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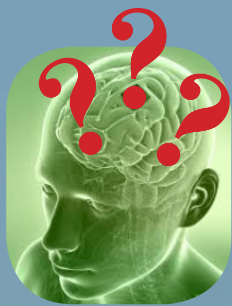
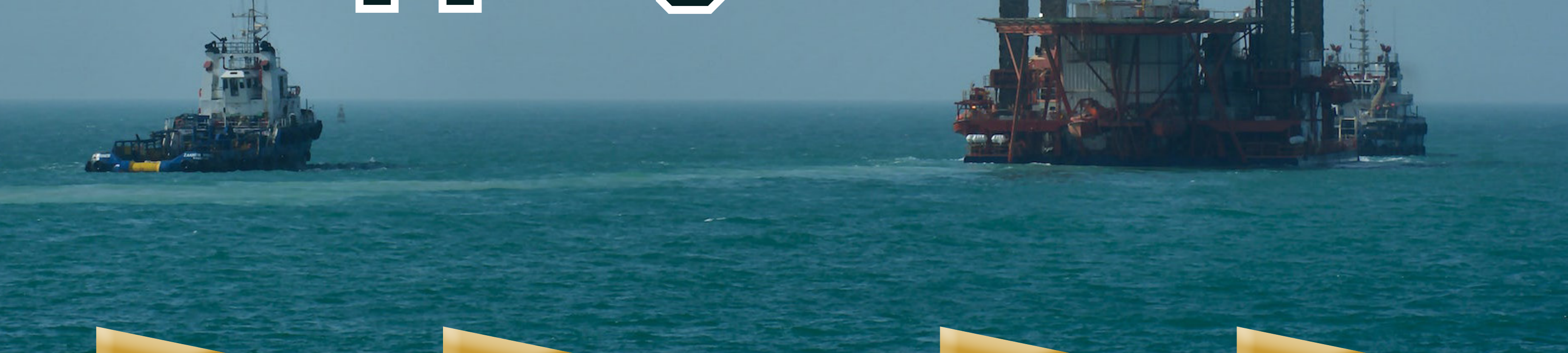


Sleep Debt & Shipping Incidents



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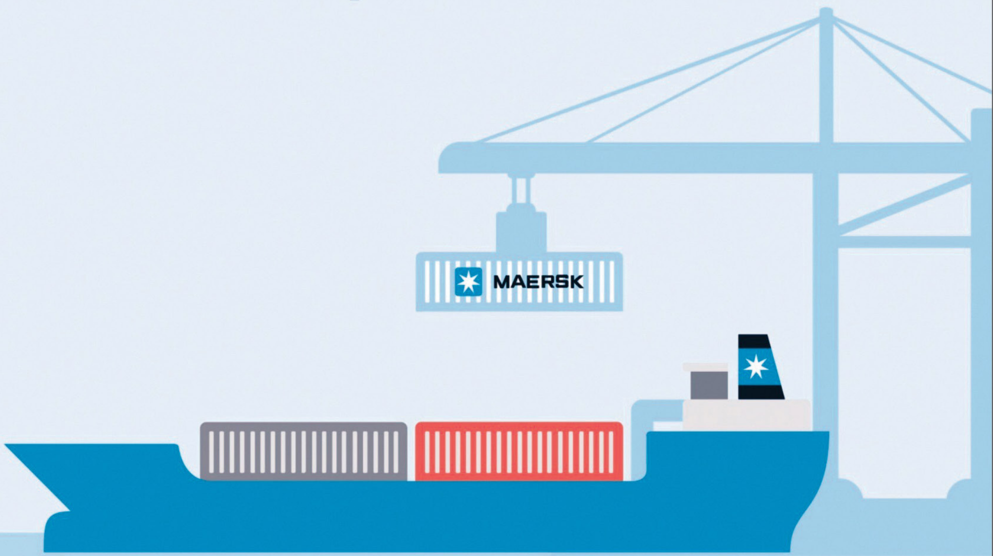

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EDITORIAL

Security is mostly a superstition. It does not exist in nature, nor do the children of men as a whole experience it. Avoiding danger is no safer in the long run than outright exposure. Life is either a daring adventure, or nothing.
- Helen Keller

Water drives today's geopolitics or rather we can call it the Canal Conundrums. The Panama and Suez are the action (or no action) theatres. In Suez, the waters are turning dangerous and in Panama, the waters have vanished.

The 82+ km Panama Canal is not fit for navigation purpose due to paucity of water resulting from dry conditions and drought. On an average, the Canal needs 200 million litres of fresh water for one vessel passage. Vessel standards have been derived for building ships to pass this water connector (Panamax etc.) but with the drying up of the feeder lakes, the number of transits and tonnage limits have been reduced. In about 100 years of its existence, this situation has no precedence. The increase in vessel volumes and the El Niño phenomenon are attributed to the crisis. The solutions sighted in practice are the land loops (Pacific/Atlantic) and the South slide through Cape Horn for about 290+ million long tons (based on WEF 2022) of cargo which otherwise passes through the Canal in a year. The situation could be termed as both nature-designed and man-made.

The Suez story relates to security and entirely man made. Spilling over from the conflicts, mainly Israel-Gaza and the Houthis' drone attacks, the region has become high-risk prone for operators and the insurers. Any gang which cannot shoot straight will also be able to muster trophies in the narrow, 20 mile wide Bab-el-Mandeb strip. Hostilities reign supreme in the Red Sea. From piracy (Somalis side is silent now, comparatively) to these precarious passages, commercial shipping is again pushed southwards towards Cape of Good Hope. Almost 12-15% of global trade passes through Suez and not to forget the crude oil (10% of global movements) and products. The rerouting option will increase the fuel costs for the ship owners/operators.

Tonne-mile factor impacts, P&I risk limitations, supply chain delays are bound to affect voyages towards generally headed destinations (US, Japan) and for big regular movers (Russia). India is not left out and has a greater vulnerability (about 15% of the global seafaring workforce being from India). The Indian Navy's engaging moves and the diplomatic dialogues might become routine in the given scenarios prevailing longer. Given knotty neighbours, needling geopolitical situations and domestic strife, India gets the best of outright exposure on risks and danger avoidance. And maritime security has become a daring adventure for India and its seamen.

In this issue...

Sunil Kumar Panda wakes us up with an interesting study on sleep debt being the cause of ship incidents. Statistical analyses are presented in support. Lack of sleep does result in work inefficiencies but there could be other contributing factors. Weather conditions and after midnight watch periods can be low-plucks for discussions, but data gives the muscle. This is an easily digestible read.

Following the sleep study, we have Dr. Veda continuing on the CO_2 sequestration. In this Part B, the need for primary studies is highlighted while progressively monitoring is proposed. Modelling the capture demands realistic considerations (e.g., water quality affects capture capacity). Dr. Veda wades through the relevant ocean experiments building up the significance. The experiments of gas release at varying depths present the case on the need for robust models. The Bay of Bengal scope and relevance is then established, followed by what needs to be done in the Indian waters. Another interesting knowledge sharing from Dr. Veda.

Ramesh Vantaram is back in the Spanner in the Works with a flash back from the rudder repair (MER November 2023) on what had caused the engine unresponsiveness, which resulted in the rudder damage.

The picks from the MER Archives (Feb 1984) are interesting as usual and the suggestions for improvements in ship designs is worth digging into the archives. Elstan Fernandez is in the Competency Corner, helping with trouble shooting of alternators. Under Heritage Hourglass, Janhavi Lokegaonkar presents a short juxtaposition of the old and new Vindhyagiri vessels of the Indian Navy. And in this issue, we take a pause on the lubrication discussions.

Hoping that the drones settle to silence, here is Feb Issue for your reading pleasure.

Dr Rajoo Balaji
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In This Issue

ARTICLES

COLUMNS

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SETTING SAIL INTO ACADEMIC EMINENCE!

Celebrating academic achievement!

Mr. Sanjeev Vakil, CEO of the HIMT Group of Institutes, was conferred a PhD by the esteemed Indian Maritime University (IMU) on October 27, 2023. Her Excellency, the Honorable President of India, Smt. Droupadi Murmu was the Chief guest for the graduation ceremony.

The event was graced by a host of distinguished guests, including Shri Sarbananda Sonowal, Union Minister for Ports, Shipping, and Waterways, and AYUSH, Shri. R.N. Ravi, the Hon'ble Governor of Tamil Nadu, Shri. Shripad Naik, the Hon'ble Union Minister of State for Ports, Shipping and Waterways, and Tourism, and Dr. K Ponmudy, the Hon'ble Minister for Higher Education, Government of Tamil Nadu.

Dr. Malini V. Shankar, Vice Chancellor of IMU, and Dr. Rajoo Balaji, the Pro Vice Chancellor of IMU presided over the ceremony, and many eminent personalities from the maritime industry witnessed such once in lifetime graduation ceremony, where in President of India was the chief guest.

Over a six-year journey marked by unwavering commitment, Mr. Sanjeev Vakil has not only steered HIMT to new heights but has also paralleled this with a scholarly pursuit that culminated in an outstanding academic feat. His seminal research titled "Maritime Education and Training of the Past, the Present, and for the Autonomous Ships of the Future", exemplifies an exceptional fusion of visionary leadership and scholarly innovation. This pivotal achievement underscores a voyage of growth for HIMT under his guidance, setting a benchmark in both educational excellence and professional maritime leadership.

A Study on Sleep Debt Influence on Vessel Incidents Happened in Indian Ocean

Sunil Kumar Panda

Abstract/Summary:

Sleep debt is a major inducer of fatigue. Sleep debt and fatigue are realised as factors for various incidents and accidents on vessels of different sizes. Very often aggravated by varying weather conditions mostly deteriorating, but occurs at any time means in any watch. These four variables such as sleep debt and fatigue, watch time of incidence, weather condition, and size (length) of the ship were subjected to statistical analysis. In some incidents, sleep debt with fatigue exists as one of the many prime reasons. In this study, it is tried to find out any relation, or association that exists among the variables and there found the relationships between them. The data used is the real-time maritime incident and accident data in the scope of the Indian Ocean area. A total of 1497 incidents were subjected to data refining, tapering down to 860 cases that were used for analysis purposes by using IBM SPSS. Sleep debt is associated with fatigue. Small vessels, night-time watches, and rough weather conditions increase the frequency of incident occurrence with an observed increase in sleep debt behaviour. A quantitative result was obtained that specifies the number of times the chance of occurrence of the incidence increases if the vessel possesses some variable parameter. For example, under certain specified conditions during night time watches the chance of incidence occurrence increases by 3.145 times more than the daytime watches.

Keywords: incident, sleep debt, fatigue, weather, vessel size, watch;

Introduction

The reduction of ships' crew numbers to the minimum number possible, alleviated the importance of the onboard crew's effectiveness and ability to perform their required tasks. There exists an acute demand for a ship to function at a specified level of readiness at any given point in time. Reduced performance of crews even from a small number of crew members may drop the overall operability of the ship and the safety of others on board raising the probability of an incident or mishap.

One of the major criteria for a reduced performance of the crew is deprivation of sleep or sleep debt which leads to fatigue. However, various other reasons also exist for fatigue. Ship's motion, unpredictable weather conditions, small vessels subjected to heavy weather conditions and many more are more or less responsible for sleep debt. It is a general acceptance that small vessels in rough weather cause sleeplessness and the watchkeeper is exhausted and stressed during night time watches. So there exists a link between the size of the ship, the weather conditions she is subjected to, the time of the watch, the influence of sleep debt, the result of fatigue, and the occurrence of an incident. In this study, it has tried to find any such relation that exists in the available data.

> *One of the major criteria for a reduced performance of the crew is deprivation of sleep or sleep debt which leads to fatigue*

Background

Seafaring is considered as the original 24-hour society (Filor, 1996). Watchkeeping is responsibly carried out by deck and engine department personnel as desired, where an officer along with a minimum of one crew will be present in a watch that continues for 4 hours. In large vessels, the concept of partially unattended machinery space changed the culture of 4 hours watch in the engine department. Apart from watchkeeping, the personnel have other duties.

Smaller vessels like fishing vessels, and inter-island vessels typically have a skipper and one or two deck persons, to carry out the watchkeeping activities. Sailing to and from port, cargo loading and unloading, fish trawling, cleaning, stowing etc., and related activities involve an extended period of work, resulting the sleep at anchor or any time of less potential for work.

The competent functionalities are performed on essential command, control and communication functions, navigational tasks, and maintenance responsibilities including preparation of food, and taking proper rest. Additionally, and more importantly, emergency situations have additional demand for proper response from the crew, competent work culture, and higher sensitivity.

On board a ship, each individual is responsible for a portion of the workload, and a reduced performance from even a small number of crew members may threaten the overall operability of the ship and safety of others. (Sanquist, T. *et.al*).

Sleep debt is commonly understood as "insufficient accumulated sleep over multiple consecutive 24-hour periods". Sleep debt will affect an individual's level of alertness and performance and in the long-term may lead to health problems. (IMO G/L, 2021). Sleep deprivation of watchkeepers, results, accruing substantial sleep debt and exhibit critical fatigue behaviour (Parker and Hubinger, 1998). Fatigue is a result of range of factors, with certain primary factors like: (IMO G/L, 2021)

1. lack of sleep, i.e. inadequate restorative sleep; Stress and fear induce lack of sleep;
2. poor quality of sleep and rest;
3. work/sleep at inappropriate times of the body clock (circadian rhythm);
4. staying awake for long periods;
5. and excessive workload (prolonged mental and/or physical exertion) resulting sleep disorders.

Again, not all sleep has the same quality or provides the same recuperative benefits, but to satisfy the human body's needs sleep must be effective with these three characteristics of quantity, quality, and continuity. Personal readiness affected by inadequate rest/sleep and lack of physical fitness are considered as personnel factors demonstrated as one of the pre-conditions of unsafe acts on board (Andrea, G. 2019).

Studies illustrate the effect of motion at sea on crew performance. Unpredictability of weather and subsequent motions are inherent to the sea going service. Hence the reduced crew size has generated a demand for a fully functional crew competent to their prescribed duties and responsibilities. This period of abnormal weather conditions and adverse ship motions, produces effect on the crew performance, fatigue, and motivation. The varying weather and sea conditions cause the crew to get exposed to a multitude of motions, hence physiological, biomechanical, and psychological responses generated and these quickly reduce the competent functionality of the crew during exposure times. These behavioural changes affect situational awareness temporarily or on a long-run basis. (Grech *et al.*)

Motion sickness is a common phenomenon to which crew is subjected, creating disturbances like imbalance in thought processes, higher energy expenditure for the same normal work, (K. Company, 2016) **increased levels of fatigue and drowsiness, performance implications from both biomechanical and physiological perspective, epigastric discomfort and stomach disorders as first symptom** (Benson, A. J. 1999), **followed by effects of nausea of increasing intensity, facial pallor due to the constriction of surface blood vessels and in some persons greenish tinge** (Griffin, M. J. 1990).

