for maritime are being planned, such ideas need a look, consideration and encouragement. I would invite the practicing marine engineers to share their comments.

Under Technical Notes, we continue with Part 2 of the Seafarers' stress and occupational therapy discussions. MER Archives from June 1985 has some interesting information (example: Roman/Greek warships had medical doctors who got double pay and hence Romans called them 'duplicarii'.)

While the ruddy sindoor has been reconciled by rendering black and blue bombings, the prayers for peace prevail. On that note, here is the June 2025 issue for your reading.

Dr Rajoo Balaji
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Robotics In Ship Repairs – Imperatives and New Paradigm Towards Enhancing Safety and Efficiency

Sudeeptho Ghosh

Abstract

A ship must have limited downtime in order to operate and perform at its highest potential. Maintenance of ships' hull conventionally involves dry docking, cleaning, inspection and repairs. The majority of the inspection and repair activities have been carried out manually in the past. Due to the constricted areas, working at heights, and extended reach, these activities are highly labour-intensive, dangerous, and time-consuming. Studies reveal that advanced robotic technologies are available for various ship inspection and repair activities which could mitigate the limitations. These advanced robotic technologies have been studied, along with field trials and cost- benefit analysis. Benefits accrued with respect to time, quality, cost savings and safety aspects have been clearly weighed along with on-ground limitations. Following that, this research paper has come up with implementable mitigation strategies, including a roadmap and thought process for policy directives toward implementation.

KEY WORDS: Robotics, Ship Repairs, Refit, Maintenance, Fouling, blasting, Proactive hull grooming.

INTRODUCTION

1. The nautical perspective of a warship is, 'To Float', 'To Move' and 'To Fight'. Therefore, the float worthiness of a warship is most crucial to its battle worthiness. Refits of warships entail Inspection of the ship's structure and equipment, preventive maintenance of hull and equipment and trials. To maximise the operational availability of a warship, it is prudent to reduce the duration of refits to the maximum extent feasible[1]. The underwater hull, tanks, and bilges are traditionally inspected manually, both visually and using thickness gauges. However, inspection by manual means is highly time- consuming and has safety constraints.[2]

This paper aims to bring out the technological advancements made in the last decade in the field of robotics, specifically addressing hull inspection, hull survey, tank survey, in-water robotic inspection, robotic blasting and painting of ship's hull. The paper also aims to examine the technological advancements that have been adopted in the recent past in the repair yards, their challenges and their limitations. The paper details the benefits accrued in terms of time savings and the safety of workers engaged in ship repairs. Finally, this paper

> *International Association of Classification Societies (IACS) is exploring the feasibility of using Robotics and Autonomous Systems to carry out remote inspections ensuring the same quality levels, as delivered by human inspectors and surveyors, at the same time reducing time, costs and improving safety*

highlights the other available technological advancements that must be explored and the scope of improvement on the available technology that can bring about a further enhancement in efficiency and safety in ship repairs.

LITERATURE SURVEY

2. **Assessment of Ship Robotic Inspections**. Studies have been carried out in the field of robotics for ship repairs by the authors[3]. The paper highlights that survey and inspection of ships are hazardous, time-consuming, labour intensive, and expensive when undertaken by human surveyors to a large extent. The need for enhancement of productivity, accuracy and safety leads to an imperative for the adoption of robotic technologies. The authors conclude that the use of robotic technology can enhance the accuracy of inspection and results, primarily owing to the possibility of a larger amount of data collection as compared to manual means of inspection. The author has indicated that the International Association of Classification Societies (IACS) is exploring the feasibility of using Robotics and Autonomous Systems to carry out remote inspections ensuring the same quality levels, as delivered by human inspectors and surveyors, at the same time reducing time, costs and improving safety. While, this paper brings out a comparison between conventional methods with robotics, highlighting the benefits accrued, it does not conclusively describe specific robots that can be used for various inspections and repairs.

3. **Recent Developments in Remote Inspections of Ship Structures**. In this paper, the authors bring out that robotics has become an important resource in engineering in recent years[4]. Furthermore, Specific robotic technologies that have been developed in the niche areas have been highlighted. The study points out that while the robots were created for use in general engineering, it is beneficial that these be modified and tested in order to be customised for the maritime industry. Based on studies, the author has also highlighted that robots facilitate the collection of a large amount of quality data, which facilitates a comprehensive assessment of ship inspection and better decision-making towards time-bound repairs.

STATEMENT OF THE PROBLEM

4. In the conventional methodology, the procedure for warship hull inspection entails drydocking, washing of underwater hull, cleaning tanks, ventilation of confined spaces, gas- free certification, and scraping, followed by a physical inspection using a hammer survey or ultrasound gauging. The above-mentioned activities are serial in nature, laborious and time- consuming. The major drawbacks of the conventional methodology are as follows: -

(a) Long lead time to determine the scope/ extent of work.

(b) **Surveyors' safety is at risk because they require to enter potentially hazardous gas-filled restricted spaces and operate at heights.**

(c) The amount of quality readings/ data collected is limited due to the accessibility and fatigue of surveyors.

(d) Inclement weather affects the smooth conduct of surveys.

(e) Documentation of data needs to be manually undertaken for posterity.

While the globe has moved to sophisticated inspection technologies utilising bots, employment of these cutting-edge technologies in the Indian Navy is still highly restricted. A survey revealed that repair yards are reluctant to change at the working level and have reservations about adopting them. It is, therefore, prudent to conduct a thorough examination of the available technology and its applicability and carry out a cost-benefit analysis considering benefits accrued in terms of time, quality, environmental considerations and employee safety. The working level needs to be convinced about the benefits of the use of robots. Furthermore, It is necessary to develop policy directives on the modalities for using these technologies, their limitations, interpretations, etc. after conducting in-depth research and field evaluation trials.

OBJECTIVES OF THE STUDY

5. The objective of the study is to examine the relevance, practicality, applications and efficacy and relevance of new robotic technologies, examine their costs and benefits and compare these with the methods of inspection in vogue. This research paper aims at the following: -

(a) Literature survey of robotic technologies available in the industry, which are relevant to warship repairs.

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> *The preparation of the hull structure viz., washing, cleaning, gas-free certification of tanks, and chipping of interior compartments takes long durations of time and therefore, a large amount of time is wasted before the scope of work is finalised*

(b) Examination of current practices used for inspection and repairs of ships.

(c) Drawbacks of the manual procedures in vogue viz limitations wrt downtime of platforms, preparation time, quality of data, safety, etc.

(d) Examination of available Robotic Technologies for ship's Hull Inspection and repairs.

(e) Detailed study of trials of robotic technology used for ship repairs in the recent past.

(f) Cost-benefit analysis and relevance of robotic technology for ship repairs in the Indian Navy.

(g) Formulation of the way ahead and road map for implementation of robotic technology.

RESEARCH QUESTIONS

6. The precise set of questions that the paper focuses on addressing are as follows:-

(a) What is the methodology used by the Indian Navy presently for survey and inspection by the Indian Navy during the refit of warships?

(b) What are the limitations due to the methodologies in vogue?

(c) What are the advanced robotic technologies available in the industry and used by the advanced Navies?

(d) What are the Robotic Technologies that would be beneficial to the Indian Navy in terms of enhancement of productivity, safety and reduction of downtime of platforms?

(e) What policy guidelines and roadmap would be required for implementation and smooth transition to using robotic technology in ship repairs by the Indian Navy?

SCOPE AND LIMITATIONS OF RESEARCH

7. The objective of this research paper is to identify the robotic technologies available in the industry and under exploitation by foreign Navies concerning survey, inspection and repairs of ship's hull. This paper aims to cover robotic technologies for inspection and repairs of only the ship's hull structure. Technology advancement in repairs and inspection of Engineering and Electrical components/ equipment is beyond the scope of this paper. Trials of Robotic Blasting machines and robotic trunking equipment have been carried out as part of the research. Trials of the 'HullSkater', the hull grooming equipment could not be undertaken due to the paucity of time and non-availability of OEM, M/s Jotun. Therefore, for the other robotic technologies, the paper relies majorly on the literature survey, primary data collected from repair yards and discussions with Industry and Subject Matter Experts.

METHODS FOR DATA COLLECTION

8. This research paper relies on published papers, results of trials undertaken at various Naval Repair Yards in India and communication with Industry representatives and Subject Matter Experts on robotic technologies available for implementation in ship repairs. Additionally, current policy guidelines promulgated by Naval Headquarters have been carefully examined, and feedback from subject matter experts in naval ship repairs and shipbuilding has been gathered in order to create a roadmap for the introduction of robotic technology in the Indian Navy for ship repairs. Technical specifications of equipment with costing have also been obtained from manufacturers and their cost-benefit analysis has been undertaken for the formulation of a roadmap toward implementation.

FINDINGS AND ANALYSIS

9. **Existing Philosophy of Ship Repairs and Refits**. Grooming of the underwater hull and the ship's structure involves washing, inspection and paint scheme restoration. Presently, ships are docked every 24 months on average for the underwater repair package based on the Ops-cum Refit Cycles (OCRC). Post docking, tanks, internal and external underwater compartments, and other underwater regions are inspected for corrosion and structural damage. Based on the assessment, structural repairs are undertaken.[5]

The preparation of the hull structure viz., washing, cleaning, gas-free certification of tanks, and chipping of interior compartments takes long durations of time and therefore, a large amount of time is wasted before the scope of work is finalised. In addition, personnel entering confined places need to adopt stringent safety procedures. In the manual procedure, the surveyor examines every crevice of the tanks/ holds and inaccessible areas and undertakes thickness gauging of suspected locations.[6]

NEW ROBOTIC TECHNOLOGIES AVAILABLE FOR SHIP REPAIRS.

10. **In water Survey**. SeaRobotics Corporation, USA has developed Semi-autonomous hull cleaning systems

The use of this technology which involves a small autonomous vehicle, weighing 30 to 40 kg, that attaches and cleans the hull, is expected to increase fuel efficiency by 5%, which will result in savings and decrease greenhouse gas emissions

that use grooming tools to remove biofouling and optimise vessel efficiency. A Hull Bio-inspired underwater grooming system named HullBug has been designed by the firm jointly with the Florida Institute of Technology's Melbourne centre for corrosion and biofouling reduction. The equipment is presently undergoing trials for US Navy Research Project at institute[7]. Examination of the trial reports reveals that the equipment is highly successful and is in the advanced stages of customisation. The HullBUG System is a robotic underwater vehicle designed to proactively groom the surface while crawling on ship hulls or other underwater structures. This highly automated cleaning procedure is expected to revolutionise hull maintenance by enabling ship hulls to remain in a clean state at all times. The use of this technology which involves a small autonomous vehicle, weighing 30 to 40 kg, that attaches and cleans the hull, is expected to increase fuel efficiency by 5%, which will result in savings and decrease greenhouse gas emissions.

M/s Jotun is one of the international paint manufacturers for the maritime industry and supplies paints to the Indian Navy as well. The firm has designed specialised robotic equipment named 'HullSkater' for proactive cleaning of the hull in afloat conditions. HullSkater is an innovative, game-changing tool for proactive hull cleaning and underwater inspections. **The equipment uses non-abrasive brushes to remove fouling without damaging the anti-fouling coating.** It has a portable unit station with a launch and recovery ramp and the need for divers is eliminated with this technique. With minimal trash or waste, the proactive cleaning strategy minimises performance loss and is both safe and environmentally friendly[8]. The system also has high-definition inspection capabilities through multiple cameras. Trials of the equipment have been scheduled at one of the Naval Repair Yards in end of 2022.

Table 1 Robotic Trunking Cleaning

	Parameter	Robotic Technology	Conventional Method
(a)	Rate of Cleaning for a spiral duct of 30 cm diameter	10 sqm/h	4 sqm/h
(b)	Set up Time	25 min	2 h

11. **Robotic Trunking Cleaning**. Ventilation trunking onboard ships are required to be cleaned periodically to remove dust, dirt, pollens, bacteria and other air contaminants. These contaminants are a potent source of respiratory diseases[9]. Traditionally, the trunking is removed, manually cleaned and fitted back. This process is tedious and highly laborious and time-consuming. Further, frequent removal and refitment cause air leakages which in turn lead to noise and reduction of the efficiency of the ventilation system. During the research study, rudimentary mechanised equipment with a camera and rotating brushes have been used on warships for cleaning ventilation trunking without removing them physically, with visual examination on an LED screen using the camera. This technique has been efficient wrt time and preparatory time. Further, the requirement of scaffolding in the compartments has also been obviated to a large extent. However, interaction with industry revealed that highly improved robotic equipment is available for cleaning of ventilation trunking. Trials of the above equipment were undertaken at Naval Ship Repair Yard (Karwar). Pictures depicting the robotic cleaning of the ducts and a comparison of performance vis-à-vis conventional methods are appended below: -

12. **Robotic Blasting**. Paints applied on the ship's underwater hull, above-water structures, decks etc have a specified service life and guarantee. On completion of the service life, the existing paint needs to be removed completely prior to the application of the new paint scheme. Further, the steel plate must have a good surface profile to guarantee strong adhesion to the fresh paint[10]. Conventionally, steel plates are blasted using an Ultra-High Pressure Hydro Jet (UHPHJ) at a pressure exceeding 30000 psi for removal of the existing paint scheme. The adhesion of the new paint scheme, and consequently the service life and performance, may not be optimal if a good quality surface profile is not attained. **Therefore, hydro jet blasting is utilised in non-essential regions whereas abrasive grit blasting is employed to create the high-quality surface profile on steel plates on the underwater hull and other vital areas.** Due to the manual nature of the aforementioned operations,

Table 2 - Robotic Blasting Performance Parameters

	Parameter	Robotic Technology	Conventional Method
Hydro-jet Blasting to achieve WJ 2 Standards			
(a)	Rate of Blasting	20 sqm/h	5 sqm/h
(b)	Set up Time	45 min	2 h
Abrasive Blasting to achieve SA2.5 Standards			
(c)	Rate of Blasting	40 sqm/h	15 sqm/h
(d)	Set up Time	45 min	2 h

> *During the research study, rudimentary mechanised equipment with a camera and rotating brushes have been used on warships for cleaning ventilation trunking without removing them physically, with visual examination on an LED screen using the camera*

scaffolding has to be set up and transported to different locations for quality inspection and rework. Therefore, the drawbacks of conventional procedures include their reliance on the weather, worker fatigue, safety concerns, the need for lengthy lead times for preparations, and sluggish operation due to human intervention. A summary of comparison of the performance of robotic blasting equipment vis-à-vis conventional blasting is appended below:-

13. **Robotic Tank Inspection**. Ballast water tanks onboard ships are either filled with seawater or are left empty during the operational period. Seawater is extremely corrosive and attacks steel. Therefore, regular inspection of these tanks is required to be undertaken. The present methodology is to wash, and clean the tanks and thereafter undertake visual inspection by a group of surveyors. Manual inspection runs the risk of injury through falls or of breathing in noxious gases. The autonomous RoboShip inspection robot precludes such risks. Additionally, using the robot increases inspection efficiency significantly. Inspectors assess the information displayed on a screen outside the ballast water tank, significantly cutting down on the time needed to examine a ship[11]. **Tank inspections can be performed while the ship is still in the drawdown phase, which significantly reduces the refit duration and aids in refit planning.** Any repairs required can then be planned before the ship is dry docked. It is envisaged that with further improvements, the robot will be able to work on the ballast water tank's surfaces using a laser. It will then be able to remove paint residues, for example, and it will also become possible to clean and coat the tanks.

COST-BENEFIT ANALYSIS

14. Based on studies and interactions with industries and trials undertaken, a cost-benefit analysis has been undertaken with respect to the above-mentioned robotic technologies. Details of the cost-benefit analysis are elaborated hereinafter. Trials of commercially available robotic hull cleaning have been commenced in the Indian Navy in 2021. Trials have been undertaken on a yard-craft and the technology has been extended to warships in 2022. Therefore, limited costing details are available and these initial costing may not be a clear indication of the benefits accrued. However, with respect to the benefits accrued, studies indicate that periodic hull cleaning can result in at least 5% savings in terms of savings on fuel consumption.

CONCLUSION AND RECOMMENDATIONS

15. The study has been undertaken based on the structure of the problem definition. From the study, it has been established that existing methodologies are outdated. Advanced robotic technology is available in industry for inspection, maintenance and repairs in the marine industry. The majority of these technologies are either in use by foreign navies or under advanced trials. The introduction of these technologies has resulted in enhanced efficiency and safety. Therefore, the following can be concluded:-

(a) Robots are the future of the world. Therefore, it is imperative to adopt robotic technology for the inspection of the ship's hull and repairs.