Australian seafarers' studies indicated that during duty, 31% of pilots had less than 4 hours of sleep per day and 65% had between 4-6hr instead of 7 to 8 hours of sleep per day when off duty. Rothblum, 2000, points out that work schedules which do not provide the individual with regular and sufficient sleep time produce fatigue. However, sleep debt is not the factor for fatigue,

> *Sleep debt is commonly understood as "insufficient accumulated sleep over multiple consecutive 24-hour periods"*

Support Transition to Zero-Emission

The shift toward a zero-emission society has accelerated in various fields, with governments making their GHG targets more ambitious and sustainable finance gaining more attention. Likewise, the time has come for the maritime industry to systematically manage the GHG emissions from shipping, as represented by the introduction of a GHG emissions evaluation framework into international shipping.

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Reports reveal that during the incidents, either the watchkeeper or the decision-making authority like the pilot or master, had been suffering from either sleep debt or fatigue or both

many other factors also exist. Quality of sleep can be as important as quantity in reducing fatigue.

Methodology

Scope of study

The study involves 860 incidents. The scope of the study includes incidents that have occurred and are reported in various forms in the coastal waters and high seas around the Indian subcontinent including the Indian Ocean, Bay of Bengal, Arabian Sea, Andaman Sea, and Laccadive Sea. These incidents spread over a period of 7 years from 2015 to 2022.

Data sampling frequency

Vessels involved in these incidents are of four different classes such as ocean-going vessels, vessels doing near coastal voyages, inter-island vessels, and restricted water vessels. The incidents involved are mentioned in **Table 01.**

Coding strategy

All 860 cases were analysed for variables such as external weather, watch timing, and the dimension

Table 01. Data frequencies for various categories

Incident type	Frequency	Percent
Accident (body), injury	26	3.0
List, flooding	21	2.4
Collision	249	29.0
Grounding	178	20.7
Machinery failure	100	11.6
Fire/explosion	149	17.3
Sinking	137	15.9
Total	860	100.0

of the vessel (length considered in this case) for the generation and influence of sleep debt and fatigue. Each factor has some categories and the frequency of each is demonstrated in **Table 02.**

Weather

The weather during the incident is classified into two categories. First is normal weather conditions include normal weather including slight swell conditions that do not require special extra care on board, while other is the abnormal condition, which are normally announced by the concerned officials and includes rough weather, heavy sea condition, low visibility, storm and cyclones and conditions that demand special care on board.

Length of the vessel

The dimensions of the vessels considered by their length are divided into two categories such as small and large vessels for convenience purposes as small vessels are less than 100 meters and others are large vessels equal to and more than 100 meters long demonstrated 'Length between perpendiculars (LBP)'.

Watch

Normally a watch on board is of 4 hours duration. However, around morning 0800 hours up to evening 2200 or 2300 hours, most of the compliments on board are in active state, carrying out their respective duty and most of the personnel found active. Whereas 0000 hrs midnight

Table 02 – Data frequencies for various categories

Weather	Frequency	Percent		Watch timing	Frequency	Percent
Normal	711	82.7		Sleep time night watch	394	45.8
Abnormal	149	17.3		Active time day watch	466	54.2
Total	860	100.0		Total	860	100.0
Length of vessel in mtrs	**Frequency**	**Percent**		**Sleep debt and fatigue**	**Frequency**	**Percent**
0 to less than 100 m	442	51.4		Found not exist	691	80.3
>=100 m	418	48.6		Exists	169	19.7
Total	860	100.0		Total	860	100.0

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to morning 0800 hrs regarded as rest hours, most of the ships only the watch-keepers are doing the duty. So here for analysis purposes 0800 to 2400 hrs are considered as 'Active time day watch (ATDW)' and 2400 to 0800 hrs are considered as 'Sleep time night watch (STNW)'.

Sleep debt and fatigue

Reports reveal that during the incidents, either the watchkeeper or the decision-making authority like the pilot or master, had been suffering from either sleep debt or fatigue or both. Sleep debt existence found in 119 cases, whereas fatigue was independently reported in 97 cases, and both were found existing in 47 cases. Hence any one condition or both exist in 169 cases **(Table 03).**

Objectives

The data is analysed to find any association among the different variables and also to find out the dependency of sleep debt and fatigue on any other variable.

Method

IBM SPSS software version 20 was used. The log-linear analysis is used to find out any significant association that exists among the variables. Later dependency among the factors was found using cross-tab analysis and determining the odds ratio.

RESULTS

Analysis of data

There are four variables in use, such as watch hours, length, weather, sleep debt and fatigue condition. The variables' correlation with each other was found very low, all below 0.1.

Fatigue existence due to sleep debt

The Cross-tab depicted by **Table 03** generates an odds ratio equal to 9.021389, indicating that under sleep debt conditions of the watchkeeper, the chance of getting fatigued increases by 9.021389 times than non-sleep debt conditions.

Log-linear analysis with a backward elimination method was used for these four variables to find the association. Step summary and convergence information showed that two interactions demonstrate a significant association, such as Watch *length of the vessel * sleep debt and fatigue; and Length * weather The frequency of incidents that happened for these interaction terms "Watch *length of the vessel * sleep debt and fatigue" and "Length * weather" is demonstrated in **Table 04 and Table 05.**

Table 03. Cross-tabulation of categories of sleep debt and fatigue.

Cases		Sleep debt		
		Not exist	Exist	Total
Fatigue	Not exist	691	72	763
	exist	50	47	97
	Total	741	119	860

Table 04. incident frequency distribution for interaction term "Watch *length of the vessel * sleep debt and fatigue"

Watch	Length	Sleep debt and fatigue	Frequency
0	0	0	209
1	0	0	144
0	1	0	203
1	1	0	135
0	0	1	14
1	0	1	51
0	1	1	40
1	1	1	64

Considering the first association "Watch *length of the vessel * sleep debt and fatigue", the overall odds ratio was found as 3.747. Hence, it can be inferred that during night watch periods, if the watchkeeper is under the influence of sleep debt, or fatigue, in smaller vessels (< 100 meters) then they are 3.747 times more prone towards the occurrence of incidents/accidents, in comparison to the other vessels during day time watches and where the watch keeper is free from any sleep debt or fatigue disorder.

Similarly, considering the second association "Length * weather", the overall odds ratio found as 2.457. Hence, smaller vessels during abnormal weather conditions are 2.457 times more prone to incidents than other vessels during normal weather conditions.

Watch time with incident type

The distribution of incident occurrence watch-wise, when the sleep debt/fatigue-laden watchkeeper was on duty, shows the highest occurrences during 0400 to 0800 watch, followed by 0000 to 0400 watch. Collision has the maximum frequency followed by grounding and then sinking cases. Active time day watch was found to have lower potency than the Sleep time night watch hours.

Watch time vulnerability with the influence of sleep debt and fatigue

Now both sleep debt and fatigue are combined and compared with incidents happened without the influence of sleep debt and fatigue. **Table 06** depicts the data.

Table 05. Incident frequency distribution for interaction term "Length * weather"

>=100m		Length	
		<100m	
Weather	Normal	372	339
	Abnormal	46	103

The odds ratio found to be maximum in 0400 to 0800 watch followed by 0000 to 0400 watch. Thereafter the data grouped as ATDW and STNW, depicted in **Table 07,** for cross-tab analysis.

Chi-square statistics of 41.883 (sig value = 0.000 which is less than 0.05) indicates that the Null hypothesis is not accepted. i.e. There is a significant association between two variables, they are watch timings (STNW and ATDW) with the existence of sleep debt and/ or fatigue.

The overall odds ratio found to be 3.144829417 indicates that during STNW incidents are 3.145 times more likely to happen if the watchkeeper suffers from sleep debt and/or fatigue, than the day active hours ATDW where the watchkeeper is not suffering from sleep debt.

The distribution of incident occurrence watch-wise, when the sleep debt/fatigue-laden watchkeeper was on duty, shows the highest occurrences during 0400 to 0800 watch, followed by 0000 to 0400 watch

The occurrence of incidents narrates that sleep debt and/or fatigue condition becomes influential over the watchkeepers. Probability of the influence that leads to incidents, is 2.519 times during STNW hours in comparison to the active day watch hours ATDW.

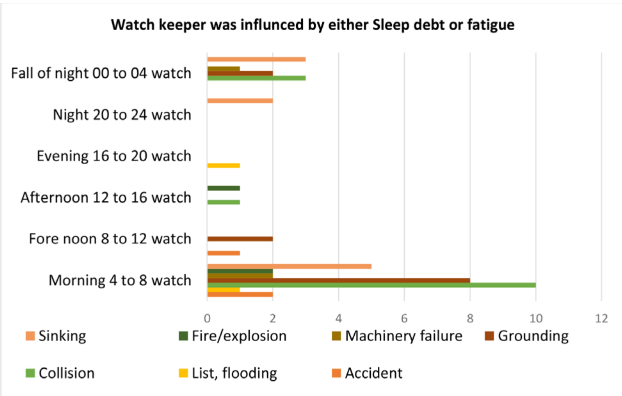

Figure 01. Different type of incident-occurrence in different watches when the watch keeper is influenced by either sleep debt or fatigue.

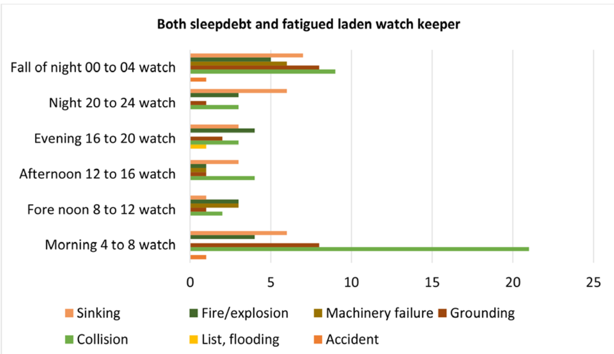

Figure 02. Different types of incident occurrence in different watches when the watchkeeper is influenced by both sleep debt and fatigue.

Weather and watch time

This normal weather condition which has the highest number of incidents and along with other weather conditions are verified with reference to the watch timing. Early morning 0400 to 0800 watch followed by 0000 to 0400 watch found with higher frequency of incidents in case of normal weather conditions, as well as during heavy weather conditions. Another important finding is that when the watchkeeper is suffering from sleep debt and fatigue during cyclonic and stormy conditions, higher number of incidents yielded during the 0400 to 0800 watch **(Figure 03 and Figure 04).**

Weather and accident type

Figure shows the comparison between two conditions of sleep debt and fatigue in reference to the weather. These are mainly grounding and sinking cases, mainly observed during heavy weather conditions **(Figure 05 and Figure 06).**

Table 07. Number of incidents reported during sleep hours and active hours when sleep debt and/or fatigue exists or not exist

	STNW	ATDW	
Sleep debt and/or fatigue	00 to 08 hrs	08 to 24 hrs	Total
Not	279	412	691
Exist	115	54	169
Total	394	466	860

Table 06. Watch wise number of incidents found with sleep debt an/or fatigue existing or not existing among active watchkeepers

Sleep debt and/or fatigue	Morning 4 to 8 watch	Fore noon 8 to 12 watch	Afternoon 12 to 16 watch	Evening 16 to 20 watch	Night 20 to 24 watch	Fall of night 00 to 04 watch	Total
Not	186	123	108	104	77	93	691
Exist	70	13	12	14	15	45	169
Odds ratio	1.919735	0.384824	0.412597	0.509801	0.776691	2.333507	

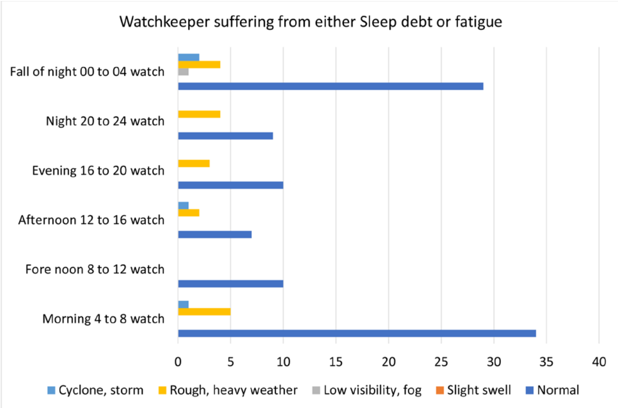

Figure 03. Number of incidents occurred in different watches in different weather conditions when the watch keeper is influenced by either sleep debt or fatigue.

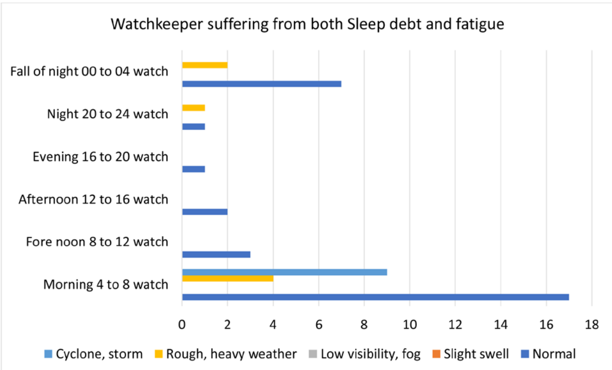

Figure 04. Number of incidents that occurred in different watches in different weather conditions when the watchkeeper is influenced by both sleep debt and fatigue.

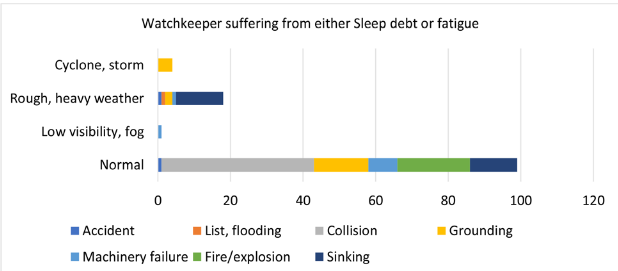

Figure 05. Different type of incident occurrence in different weather conditions when the watch keeper is influenced by either sleep debt or fatigue.

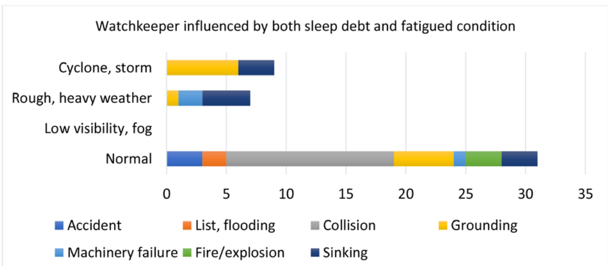

Figure 06. Different type of incident occurrence in different weather conditions when the watch keeper is influenced by both sleep debt and fatigue.