(b) Based on cost-benefit analysis, it can be inferred that on the plough back of the capital investment in a period of three years or so, robotic technologies are cheaper than conventional methods in the long run.

(c) The trials of Robotic technology in ship repairs have shown significant enhancement in efficiency and safety of personnel.

(d) It is prudent to note that the manpower required for the maintenance of upcoming platforms would not be made available due to limited vacancies and government sanctions. Therefore, the use of robotics to address the shortage of manpower is imperative.

> *Conventionally, steel plates are blasted using an Ultra-High Pressure Hydro Jet (UHPHJ) at a pressure exceeding 30000 psi for removal of the existing paint scheme. The adhesion of the new paint scheme, and consequently the service life and performance, may not be optimal if a good quality surface profile is not attained*

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> *For instance, in the manual method of hull survey and inspection, say five readings of plate thickness are taken and the state of the hull is estimated. However, in the case of robotic technology, 50 readings may be possible for the same size of the grid*

(e) The use of robotics in ship repairs can reduce downtime and refit durations, thereby increasing the operational availability of platforms, which is a strategic imperative for maintaining the minimum force levels of the country.

RECOMMENDATIONS AND WAY AHEAD

16. A plan for the implementation of robotic technology for ship repairs has been developed based on the research conducted, the constraints faced by repair yards, and the cost-benefit analysis. A roadmap for the implementation of robotic technologies for ship repairs is given below and the same has been elaborated thereafter.

17. **Cost Benefit Analysis**. Upon completion of FET, a comprehensive cost-benefit analysis needs to be undertaken. The analysis needs to meticulously weigh the advantages accrued in terms of time, the safety of personnel and other intangible benefits like the availability of platforms for operations. Field units also need to consider the fact that manpower augmentation will not be commensurate with the augmentation of force levels or the number of platforms planned in the near future. Therefore, migration to robotics and higher levels of automation is imperative.

18. **Policy Directives and Amendment to Standards.** The policies in vogue for inspection and maintenance are inclined towards the conventional manual methods. Therefore, Naval Headquarters needs to assess the need for amending regulations and standards to be followed with regard to robotic technology as the FETs are progressing at the field units. For instance, in the manual method of hull survey and inspection, say five readings of plate thickness are taken and the state of the hull is estimated. However, in the case of robotic technology, 50 readings may be possible for the same size of the grid. Detailed policy directives would also mitigate the limitation of the lowest pricing problem faced by the repair yards.

19. **Conclusion of Rate Contracts**. Considering the complexity of advanced equipment, requirement of spares and maintenance by OEM/ experts, it is prudent to operate rate contracts on the principle of provision of equipment and services till such time the in-house teams are totally competent to use the equipment to their full potential. This would solve the initial nags on the equipment which may otherwise hamper the smooth transition from manual methods to robotics. Similar recommendations have been forwarded post trials of robotic equipment based on trials and policy guidelines are underway.

20. **Equipment Procurement and Operations**. Once the technology is ripe and the working level is competent with the operation and maintenance of equipment, it would be considered prudent to undertake procurement of equipment for mass implementation.

[This Paper was presented in the WMTC 2024; 4-6 Dec 2024, Chennai]

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Understanding the Impact of Decarbonisation on Seafarers' Wellbeing: Findings of an ISWAN Survey[1]

Katie Earnshaw, Chirag Bahri

Decarbonisation is one of the key drivers of transformation in the maritime sector. There is widespread acknowledgement of the significant training challenges that the maritime sector faces to safely operate technologically complex low-carbon ships. There has, however, been little attention paid to the impact that the drive to decarbonise is having on seafarers' wellbeing. In order to shed light on this issue, in 2023, ISWAN carried out a survey of 400 seafarers to better understand how the rapid adoption of new technologies and regulatory regimes is affecting their wellbeing and job satisfaction. The findings indicate that, whilst many seafarers are broadly supportive of journey to zero carbon, the pressures of decarbonisation are having a negative impact on many in terms of workload, stress, fatigue, mental health and fear of criminalisation. The paper builds on the survey findings to provide recommendations for how maritime employers can better support the wellbeing of seafarers through the zero-carbon transition, including by proactively mitigating against the health and wellbeing impacts of technostress, enhancing psychological safety through inclusive leadership cultures and taking steps to improve job security.

Keywords: Communication; fatigue; just cultures; mental health; psychological safety; technostress.

INTRODUCTION

Decarbonisation is one of the key drivers of transformation in the maritime sector.[1] To address shipping's contribution to the climate emergency, maritime companies are mandated to take rapid steps to meet mandatory carbon emission regulations.[2] At an institutional level, there is widespread acknowledgement that seafarers are central to meeting the maritime sector's decarbonisation obligations. The stated aim of the Maritime Just Transition Task Force, established following the 2021 UN Climate Change Conference in Glasgow (COP26), is to ensure that shipping's response to the climate emergency puts seafarers at the heart

[1] ISWAN thanks The Shipowners' Club for its sponsorship of this project.

1 A report by DNV [1] provides in-depth analysis of the impact of the drive to decarbonisation on the sector.

2 A survey by the Global Centre for Maritime Decarbonisation (GCMD) and Boston Consulting Group (BCG) [2] demonstrates the wide spectrum of responses of shipowners and operators to the challenges of decarbonisation.

> *For many seafarers, the potential benefits of technological modernisation and environmental sustainability are countered by the impact of rapid change on their psychological wellbeing*

of the solution [3]. To date, however, the majority of discussions of what a "Just Transition" might look like in a maritime context focus on the pressing need to ensure that seafarers have the training and skills that they need to operate more complex technologies and handle potentially more hazardous alternative fuels.[3]

Comparatively little attention has been paid to the impact that the rapid pace of technological change is having on seafarers' wellbeing and job satisfaction. For this reason, between July and September 2023, ISWAN conducted a survey to ask seafarers about the impact that decarbonisation is having on their work. It is hoped that the insights will contribute to understanding what it will take to achieve the International Maritime Organization (IMO)'s goal to "ensure a just transition for seafarers and other maritime workforce that leaves no one behind" [4].

DEMOGRAPHICS

The survey received 400 valid responses from seafarers of 29 nationalities, with the majority from India (42.8% of responses) and the Philippines (15.6%). This reflects ISWAN's physical presence and extensive networks in these two major seafarer-supplying nations. Almost 90% of respondents were working in officer roles and 97% identified as men. The largest number of seafarer respondents were aged between 35 and 44 (34.3%), whilst just under 90% were aged between 25 and 54. The majority of respondents (83.4%) worked on oil

3 The Task Force's commissioned report on this issue [3], as well as [1] identify very substantial skills gaps that require rapid and significant investment in infrastructure.

Characteristic	% respondents
Country	
India	42.8%
Philippines	15.6%
Russia	7.7%
Egypt	5.1%
Croatia	3.6%
Bulgaria	3.6%
Georgia	3.3%
Ukraine	3.1%
Pakistan	2.1%
United Kingdom	1.3%
Poland	1.3%
Saudi Arabia	1.3%
Montenegro	1.3%
Bangladesh	1.0%
Latvia	1.0%
Other	5.9%
Age	
18-24	1.8%
25-34	32.8%
35-44	34.3%
45-54	21.8%
55-64	8.0%
65+	0.5%
Prefer not to say	0.8%
Gender identity	
Male	97.2%
Female	2.0%
Prefer not to say	0.5%
Non-binary	0.3%
Role	
Engineer/Chief/Second/ Third/Fourth/ Junior	42.5%
Master/Chief/Second/ Third/Fourth/ Junior	39.4%
Electrical officer	7.5%
Deck Rating - Bosun / AB / OS / Pumpman	2.0%
Deck cadet	1.8%
Engine room Rating	1.8%
Galley : Cook / steward / messman	1.8%
Prefer not to say	1.5%
TME / Engine cadet	0.3%
Other	1.5%
Vessel type	
Tanker – oil	37.9%
Tanker – chemical	25.3%
Cargo, including general and bulk carriers	20.2%
Tanker Gas/LPG/LNG	3.8%
Ferry/Ro-Ro ferry	3.0%
Container ship	2.0%
Prefer not to say	1.8%
Supply ship	0.8%
Cruise ship	0.8%
Tug	0.3%
Other	4.3%
Trading pattern	
Unfixed	54.8%
Fixed	25.1%
Partially fixed	20.1%

The ships are brand new, but nobody knows what they're dealing with. Even the manufacturers have themselves designed it for the first time. So, it's like a pilot project with testing being done on live sailing ships. The crew is having [an] extreme[ly] hard time with no shore assistance

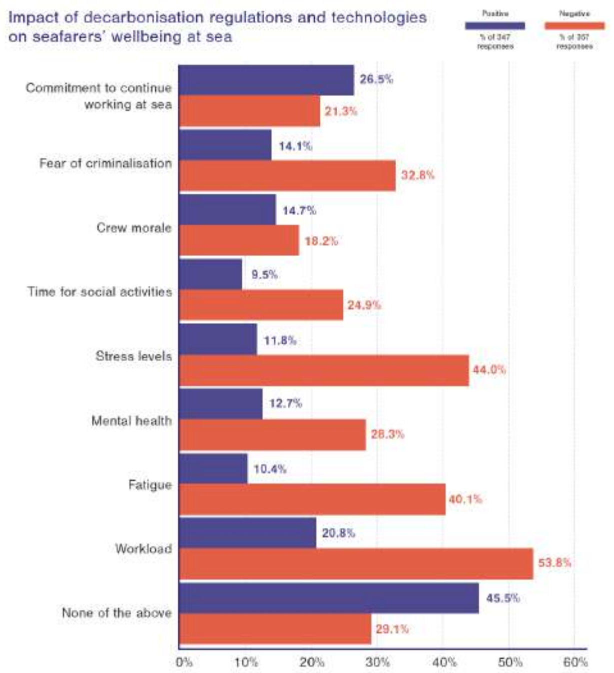
tankers (37.9%), chemical tankers (25.3%) or cargo ships, including general or bulk carriers (20.2%). Just over half (54.8%) worked on vessels without a fixed trading pattern.

SURVEY FINDINGS

The survey indicates significant support in principle from seafarers as regards the decarbonisation agenda. For some seafarers, concern about the climate emergency is part of their motivation to support the transition to zero carbon. For example, one seafarer commented that: "I get more motivated knowing that the reason for all these carbon regulations is for the planet".

The findings indicate that there is, however, considerable disquiet about the realities of seafaring during the transition to zero carbon. For many seafarers, the potential benefits of technological modernisation and environmental sustainability are countered by the impact of rapid change on their psychological wellbeing.

The most significant impact related to the increase in workload associated with adapting to new technologies and reporting requirements, with over half (53.8%) of respondents stating that the impact on their workload had been negative.[4] For 44.0% of respondents, this was associated with increased stress, whilst 40.1% reported increased fatigue. A quarter (24.9%) of respondents felt that the additional pressures of decarbonisation were negatively impacting on the time available for social activities,[5] whilst just under a fifth (18.2%) believed that the impact on crew morale was detrimental. Just under 30% of survey respondents (28.3%) felt that change associated with decarbonisation was negatively affecting their mental health. Almost half (45.5%) of respondents reported that the introduction of decarbonisation regulations and technologies had not had a positive impact on any of the wellbeing areas included in the survey.



In free text comments, some respondents emphasised that the complexity of the regulatory environment is having the greatest impact on stress levels and workloads, as this requires constant adaptation to meet reporting requirements in different parts of the world. Frequently, this additional work is not reflected in crew size. For example, one seafarer stated that: "A lot of complicated rules and regulations set by the shipping committee resulting [in] an extra load, thus extra stress and fatigue to the crew onboard."

Some respondents raised concerns that excessive workloads are compromising safety at sea, with one stating that: "extra paper work and adherence to varying rules leads to fatigue and increases [the] probability of accidents and poor health due to fatigue." Another expressed concerns that the safety and wellbeing of seafarers is being overlooked in the rush to adopt new technologies that may not, in the seafarers' view, have been sufficiently tested: "The ships are brand new, but nobody knows what they're dealing with. Even the manufacturers have themselves designed it for the first time. So, it's like a pilot project with testing being done on live sailing ships. The crew is having [an] extreme[ly] hard time with no shore assistance."

The survey indicates that the complexity of the regulatory environment is also substantially increasing fears of being criminalised as a result of administrative errors or inadvertently contravening one of the overlapping environmental regimes. Almost a third of respondents (32.8%) reported increased fears of criminalisation, with one seafarer commenting that: "One is always scared of getting into trouble with the authorities or company due to an oversight or mistake by self or staff. This is mainly due to varying rules and

4 Based on feedback from seafarers during the testing phase of the survey, respondents were asked about broadly positive or negative impacts, rather than using a five-point scale, due to limitations in using matrix question layouts on mobile phone technology.

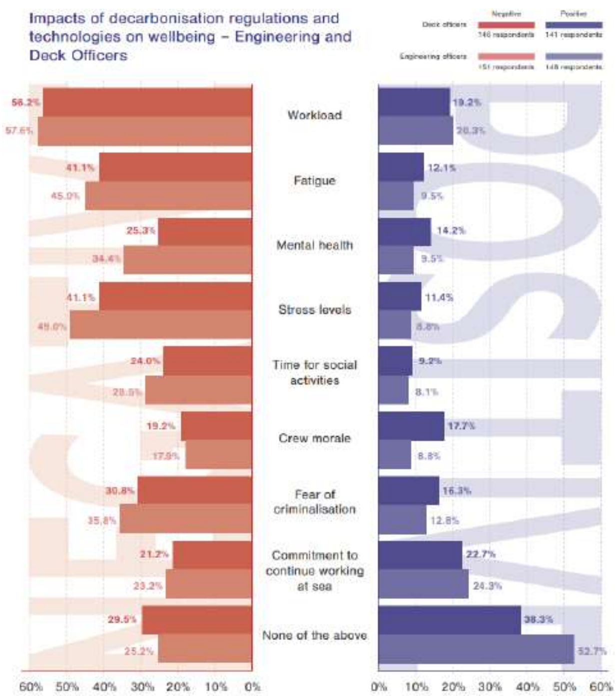
5 ISWAN's Social Interaction Matters (SIM) project [5] explores the crucial importance to seafarers' health and wellbeing of having quality social interaction and rest time.

The only area of wellbeing in which respondents deemed the positive impacts of decarbonisation to outweigh the negative related to their commitment to continue working at sea

limits in different parts of the world. Also interpretations are also different in different countries and the seafarer is always wrong!"

The only area of wellbeing in which respondents deemed the positive impacts of decarbonisation to outweigh the negative related to their commitment to continue working at sea. Just over a quarter (26.5%) responded that decarbonisation was having a positive impact on their commitment to remaining in the maritime sector, whilst for just over a fifth (21.3%) the impact was negative. Again, this could reflect the two sides of seafarers' experiences of the journey to zero carbon: many find it motivating to be part of finding solutions to the climate emergency; however, for a significant minority, the day-to-day impact on their workload and stress levels are so substantial that they are undermining their commitment to working at sea.

There was substantial variation between deck officers and engineering officers in terms of the impact of the decarbonisation transition on their wellbeing. A greater proportion of engineering officers, who are tasked with the complexities of adopting multiple fuels, evaluated the impact on their wellbeing as negative across all wellbeing



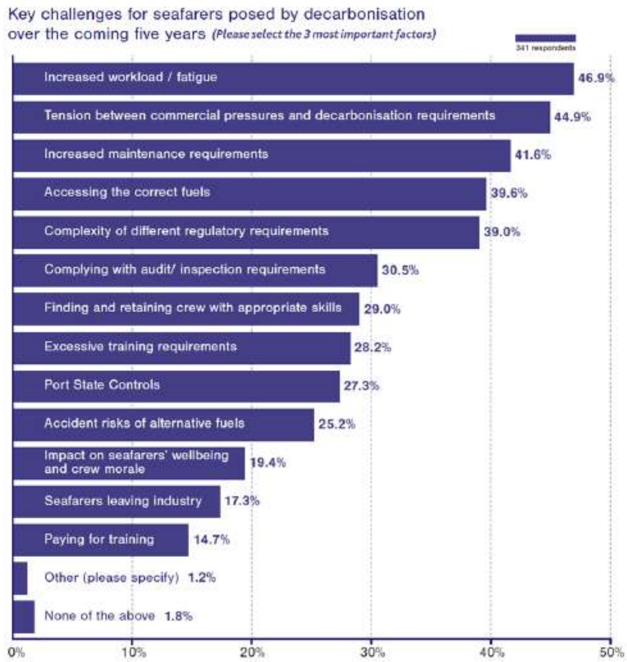
categories, with the exception of crew morale. **Indeed, over half of engineers (52.7%) responded that there had not been a positive impact on any of the wellbeing areas surveyed, in comparison with 38.3% of deck officers.** The differential was most striking in terms of impacts on mental health, with 34.4% of engineers stating that decarbonisation was having a negative impact on their mental health, in comparison with 25.3% of deck officers.