Weather with sleep debt and fatigue

The weather condition data was segregated into two groups normal weather conditions and abnormal weather conditions for cross-tab analysis as depicted in **Table 08.**

Chi-square statistics of 4.857 (sig value = 0.028 which is less than 0.05) indicates that the Null hypothesis is not accepted. i.e. there is a significant association between two variables, which means there exists an association between normal and abnormal weather conditions with the existence of sleep debt and fatigue conditions.

The overall odds ratio found to be 1.58478605 indicates that in heavy weather conditions causes the sleep debt and fatigue conditions and it has 1.585 times more probability towards the happening of incidents than in normal weather conditions. Also, when the weather becomes abnormal, sleep debt and fatigue conditions rise by 1.432 times more than in the case of normal weather conditions.

Length and the watch time

The length of the ship is taken as a representative for the size of the ship. **Figure 7** depicts that the number of accidents occurred is highest for the vessels 50 to 100 meters long followed by the vessels less than 50 meters, in both cases of either of sleep debt or fatigue present or both present. In any case, the incidents occurred during 0400 to 0800 hrs is the highest.

Table 08. Number of incidents observed in different weather conditions with the existence of sleep debt and fatigue

Sleep debt and fatigue \ Weather	Normal	Abnormal	Total
Not	581	110	691
Exist	130	39	169
Total	711	149	860

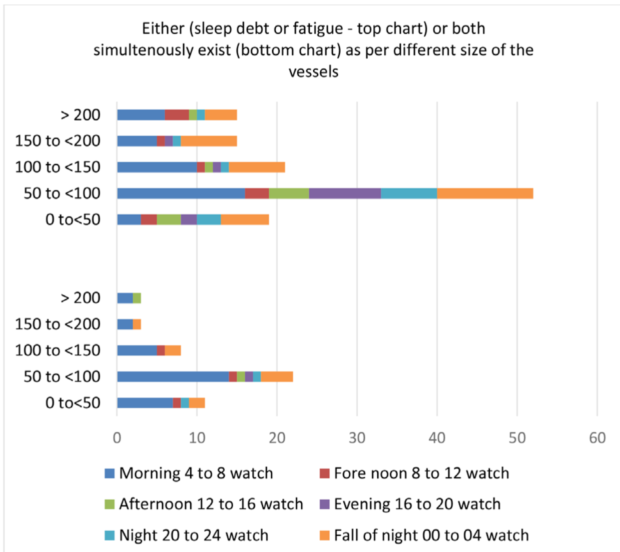

Figure 07. Number of incidents that occurred for different lengths of ships in different watches when the watch keeper is influenced by either sleep debt or fatigue (top set) and by both sleep debt and fatigue (bottom set).

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Length and the weather condition

This is a significant association as demonstrated by the Loglinear analysis. **Table 05** depicts the number of incidents, where the vessels were grouped into two categories of length less than 100 meters and the rest of all is the other category. **Figure 08** depicts the number of incidents weather-wise and lengthwise. In normal weather conditions, the incidents are highest. Again, in both cases of sleep debt and fatigue which may individually or jointly exist, the 50-meter to 100-meter length vessels have maximum incident cases followed by vessels below 50 mtr length. This is in all weather conditions.

Length with sleep debt and fatigue

Chi-square statistics of 8.663 (sig value = 0.003 which is less than 0.05) indicates that the Null hypothesis is not accepted. i.e. There is a significant association between two variables, sleep debt and fatigue condition with the length of the vessels.

The existence of sleep debt and fatigue condition leading to an incident, in this case, lower length (less than 100 m) vessels are 1.671 times more prone towards the occurrence of incidents than higher length vessels.

Analysis of incidents conferred that fatigue and sleep debt conditions found in smaller vessels are 1.513 times higher than that found in the larger vessels, during the occurrence of incidents.

Table 09. Number of incidents observed vessels of different lengths with the existence of sleep debt and fatigue

Sleep debt and fatigue	0 to <100	100 and above	Total
Not	338	353	691
Exist	104	65	169
Total	442	418	860

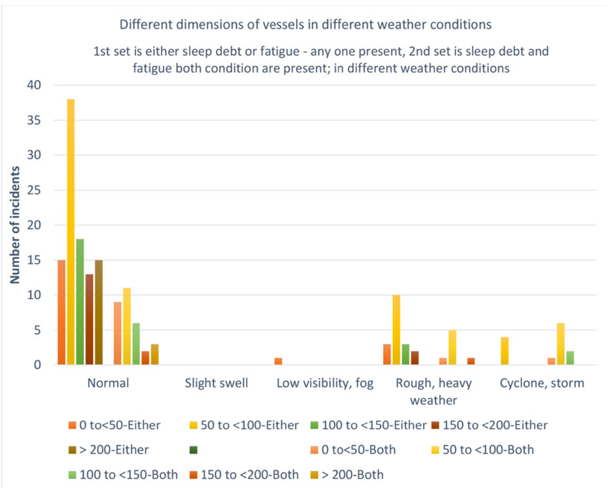

Figure 08. Number of incidents that occurred for different lengths of ships in different weather conditions when the watch keeper is influenced by either sleep debt or fatigue (first set) and by both sleep debt and fatigue (second set).

Conclusion

This analysis shows that the vessel incident reports are a rich source of descriptive data showing the association between sleep debt, and fatigue with the occurrence of incidents. Around nineteen per cent of reports reveal sleep debt and/ or fatigue contributing to the occurrence of incidents.

Sleep debt conditions in the night watch between midnight to morning times increase the chance of occurrence of incidents, same in the case of smaller vessels and also when the vessel is subjected to abnormal weather conditions. Similarly, smaller vessels in the night watch conditions are highly associated with incidence occurrence if the watchkeeper suffers from sleep debt and fatigue. Again, the smaller vessel in heavy weather conditions was found to have more contribution towards the occurrence of incidences.

The difference between fatigue and sleepiness is not uniform in the literature. It demands both qualitative and quantitative approaches. However, fatigue and sleep debt are closely associated due to disrupted circadian sleep patterns, extended job time, insufficient sleep and so on.

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Sunil Kumar Panda is an Associate Professor attached to the Kolkata Campus of Indian Maritime University. He has a MEO Class1 (Motor), B. Sc. Honours in Physics, B.E. in Marine Engineering (from MERI, Kolkata), M.S. in Manufacturing Management from BITS Pilani, and an M. E. in Mechanical Eng. His research interests include accident analysis of vessels and related systems and data analyses. He is a member of IME(I) [M 12494].

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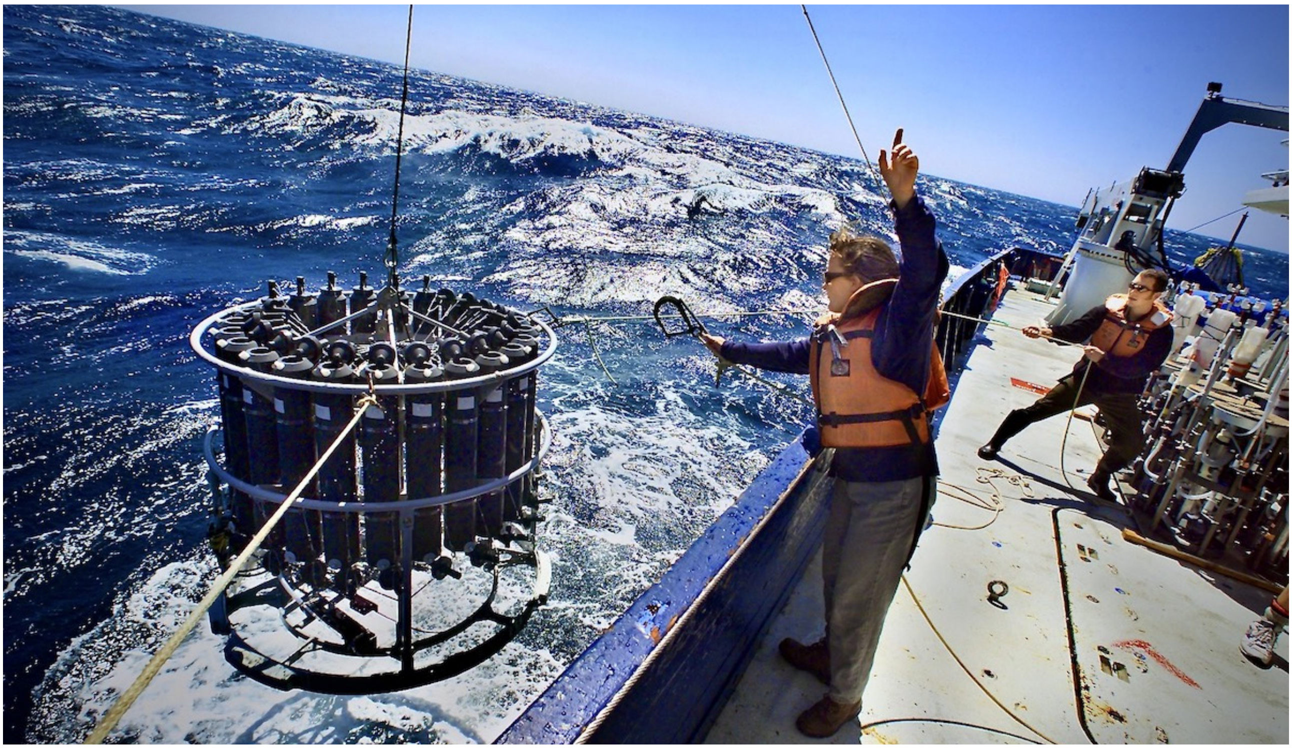
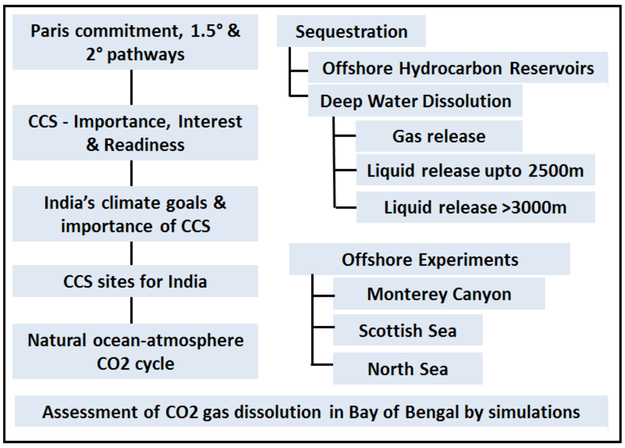
Importance of Ocean CO_2 Sequestration in India's Climate Goals and Assessment of CO_2 Gas Dissolution in the Bay of Bengal - Part B



N. Vedachalam

Abstract

Clean, sustainable, cost-effective and reliable energy supply is essential to meet the social, economic and environmental targets. Carbon Capture and Sequestration (CCS) technologies provides a near-term pathway to rapidly reduce the impacts of existing emissions-intensive infrastructure/processes, while zero-carbon alternative solutions mature. The first part of the series discussed on the global developments in CCS, its importance in the Indian energy sector, emerging scientific and technological trends in ocean CO_2 sequestration. This (second) part details on the outcome of the key offshore CO_2 release experiments conducted hitherto. The gaseous CO_2 dissolution when released at 1000m water depths in the Bay of Bengal is presented using NIOT-developed bubble dissolution modelling and simulation software. The details presented indicates the opportunities for CCS in India, need for carrying out site specific CO_2 release experiments and environmental impact assessment in support of national legislation and public acceptance of CCS.



Need for ocean CO_2 pre-sequestration experiments

Before CO_2 sequestration is carried out at larger/industrial scales, potential ecological consequences and adverse environmental impacts of any unintended CO_2 seepages need to be identified. **Currently, ocean CO_2 sequestration monitoring comprise of five stages including background (baseline) measurements, assessment of CO_2 storage performance in the reservoir, detection of leakage, quantification of leakage (if leakage is detected, suspected or alleged) and environmental impact assessment (EIA).** Numerical simulations, laboratory and field experiments are conducted globally for understanding the influence of CO_2 release into ocean

Before CO_2 sequestration is carried out at larger/ industrial scales, potential ecological consequences and adverse environmental impacts of any unintended CO_2 seepages need to be identified.

ecosystem and the possibilities of it getting vented into the atmosphere. Dispersion and dissolution of CO_2 bubbles in seawater are of special interest from the biological point of view, because of its importance in the changes of water quality. Field experiments provide increased understanding and validation of numerical models. Such tests were conducted in Monterey Canyon, Scottish Sea and North Sea. The experiments help to understand the chemical stability, lifetime of the clathrates exposed at the seafloor, dissolution rates of CO_2 hydrates within the nominal pressure-temperature (P-T) range of the hydrate stability zone, influence of variable flow velocity and under saturation of seawater with respect to the hydrate-forming species.

Ocean CO_2 release experiments and observations

Monterey Canyon experiments

During the Monterey Canyon experiments, four cylindrical test specimens of pure, polycrystalline CO_2 hydrate were grown and fully compacted in the laboratory, then transferred by pressure vessel to the ocean floor at 1028 m depth, monitored and recorded by cameras of Remotely Operated Vehicle (ROV) Ventanna. At the right in **Figure. 1** is the time-lapse camera system with the sample rack containing four hydrate samples. At the left is the open pressure vessel with release valve and a differential pressure gauge, secured by one of the ROV's two robotic arms. The other arm is just visible at the upper right. Video analysis showed CO_2 bubble diameter reduction rate between 0.94 and 1.20 µm/s, corresponding to a dissolution rates of 4.15± 0.5 mmol CO_2/m^2s. The observation helped to understand that dissolution process is diffusion-controlled [1].