Amongst engineers with no fixed trading pattern, the impact appears to be even more stark: 59.2% reported a negative impact on their workload, whilst 52.4% reported increased stress levels. Just over 40% (40.5%) reported increased concerns about criminalisation.

Engineers who took part in the survey commented on the strain that the requirement to undertake additional tasks with the same, or fewer, crew was placing on their health and wellbeing. One stated that: "[The] negative effects are both physical and mental. Understanding the scope of change was a challenge because shore staff were also not clear how the change was going to take shape. Then cleaning and preparing the bunker tanks were a physical challenge. Use of different fuels required a lot of training and understanding. Maintaining machinery has added burden to already stressed crew. [The] final blow is ongoing with compliance checks from Port and Flag states plus third-parties."

FUTURE IMPACTS OF DECARBONISATION ON SEAFARERS' WELLBEING

Survey respondents were asked to select the top three challenges that decarbonisation was likely to pose for



> ***The differential was most striking in terms of impacts on mental health, with 34.4% of engineers stating that decarbonisation was having a negative impact on their mental health, in comparison with 25.3% of deck officers***

their work over the coming five years. Increased workload and fatigue was viewed as the most significant challenge, selected by almost half (46.9%) of seafarer respondents. The practical and technical challenges of the journey to zero carbon were also apparent, with substantial numbers highlighting the tensions between commercial pressures and regulatory requirements (44.9%), increased maintenance requirements (41.6%), difficulties accessing the correct fuels (39.6%) and the complexity of regulatory requirements (39.0%) as key concerns.

Survey respondents were asked to share their views about the most important steps that maritime employers could take to support them through the zero-carbon transition. Over half of respondents (53.4%) selected improving technologies, systems and processes key, potentially indicating a current lack of coordination, consistency and joined-up planning in the rush to meet new regulatory requirements. For over a third of seafarers (37.7%), strengthening focus on a "no blame" culture was deemed a top priority, reflecting the increased anxieties that the decarbonisation transition has brought as regards making mistakes and potential criminalisation.

In free text comments, several seafarers expressed the opinion that ensuring appropriate crewing levels to meet the challenges of zero carbon should be a priority for maritime employers. A number of seafarer respondents also reflected on the importance of ensuring that seafarers' contributions to implementing rapid technological change are appropriately valorised.

Some commented that salaries should be increased to reflect the additional pressures and responsibilities that seafarers are being asked to assume. For example, one stated that there are: "so many new things to implement, but wages and care from company is still the same. Why would the crew sacrifice their mental peace for someone else's experiments? Either increase remuneration or increase manpower."

Other seafarers stressed the need for effective information flows to help to ease information overload and to make transitions between different regulatory requirements as smooth as possible. One seafarer called for companies to: "prepare your ships well in advance and don't burden [seafarers] with information and queries at the last minute."

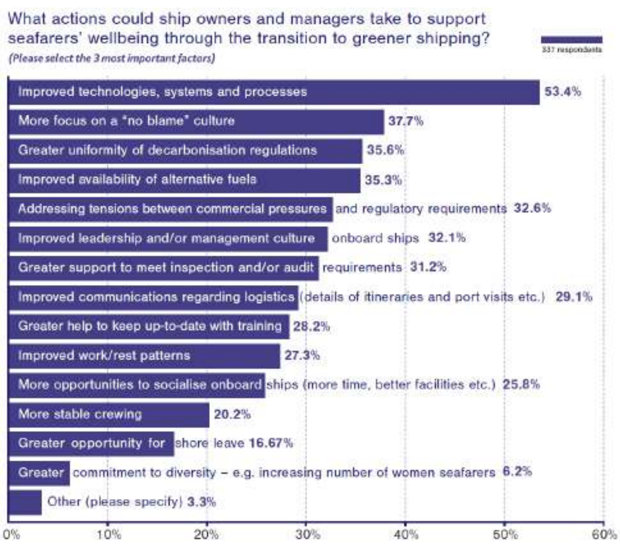
CONCLUSION AND RECOMMENDATIONS

ISWAN's survey suggests that many seafarers understand and support the urgent need to decarbonise shipping. However, the findings also suggest that the potential for the rapid adoption of new technologies and regulations to have a detrimental impact on those tasked with implementing them is currently being overlooked. As one seafarer commented: "I am a big supporter of decarbonisation and taking steps to reduce our negative impact on the planet and our surroundings. I just wish it was done in a much better way."

The survey points to a number of concrete steps that maritime employers can take to better support seafarers through the zero-carbon transition.

A proactive approach to seafarer welfare:

- Acknowledge and address the **impact on workloads, particularly amongst engineers**, and proactively factor in the impact of decarbonisation into crew sizes.
- Recognise the psychological impacts of **rapid change and technostress** and include these in stress management and mental health trainings.
- Consider both **physical and psychological safety**. Seafarers must feel confident that the technology that they are being asked to adopt is safe; that they and their colleagues have appropriate training and support to implement it; and that they can speak out about any concerns without fear of recrimination.
- Commit to **inclusive, supportive leadership cultures**. The challenges of rapid adaptation to change should be proactively built into the development of good practice as regards leadership at sea.
- Improve terms and conditions. Many seafarers feel that the additional effort that the zero-carbon



> *so many new things to implement, but wages and care from company is still the same. Why would the crew sacrifice their mental peace for someone else's experiments? Either increase remuneration or increase manpower*

transformation demands of them is not appropriately remunerated. The short-term nature of many maritime contracts can also act as a disincentive for employers to invest in providing seafarers with the training that they need to carry out increasingly complex and technical work.

A human-centred approach to systems and processes:

- Protect against technostress in system design. Attention should be given to ensuring that new technologies, systems and processes function in cohesive, joined-up and accessible ways in order to reduce duplication and mitigate against the negative impacts of technostress.
- Employers should also proactively seek input from those tasked with implementing new technologies to better understand the impacts on their work and wellbeing.
- Build strong communication channels. Ensuring that seafarers understand the rationale for new technologies and reporting requirements will help to ensure that they feel fully engaged in the decarbonisation journey. It is, furthermore, important to ensure that engineering and deck officers understand the differing impacts of decarbonisation on their work, to build a culture of safe and effective team work and shared responsibility.
- Investigate benefits of fixed trading patterns. ISWAN's survey findings indicate that adopting fixed trading patterns may help to mitigate against the negative effects of decarbonisation on wellbeing. As the adoption of alternative fuels accelerates, maritime employers should factor in potential impacts on seafarer wellbeing when making decisions about trading patterns.
- Consider crewing models that best meet the challenges of decarbonisation. The proliferation of new technologies can lead to a steeper learning curve for seafarers joining a new ship. Additional research should be carried out into the crewing models that will best support seafarers through the zero-carbon transition.

Just and coherent regulatory regimes:

- Harmonise reporting regimes and requirements. ISWAN fully supports the commitment on behalf of individual ports, nations or regions to go beyond the requirements of international legislation in tackling carbon emissions. However, regulatory and reporting requirements should be simplified and harmonised to limit the bureaucratic and administrative burden this poses.
- Proactively build collaborative, just cultures. Despite considerable support for decarbonisation, it has heightened fear about inadvertent errors and criminalisation. Particularly in light of the current complexity of reporting regimes, it is vital to build a culture that supports joined-up, collaborative action to achieve zero-carbon goals.

Above all, ISWAN's survey points to the need to valorise seafarers as crucial partners in the decarbonisation journey. Many working in the maritime industry understand only too well the vital importance of taking rapid action to address the climate emergency and are strongly motivated to play their part. The industry can benefit from their expertise and continue to build a sense of partnership by proactively consulting seafarers in decision-making about the development and implementation of new technologies. ISWAN's helpline data and insights from our projects tell us that too often seafarers feel overlooked and under-valued. Having their concerns about decarbonisation acknowledged and acting on their suggestions for change would be an important step in empowering seafarers to be proponents and drivers of the journey towards zero carbon, rather than becoming another factor that risks driving many out of the industry.

[This Paper was presented in the WMTC 2024; 4-6 Dec 2024, Chennai]

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Technologies Enabling Polar Under-Ice Investigations (Part A)

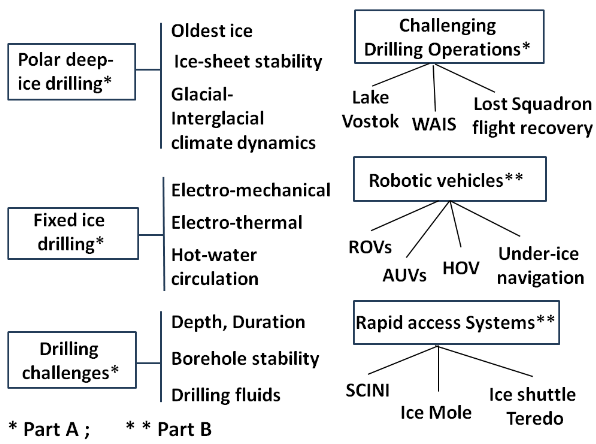
N.Vedachalam

Abstract

The accelerating pace of current climate change creates urgency to understand the behaviour of abrupt changes in the past as a guide to future changes, and also the need to predict rates of mean sea level rise. Glaciers, ice-sheets, and subglacial environments directly record, in layers, components of past atmospheres ranging from a single storm event to states of the Earth's climate system. Understanding glacial dynamics, stability of ice sheets and ice sheet response to climate change are imperative for predicting rapid sea level rise. The under-explored cryosphere realm is the only established archive that preserves the unique evolution and interaction of atmosphere, biosphere and geosphere for millions of years. For all of these areas of science, extracting this evidence involves deep-drilling and coring into and through glaciers and the Polar ice sheets, a specialised and challenging endeavour that requires innovative technology. Part-A presents the progress in Antarctic research, ice-drilling challenges and fixed drill systems for under-ice sampling based on rotary, thermal and hybrid technologies. Part-B shall describe robotic-based systems and upcoming unconventional drilling systems.

Introduction

Interactions between the global oceans, cryosphere and atmosphere influence the climate, biogeochemical cycles and biological productivity on global scales. Scientific investigations in the Polar Regions (including glaciers and ice sheets covering ~16 million km^2 or ~11% of the entire global area) provide valuable insights. These include functioning of the Earth's regulating systems and help in enacting strategic environmental policies for conserving the planet life and ecology.



> *Scientific investigations in the Polar Regions (including glaciers and ice sheets covering ~16 million km2 or ~11% of the entire global area) provide valuable insights*

Polar oceans are amongst the most rapidly changing oceans of the world, with consequences for global-scale storage and cycling of heat, carbon and other climatically- and ecologically-important properties.

Detailed studies of ice mass loss in Antarctica demonstrate that, while the East Antarctica ice sheet has a nearly constant mass, the rate of ice mass loss in West Antarctica has tripled. This is a matter of concern for estimating global environmental consequences, including changes in the global mean sea level (GMSL) and ocean salinity. During the past decade, Greenland Ice Sheet (GIS), Antarctica Ice Sheet (AIS) and remaining global glaciers lost ice mass at an average rate of ~280, ~160 and 220Gt/year, respectively. They contributed to GMSL rise of 0.77, 0.43 and 0.6 mm/yr., respectively. The rate of GMSL rise during 2006–15 was 3.6 mm/yr., which is ~2.5 times the rate during 1901–1990.

The alarming increase in the GMSL, collapse of the West Antarctic Ice Sheet (WAIS/primarily by increased melting of the underside of floating ice shelves due to interactions with the Southern Ocean which is responsible for ~50% of the global ocean heat increase during 2005-17), identification of microbial life in the subglacial lake Whillans in the Western Antarctica are some of the most dramatic examples of recent changes that have captured the scientific attention, and have triggered pioneering research needs in the areas of biology, geology, geophysics, atmospheric science, oceanography, sea ice, anthropogenic impacts, climate variations and glaciology.

Progress in Antarctic Research

Drilling and ice-coring operations in the Polar Regions are complicated by extremely low temperatures at the surface and inside the ice sheet, glacier flow, the absence of roads and infrastructure, storms, wind, snowfall, other natural obstacles and logistical factors. Hence, deep-ice drilling in such harsh and remote Polar environment is a challenging process that demands special purpose-built reliable ice-drilling/coring technologies, strong international cooperation, extended planning horizons, sizable budgets and long-term investment.

In 1958, through an international initiative involving scientists and policymakers, the Scientific Committee on Antarctic Research (SCAR) was formed. The SCAR that comprised of 44 member countries and 9 international unions prioritised major research themes (~80 scientific questions) and strategies for Antarctic research.

A network of stations, field camps, laboratory facilities, ships, airplanes, observing networks, and other support infrastructure has been developed over the years in both the Arctic and the Antarctic. **Figure.1** shows the countries involved in Polar research, research stations in Antarctica, except the Antarctic Peninsula (red squares represent summer-only stations).

Antarctica is thus a home to ~4000 people in the summer & ~1000 in the winter. The inhabitants settled on the continent's multiple research stations and tourist camps, are regularly supplied by chartered cargo jets. Significant Antarctic developments include landing of the first US aircraft R4D-5 Sky-train in the South Pole in 1956 **(Figure.2a),** Airbus A340 that landed in 2021 **(Figure.2b),** US research station in Amundsen-Scott built in 1956 **(Figure.2c)** and the new Indian research base Bharati built in 2012 **(Figure.2d).**

In addition to Polar region, active research is also underway in high altitude mountains such as Everest, Dasuopu, Dunde, Elbrus, Mont Blanc, Fiescherhorn, Coropuna, Sajama, Logan, Bona-Churchilll, Kilimanjaro, Ushkovishi and Puncak Jaya.

Hitherto, the research conducted in the Polar regions include analysing the past climate changes in deep-ice

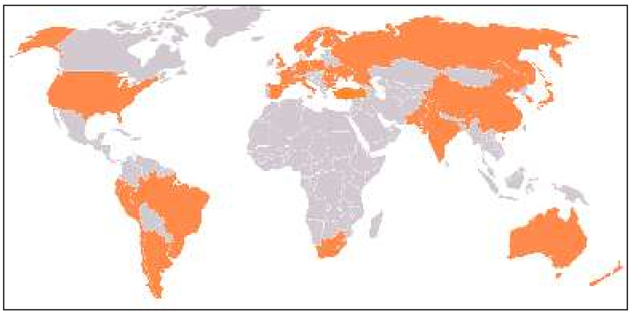


Figure.1. Countries involved & research stations in Antarctica

Figure.2. Significant Antarctic developments

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Paleoclimatologists seeking information about the past climate use proxy data gleaned from natural resources such as Polar ice cores, ocean bottom sediment and tree rings

cores and sedimentary sequences, role of sub-glacial environment in controlling ice-sheet dynamics and its contribution to sea level rise, role of the Southern Ocean in driving the deep-ocean conveyer belt, methane release to the atmosphere due to melting permafrost, global transport of pollution and contamination to the Polar regions and consequent impacts on biodiversity and changing eco-system patterns, molecular and genetic mechanisms of living systems that are coping with freezing conditions, presence and cause of the Ozone hole, the slowest spreading centre on the thinnest ocean crust on Earth and meteorological observations. The importance of ice-related research in the Polar Regions is summarised in **Figure.3.** They include Ice sheet stability, Oldest Ice (that provides novel records of past atmospheric greenhouse gases, the Mid-Pleistocene transition when glacial-interglacial cycles of 40 kyr duration shifted to 100 kyr cycles, and climate sensitivity under differing boundary conditions) and Glacial-Interglacial Climate Dynamics.

Fixed Ice-drilling/Coring Systems

Paleoclimatologists seeking information about the past climate use proxy data gleaned from natural resources such as Polar ice cores, ocean bottom sediment and tree rings. From the isotopic and chemical composition of ice and dust in Polar ice cores, scientists estimate the past regional average air temperatures, variations in atmospheric circulation, precipitation, atmospheric composition, solar activity, volcanic eruptions and changes in the global biotic and abiotic patterns. Although the practices involved in drilling and coring ice may be comparable to those used in offshore hydrocarbon field operations, the rock and ice in-place behave differently. **Unlike rock, as ice is plastic, it flows downward and outward (blue arrows) from the summit of the dome.** Therefore, ice cores taken from the summit of the dome (horizontal black lines) retain true depth-age correlation. The black lines represent layers that become thinner with depth as they are compressed by increasing overburden **(Figure.4).**

In 1841, Louis Agassiz, one of the creators of glacial theory, made his first attempt to drill into the bed of Unteraargletscher glacier, Swiss Alps. With the progressing drilling technologies, through various

<u>Oldest Ice</u>
Records of past atmospheric greenhouse gases

<u>Ice sheet stability</u>
- Timing
- Speed
- Magnitude of ice loss
- Forcing mechanisms

<u>Glacial-Interglacial Climate Dynamics</u>
- **Mechanisms driving glacial interglacial cycles**
- **Abrupt climate change**
- **Forcing mechanisms**
- **Dynamics of global climate system**

Figure.3. Major areas of deep ice-drilling research

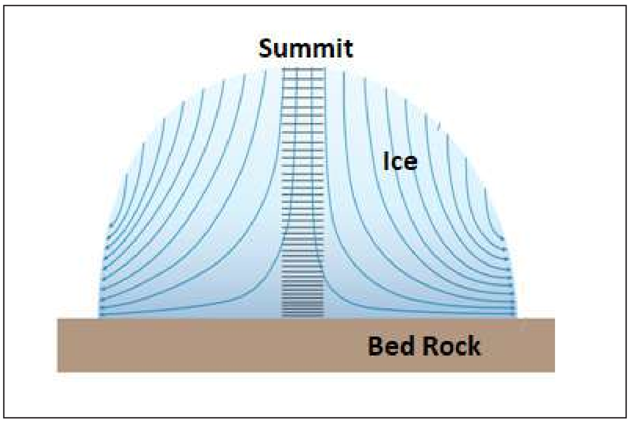

Figure.4. Accumulation pattern of ice in Polar environment

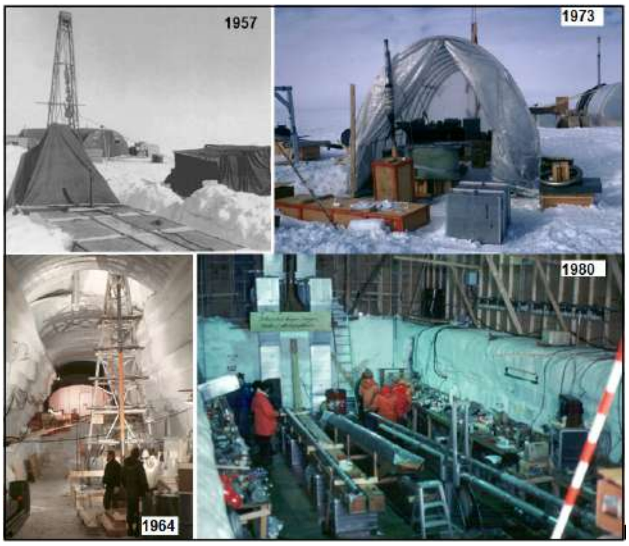

Figure.5. Polar ice drilling/ coring expeditions since 1957

There are multiple technological challenges in deep-drilling for ice core sampling, including drill head design, BH stability and use of proper drilling fluids

challenging expeditions **(Figure.5)** deep-ice cores were collected from Antarctica (including Dronning Maud Land, Vostok, Law Dome, Taylor Dome, Dome C, Dome F, Talos Dome, Byrd Station, Siple Dome, WAIS Divide, Roosevelt Island, Berkner Island and Fletcher Promontory). The oldest continuous ice core records to date extend 123,000 years in Greenland and 800,000 years (3km deep cores) in the Antarctic. These deep-ice cores allow us to generate continuous reconstructions of past climate, going back at least 800,000 years, providing information on glacial-interglacial cycles, changing atmospheric CO_2, methane and nitrous oxide concentrations, as well as climate stability.

India's Ministry of Earth Sciences- National Centre for Polar and Ocean Research (MoES-NCPOR) in association with Research Council of Norway undertook geophysical measurements and ice core studies as a part of Mass balance, Dynamics, and the Climate of the Central Dronning Maud land coast, East Antarctica (MADICE), in which drilling was done at the summit of Djuprenen and Leningradkollen ice rises. About 122m ice core was recovered in 2016-17, and 153m during 2017-18 using two types of electro-mechanical drills **(Figure.6).**

Figure.6. Ice-drilling by Indian scientists in summit of Djuprenen and Leningradkollen ice rises

Depending on the nature of ice disintegration at the bottom of a bore hole (BH), deep-ice drilling methods can be classified into mechanical and thermal types **(Figure. 7). Mechanical drilling** tools use percussion or rotary fracturing of ice, but most commonly use cutting. **Thermal drills** use electric heaters, hot water, steam or high-temperature gases for ice melting. Thermal drills are simpler and more attractive than mechanical drills because they do not rotate and, therefore, do not require driving down-hole or surface units, anti-torque systems and slip rings.

However, the specific energy required for electro-thermal drilling in ice (590–680 MJ/m^3) is much higher than the energy required for mechanical systems (1.9–4.8 MJ/m^3). From the schematics of fixed deep ice-drilling systems shown in **Figure.7,** on the left is the electro-thermal and electro-mechanical drills suspended on cables have similar surface equipment such as mast, winch, and control system, but their operational principles are different.

Electro-mechanical rotary drills

Drilling speed is one of the important factors in deep-ice drilling systems. The gravity-aided lowering speed of the drill in a BH depends on a number of factors which described in the below equation, in which g is the acceleration due to gravity, BH diameter (m), μ is the

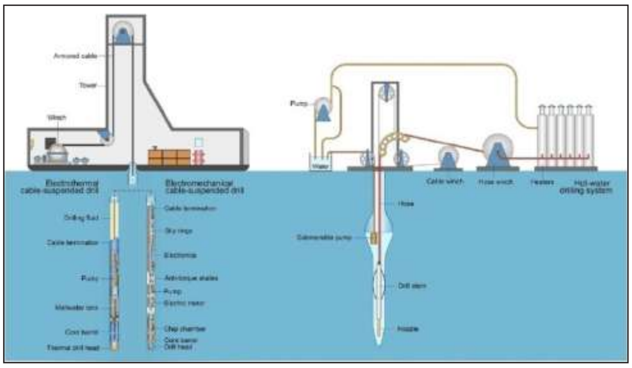

Figure.7. Mechanical, electro-thermal & hot water drilling system

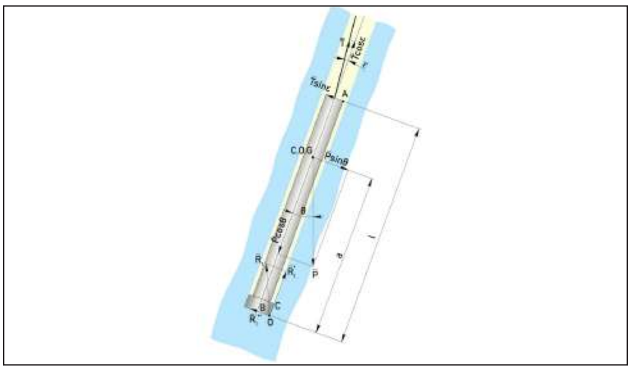

Figure.8. Diagram of forces acting on the drill inside a slant hole

dynamic viscosity of BH fluid, (kg/m/s), Dd is the drill outer diameter (m), md is the drill mass in kg, L is drill length in m, β is the density of the BH fluid, Dcb is the inner diameter of the core barrel and rc = D cb/D.

$$V_{tc} = \frac{gD^2}{4\mu L}\left[(1 + r_a^2)\ln\frac{1}{r_a} - (1 - r_a^2)^2\right]\left(\frac{4m_d}{\pi D_d^2} - \rho f l^L\right)$$

When BH are drilled in ice, the cable-suspended drill tends to deviate from the vertical if the cutter head is in constant contact with the BH bottom. For this reason, almost every BH drilled in ice sheets has an inclination of >1º. **Figure.8** shows a diagram of forces acting on the drill inside a slant BH, in which, P is the weight of the drill applied to the centre of gravity; T is the tension of the carrying cable; l is drill length; θ is borehole inclination angle; ε is the angle between the BH axis and cable; R″ 1 is BH bottom response; R′ 1 is BH wall response; R1 is the total overall response; a is the distance from the bottom of the cutter head to the centre of gravity; A, B and C – characteristic points of the drill used in calculations; and O is the centre of drill rotation.

Electro-thermal drills

The first thermal corer was developed in the Meteorological and Geophysical Institute of University of Vienna, Austria at the beginning of the 1950s to obtain ice samples from the surface of glaciers. This was a portable rim-heated device enabling the extraction of cores 80 mm in diameter and up to 20 cm in length. **Electro-thermal drills are more advantageous than electro-mechanical drills in temperate, near-temperate, and polythermal glaciers because they can avoid problems arising from refreezing of wet chips, which causes drills to become stuck in the BH.** When the refreezing rate of melt water in BH is expected to be too high and there is no considerable englacial water flow, thermal drills with meltwater removal system are optional for open-hole shallow (200–300 m) ice-coring. To reach a sufficiently high rate of penetration of approximately 6–7 m/h, the power density of thermal head should be maintained in the range of 100–110 W/cm^2, which can be provided by tubular elements cast integrally with an aluminium or copper annulus. Thermal coring drills without a meltwater removal system have simplest configuration. They contain an annular thermal head, core barrel with core catchers **(Figure.13)** at the lower end and a cable termination.

The refreezing of melt water in BH drilled in temperate glaciers is relatively slow. The produced BH is a few millimetres larger than the drill head, which provides a slight leeway for meltwater refreezing. A difference of ~5 mm between the thermal head diameter and BH diameter is a good design guideline to achieve a useful, efficiently drilled BH in temperate glaciers of smooth and constant cross-section with minimum risk. The main element of

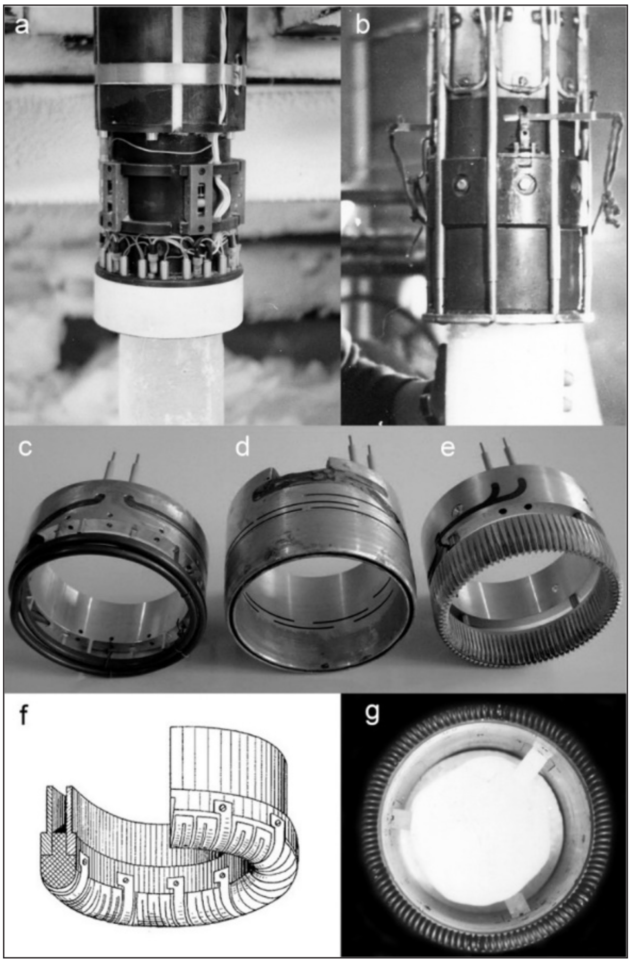

Figure.9. Electro-thermal drill heads in operation

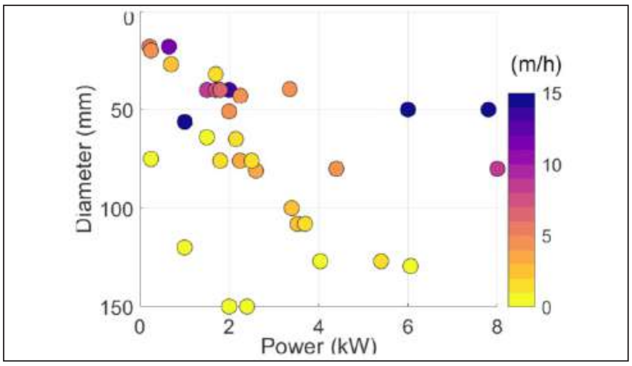

Figure.10. Technological maturity of electro-thermal drills

Figure.11. Hot water drilling systems

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thermal core drills facilitating penetration into ice is the electrically heated annular head. The rate of penetration depends on multiple variables including input power, cross-sectional area of the thermal head, temperature of the drilled ice, axial load, and design features such as the material and shape of the head and properties of thermal element. Different designs of thermal heads are in use including drill head of CRREL thermal drill with 18 cartridge heaters rated 3.5–4 kW **(Figure.9a),** drill head of TELGA-14M thermal drill consisting of a copper body, which has a 1.1-mm-diameter nichrome wire element insulated with ceramic beads **(Figure.9b);** 9c, d and e are three designs of the thermal head of Ice-drill. The technological maturity of the electro-thermal drills (BH diameter which they make, power and drilling speed) are plotted in **Figure.10.**

Hot water drills

Hot-water drilling systems **(Figure.6, right)** have faster ice penetration rates ranging 120–200m/h, which are orders of magnitude faster than those of electro-thermal and mechanical/rotary drills. They are used to produce only access BH for sub-glacial exploration and other scientific experiments. During the initial stage of drilling operations, several m^3 of water must be prepared to enable drilling. The method has the risk of losing the drill in the BH because of refreezing, which demands periodic reaming by hot-water spraying. Advanced hot-water ice-drilling operations are shown in **Figure.11,** in which (a) shows aerial view of the AMANDA drilling site in South Pole during 1993–1994 season (b) shows the Ice Cube down hole assembly retrieving from the hole at the South Pole and (c) lowering of the submersible pump into return hole at Sub-glacial Lake Ellsworth site during 2012–2013 season and (d) shows the BEAMISH hot-water drilling setup on Rutford Ice Stream during 2019.

The technological maturity of the electro-mechanical, electro-thermal and hot-water based ice-drilling systems over time can be understood from their performances in various deep-ice drill sites **(Table.1).**

As typical examples, an electro-thermal drill with a 7.5kW drill head power and 22m length was used at drill site Adelie Land to acquire 8m long ice cores. A 2.2 kW rotary drill used in Taylor dome had a penetration speed of 60m/h up to 1000m; and the one used in WAIS divide had a drilling speed of 28 m/h up to 3400m for which using 2 kW motor was used. In hot-water drilling at the Ice-cube Neutrino Observatory in South Pole, ~760 LPM of hot water was used to make a 600mm bore diameter at a speed of 90m/h.