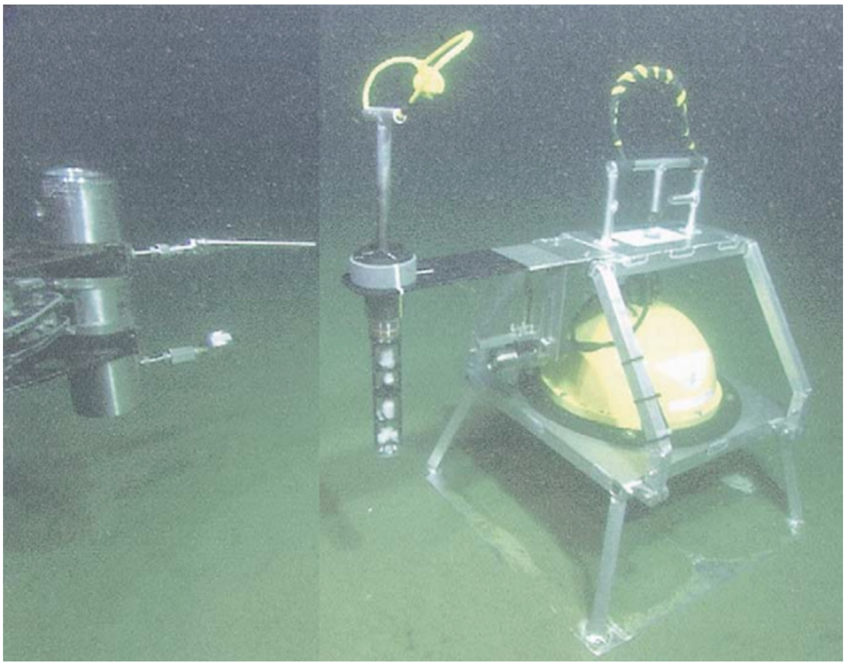


Figure 1. Experimental apparatus on the seafloor as recorded by the video camera on ROV Ventana [1]

QICS experiments in Scottish Sea

QICS is a scientific field research project involving an experiment in which CO_2 is injected into shallow marine sediments. The objectives of the project include development of monitoring and observation methods and generate experimental data to calibrate and develop models for predicting the change in pH or pCO_2 of the seawater in and above the sediments from leaked CO_2. The changes in pH (or pCO2) are vital data for the biogeochemical and ecological models in order to predict the impact of CO_2 leakages on the marine biological system in a variety of situations.

The CO_2 release experiment was carried out in the Scottish sea at Ardmucknish Bay by drilling a borehole 12 m deep underlying the sandy mud sediments **(Figure 2).** The dynamics of the CO_2 bubbles were captured using high-definition (HD) video system to investigate the rise of CO_2 bubbles in seawater. The images of the released CO_2 bubble plume rising in the seawater were captured from which the size and velocity of the ascending CO_2 bubbles were measured. It was found that most of the bubbles deform to non-spherical bubbles and the measured equivalent diameters of the CO_2 bubbles observed near the sea bed are in the range of 2-12 mm [2].

North Sea experiments

In order to understand the challenges in scaling up of present ocean sequestration, formulate regulations

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FOR MORE INFORMATION please email to **training@imare.in** or **contact on M: 8454847896** 022 2770 1664 & 27711663 for monitoring and verification at storage sites, and implement reliable monitoring strategies for detection and quantification of seepage of the stored carbon, the subsea CO_2 release experiment was performed in the north-western North Sea by the EU STEM– CCS project.

The experiment was carried out at the Golden eye site (58 ◦N, 0.4 ◦W) in the North Sea where a controlled mixture of CO_2 and tracer gases was released into the sediments at 3 m below the seafloor. The suitability of existing and new methods for the monitoring, detection and assessment of potential environmental impacts of the CO_2 release were demonstrated/ evaluated. Before the release experiment, the STEM–CCS project conducted a number of cruises around the Goldeneye site in order to establish environmental and ecological baselines [3].

Figure 3a shows the Benthic Lander equipped with the LOC sensors (white arrows) attached with inlets (red arrows) at 87 and 17 cm above the seafloor to monitor CO_2 plume in the benthic boundary layer. **Figure. 3b** shows the towed video-CTD water sampler rosette being deployed for continuous water sampling using an attached underwater pump and 1-inch tubing/hose.

Figure 2. CO_2 release experiment in the Ardmucknish Bay [2]

Physiochemical processes of CO_2 gas/liquid release

The behaviour of CO_2 released directly into the ocean water depends on the hydrostatic pressure (water depth) and the temperature of water. Three cases are presented including release at water depths <500m, 500-2500m and >2500m **(Figure. 4).**

Gas release < 500m

When gaseous CO_2 is released at ocean depths < 1000m, the released CO_2 gas bubbles would be less dense than the surrounding sea water and hence rises in the water column **(Figure. 4 & 5 b).** The CO_2 gas transport through the rising bubbles is governed by a combination of physical and chemical processes. As the gas bubbles rise through the water column, CO_2 exchange occurs between the bubble and the ambient seawater resulting in the dissolution of the CO_2. The solubility of the CO_2 gas in the water column is governed by the water temperature, surrounding fluid flow field and the trajectory oscillations experienced by the by the gas bubble during the vertical ascent. Predicting the dissolution pattern of the CO_2 gas bubbles released within the hydrate stability zone (HSZ) **(Figure. 5a)** is complex due the potential formation of the hydrate envelope, allowing CO_2 to reach relatively shallower depths.

The thermodynamic phase equilibrium curve of the hydrate and the water temperature profile for a typical marine setting is shown in **Figure. 5a.** To the left of the equilibrium curve, the gas is stable in the hydrate form. At the intersection of the two curves, is the level at which hydrate cover begins to dissociate. When a CO_2 gas

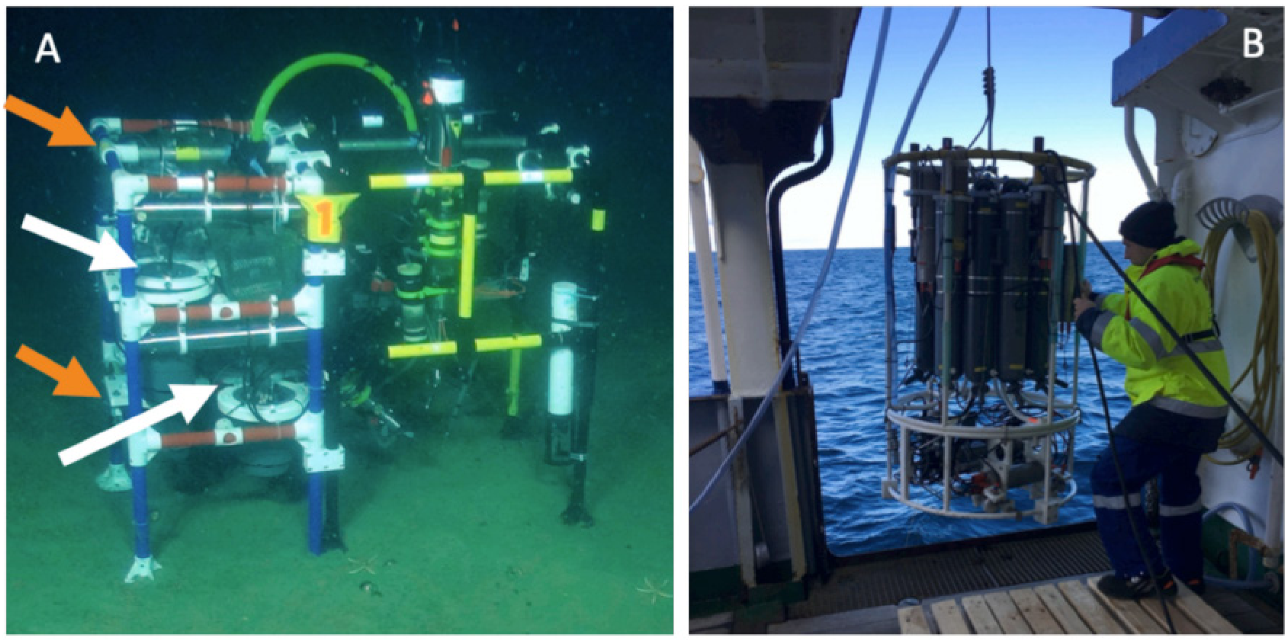

Figure 3. Benthic lander and water sampler used in STEM– CCS experiments in North Sea [3]

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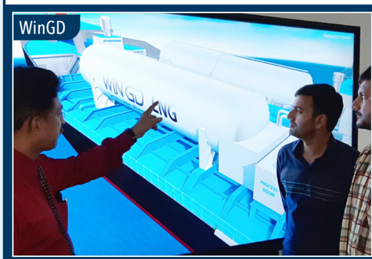

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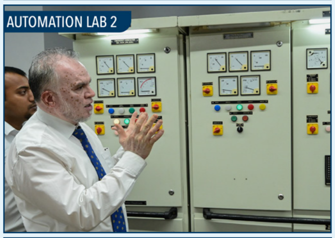

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Hence, precisely understanding and incorporating these physical and chemical processes involving dynamically changing ambient conditions into the bubble models are necessary to estimate the CO_2 transport up the ocean water column. It is important to understand the dissolution pattern of rising CO_2 bubble from the release point and effect of dissolving CO_2 in terms of dissolved oxygen for the sustainability of the biodiversity in the ocean environment.

When the CO_2 bubble passes through the HSZ, a hydrate envelope is formed in the gas-water interface by consuming the required CO_2 gas from the bubble. The kinetics of the hydrate envelope formation and the corresponding bubble gas consumption rate are based on the mass conservation and Clapeyron-Mendeleev state equation as detailed below.

$$\frac{dm}{dr} = 4\pi r \rho_{gh} \kappa$$

> *The behaviour of CO2 released directly into the ocean water depends on the hydrostatic pressure (water depth) and the temperature of water*

$$P_1\left(\frac{4}{3}\pi r^3\right) = \left(\frac{m}{\mu}\right) R_g T$$

Where m is the mass of free gas in the bubble , κ is the mass fraction of CO_2 in hydrate, ρ_{gh} is the density of CO_2 hydrate in g/cm^3, μ is the molar mass of CO_2 in g/mol, Rg is the universal gas constant in atm cm^3/mol °C , T is the thermodynamic temperature in °C, P_1 is the pressure inside the bubble in atm, r is the internal radius of the hydrate envelope of bubble in μm.

The reduction in the gas pressure P_1 inside the bubble with growth of hydrate envelope is defined by,

$$P_1 = A + (1 - A)/R^3$$

where A is the surface area of the bubble and R is gas constant.

During ascent, pressure reduction inside the enveloped bubble causes the bubble to shrink, while the

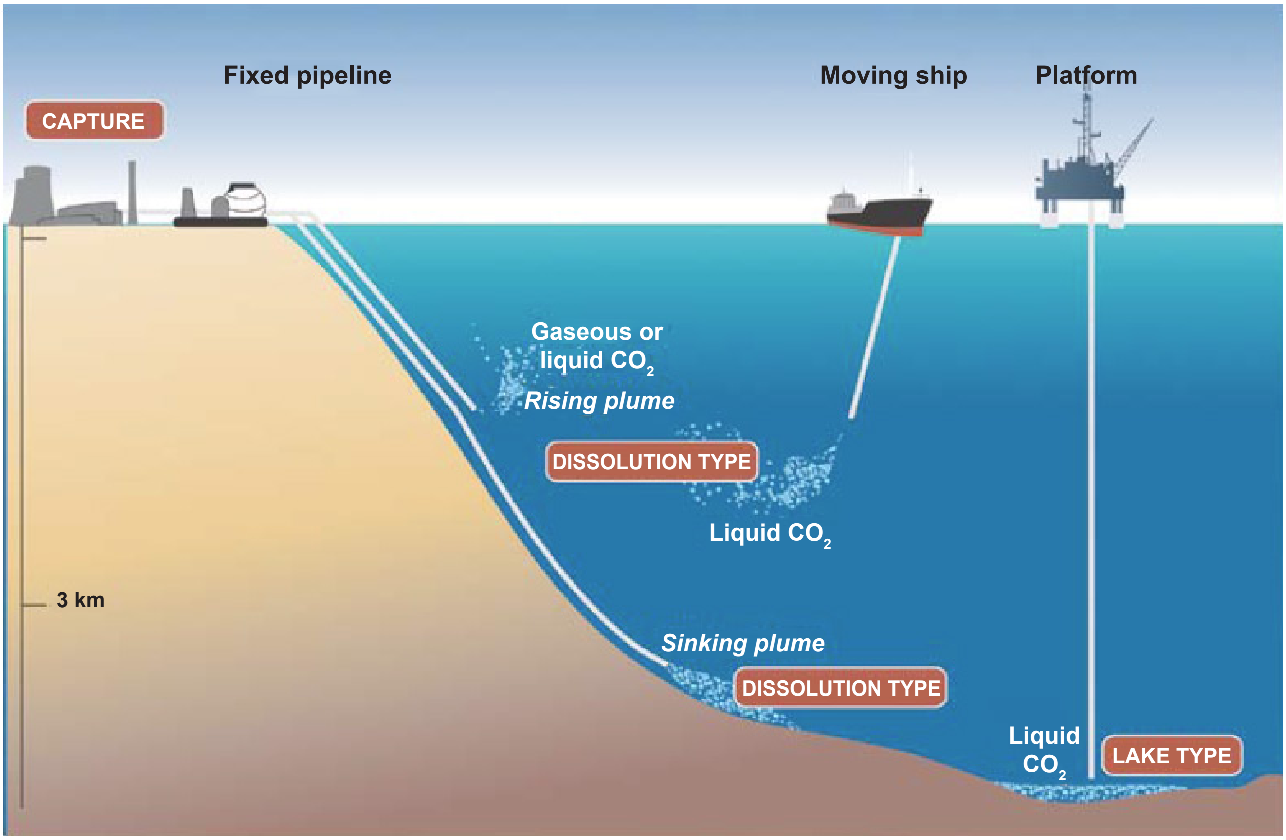

Figure 4. Gaseous/Liquid CO_2 released in various ocean depths [4]

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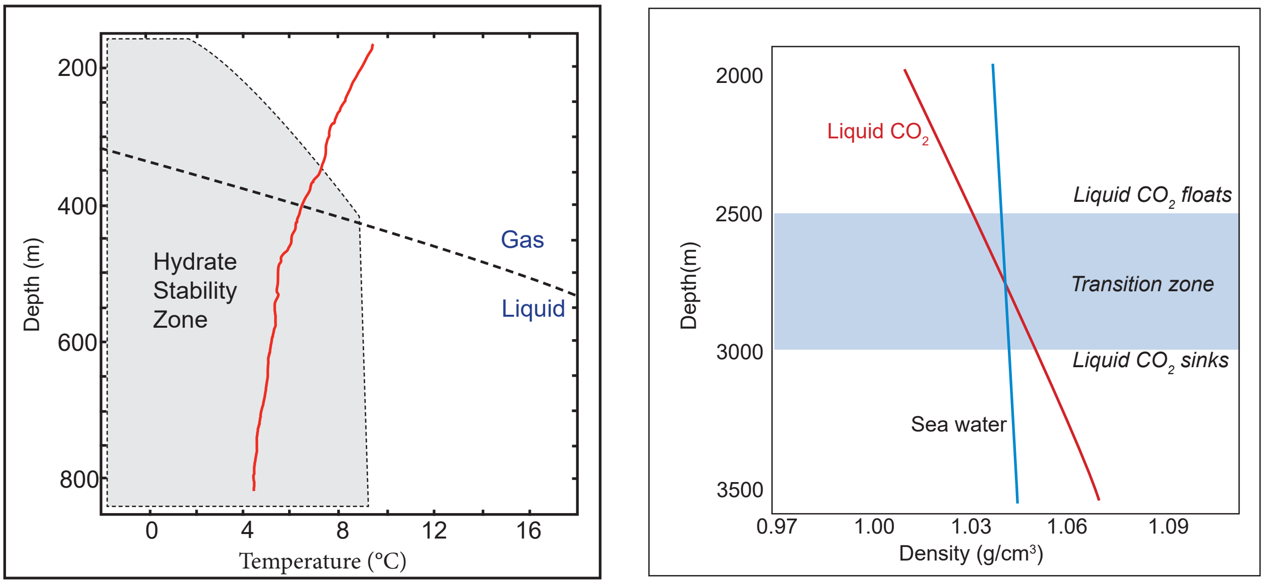

Figure 5. CO_2 hydrate stability zone & buoyancy at different depths [4]

continuously decreasing hydrostatic pressure allows the bubble to expand. Under such dynamic circumstances, if the stresses in the hydrate envelope surfaces exceed the compression/tensile strength of the hydrate material, the envelope develops micro cracks/channels which aid the water to get filtered into the bubble favouring new hydrate formation in the internal surface of the bubble **(Figure. 6).** The increasing envelope thickness due to hydrate formation and the geometrical constraints results in the shedding of hydrate flakes from the rear side of the bubble are important to understand the gas bubble dynamics.

Thus the net change in the bubble size during the ascent is the resultant of four key processes **(Figure. 7).**

Hence a realistic numerical propagation model for the CO_2 bubbles released at depths up to 2000m requires due consideration on twelve important physiochemical parameters indicated in **Figure. 7.** Hence, site specific studies are to be carried out to understand the dynamics. Bubble spatio-temporal dissolution models are developed by integrating the analysed complex process to avoid uncertainties. Small bubbles are carried over by the water current and cannot reach the surface by buoyancy and hence dissolve completely before reaching the surface.

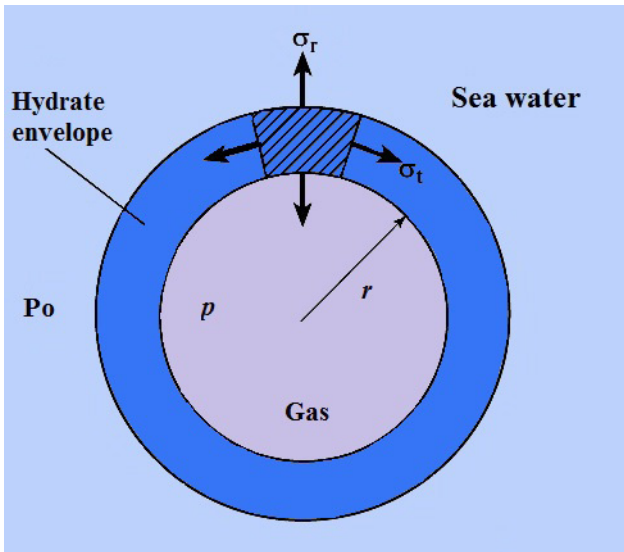

Figure 6. CO_2 gas bubble dissolution process

Liquid release 500-2500m

When CO_2 is released as a liquid below 500m water depths, it remains as a liquid. Above roughly 2500m depth CO_2 is less dense than sea water, so liquid CO_2 released shallower than 2500m would tend to rise towards the sea surface **(Figure. 5b).** Because most ocean water in this depth range is colder than 9°C, would tend to form a hydrate shell around individual liquid droplets. Under these conditions, 1 cm diameter droplet would rise ~400 m in 1 hour before dissolving (~3 μmol cm^2/s) completely, while 90% of its mass would be lost in the first 200m. When the remaining droplet reaches 500m water depth, it turns into a gas bubble. Thus at depths shallower than ~2500m, depending on the droplet size and hydrate skin thickness, the resulting plume would be positively buoyant and would rise while individual droplets slowly dissolve.

Liquid release > 3000m

At release depths >3000m, liquid CO_2 is denser than the surrounding sea water and hence sinks due to higher density, while at intermediate depths neutral buoyancy (isopycnal) spreading of the plume would occur **(Figure. 5a).** CO_2 release nozzles could be designed to produce large droplets that would sink to the sea floor or small droplets that would dissolve in the sea water before contacting the sea floor. Natural ocean mixing and droplet

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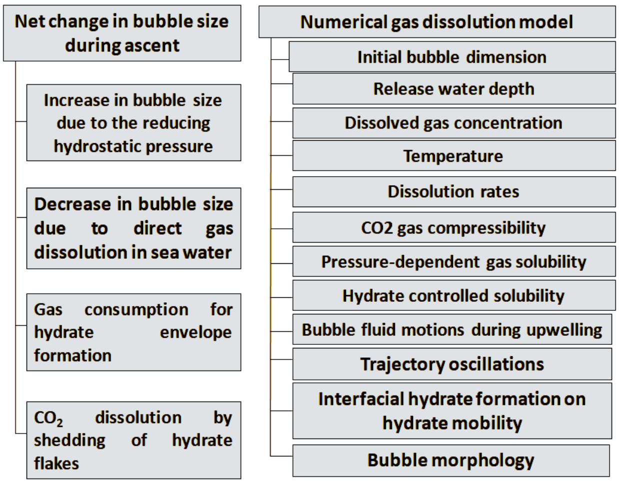


Figure 7. Key bubble size determinants and major parameters for gas dissolution model

motion helps prevent concentrations of dissolved CO_2 from approaching saturation, except near liquid CO_2 that has been intentionally placed in topographic depressions on the ocean floor. Hence the negative buoyancy of liquid CO2 below 3000m water depths provides the possibility of sequestering CO2 as a liquid lake in an ocean-floor depression or deep trough. Such a lake could be formed either by releasing liquid directly into a depression or by releasing negative-buoyancy droplets or hydrated particles sufficiently close to the bottom that a substantial proportion of the released liquid mass would reach bottom before complete dissolution.

Thus depending on the methods of release and local sea floor topography, the CO_2 stream could be engineered to dissolve in the ocean or sink to form a lake on the sea floor. The CO_2, dissolved in the sea water at high concentrations can form a dense plume or sinking current along an inclined sea floor. If release is at depths >3000m, CO_2 liquid will sink and could accumulate on the sea floor as a pool containing a mixture of liquid and hydrate. In the short-term, fixed or towed pipes appear to be the most viable methods for oceanic CO_2 release, relying on technology that is already commercially available.

Numerical modelling for assessing the dissolution pattern when CO_2 is released in Bay of Bengal

The architecture of the numerical CO_2 bubble dissolution model (BDM) developed using MATLAB software for determining the vertical dissolution pattern (VDP) of the CO_2 gas bubbles released at depths of ~1000m is shown in **Figure. 8 and 9.** The software is already used for assessing the impact of seafloor methane gas leaks with appropriate input data [5]. The bubble dimension block computes the radius of the released CO_2 gas bubble based on the water depth. The depth-temperature profile block is coded to incorporate the sea water temperature profile and the CO_2 hydrate phase boundary of the Bay of Bengal location **(Figure. 10).** The bubble ascent velocity model block computes the velocity of the bubbles of radius up to 10mm since most of the bubbles of bigger than this size are unstable [6]. The model is developed based on the literature reported laboratory observations carried out by releasing bubbles in saline medium and the below derived relationship in which the radius of the generated bubbles are found be in the range of 0.1 mm [7].

$$v = ae^{bx} + ce^{dx}$$

where, x is bubble radius, v is the ascent velocity and the constants, a= 216; b= 0.0012; c = -453; d=-2.31.

The bubble shrinkage block is coded on the basis of the bubble radius shrinkage rates (dissolution kinetics) reported during the Monterey Bay CO_2 release experiments done using ROV Ventana, where the bubble dissolution inside the HSZ is found to vary with a rate of change of radius of 0.94µm/s to 1.2µm/s, corresponding to dissolution rate of 4.15± 0.5 mmol CO_2/m^2 s [1].

The identified shrinkage rates with depth for the study locations are incorporated in the bubble shrinkage block. The CO_2 gas compressibility with water depth is incorporated in the model. The bubble hydrate envelope formation time of 224s, once the CO_2 bubble is released inside the HSZ as reported by the ROV and laboratory experiments are also incorporated in the shrinkage model. The BDM logic is based on the compressibility-corrected CO_2 gas equation PV= nRTz, where z is the depth-dependent compressibility of CO_2. When the gas bubble ascends from a depth Z_1 (with an ambient hydrostatic pressure P_1 containing n moles of gas and with volume V_1) to a depth Z_2 (with a relatively lower hydrostatic pressure P_2), the CO_2 flux out of the bubble (Δn) is computed based on the volume change (V_2)

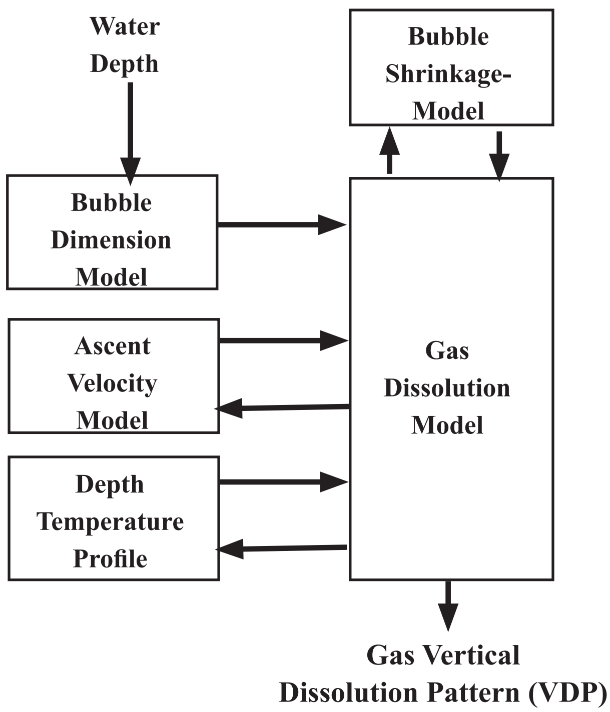


Figure 8. Architecture of the bubble dissolution model

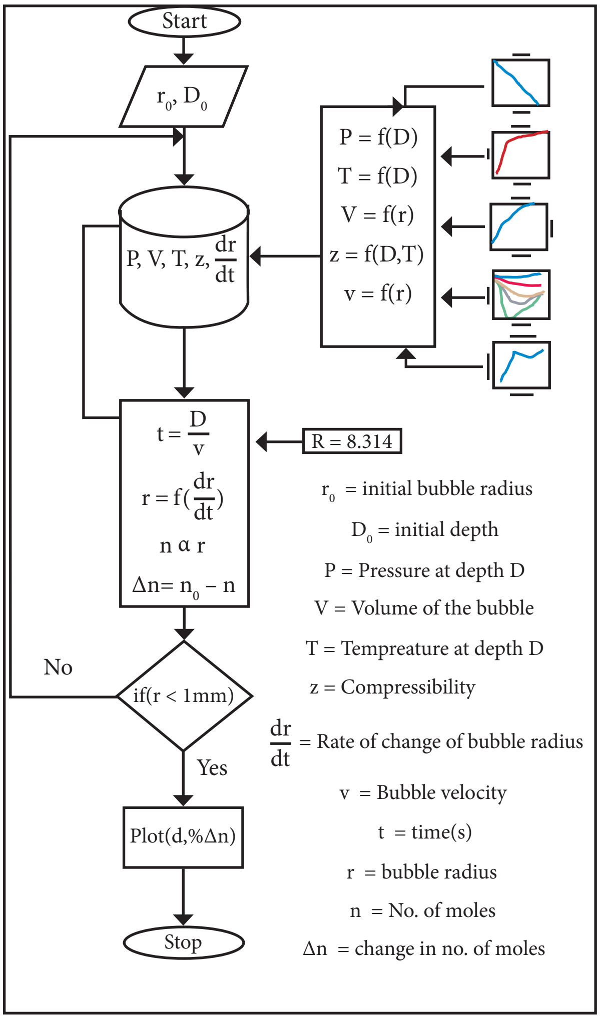


Figure 9. Bubble dissolution algorithm in MATLAB

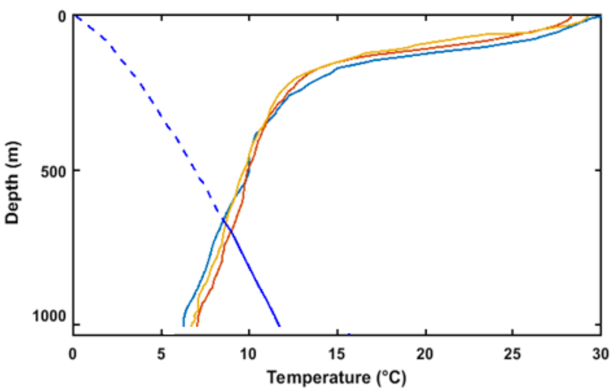


Figure 10. Water temperature profile in the Bay of Bengal [5]

obtained from the net radius reduction, compressibility and temperature corresponding to the depth Z_2. During the simulations, the BDM block dynamically queries and exchanges the parameters such as bubble velocity, shrinkage rate, temperature, pressure and compressibility with the respective blocks.

The BDM model simulation shows the results for the CO_2 gas bubbles of radius ranging from 4 to 10 mm released at a water depth of 1000 m **(Figure. 11).**

Results indicate that a bubble of 10 mm radius is capable of transporting CO_2 gas till 600 m (with its radius reduced till 1 mm). The bubbles of 4 mm radius are found to get dissolved within 22 m from the release point. It is also observed that an ascending 10 mm bubble dissolves 50% of the CO_2 flux (molar mass) within 200s from the time of release, while the rest of the flux gets dissolved gradually **(Figure. 12).**

The observed higher dissolution rates during the initial period is due to the hydrate free bubbles, while the hydrate envelope formed reduces the rate of dissolution during the rest of the ascent within the HSZ. The dissolution rates within the HSZ are found to increase with depth due to the increasing sea water temperature, as the diffusion is temperature dependent. As the bubble velocity decreases with the bubble radius, it takes a relatively longer time for disappearance. It is found that a bubble of 10 mm diameter could rise up to ~600m, respectively, from 1000m release depth, before its radius reduces to 1 mm.