Key challenges in deep-ice drilling

There are multiple technological challenges in deep-drilling for ice core sampling, including drill head design, BH stability and use of proper drilling fluids. For drilling

Table.1. Technological trends in deep-ice drilling systems

Location	Depth	Period
Mechanical drills		
Talos Dome	1620m	2003-2008
South Pole	1751m	2014-2016
Byrd	2193m	1966-1968
Kohnen	2774m	2002-2006
Dome F	3035m	2003-2007
Dome C	3270m	1999-2004
Wais Divide	3405m	2006-2011
Vostok 5G	3769m	1994-1998; 2005-2012
Electro-thermal drills		
Vostok 3G	2201m	1980-1985
Vostok 4G	2546m	1983-1989
Vostok 5G	2755m	1990-1993
Hot-water drilling systems		
Rulford Ice Stream	2154	2004-2005;2018-2019
South Pole (AMANDA)	2400	1993-2000
South Pole (Ice Cube)	2500	2004-2011

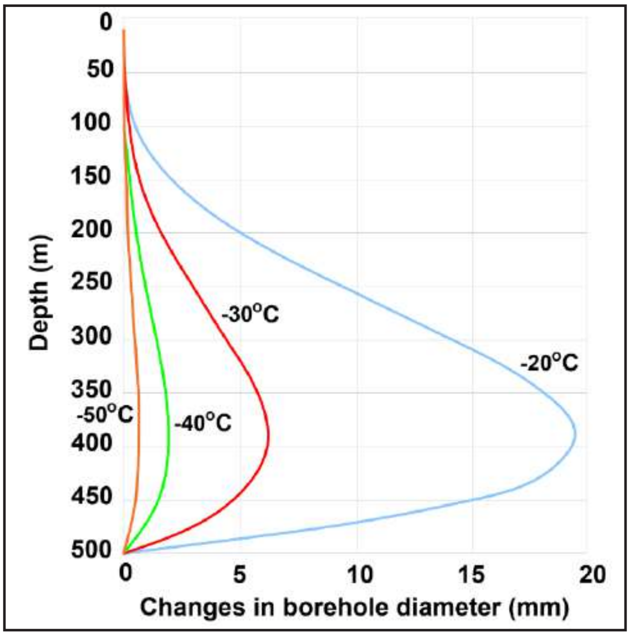

Figure.12. Anticipated diameter changes of dry BH Vs depth

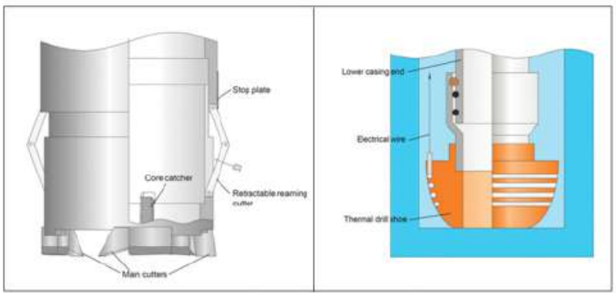

Figure.13. Subcomponents of rotary & thermal ice corers

up to 300m, dry-drilling is the preferred option. When drilling >300m, drilling fluids are used to maintain the stability of the BH and to transport cuttings (or melted water) from the bottom to the down hole chamber or to the surface (wet-drilling). A dry BH will close because the ice pressure is not compensated by the pressure inside the BH. **Figure.12** shows the BH closure prediction for four ice-temperature options at 10m depth: –20, –30, –40 and –50°C. The BH with a near-surface temperature of –20°C closes very fast, at a rate of 7 mm/day at the bottom of a 500m deep BH. The critical depth is 90–110m above the target depth, where the BH diameter changes to the maximum extent.

To optimise the BH enlargement while drilling, the drill head contains reaming cutters **(Figure.13)** that are able to be withdrawn into the drill head body during tripping operations. Reaming cutters are opened when the drill head stands on the BH bottom, and ream the hole jointly with the main cutters. Adjustable stop blades limit the offset of reaming cutters and specify the reaming diameter. All cuttings are picked up by the near-bottom air reverse circulation and collected in the inner chamber. The important part of BH planning is the selection of the casing. The BH-liner is used to isolate the permeable near-surface snow–firn formation, the thickness of which depends on the accumulation rate and the temperature conditions prevailing at the drilling site**. It is recognised that firn becomes impermeable ice when its density reaches 830 kg/m³.** In different regions of inland Antarctica and Greenland, the depth of the firn–ice transition varies in the range 64–115m.

The first drilling in ice with a fluid-filled BH was carried out by the US Army Cold Regions Research and Engineering Laboratory (CRREL) at Camp Century, Greenland, in 1966. The method was subsequently used at Byrd Station, West Antarctica, in 1967/68. The lower part of the boreholes was filled with aqueous ethylene glycol solution, and the upper part was filled with a mixture of diesel fuel (arctic blend DF-A) with trichlorethylene as a density-increasing additive (‘densifier’).

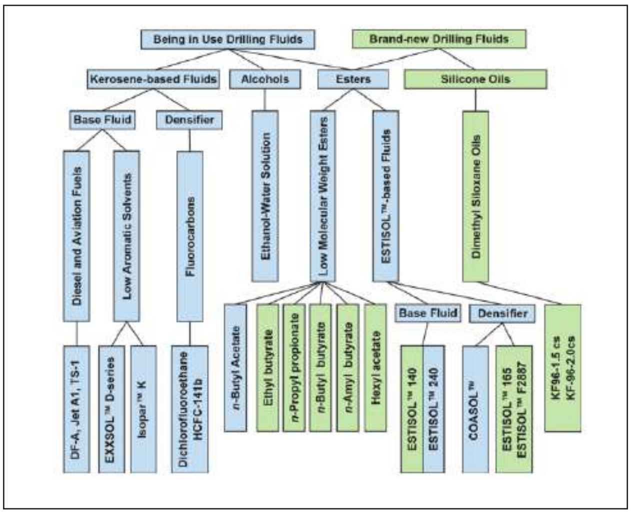

Figure.14. Classification of low-temperature drilling fluids

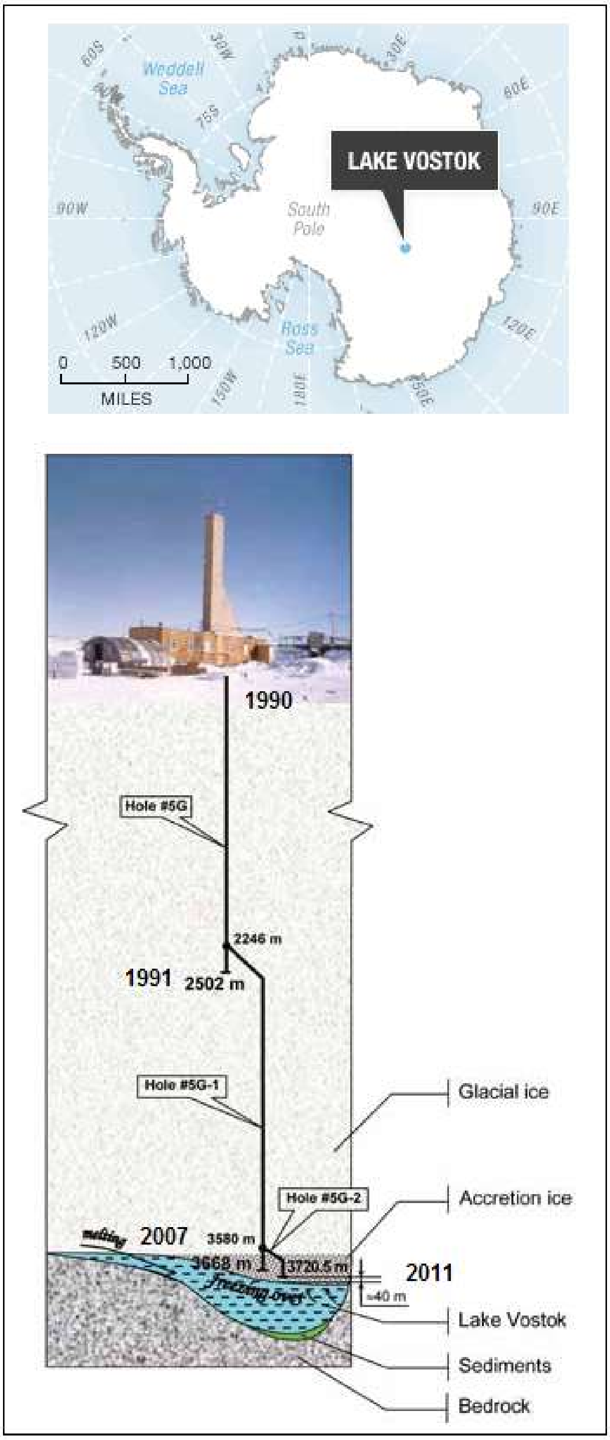

Figure.15. Ice coring in Vostok, Antarctica

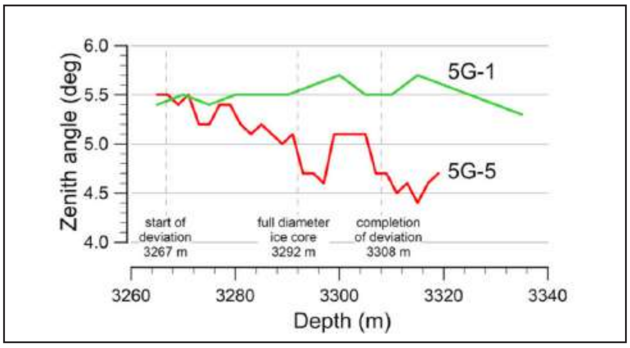

Figure.16. Inclination of boreholes 5G-1 and 5G-5 within a depth interval of 3265–3320 m

Hitherto, various low-temperature drilling fluids are used for ice drilling. Drill fluids are classified into three main groups including two-component kerosene-based fluids with density additives, alcohol compounds and ester compounds **(Figure.14).** Identification of a non-toxic, non-flammable, density appropriate, hydrophobic, inexpensive, environmentally friendly and readily available fluid(s) with predictable performance characteristics is important.

Challenging deep-ice drilling operations

Ice coring in Subglacial Lake Vostok

The subglacial Lake Vostok (found in 1957) is located 1000km inland from the coast and lies beneath an ice sheet with a thickness of 3700-4000m within the tectonically stable Eastern Antarctic platform. On 16th Dec 1957, during the International Geophysical Year, Vostok station was established near the Geomagnetic Pole, the point where the Earth's magnetic dipole axis crosses the Earth's surface. In the early 1970s, Russian scientists of the Leningrad Mining Institute initiated a deep-ice drilling project in the southern-most part of Lake Vostok **(Figure.15).** The cores collected provide 420,000 years of paleo-environmental information.

During the drilling operations undertaken during the period 1990-2012, covering 12 expeditions drilled up to ~3720m **(Figure.15).** Five deep holes were cored, in which Hole no.1 to 952 m; Hole No. 2 to 450m; Hole No. 3G (3G-1, 3G-2) to 2202m; Hole No. 4G (4G-1, 4G-2) to 2546m; and Hole No. 5G (5G-1) to 3650m depth. All the deep holes at Vostok have undergone at least one offset drilling operation because of problems with lost drills **(Figure.16).**

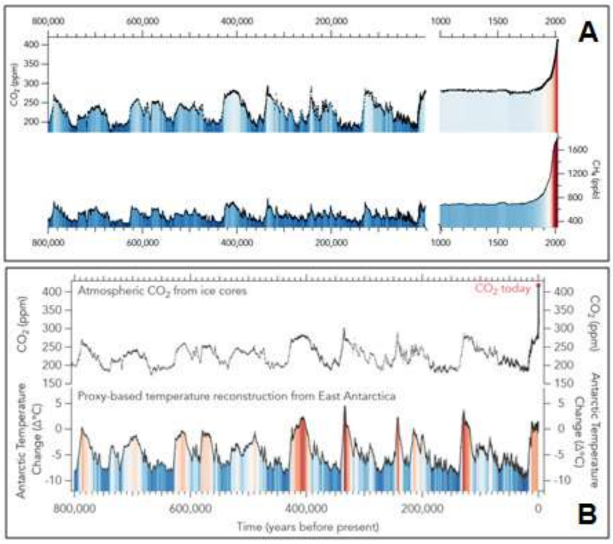

Figure.17. Reconstructed climate history from Vostok core

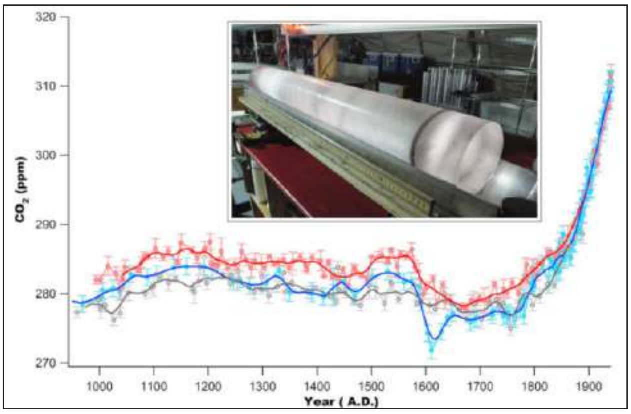

Figure.18. WAIS Divide sample and its CO_2 records

Figure.19. Recovery of one of the Lost Squadron's planes

Figure.20. View of NSF- Ice Core laboratory in Denver

These deviations were made successfully using a thermal drilling technique.

Figure.17. shows the 800,000 years of atmospheric CO_2 and CH_4 as recorded in these ice cores and atmosphere sampling. Direct and continuous measurements of CO_2 in the atmosphere extend back only to the 1950s. Measurements from older ice cores confirm that both the magnitude and rate of the recent increase are almost certainly unprecedented over the last 800,000 years. The fastest natural increase measured in older ice cores is ~15ppm over ~200 years. For comparison, atmospheric CO_2 is now rising 15ppm every 6 years. From the air in the oldest Antarctic ice core, it can be seen that CO_2 changed in a remarkably similar way to Antarctic climate, with low concentrations during cold times, and high concentrations during warm periods. This is entirely consistent with the idea that temperature and CO_2 are intimately linked, and each act to amplify changes in the other (positive feedback). In our modern era, of course, it is anthropogenic emissions of CO_2 that are expected to kick-start the sequence of events, as we see no examples in the ice core record of a major increase in CO_2 that was not accompanied by an increase in temperature.

The next crucial and ambitious scientific challenge is to sample the bottom of the lake using the 5 G or the new BH. The sedimentary strata is expected to contain a unique record of environmental and climatic changes in Central Antarctica over the past 20–30 Million years However, the rigorous environmental safety requirements for lake research operations and bottom-sediment sampling prohibit use of conventional drilling methods, as filling liquid from the well would contaminate the lake. Further, the thickest Antarctic ice in the Astrolabe Sub-glacial Basin is 4897 m deep. Therefore, the deepest Polar ice on Earth is yet to be reached.

Ice coring in West Antarctic Ice Sheet

Ocean-driven melting of floating ice-shelves in the Amundsen Sea is currently the main process controlling Antarctica's contribution to sea level rise. The WIAS is identified to be responsible for the higher sea level during the last interglacial period. Continued trends in ice-shelf melting have the potential to cause irreversible retreat of the WAIS glaciers, which together contain enough ice to raise GMSL by 5.3m.The WAIS Divide ice core was recovered at a field camp in the centre of West Antarctica, 1040km from the geographic South Pole, where the ice is more than 3460m thick. Successfully retrieving the ice core is the culmination of an 8-year project to obtain a paleoclimate record (with greater time-resolution than previous Antarctic ice cores) from one of the remotest parts of the Antarctic continent. The maturity of the present-day ice coring/drilling technology can see seen from the ice cores obtained from WAIS **(Figure.18).** Because snowfall at WAIS rarely melts, ice layers for the past 40,000 years are unbroken, and their divisions are visible. The graph depicts atmospheric CO_2 in the past 1000 years based on ice cores collected at WIAS Divide (red), Law Dome (Blue), and Droning Maud Land (Black), which are alarming sign of rapid CO_2 increase and associated global warming.

Recovery of Lost Squadron aircraft- Glacier Girl

The technological advancements in drilling, understanding of ice movements, subsurface sensing systems, such as ground-penetrating radar and magnetometers over the past decades is evident from the discovery (by the Greenland Expedition Society in 1988) and recovery (in 1990) of one of the Lost Squadron's planes that made an emergency landing on Greenland ice sheet in 1942 (during WW-II, Operation Bolero) and eventually buried under the snow, and ice that built up over the subsequent decades. Recovery system was constructed on the ice sheet surface with a hoist to suspend a gigantic hot point, called the Thermal Meltdown Generator, which had a diameter of ~1.2 m and a height of 1.5 m, A team that descended into the ice cavern (82m deep) and disassembled the aircraft so that it could be shuttled to the surface piece-by-piece, biggest piece being 2.7t **(Figure.19).** The recovered aircraft was later restored to flying condition and was popularly called as *Glacier Girl.*

Ice Core Laboratory

The National Science Foundation (NSF) - Ice Core Laboratory in Denver serves as an important centre for preparation and storage of ice cores **(Figure.20).** The lab currently contains >17 km of ice cores (~1600m^3) from around the world from more than 35 drill sites stored at -36ºC. More than 500m of ice cores, which were collected in Dronning Maud Land, East Antarctica are preserved in the ice-core laboratory at MoES-NCPOR in Goa.