Discussion and Conclusion

In order to meet the ambitious Paris targets, India needs to achieve a cumulative GHG emission reduction by 24 $GtCO_2$ in the energy sector till 2047. The recent pandemic and geo-political disturbances have set in various uncertainties in sustained funding required to achieve the targeted clean transition. Government need to tailor economic recovery programs to speed up the phase-out of fossil fuels and deploy renewable and increase the use of

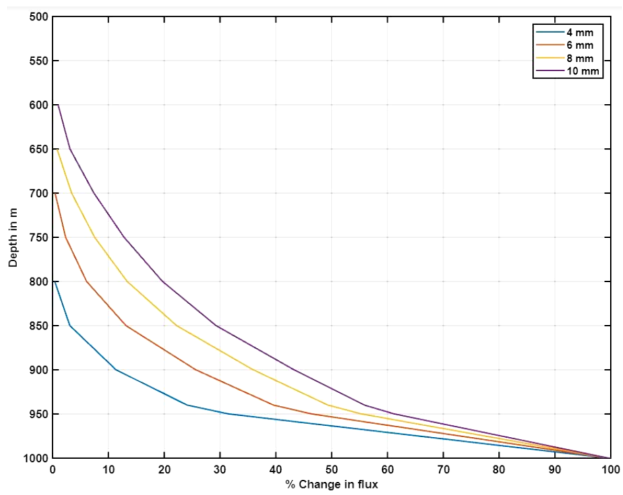
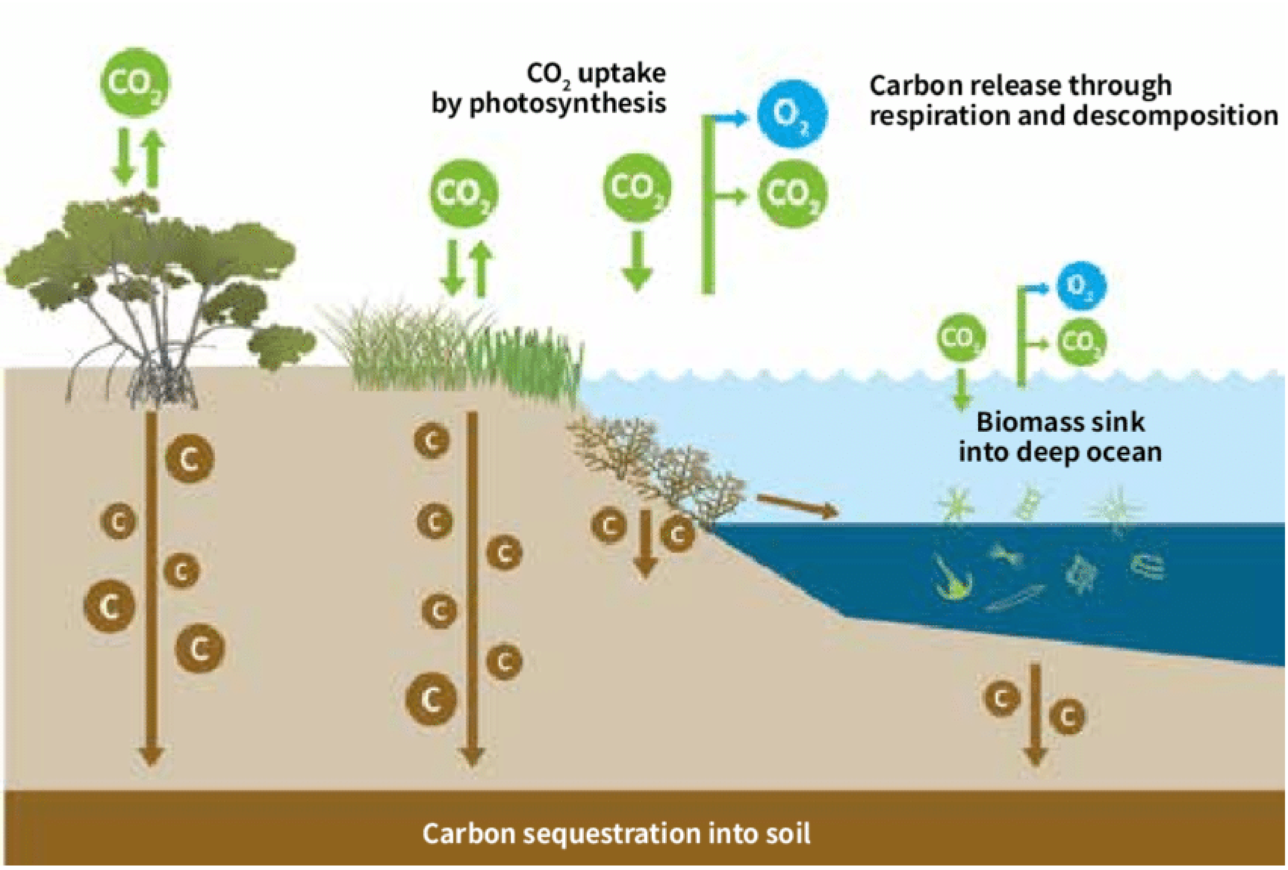


Figure 11. BDM simulation results in the BoB



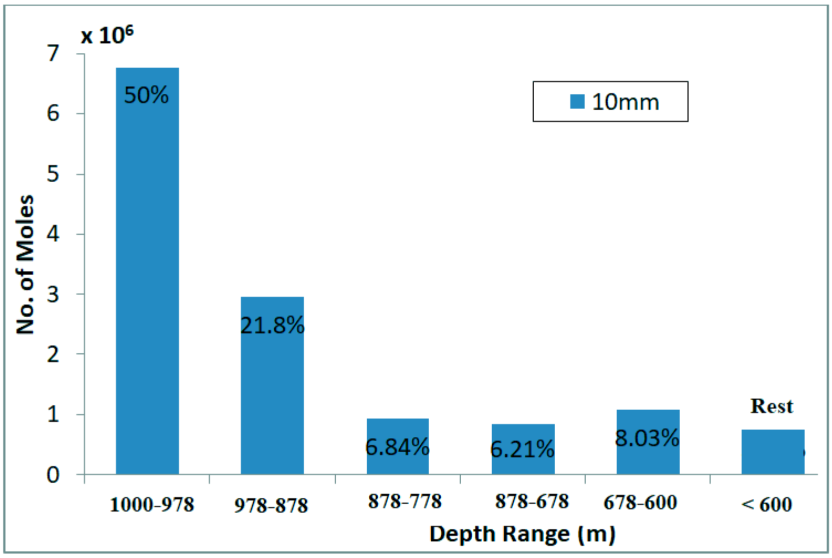


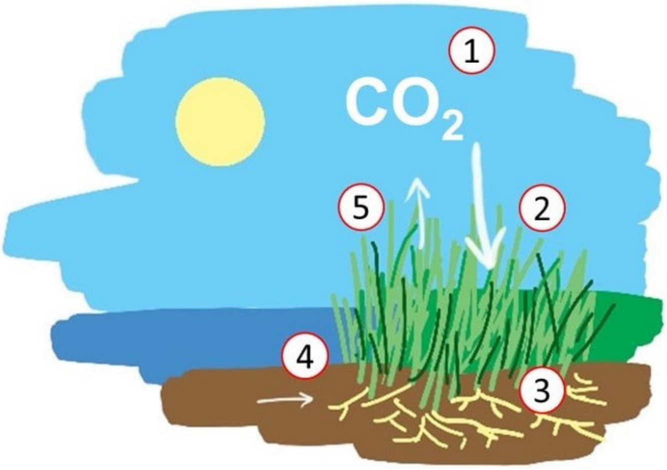
Figure 12. Bubble dissolution pattern for 10mm bubble

cleaner fuels. The efforts by the Government of India such as the clean environment tax on domestic coal production and coal imports may not be able to fully support the clean development targets. Globally, from the interest showed by high emission countries, it is understood that CCS technology could retrofit in the existing industrial and energy facilities and help to bridge the clean energy systems implementation delays. In India, the identified 105 Gt of CO_2 storage capacities in deep saline aquifers and 360 Gt in deep waters could offer significant and cost-effective CCS solutions for the fossil-fuel plants which are located in the coastal regions.

Despite its lower costs, onshore storage of CO_2 in geological structures has received public opposition owing to perceived health risks from leaks, effects on local geology, as well as a resistance to what may be seen as waste disposal, and hence many countries opt to investigate offshore storage. Research results also suggest that the probability of CO_2 leaks from offshore CCS schemes in shelf sea waters is low. If they do occur their spatial scale of impact is small, and the potential environmental impact is low. Even though, direct impact on local communities is not a principal concern for offshore CCS schemes, public perception should be considered when developing offshore CCS. Hence public acceptance of offshore CCS depends on the scientific evidence presented to the public and the trust they have in the regulatory bodies, and hence the need for national marine monitoring and management agencies to have a sound scientific understanding of the whole system related to offshore CCS.

Based on the return of experiences from offshore CCS projects, it is evident that the probability of leaks from

these geological storages, through faults or abandoned wells, is site dependent and can be minimised by the site selection process. Hence Indian national legislation with technical and environmental experts are to be formulated to evolve how much CO_2 may be needed to be sequestered in the oceans each year, appropriate CCS schemes, monitoring plans, assurance monitoring (surveillance for leaks), environmental impact monitoring (surveillance for environmental impact), post-closure monitoring, baseline data collection (prior to scheme commencing), environmental impact assessments (EIA), archiving and publication of monitoring and EIA reports and data.



ABBREVIATIONS

BDM	Bubble Dissolution Methodology
BoB	Bay of Bengal
CCS	Carbon Capture and Sequestration
CO_2	carbon dioxide
CTD	Conductivity-Temperature-Depth
EIA	Environmental Impact Assessment
EU	European Union
GHG	Greenhouse Gases
Gt	Giga Tons
HD	High definition
HSZ	Hydrate Stability Zone
LOC	Lab-on-chip
MATLAB	Matrix Laboratory
PCO_2	partial pressure of carbon dioxide
QICS	Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage
ROV	Remotely Operated Vehicle
STEMM	Strategies for Environmental Monitoring of Marine Carbon Capture and Storage

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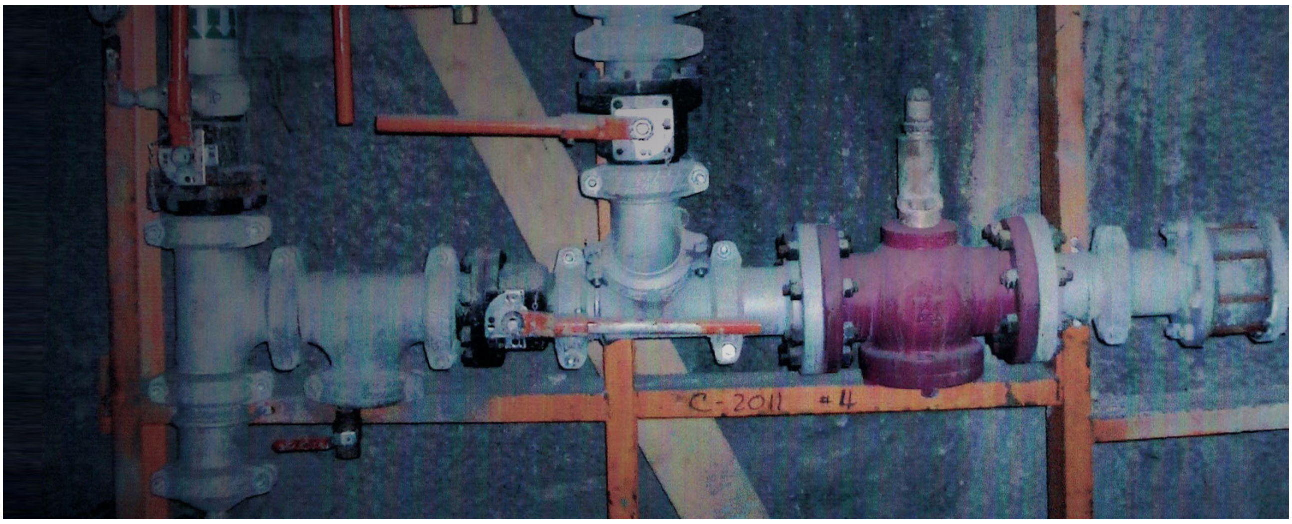
REDUCING VALVE FAILURE

(Ruptured Diaphragm causing Rudder damage)



Ramesh Vantaram

OVERVIEW:

The M.V. Chennai Polivu was scheduled to transit the Suez Canal on 28 April 1991 on the North bound convey. In preparation for the transit passage, at around 0745 hrs (LT) the main engine was satisfactorily tried out in both the Ahead and Astern directions. Standby was given at 0818 hours and the manoeuvring was being done from the engine control room. The first engine movement was Dead Slow Ahead at 0854 hours. From then on there were a number of movements until the engine was ordered to STOP at 1124 hours. All was well until then.

At 1142 hrs Slow Astern was the telegraph order. The engine failed to reverse. At engine room's request the engine was brought to STOP and the Slow Astern order was repeated. This time also the engine failed to respond. The camshaft reversal indication did not register in the ECR. The manoeuvring was immediately changed over to the Emergency Control Stand, so as to bypass large parts of the control system. Attempt to reverse the engine failed yet again.

Meanwhile the EOW noticed that Pressure gauge (120) that registers the pressure of the reverse supply air to the pressure intensifier (Posn. 110) was ZERO. The standby line was immediately pressed into service. The engine was reversed successfully and the situation was under control. The Engine had failed between 1142hrs and 1146 hrs. Thereafter manoeuvring was satisfactorily carried out as per Bridge request until 1348 hrs when Finished With Engine was ordered on the engine telegraph.

However during the 4 minutes when the engine was unresponsive, the vessel touched the banks of the canal resulting in spate of alarms emanating from the Steering system. The Bridge informed that vessel steered mid-ships when the rudder angle indicator showed 28° S! Yes there was indeed a huge crisis on hand! The engine failure and steering damage and the repair on the latter will be discussed as two separate issues.

The same 4 minutes (when engine was unresponsive), arguably, were instrumental in deciding my future career; taking up the job of a Classification Surveyor became a very interesting option.

DETAILED DESCRIPTION OF ENGINE FAILURE:

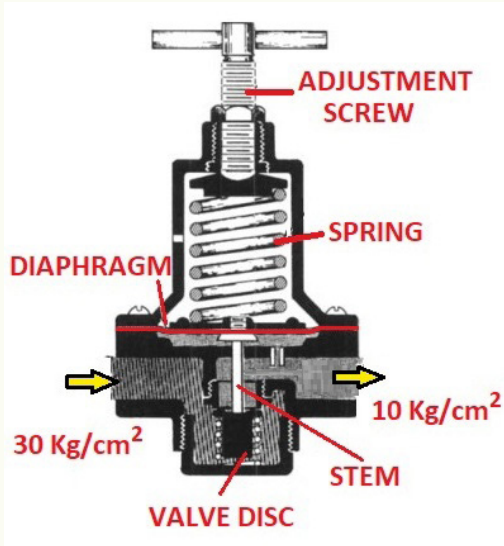
The schematic diagram shows the area of interest with regarding to the reversing process. AT the time of the failure, air from the air bottles at 30 kg/cm^2 was being admitted to the reversing supply line via valves 100-4; 97-2; 95-2 and 104-2. The EOW noticed the pressure gauge (120) was down to zero pressure, and immediately changed over to the standby line. Under normal circumstances, under all operating conditions be it STARTING, RUNNING or REVERSING in both AHEAD and ASTERN directions, air (9kg/cm^2 to 10kg/cm^2) is always available up to the control valves (91) or (92)

Depending on the direction of rotation, either valve (91) or (92) is activated thereby the reversing air passes through activated valve and becomes the control air to the pressure intensifier.

The same 4 minutes (when engine was unresponsive), arguably, were instrumental in deciding my future career; taking up the job of a Classification Surveyor became a very interesting option.

The spring-loaded pressure-reducing valve is commonly used in pneumatic systems. It is often referred to as a pressure regulator. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, the outlet pressure of the valve forces the diaphragm upward to shut the valve. When the outlet pressure drops below the set point of the valve, the spring pressure overcomes the outlet pressure and forces the valve stem downward, opening the valve.

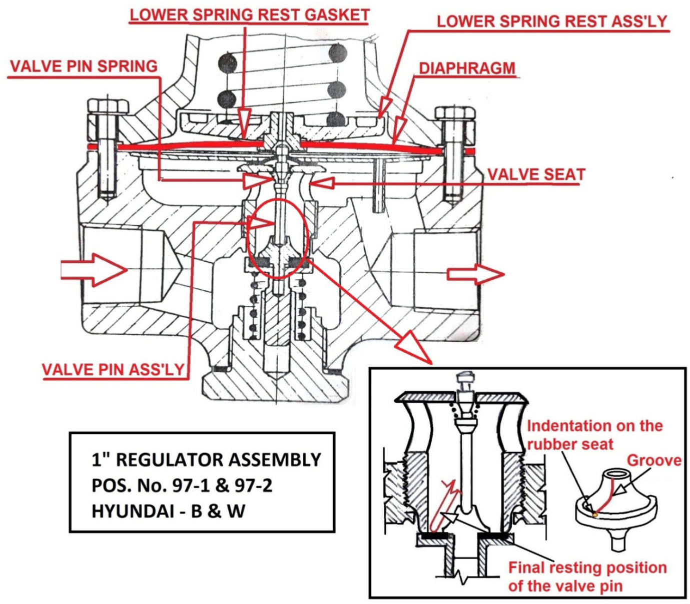
As the outlet pressure increases, approaching the desired pressure, the pressure under the diaphragm begins to overcome spring pressure, forcing the valve stem upward and closing the valve. Adjustment of the downstream pressure is brought about by turning the adjusting screw, which varies the spring pressure against the diaphragm. **This particular spring-loaded valve will fail in the open position if a diaphragm rupture occurs**.



After FWE, the pressure regulator valve (97-2) was dismantled and not only was it found that the diaphragm was ruptured; the valve pin was found on the side of the valve so the same was replaced and the reversing system was restored to normal. In view of the Suez transit no further thought was given.

The vessel anchored in the Bitter Lake and the Class Surveyor (Lloyd's Register) came on board. He had a diver take a look at the situation below water and the Report was alarming to say the least. The most obvious damages were that the upper pintle had ripped off the rudder and with helm order at mid-ships, the rudder was around 25° to 30° Starboard.

The vessel transited the rest of the Suez Canal with a 4-tug escort. Once out of the Suez, Steering trials were carried out and it was



Posn. No	Description of the Component
91	**2posn /3 way valve** – Feeds pressure intensifier (110) with air at 10/kg/cm² during AHEAD manoeuvre
92	**2posn /3 way valve** – Feeds pressure intensifier (110) with air at 10/kg/cm² during ASTERN manoeuvre
93	**2posn /3 way valve** – Air is blown off to the atmosphere through throttle valve (108) to ensure closure of the valve (93) when safety valve is closed
94	**Safety Valve** – Set to lift at 11 kg/cm², thereby activating valve (93)
95-1; 95-2	**Oiler**
97-1; 97-2	**Pilot operated pressure regulator -** Reduces air pressure from 30kg/cm² to 10kg/cm² for reversing
99-1; 99-2	**Shut off Valve** – For venting the air in the reversing system when the shut off valves (100-3) or (100-4) are closed
100-3;100-4 104-1; 104-2	**Shut-off valve** – For manually shutting off the starting air to reversing system
	Normal condition: 100-1 & 100-2 – **OPEN**; 200 **CLOSED**; Either 100-3 & 100-4 or 104-1 & 104-2 **OPEN**
	Finish with Engine : 100-1 & 200 **CLOSED;** Either 99-1 or 99-2 **OPEN**
108	**Throttle Valve** – For venting to atmosphere, the air for reversing to avoid closing of valve 93 when safety valve 94 is closed
110	**Pressure Intensifier** – Converts 10kg/cm² into 40kg/cm² hydraulic oil pressure. By means of this oil pressure the hydraulic motor reverses the camshaft from AHEAD position to ASTERN position and vice versa.
120	**Pressure Gauge.**

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Theme: AI and Machine Learning in Marine Sector

Participants: Engineering- Marine. Ocean, Subsea, Naval Architecture, Maritime Electrical and Electronics, Fire and Life Saving Engineering, Fuel and Lubrication Engineering, Defence Specialisations, Traditional and Specialisedpropulsion systems and allied Engineering, etc

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5. Authors shall solely be responsible for their papers for trueness of content.
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7. It will be the endeavour of the Organisers to allow all the papers for presentation at seminar. However due to paucity of time, some papers may not get chance for presentation. However all the accepted papers will be published.
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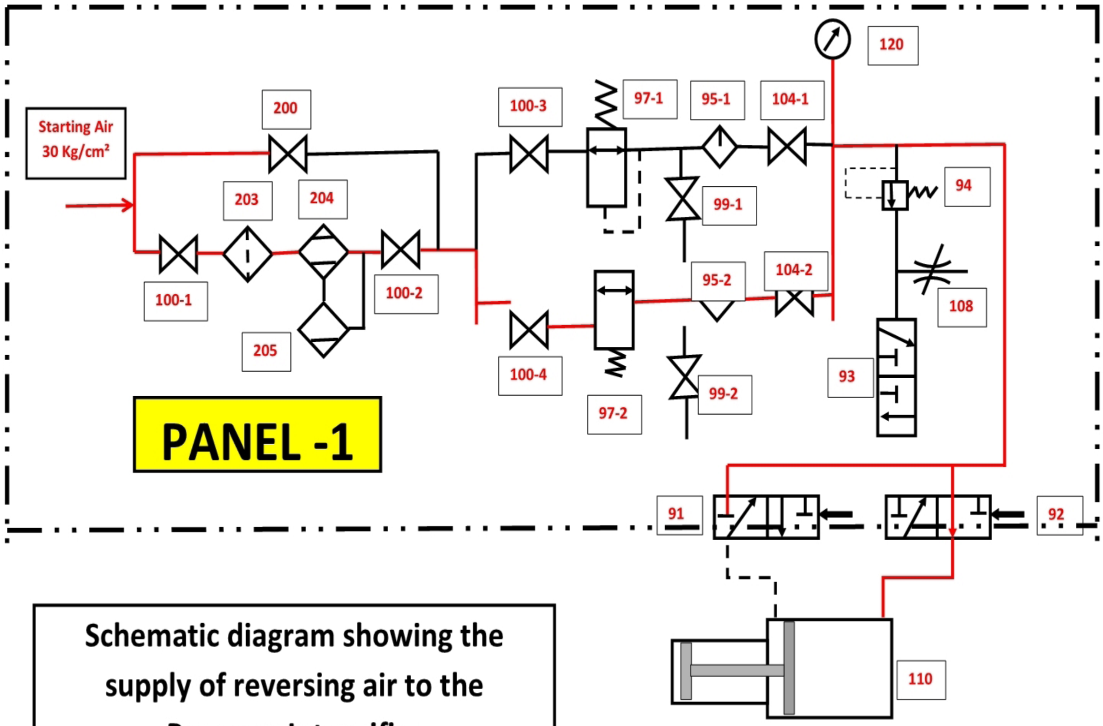


Schematic diagram showing the supply of reversing air to the Pressure Intensifier

decided that the vessel is not safe to sail with the steering in the present condition. After much deliberation it was decided that the best option was to proceed to Dunkirk and discharge the cargo, thereafter proceed to Antwerp Ship Repair NV for repairs.

With so much happening in such a short time, the pressure regulating valve was not matter of importance. It was only when the tow wire was rigged did the thoughts go back to the pressure regulating valve. First and foremost observation: the rupture of the diaphragm would not in any way restrict a passage of air downstream of the valve.

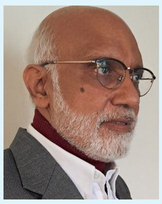
It was only now that the position in which the valve pin was found came into focus. After a closer inspection of the components following abnormalities/damages were observed:

- **Indentation on the rubber seat** of the pressure regulating valve
- **Reduction in the wall thickness** (squeezing) at the top of the valve
- A **groove on the side wall** of the valve that commenced where the wall thickness reduced and terminated at the indentation on the rubber seat.

The sequence of events was reconstructed based on the abnormalities observed. The diaphragm must have ruptured. The pressure downstream of the regulating valve would have dropped rapidly, cause the lower spring to open the valve and admit air downstream. The jerk on the pin would have been very rapid and somehow dislodge it from its position. Under spring pressure the pin traced a path on the side wall of the valve (groove) and came to rest on the rubber seat (indentation). The illustration below is self-explanatory.

[The discussion on the Rudder Repairs were published in MER November 2023 issue.]

About the author



Ramesh Vantaram is an alumnus of D.M.E.T. (1974-1978). The sea career started with The Shipping Corporation of India. After obtaining MEO Cl II certificate, he served with Hongkong-Borneo Shipping Company. After obtaining MEO Cl I certificate in 1983, he served with Anglo Eastern Management Services until 1987. Thereafter he was associated for 3 years with an FAO (UN) regional Project known as The Bay of Bengal Program. The objective of the project was to provide fisher-folk with a viable alternative to Outboard Motors on their FRP boats. The work-scope involved Prototype testing of power tiller engines and multiple propulsion systems.

He worked with Lloyd's Register of Shipping from April 1992 to June 2005 at Chennai, Ahmedabad and Marmagoa. Just before and soon after his stint with LRS, he served as Chief Engineer, with South India Shipping Company and United Ocean Ship Management Co.

In 2008, he joined Great Offshore as Head of Quality, Health Safety and Environment, in charge of the Company's International Safety Management and Integrated Management System Certification processes.

In 2014, he moved to Ocean Sparkle Limited as Senior Vice President and served as Regional Head of North West Region. In 2018, took over as Head of Quality in charge of the Company's Integrated Management System and Certification.

In February 2022, he retired from Ocean Sparkle Limited and took up part-time teaching. Currently he is a visiting faculty at the Institute of Marine Engineers (India) at Navi Mumbai. He regularly writes technical articles especially for student readers in iMélange.

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Troubleshooting of Alternators Part 2A

Elstan A. Fernandez

Abstract/Summary

This is the concluding part of the basics of troubleshooting Marine Electrical equipment, in a series of exclusive articles for MER that will attempt to highlight the various aspects of Maintenance and Troubleshooting of almost all commonly-used Electrical and Electronic Equipment onboard commercial ships. It is based on the current requirements of Marine Engineers and ETOs.

Key Points

- ✯ Reading Electrical Diagrams
- ✯ An Alternative (logical) approach to troubleshooting

Some of the key features to be determined from Blue Prints and Diagrams are:

- How should the circuit operate?
- What kind of features does the circuit have?
- What voltages should you expect at various points on the circuit?
- Where are the components physically located?
- How are the components wired together?

Introduction

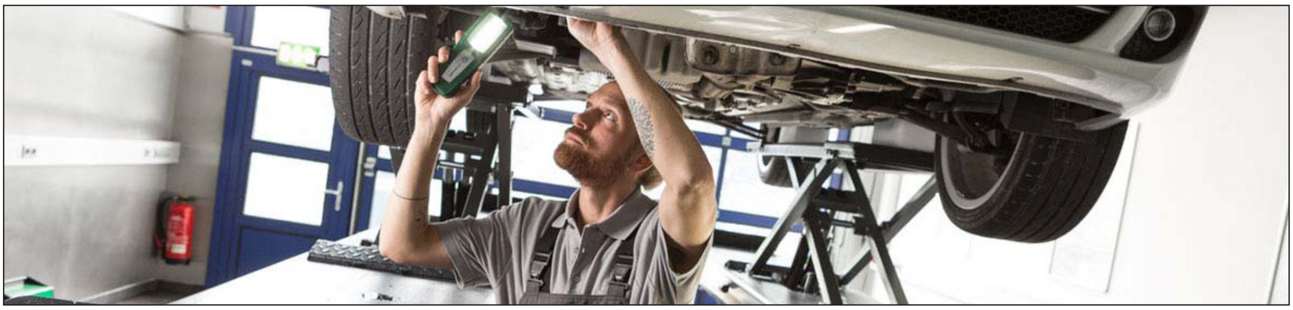
Troubleshooting of Alternators is published in three parts. Part 2A, presented in this article has tabulated information to help an engineer to quickly scan through and address related issues (that are mentioned in this article.

1. Troubleshooting an Alternator, its AVR and other Main Components

The AVR is Showing Signs of Faulty Operation		
Failure	**Possible Cause**	**Suggested Remedies**
Voltage does not build up	There is low remanence of magnetism.	Carryout flashing of the field / separate excitation while running, then permit self-excitation while running.
	The AVR's wires are disconnected.	Rectify the same
	There is a problem with the rectifier	Check the diodes
	There is a defective AVR card.	Change the AVR.
	The generator is defective	Refer to the manual onboard.

The AVR is Showing Signs of Faulty Operation

Failure	Possible Cause	Suggested Remedies
The voltage is low	Avr wires disconnected.	Check the AVR's connections.
	The generator is defective	Refer to the manual onboard
	There is a problem with the rectifier bridge.	Change the diode(s).
	The output is below the allowed Frequency.	Correct the engine's speed.
The voltage is high	The original AVR settings are Incorrect.	Adjust the voltage trimmer.
	The AVR wires are disconnected.	Check the AVR's connections.
	The AVR is defective.	Change the AVR.
The voltage is unstable.	There is a deviation from the original AVR settings	Adjust the stability trimmer.
	Variable running speed.	Correct the engine's speed.
	The AVR connections are wrong.	Check the AVR's terminals.
	The AVR is defective.	Change the AVR.
The voltage is lost while the generator is running	The generator is defective.	Refer to the generator manual.
	There is a defective rectifier.	Change defective parts.
	The AVR is defective.	Change the AVR.