Next Part

Part B will describe robotic-based systems including remotely operated Vehicles (ROV), Autonomous Underwater Vehicles (AUV), Human Occupied Vehicles/ Manned Submersibles the under-ice techniques. The upcoming unconventional drilling systems including Submersible Capable of Under ice Navigation and Imaging, Ice Mole and extra-terrestrial probes shall also be discussed.

Abbreviations

AIS	Antarctica Ice Sheet
BH	Bore hole
CRREL	Cold Regions Research and Engineering Laboratory
GIS	Greenland Ice Sheet
GMSL	Global mean sea level
kyr	Kilo-year
LPM	Litres per minute
MoES	Ministry of Earth Sciences
MIZ	Marginal Ice Zone
MJ	Mega Joules
NCPOR	National Centre for Polar and Ocean Research
NSF	National Science Foundation
SCAR	Scientific Committee on Antarctic Research
SODA	Stratified Ocean Dynamics of the Arctic
WAIS	Wear Antarctica Ice sheet
WCRP	World Climate Research Program

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Navigating the High Seas: Occupational Therapy Strategies for Managing Stress and Improving Well-being Among Marine Seafarers (Part 2)

(Supporting Seafarers' Mental Health in the Demanding World of Maritime Work)

Neha Jain, Yash Jain

The Impact of Maritime Work on Health and Well-being

Marine seafarers work in a challenging environment that requires them to spend long periods away from home, face extreme weather conditions, and perform physically demanding tasks. These challenges can significantly impact their health and well-being, both physically and mentally.

Physical Demands of Maritime Work

The physical demands of maritime work include factors such as prolonged standing, heavy lifting, exposure to extreme weather conditions, and performing tasks that require physical strength and endurance.

The physical demands of maritime work can vary depending on the type of vessel and the role of the seafarer. For example, deckhands and engineers may have different physical demands than cooks or officers. Deckhands may be responsible for heavy lifting, line handling, and other strenuous tasks. Engineers may spend long hours in confined spaces, performing maintenance and repair work on machinery. Cooks may spend long hours standing and working in hot and cramped conditions.

Seafarers often work long shifts without the opportunity to sit down or rest, which can lead to fatigue and physical exhaustion.

Another physical demand of maritime work is heavy lifting. Seafarers are often required to lift heavy objects such as equipment, cargo, and supplies. This can place significant strain on the body, particularly the back, shoulders, and arms. Lifting heavy objects can lead to back injuries, strains, and sprains, which can be painful and debilitating.

Exposure to extreme weather conditions is another physical demand of maritime work. Seafarers may be exposed to extreme heat or cold, high winds, and rough seas, which can be physically challenging and exhausting. Exposure to extreme weather conditions can also increase

> *Deckhands may be responsible for heavy lifting, line handling, and other strenuous tasks. Engineers may spend long hours in confined spaces, performing maintenance and repair work on machinery. Cooks may spend long hours standing and working in hot and cramped conditions*

the risk of hypothermia, heat stroke, and other weather-related illnesses.

Performing tasks that require physical strength and endurance is another physical demand of maritime work. Seafarers may be required to climb ladders, work in confined spaces, or operate heavy machinery and perform maintenance tasks that require bending and kneeling for extended periods. These tasks can be physically challenging and require a high level of fitness and strength.

The physical demands of maritime work can have a significant impact on the health and well-being of seafarers. Prolonged standing and heavy lifting can lead to musculoskeletal disorders such as back pain, strains, and sprains. Exposure to extreme weather conditions can increase the risk of weather-related illnesses such as hypothermia or heat stroke. Performing tasks that require physical strength and endurance can lead to fatigue and exhaustion, which can impact overall well-being.

Occupational therapists can work with seafarers to develop strategies to manage the physical demands of maritime work. This may include exercises to improve strength and flexibility, ergonomic assessments to reduce the risk of musculoskeletal disorders, and education on injury prevention and safe lifting techniques. By addressing the physical demands of maritime work, occupational therapists can help to promote the health and well-being of seafarers and support them in their work at sea.

The Risks of Injury and Illness

Marine seafarers are exposed to a variety of risks that can lead to injury or illness. These risks can be physical, such as falls, cuts, and fractures, or they can be related to exposure to hazardous materials or extreme weather conditions. In this section, we will explore the specific risks that seafarers face and how these risks can impact their health and well-being.

Physical Risks: Seafarers are often required to work in challenging and physically demanding environments. They may be required to perform tasks such as heavy lifting, climbing, or operating machinery for extended periods. This can lead to physical exhaustion and fatigue, increasing the risk of accidents and injuries. Additionally, due to the movement of the ship and the often-uneven surfaces on board, slippery surfaces and unstable footing can lead to slips, trips, and falls, which can result in injuries such as sprains, fractures, and head injuries.

Exposure to Hazardous Materials: Seafarers may also be exposed to a variety of hazardous materials, including chemicals, fuels, gases, fumes, and other hazardous materials while performing tasks such as painting, cleaning, or working in the engine room. Exposure to these materials can lead to a range of health problems, including respiratory illnesses, skin irritations, and other types of poisoning. Long-term exposure to these materials can also increase the risk of cancer and other chronic illnesses.

Extreme Weather Conditions: Seafarers may also face a range of extreme weather conditions, including high winds, heavy rain, and extreme temperatures. Exposure to these conditions can lead to hypothermia, heatstroke, and other weather-related illnesses. Additionally, seafarers may be at risk of developing musculoskeletal disorders due to prolonged exposure to cold or damp environments.

Psychological Risks: In addition to physical risks, seafarers may also face a range of psychological risks that can impact their mental health and well-being. These risks may include isolation, loneliness, and separation from family and loved ones. Seafarers may also experience stress and anxiety related to the demands of their work, such as long hours and tight schedules.

Overall, the risks associated with maritime work can have a significant impact on seafarers' physical and mental health. It is essential to develop strategies to mitigate these risks and promote the health and well-being of seafarers. Occupational therapists can play a critical role in this process by developing interventions to manage stress, promote resilience, and support seafarers' overall health and well-being.

Psychological Impact of Maritime Work

In this section, we will explore these challenges and their potential impact on seafarers' mental health.

One of the most significant challenges seafarers face is isolation. Many seafarers spend long periods at sea, away from their families and loved ones. This isolation can lead to feelings of loneliness, which can have a negative impact on mental health. Seafarers may also feel disconnected from the rest of the world, leading to a sense of isolation and a lack of support.

Living and working in confined spaces can also be challenging for seafarers. This can lead to a sense of claustrophobia, which can exacerbate feelings of isolation and loneliness. Seafarers may also feel stressed due to the

> *Furthermore, seafarers may also experience traumatic events such as piracy, accidents, or shipwrecks. These events can have a significant impact on mental health, leading to symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety*

constant noise and vibration of the ship, which can make it difficult to sleep or relax.

Furthermore, seafarers may also experience traumatic events such as piracy, accidents, or shipwrecks. These events can have a significant impact on mental health, leading to symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety.

The psychological impact of maritime work is also affected by cultural and social factors. Many seafarers come from diverse cultural backgrounds and may face discrimination or exclusion while working on ships. This can lead to feelings of loneliness, stress, and anxiety. Additionally, seafarers may struggle to maintain relationships with their families and loved ones, which can cause feelings of guilt and stress.

Addressing the psychological impact of maritime work is essential for promoting seafarers' mental health and well-being. Occupational therapists can work with seafarers to develop strategies to manage stress, build resilience, and promote well-being. These strategies may include cognitive-behavioural therapy, relaxation techniques, and mindfulness-based practices.

Overall, seafarers face a unique set of challenges that can have a significant impact on their mental health. Understanding these challenges and developing targeted interventions to promote mental health and well-being is essential for supporting seafarers in the demanding world of maritime work.

Cultural and Social Factors

Cultural and social factors can have a significant impact on seafarers' mental health and well-being. Many seafarers come from diverse cultural backgrounds and may face discrimination or exclusion while working on ships. These experiences can lead to feelings of isolation, stress, and anxiety, which can affect their overall health and well-being.

One of the main challenges that seafarers face is the cultural differences between themselves and the crew members they work with. This can lead to misunderstandings, conflicts, and a lack of cohesion within the crew. For example, seafarers from different cultures may have different communication styles or ways of expressing themselves, which can lead to misinterpretations and misunderstandings. This can cause tension and conflict, which can have a negative impact on the mental health and well-being of seafarers.

Another challenge that seafarers face is discrimination and exclusion based on their race, ethnicity, or nationality. This can manifest in many ways, including being excluded from certain activities or social events, being treated unfairly, or experiencing verbal or physical abuse. These experiences can lead to feelings of isolation, anxiety, and depression, which can affect seafarers' mental health and well-being.

The isolation that seafarers experience while working on ships can also be a significant factor in their mental health and well-being. Seafarers may spend months at sea without seeing their family or loved ones, which can be incredibly difficult and stressful. This can lead to feelings of loneliness and depression, which can have a negative impact on their overall well-being. Seafarers may also experience feelings of homesickness or cultural dislocation, which can exacerbate their sense of isolation.

The lack of social support and connection can also contribute to seafarers' mental health and well-being. Seafarers may not have access to mental health services or support networks while at sea, which can leave them feeling unsupported and alone. This lack of support can lead to a range of mental health concerns, including depression, anxiety, and post-traumatic stress disorder (PTSD).

To address these cultural and social factors, occupational therapists can work with seafarers to develop strategies to manage stress, build resilience, and promote well-being. For example, occupational therapists can provide cultural awareness training to crew members to help them understand and appreciate cultural differences. They can also provide counselling and support services to help seafarers cope with feelings of isolation and homesickness.

Overall, addressing cultural and social factors is essential in promoting seafarers' mental health and well-being. By recognising and addressing the unique challenges that seafarers face, occupational therapists can help seafarers thrive both at sea and on land. [1][2][3][4][5]

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UMSD (Unified Monitoring Safety Device)

Nirjhar Sarkar

Abstract: This safety-centric device, integrated with advanced technological features, is designed to improve the performance of the device in hazardous environments. The AI integration enhances the functionality of the device in a number of areas, such as:

1. Health Parameter Optimization:

AI algorithms for dynamically optimizing health parameter monitoring work according to the requirements of every individual user.

2. Predictive Accident Detection:

Ingrained AI-powered algorithms can predict the possibility of accidents through patterns in historical data analysis.

3. Personalized User Experience:

AI personalizes the features of the device according to the preferences and historical health data of the user.

4. Centralized Data Analysis:

Advanced analytics centralized by AI to provide trends and health insights while optimizing safety protocol application.

5. Emergency Response Optimization:

AI-driven systems optimize emergency response times by analysing the patterns in historical data.

6. Integration of the Adaptive Support Component:

AI substantially increases the accuracy of the device in measuring oxygen levels, detecting gases, and evaluating environmental conditions.

The device matures over time to advanced performance and, using AI, operates as a dynamic safety solution in marine environments.

Keywords: Safety-centric device, Hazardous environments, Artificial Intelligence (AI), Accident detection, Maritime safety

Introduction

According to the graphs in **figure 1.** and **figure 2.,** even with advancements in technology, the number of fatalities and health-related hazards happening every year is quite alarming.

Looking upon the chart of accidents recorded from all types of ships, it gives the highest number of accidents happening on the merchant vessels. Keeping in view the safety measures to be followed by the crew, the level of accidents is still persistent.

It shall be designed more particularly for the crew. In case the crew member is under some health-related

emergency, a signal will be issued to the bridge and engine control room so that immediate actions could be taken and the accident can be dealt with.

2. Device details

The device could possibly be a ground-breaking contribution to safety on board ships. Some of its key aspects include: -

- **Intrinsically Safe Design:**

  The inherent safety of the device can be of utter significance in the maritime atmosphere where safety is of the essence. This basically means that the device is designed with the capability of operation in potentially explosive environments such as are common in ships.

- **Versatility:**

  The device can be applied on various kinds of vessels, thus adding to its versatility and, therefore, able to suit many types of ocean-going operations.

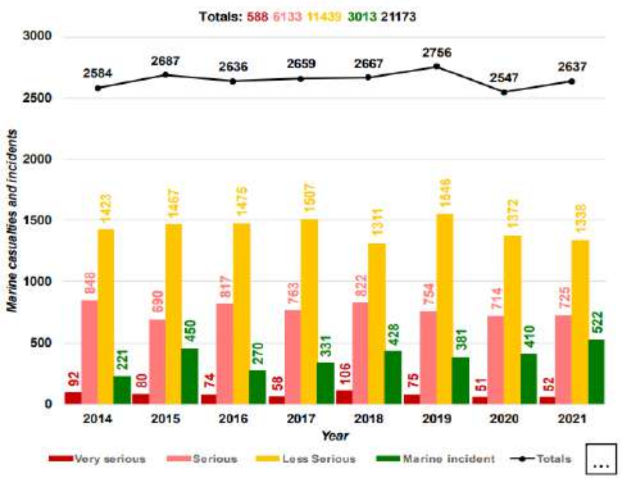


Figure 1.

- **Man-Overboard Detection:**

  The major function of the device in terms of detection and signalling the man-overboard situation is very significant in terms of quick response and operations of salvation. Through this, one can be able to increase the chance of saving lives in times of emergency.

- **Identification and Signalling of Injury:**

  It is capable of detecting and indicating injuries, making it another safety feature. Immediate notifications to the monitoring system allow for prompt response with the appropriate medical care.

- **Expandable Attachments:**

  Separate attachments, read gas detection, enclosed space entry monitoring, automatic illumination, and emergency call alerts with its built-in capability, which maximizes the utility of this device full-featured safety tool for proper working condition.

- **Smartwatch Design:**

  The device, when designed in the smart-watch form, adds to the overall portability and convenience of the device. Wearability, in general, is widely accepted due to ease of use and comfort, especially in challenging dynamic environments like ships.

- **Seamless Communication:**

  This would require several receivers to be installed inside the ship to make sure that Faraday's Electromagnetic Shielding can be defeated to have continuous communication. This was thought of and quite logical since the device is so small that this would be cumbersome unless this has continuous communication.

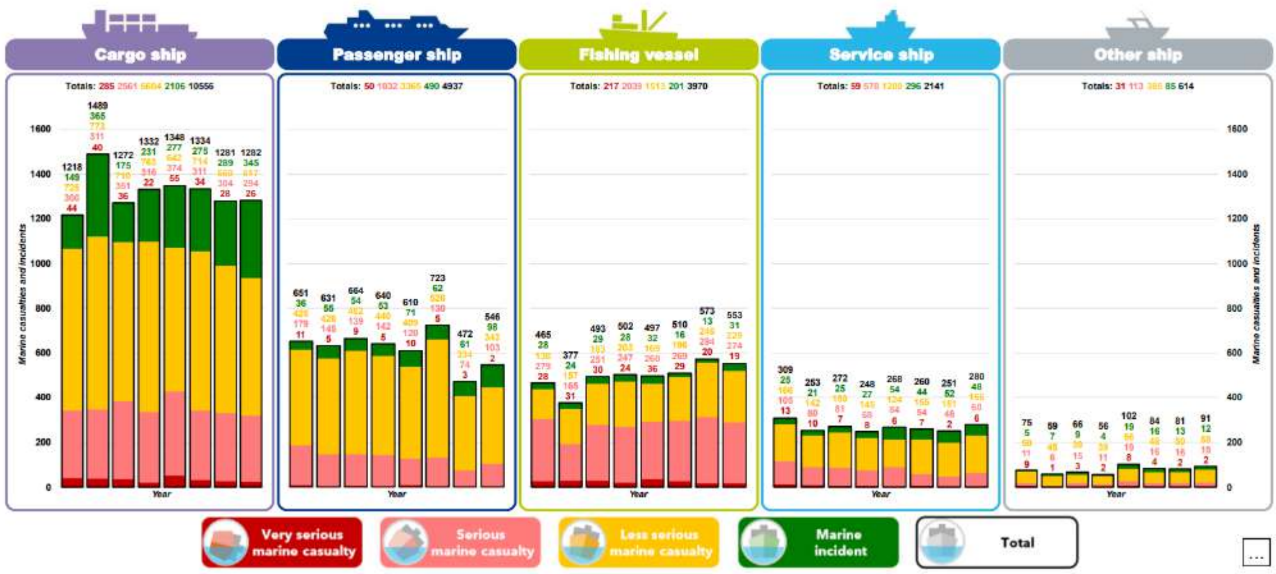


Figure 2.

> *Looking upon the chart of accidents recorded from all types of ships, it gives the highest number of accidents happening on the merchant vessels*

3. Device Construction

3.1. Battery

- **Power Source:** It contains a 450mAh lithium-titanate cell as compared to lithium-ion cells.
- **Thermal Performance:** Lithium-titanate cells are specially selected for their strong performance at very low temperatures and their striking reduction of the short-circuit risk, which leads to improved safety.
- **Applicability in Hazardous Environments:** Their intrinsic safety makes them a good fit for applications aboard vessels where the safety requirements are stringent—oil tankers and gas carriers.
- **Performance Metrics:** Lithium-titanate cells have a better energy density, better charging rates, and cyclic life in comparison to their lithium-ion counterparts.
- **Electrical Characteristics:** Although lithium-titanate cells possess a slightly lower intrinsic value voltage, it is at 2.4 V, with a specific energy of around 30 – 110 Wh/kg. It is noted that some specific lithium-titanate batteries can give volumetric energy density values as high as 117 Wh/L.

- **Overall Benefit:** An accumulation of the technical advantages of safety, efficiency, and long operational hours adds to the lithium-titanate cell as a better power source for the device, more so in the harsh and safety-cognizant maritime environments that the device will operate in.

3.2. Chipset

- **Power Courteous:**

The 5nm chipset is power favourable in the design and guarantees that energy is used in only economical means for an extended period of operation while at the same time minimizing the frequent recharging.

- **Real-time Processing:**

The chipset is designed for real-time processing. It embraces quick and accurate data acquisition from various sensors and modules. This could be critical in monitoring situations, like timely response to critical situations.

- **Encryption Protocols:**

Advanced protocols of encryption to protect the data while in storage or during its transmission from one point to the other. This ensures that sensitive information doesn't fall into the wrong hands but remains compliant with the set data protection standards.

- **Customization Capabilities:**

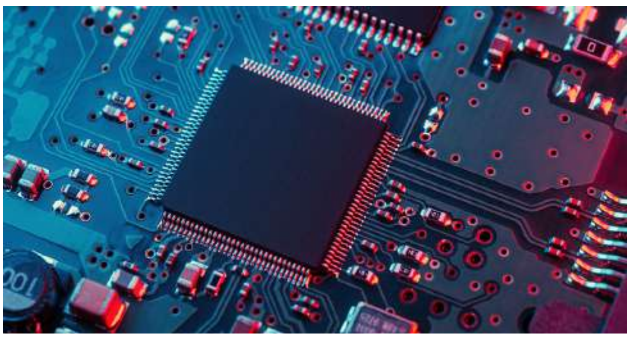
The chipset architecture allows flexible customizing by users to cater to their operational needs and preferences in its features and functionalities.

- **Firmware Upgradability:**

Support firmware up-gradation that will allow advanced features, security patches, and overall performance optimization to be carried out as technology progresses alongside changing user needs.

- **Integration with IoT Ecosystem:**

Built to mesh with the IoT world; it is designed to interact with the other intelligent objects on the



> *The major function of the device in terms of detection and signalling the man-overboard situation is very significant in terms of quick response and operations of salvation*

vessel. This will ensure a fully interfaced responsive maritime environment through human-machine interfacing methodologies.

- **Robustness and Reliability:**

  Maritime Corning chipsets are manufactured for robust maritime experience. Reliability and robustness are tested though variable environmental and mechanical attack to ensure no failure.

- **Low Latency Communication:**

  It prioritizes low-latency communication; thus, the reactivity of the device is improved to ensure that crucial data is passed on time to the central monitoring system for effective decision-making.

- **Compliance Standards:**

  The chipset developed will be in accordance with the industry standards and certification; thus, compliance with the regulator's needs on maritime safety and communication makes one confident about its reliability and conformance with set norms.

  The chipset of the device does not only incorporate the latest technical specifications in it but also supports some other features for efficiency, security, adaptability, and reliability in maritime applications.

3.3. Memory

- **Storage Configuration:**

  It has a 32GB Read-Only Memory with the capability of storing a vast amount of data and applications.

- **Memory Capacity:**

  It has a capacity of Random Access Memory of 1.5GB so that more capabilities are put in for better multitasking and enable the functioning of the applications more smoothly.

- **eMMC Technology:**

  In storage, eMMC technology provides a reliable and cost-effective solution for data storage and retrieval.

- **Data Transfer Speed:**

  The eMMC technology is characterized by its suitability in dealing with information transfer in a very fast and efficient way. Thus, it allows a quick response and quick access to the data stored.

- **Stability and Durability:**

  This eMMC configuration offers more excellent stability and durability for their use in maritime environments, as devices are usually exposed to vibrations and temperature changes, among other challenging conditions.

- **Application Performance:**

  The 32GB ROM with 1.5GB RAM makes for a nice fit to ensure the maximum performance of applications, include storage, and running a wide range of software and data.

- **Multitasking:**

  The available RAM accommodates multitasking without hitches during any number of concurrent processes without degradation in performance.

- **Expandability:**

  In as much as the current storage and memory are well suited to the task at hand, the gadget is well architected to support any possible additional increments should the user requirements grow abruptly.

- **Effective Resource Management:**

  The configuration of eMMC allows effective management of resources, thus contributing to system stability and responsiveness.

In summary, the sum total of all—32GB ROM, 1.5GB RAM, and the trifling support of eMMC technology—

results in a very sound and effective storage architecture on this device, ensuring high performance and flawless durability of any given application within the maritime environment.

3.4. Display

- **Display Technology:**

  It uses Gorilla Glass DX+ for the added ability to withstand tough impacts, scratch externalities, and secure adequate durability for the screen.

- **Size Variants:**

  Available in two-size variations- 40mm and 44mm to meet all user specifications.

- **Adaptive Technology:**

  May change based on the packages available and with updated development in display technology to support new standards set by the industry.

3.5. Body of the Device

- **Body of the Device Material:**

  Made of an aluminium body and a vulcanized rubber coat, which is efficient in insulating and forming the body.

- **Intrinsically Safe Makeup:**

  The aluminium and vulcanized rubber construction renders the design intrinsically safe, reduces the risks related to electrical hazards, and promotes ruggedness.

- **Water Resistance Rating:**

  Housing designed to accept a 50m water-resistance rating meets IP68 standard to help protect against the ingress of water.

- **Military Standard Compliance:**

  The standards of MIL-STD-810G are met to ensure endurance and resilience in various environmental conditions and operational stresses.

- **ECG Certification:**

  Certified to Electrocardiogram (ECG) functions, meeting standards to ensure accurate and reliable monitoring of the heart rate.

3.6. OS/Software

- **Operating System:**

  Optimum support for the wearable device through the Android Wear OS accessed, providing a platform of high compatibility currently with a user interface.

- **Software Customization:**

  It can easily be customized upon consumer demand; therefore, it is easy to adjust the essential adaptation for any demand in monitoring inquiry software for marine applications.

- **Wearable Ecosystem Integration:**

  Interoperability with other wearables is guaranteed by full integration into the Android Wear OS environment, therefore increasing the functionality while adding more functionalities.

- **Security and Updates:**

  It utilizes all the security features of Android Wear OS while allowing the adoption of extra consumer/ security measures from the consumer/enforced by the consumer. Regular updates refresh the device while ensuring its security.

- **Technical Adaptability:**

  The software architecture can be dynamically adjusted to the technical requirements and safety-related issues on the board that doctors powerful and technically sophisticated solution adaptively.

4. Functionality

The device offers various inbuilt and customizable functionalities, as per-user requirement, that is integrated with other equipment. The main functionalities are:

4.1. Off Boundary Limit Alarm / Man Overboard Alarm

- **Accurate Tracking:** With multiple receivers on board, track the precise position of every individual who is going to wear this device.
- **Breaching of Boundary Alarm:** Sound an off-boundary or MOB alarm in case any individual leaves beyond the limits of the ship.
- **Central Monitoring System Notification:** The alarm triggers a notification to the central monitoring system, after which immediate response protocols are initiated.
- **MOB Marker Deployment:** A MOB marker with a Lifebuoy is deployed at the location the person went overboard to rapidly identify and rescue him/her.
- **Sensor Integration:** It uses an accelerometer, gyro, and GPS to allow for perfect tracking of the individual's location.
- **Location Determination:** Sensor data is fused to identify the location of the individual, which is to be used for efficient rescue operations.

This functionality would provide an immediate, very accurate response in overboard situations, improving the safety of vessels.

4.2. Accidental Alert

- **Health Monitoring Fusion:** The heart rate and blood pressure monitoring are fused to create an overall health monitoring system.
- **Accident Indicators Analysis:** This module analyses the output from detection algorithms that identify sudden spikes in heart rate and drops in blood pressure as potential indicators of an accident.
- **Identification of a Critical Event:** On the basis of such patterns, it will identify a critical event like a shock or heart attack due to real-time changes in heart rate.
- **Automated Alert Mechanism:** The system triggers an alert in case of abnormalities, which shall promptly invoke response mechanisms.
- **Crew Notification System:** The crew members are alerted in time so that they can rapidly respond in case of injury or any accident-prone situation.

This framework puts together advanced algorithms and monitoring capabilities to proactively detect an accident and crew response.

4.3. Low Oxygen Level Alarm

- **Oxygen Saturation Monitoring:** Continuously monitor oxygen saturation in the wearer to trigger an alarm on its drop.
- **Gas Inhalation Analysis:** The device detects a drop in oxygen levels as an indication of hazardous gas inhalation and actuates immediate action.
- **Synergy with Location Tracking:** The device synergizes with location tracking, verifying whether the user is in areas where hazardous gases exist.
- **Hazardous Zone Validation**: Using location tracking, it validates whether the wearer has entered predefined hazardous zones.
- **Central Monitoring System Integration:** Technical alerts in case of low oxygen levels or hazardous zone

entry will be sent to the central monitoring system to facilitate prompt action.

This feature monitors oxygen levels in the area and checks for hazardous zone presence to enhance safety and facilitate a quick response.

4.4. Dedicated Emergency Button

- **Emergency Activation Switch:** A manual switch is provided for emergency scenarios, where wearers can promptly send an urgent alert to the crew.
- **Manual Safeguard Measures:** Designed to be deliberately activated and not to trigger by accident, it ensures that it is deliberately used only during an emergency.
- **Tamper-Resistant Casing:** This allows placing the emergency switch inside a tamper-resistant casing to prevent any accidental activation while maintaining its accessibility.
- **Secure Signalling Protocol:** The switch activates a secure signal if it has been triggered, effectively warning other crew members of potential danger.

This makes up a safe and deliberate mechanism to alert in case of an emergency, thereby increasing the effectiveness of such response in critical situations.

4.5. Sleep Alerting System

- **Activity Monitoring Feature:** This feature will continuously monitor the user's movements and activity.
- **Drowsiness Detection:** It detects drowsiness or non-activity with the help of sensor data, thus indicating fatigue.
- **Alert Trigger Mechanism:** It raises an alert in cases of drowsiness or prolonged inactivity detection and warns the user and the concerned authorities.

This module deals with issues related to fatigue. It makes the application safer by detecting and acting on drowsiness in ultra-critical environments.

4.6. Other Functions

- **Direct Connection to Master Clock:** No need for extra applications since it is directly connected to the master clock.
- **Telecommunication Channels:** Direct communication with crew members makes communication easier on any ship.
- **Pre-set Crew Communication Channels:** Always connected to the essential crew communication channels which are set in advance.
- **Message Receiving System:** Used for receiving alert messages and other important messages from crew members to enhance real-time communication and situational awareness.

This design aims to increase communication efficiency by addressing basic telecommunication functions and introducing direct connectivity.

4.7. Ancillary Functions:

- **Additional Equipment Linkage:** It links up with other equipment, such as O2 gas analysers and gas analysers, to expand functions and generate data.
- **Sensors:** It provides sensors for humidity and temperature, thus monitoring environmental conditions.
- **Safety Machinery Operation:** This feature prevents any accidental start-up of the machinery on board a semi-autonomous vessel. It detects whether some maintenance is going on by logging it and trips/ inhibits the start-up of the machinery automatically.

This kind of functionality enables better adaptability for the device to increase its possibilities in application and safety on board maritime vessels.

5. Costing

- **Production Cost Estimate:** The cost of production per piece would come to about 15,000 – 16,000 Indian rupees.
- **Deployment and Setup Cost:** Another 50-60 lacs Indian rupees for its setup and deployment on the ship is estimated, depending upon the requirements.
- **Subscription Model:** Subscription fees after set up for monitoring and data services lie between 3 lacs and 15 lacs, which are negotiable as per the customer's requirements.
- **Scalability and Profitability:** The initial development cost will go towards software development, production setup, and design. The rate of the subsequent productions can be worked out to make it scalable and profitable.

This cost structure and subscription model provide a feasible and scalable approach that includes financial flexibility for the user.

6. Advantages

1. **Accident Prevention:** Reduce onboard accidents through protection using its inbuilt safety features and real-time monitoring.
2. **Continuous Health Monitoring:** Provides constant health reports with sensor and analytics-based services for health monitoring.
3. **Inter-industry Integration:** Modular design and interoperability are obvious as it finds applications across most industries.

4. **Activity Monitoring and Work Hours Analysis:** It monitors user activity and provides insights into work hours and general activeness.
5. **Gas/Oxygen Level Monitoring with Attachments:** The devices are attached to monitor the gas and oxygen levels in confined spaces with great accuracy.
6. **Sleep Pattern Analytics:** The sleep patterns are analysed to return data on hours of sleep and even the quality.
7. **Emergency Response System:** Engineers rapid response mechanisms through the aid of sensor data and channels of communication.
8. **Digital Hazardous Work Checklist:** Digitizes checklists from work permits into digital forms to ensure adherence to safety procedures.
9. **Centralized Alerting Mechanism:** Communicate over telecommunication channels to facilitate real-time alerting of the monitoring centre in crisis situations.
10. **Precise Location Tracking:** Provides exact location information with the help of GPS to send out a correct emergency response.
11. **Paperwork Reduction by Means of Automation:** Reduces time spent on paperwork by automating the processes involved in data collection.
12. **Modifiability and Customization Platform:** Offers a modifiable structure for evolving technical requirements.
13. **Customizable Firmware and Functionalities:** The device comes with customizable firmware to tune the device for specific needs.

7. Disadvantages

1. **Product Designing and Testing Phase:** It requires extended periods of designing and testing of the product for the validation of functionality and reliability.
2. **Battery Back-up Testing:** Constant evaluation of the system of battery backup for performance and longevity.
3. **Cost-Effectiveness Analysis:** Detailed analysis of manufacturing processes and component costs under way.
4. **Modelled Ship Installation Procedures:** Individual installation procedures customised for optimum integration on various ships.
5. **Global Launch Preparation and Research:** Ongoing R&D works towards its global launch, emphasis laid on fine-tuning technology and international standards.

8. Conclusion

- **Integrated Safety Features:** Integrates advanced safety features that minimize onboard accidents with respect to health and safety concerns related to crew members.
- **Multi-functionalities:** It provides multi-functionalities, like location tracking and strong communication protocols.
- **Accident Detection through Sensor Technology:** Accident detection through the use of sensors provides accurate data related to accidents and real-time location information.
- **Smooth Data Monitoring System:** A state-of-the-art monitoring system is provided which can be accessed by onshore and onboard authorities.
- **Work Scheduling through Analysis of Data:** The analysis of obtained data offers efficient work scheduling and resource allocation.
- **Pro-Active Accident Prevention Measures:** Continuously monitors parameters to provide pro-active accident prevention measures.
- **Technological Innovation in Maritime Safety:** This will precipitate a sea change in maritime safety and raise the bar for industry standards in terms of standard and operational efficiency.

4. Acknowledgement

Course In-charge GUNI Maritime Studies Chief Engineer Arun Rathi for his technical supervision and intelligence.

[A paper on this was presented in the GLOMARS Conference, March 8-9, 2024]

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About the Author

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1st position in Technical Paper Presentation IN GLOMARS24

2nd position in Technical Paper Presentation IN TRANSTECH23

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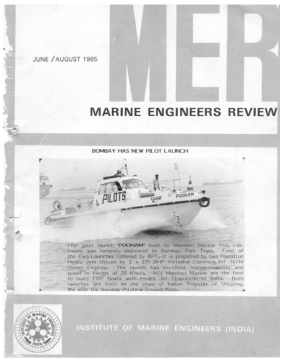
Going Astern into MER Archives…



We start with the Editorial penned by Shri. H.K. Taneja on robots. The premise is that robots are being fashioned emulating the humans which is not in consonance with requirements one may have for manufacturing. True. Robots have to be purpose based especially when it comes to manufacturing.

Issue Content

The first article discusses condition monitoring and pitches for a rational approach. Some excerpts on bearing CBM are reproduced. This is an educative read applicable for present times also. Following this is a discussion on fibre optics/endoscope usage with examples of how the turbine insides are viewed and condition ascertained. And one on combustion performance analysis system.

Following these is an article on the merits of Cu alloys, especially Cu-Ni and the claddings.

The next article is a very interesting one on medical facilities and health care on board. There are a few interesting information and advise to avoid a health situation.

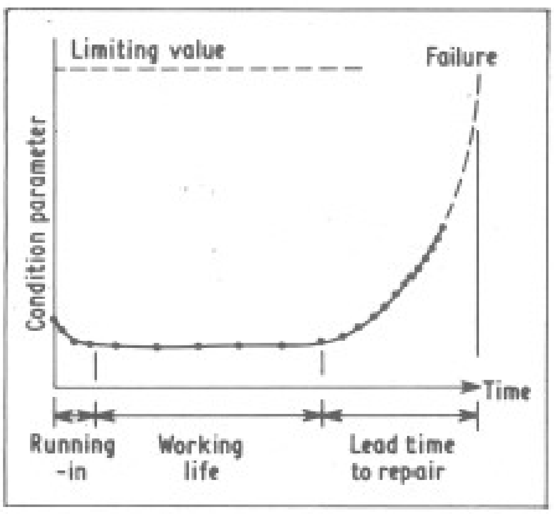


Fig 1: Condition trend monitoring

The article on fuel savings by monitoring fuel/speed characteristics and 'cost of speed' with a few econograms will be of interest to sailing marine engineers.

There is one article on Smoke & Toxic Gases from polymers that are burnt on board.

There is one Transaction on 'Marine Casualties and how to prevent them' (from 1983). Being packed with information and cases (and not technical equations etc.), this is an easily digestible read (the photograph of the hogged tanker is from the Transaction).

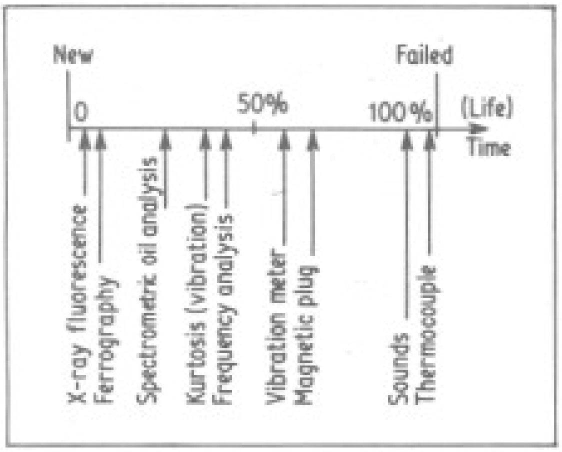


Fig 3: Sensitivity of different techniques applied to the condition of plain bearings

Fig 4: Stages of wear and debris formation

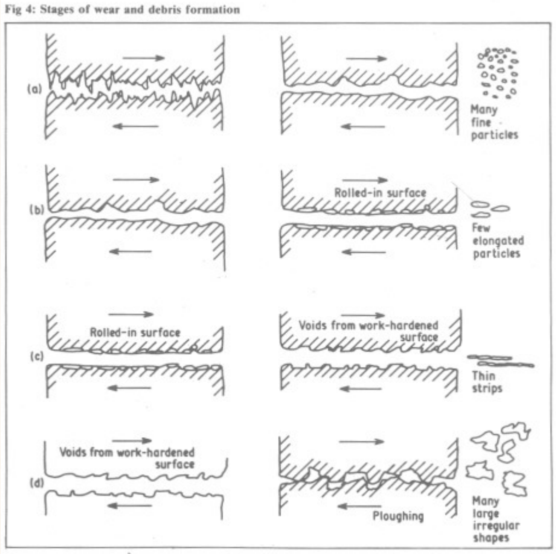
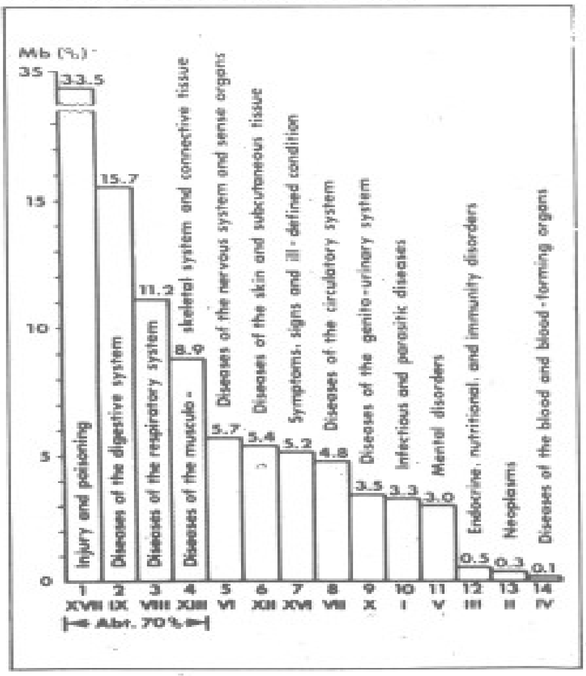


Fig 1: Sequence of seamen's diseases according to the international classification of diseases from seven countries, 1954—1979.



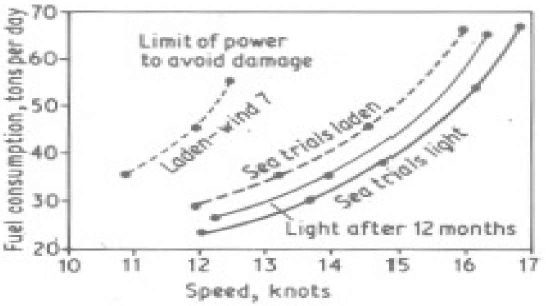
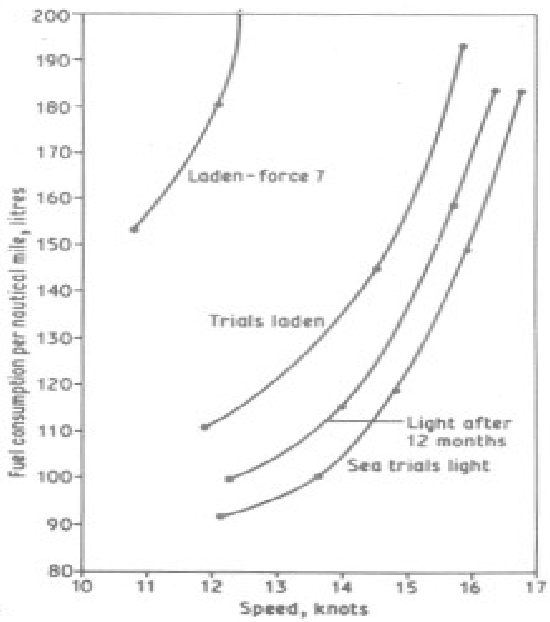


Fig 1: The econogram for a 20 000 bhp vessel (fuel consumption against speed)

Fig 2: Distance-related consumption vs speed



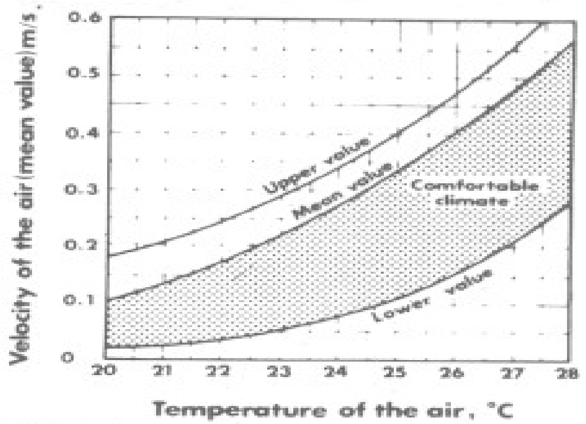


Fig 2: Air movement required in occupied areas (ISO/DIS 7547).

Table 1: Examples of recommended climatic values

Kind of activity	*Air temperature (°C)*			*Relative air humidity (%)*			*Max. air velocity (m/s)*
	min.	*opt.*	*max.*	*min.*	*opt.*	*max.*	
Light office work	18	21	24	30	50	70	0.1
Light hand work in sitting position	18	20	24	30	50	70	0.1
Hand work in standing position	17	18	22	30	50	70	0.2
Heavy work	15	17	21	30	50	70	0.4
Heaviest work	14	16	20	30	50	70	0.3

Note: The difference between the room temperature and the temperature of the environmental objects and walls should not exceed 2°C for optimal air-conditioning.

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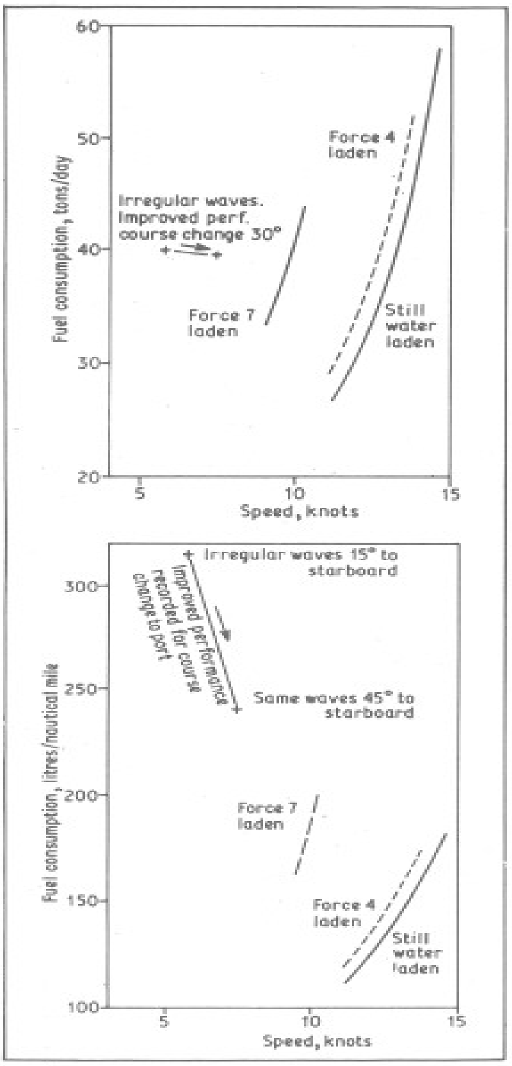
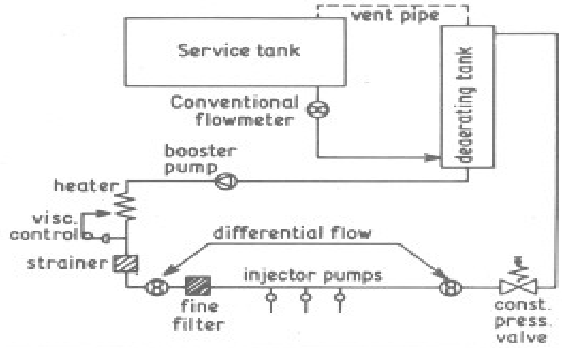


Fig 3: Performance sheets (consumption per t/ day and consumption per nm)

Fig 4: The two alternative fuel consumption monitoring principles



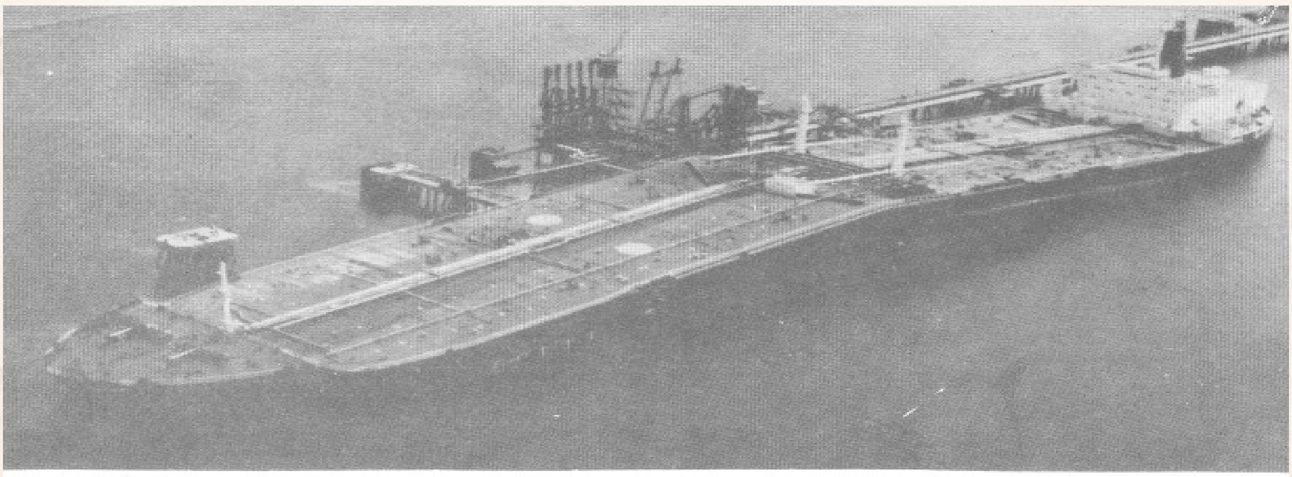


FIG. 9 (a) VLCC *Energy Concentration* hogged at Europort, Rotterdam

We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages. – Hon.Ed.

IME (I) GOVERNING COUNCIL, BRANCH, AND CHAPTER COMMITTEE ELECTIONS 2025-27

As the elections for The Institute of Marine Engineers (India) approach, we wish to notify all Corporate Members of the following procedures:

SCHEDULE

Soft Copy of Nomination Papers:

- The entire election process will be communicated exclusively through electronic media.
- Nomination forms will be sent via mass email and can also be downloaded from the IME(I) website. Completed forms must be returned to the Election Officer.
- Nomination papers for Council elections will be emailed by **15th May 2025** to the registered email ID.
- The Institute's office must receive the completed nomination papers by **15th June 2025**.
- The last date for withdrawing nominations is **30th June 2025**.
- The Election Committee will complete the scrutiny of nomination papers by **5th July 2025**.
- After scrutiny, the Election Officer will publish the CVs of eligible candidates on the IME(I) website.

E-VOTING

As a Corporate Member (on the Roll as of **15th May 2025**), you can cast your vote in the upcoming IME(I) elections using the **e-Voting** system exclusively.

- Two voting options will be available:
  - o **Head Office (HO) Elections**
  - o **Branch Level Elections** (if applicable)
- Overseas Members will have the option to vote **only for the HO level elections**.
- If your email address has changed, you must update it by emailing **electionofficer@imare.in** no later than **15th June 2025**.
- Members will receive the e-Voting link **only** at their registered email addresses as per IME(I) records on **1st June 2025**.
- To update your email ID or contact details, write to **membership@imare.in** by **10th May 2025**.
- E-Voting will commence on **15th July 2025** and remain open until **1700 hrs on 31st August 2025**.

ELIGIBILITY TO STAND FOR ELECTION

- All office bearers of the **Council and Council Members** must be **Fellow Members** from branches or chapters only.
- Office bearers and Council Members must have been Corporate Members for at least four years at the time of filing their nomination and must have served at least one full term on the executive committee of a local branch or chapter before being eligible to stand for election from that branch.

USE OF WORKPLACE / OFFICIAL EMAIL IDS

- In the past, mass emails have been blocked by certain organization domains, flagged as spam, or led to the blacklisting of the IME(I) domain. To avoid this, we **strongly recommend using personal email IDs only**.
- Using your personal email ensures you receive all important election-related communications.

For any queries, please contact: **Election Officer**
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