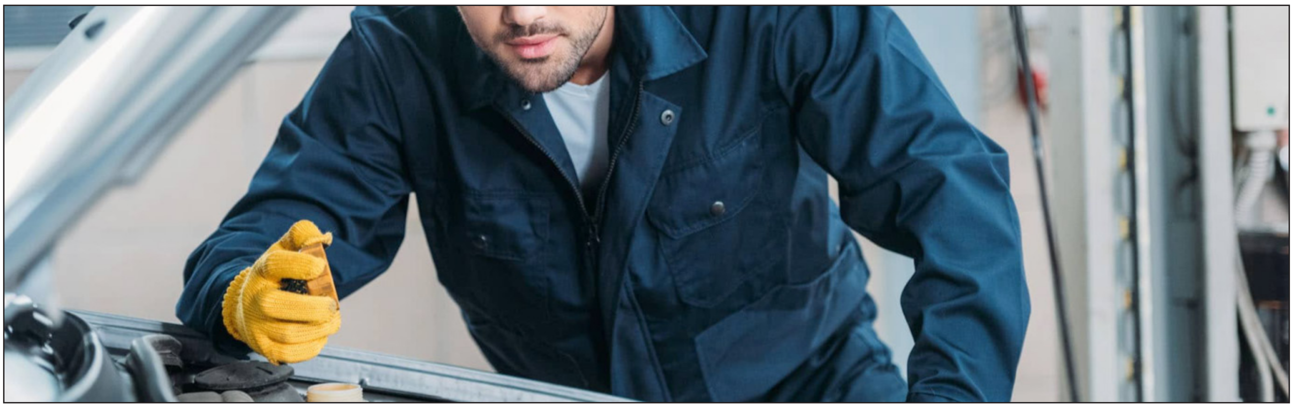


The Alternator Does Not Deliver Any Voltage Output

Symptoms	Probable Causes	Remedy
No voltage at the exciter's output	Exciter field resistance is too high or there is a loss of residual magnetism.	Cut out all exciter field regulator resistance and check excitation circuit connections. Re-excite the alternator as explained If the generator is equipped with a PMG, field flashing is not necessary -- check the regulators fuse and input power from the PMG.
The exciter gives full voltage but no current flows through the alternator field coils.	Open circuit in excitation circuit. Probably in leads or in the field regulator, rarely in field coils.	Carry out continuity test to confirm. Isolate and search for a break and repair.
The exciter gives excessive current when the alternator field circuit is closed	Short-circuit in excitation circuit probably between leads to field or alternator slip rings.	Locate the short-circuit and repair the same.
The stator of alternator shows correct voltage across one phase only. If it is a single-phase alternator, no voltage is available.	Break in one phase of the stator winding probably in external connections rarely in slot coils.	Locate the break by a continuity test. If it is accessible, repair it. If it is in the slot coil, get an expert armature winder on the job because the faulty coil must be removed and replaced.

The Alternator Does Not Deliver Any Voltage Output		
Symptoms	**Probable Causes**	**Remedy**
No voltage (on no load)	Voltmeter connected incorrectly, or faulty.	Check and verify voltage at the Generator terminals with a multimeter.
	Loose broken or corroded connections.	Check all auxiliary terminals. Check the AVR push on terminals for tightness. Repair or renew where necessary.
	Very low insulation resistance with respect to the earth (ground), on exciter stator or main stator.	Check the insulation resistance value with a Megger as explained in 8.1.2 of this chapter. (Disconnect AVR during this test, and remove any Neutral earth connection).
	Surge suppressor on main rotating rectifier short circuit.	Check the surge suppressor resistance
	Main rectifier diode(s) short circuit.	Check the diodes and replace them where necessary.
	Winding faulty. Open circuit or short circuit on any winding in the machine.	Carry out all tests as listed in this chapter Check winding resistance values.

The Alternator Does Not Deliver Any Voltage Output		
Symptoms	**Probable Causes**	**Remedy**
No voltage (on no load)	Exciter stator polarity reversed by battery tests. Also see “Loss of Residual Voltage” which may be caused by polarity reversal.	Re-connect battery to exciter stator ensuring that polarity is correct, and retest. Restore residual magnetism.
	Fault in the AVR.	Replace the AVR and re-test the machine.
	Load applied to the machine during the run up of the engine.	The voltage may not build up until the load is disconnected from the machine. Open the circuit breaker and re-test it. In ships this will be rare as we have a Voltage sensing relay and will not allow the breaker to close at < 95% Vnominal for example.
	Open circuit power supply from main stator to the AVR terminals.	Separately excite the machine. Check the voltage across AVR terminals P2, P3, P4, or 7 and 8. AVR power supply should be between 190 to 240 V AC.
One or more stator coils heat up when the alternator is excited.	One or more stator coils are short-circuited.	Locate and have defective coils replaced.
The stator phases show different voltage.	Some stator coils are connected in the wrong sequence probably after local repair.	Check stator winding for symmetry and re-connect any wrongly connected coils.



Low, High and Unstable Output on No Load and While the Generator is On Load		
Symptoms	**Probable Causes**	**Remedy**
Low Voltage (On no Load)	Engine speed low. Under frequency protection (UFRO) circuit activated.	Check the AVR LED. If it is lit, UFRO is activated, indicating low speed. Check speed with tachometer. Adjust governor control to nominal speed, or up to maximum (+4%) of nominal speed.
	AVR 'VOLTS' adjuster, or external hand trimmer control incorrectly set.	Adjust voltage on AVR 'volts' trim, or remote trimmer. Ensure that speed is correct, and UFRO is OFF. (See above).
	Voltmeter faulty or sticking.	Check and verify voltage across machine output terminals, with a Multimeter.
	Fault in the AVR.	Replace the AVR and re-test.
	Loose broken or corroded connections.	Check the wiring for poor connections. Repair or replace it where necessary.
Low Voltage (on no Load)	Fault on the power supply from the main stator.	See the previous test under "No voltage, at no load".
There is an abnormal voltage decrease	Short-circuit of the current transformer's secondary side	Repair or replace it.
	Short-circuit of the thyristor in the AVR	Replace the AVR.
	Out of control owing to the printed circuit board's failure	Replace the AVR.
	An abnormal temperature rise in the field of the main generator.	Decrease the load on the generator.
High Voltage (on no Load)	Sensing supply from the Main Stator to AVR is open circuited or too low.	Refer to article 8.1.11
	AVR 'VOLTS' control or hand trimmer incorrectly set.	Adjust it as necessary. Ensure that the engine speed is correct first.
	Sensing supply transformer faulty.	Check and establish AVR sensing supply circuit via dropper transformer, (4 or 6 wire Generators), or sensing PCB. Refer article 8.1.11
	Burden resistor, fitted in AVR sensing supply, is corroded or open circuited. (Pre 1987 Generators only.)	A fault on the burden resistor can create a high-voltage condition. Check the tapping bands. The normal resistance value 215 ohms.
	The AVR is faulty.	Replace the AVR and re-test it.
	Loose, broken or corroded connections.	Check the connections on the auxiliary terminal board and the AVR terminals. Repair or replace it if necessary.
	Unbalanced load.	Check voltages on all phases. If they are unbalanced, re-distribute the loading over three phases.
	Leading Power Factor load (capacitor banks).	Check the excitation voltage across X+, (F1) and XX- (F2). A leading power factor will give an abnormally LOW DC excitation. Remove the power factor correction equipment at low loads.
	Parallel droop current transformers reversed.	Check for droop reversal.
High Voltage (While on Load)	Burden resistor incorrectly set across improved regulation transformer. (Pre 1989 machines only).	Reduce the amount of resistance across the improved regulation transformer until on-load voltage is correct.

About the author

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Resilience and Self Reliance: A Tale of Two Vindhyagiris

Janhavi Lokegaonkar

'Old ships never die...their legacy remains' is an old adage used in maritime folklore. For the unversed, as per naval traditions, new ships that are commissioned are christened with the names of old ships that have accomplished exemplary achievements. Keeping up with this tradition, Vindhyagiri, an advanced stealth frigate under Project 17A was launched by the Honourable President of India Smt. Droupadi Murmu on 17 Aug 2023 at Garden Reach Shipbuilders and Engineers Limited, Kolkata.[1]

A follow-on of the Project 17 Shivalik class frigates, the new Vindhyagiri is the sixth ship of the Project 17A frigates.[2] A technologically advanced, state-of-the-art vessel, Vindhyagiri pays homage to the legacy of its predecessor- INS Vindhyagiri (F42). This article expounds the history and heritage of its namesake.

The old avatar, an advanced Leander class frigate, INS Vindhyagiri (F42) was commissioned into the Indian Navy on 08 July 1981 which was indigenously built at Mazagon Dock Limited, Mumbai.[3] The Nilgiri-class frigates served as the backbone of the Indian Navy during the 1980s and early 1990s. All the six vessels of this class including the old INS Vindhyagiri formed the 14th Frigate Squadron with INS Nilgiri as the lead ship of the class. It was the first improved Leander with the steam atomised-diesel burning system, which reduced the boiler refractory problems that had plagued earlier Leanders. INS Vindhyagiri also held another distinction. The ratio of imported to indigenous content of the ship was 30:70 as against the lead ship which had more than 70% imported content.[4]

The Nilgiri class vessels hold a special place of importance in naval architecture and engineering. Their legacy as our first indigenously built warships of their size and stature remains. The ships of the Nilgiri class were the first multi-role capable indigenous platforms wherein the Indian Navy got hands-on experience to build progressively better combatants on the same hull form. While INS Nilgiri- the lead class of the ship was a classic Leander frigate, by the time the sixth vessel i.e. INS Vindhyagiri was commissioned into service, it was an improved version of the Leanders.

The ratio of imported to indigenous content of the ship was 30:70 as against the lead ship which had more than 70% imported content

Figure 1. INS Vindhyagiri (F42)
Source: Indian Navy

The ship was named after the Vindhyagiri mountain range in Karnataka which symbolised stability and strength. And, it proved to be worthy of its name. Throughout its illustrious career service, INS Vindhyagiri played a vital role in numerous operations and deployments. 'Operation Flowers are Blooming was a landmark operation wherein INS Vindhyagiri was deployed to help avert a threatened coup against the President France-Albert René and government of Seychelles in 1986'.[5] The ship also played an important role in Operation Leech which was executed by the Indian Navy against drugs and gun traffickers in the Andaman Sea which enabled the capture of a number of militants and considerable quantities of weapons and ammunition.

'In terms of the ship's technological characteristics, it was modified with the addition of a Sea King (MK42 A) Anti-Submarine Warfare Helicopter and a range of updated naval armament which included the ILAS 324 mm Triple Torpedo Tubes and a BOFORS Anti-Submarine Warfare twin barrel mortar enabling the ship to undertake a wide spectrum of maritime operations.'[6] The Indian Navy completed these design modifications on its own, giving it the much-needed experience and confidence in ship design and modification.

Unfortunately, INS Vindhyagiri's glorious legacy at sea ended abruptly. On 30 Jan 2011, the ship met with an accident as it collided with MV Nord Lake at Mumbai harbour and caught fire. The ship's crew swiftly rescued all personnel and members onboard due to which no casualties were incurred. It took more than fifteen hours to control the fire after which it sank and hit the seabed alongside its berth in naval harbour. After incessant efforts, the vessel was recovered in June 2011 and was 'ceremoniously decommissioned with full honours on 11 June 2012'.[7] While this displayed the professionalism and solidarity in the Indian Navy towards the prized vessel that had relentlessly served the nation, it also called for improved safety protocols and improvement in the standard operating procedures to combat such exigencies in the future.

> *INS Vindhyagiri embodied the dedication and commitment of the Indian Navy to serve the nation and left an indelible mark in the annals of Indian Naval history, which shall be taken forward by its new avatar and create more milestones in its own right*

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Figure 2. Vindhyagiri being launched on 17 Aug 23
Source: Press Information Bureau, New Delhi

INS Vindhyagiri embodied the dedication and commitment of the Indian Navy to serve the nation and left an indelible mark in the annals of Indian Naval history, which shall be taken forward by its new avatar and create more milestones in its own right. The launch and subsequent commissioning of the new Vindhyagiri- which is indigenously designed and built is a nod to the Make-in-India initiative and proves India's mettle in warship building. Under Project 17A programme, the innovation and vision of the Indian Navy's Warship Design Bureau combined with the construction and technological prowess extended by Mazagon Dock Limited and Garden Reach Shipbuilders and Engineers Limited is a testament to the indigenous capabilities that promote self-reliance in the shipbuilding sector.

The new generation Vindhyagiri will be equipped with advanced weaponry, cutting-edge sensors, and state-of-the-art operations system. It has a displacement of 6670 tonnes, a length of 149 meters, and a beam of 17.8 meters and will be propelled by a CODOG combination of two Gas Turbines and two main diesel engines which are designed to achieve a speed in excess of 28 knots.[8]

The Indian Navy's *Aatmanirbharta* in the maritime domain is an affirmation of the progress it has made in building a resolute naval force which is also a testament to its sea power capabilities. Upon its launch, Vindhyagiri is presently undergoing extensive sea trials and will be handed over to the Indian Navy after which it will be formally commissioned into the Indian Naval Fleet in service of the nation.

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About the author

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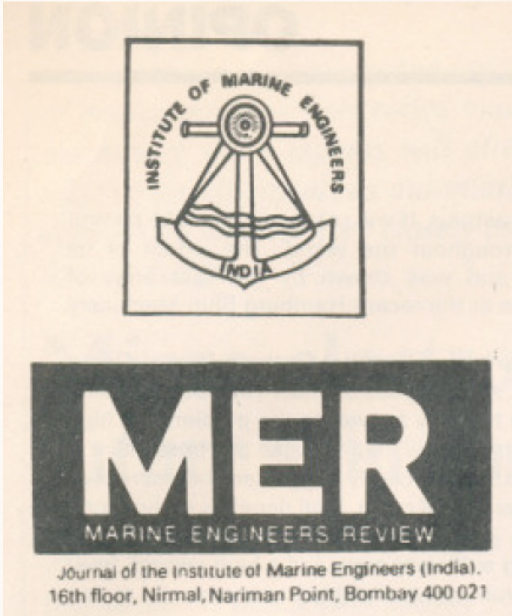
Going Astern into MER Archives...



The February 1984 issue starts with the lament on the state of shipping and laid up tonnage. The Editorial urges the Government to step in with measures. That was the period when recession was pulling the trough deeper and interestingly many companies turned to 'asset monetisation' by scrapping tonnage. Ship managers of those times may enlighten further on what the shipping companies did to stem the rot.

The next focus is on Port State Control and countries achieving 25% targets (inspection of ships in their waters). Following this is an interesting write-up on the state of seafarer training. More to come by in the March 1984, it observes, from an IMarE Conference, which is to follow. Will take up the conversation in March 2024 issue while we dig up the March 1984 issue.

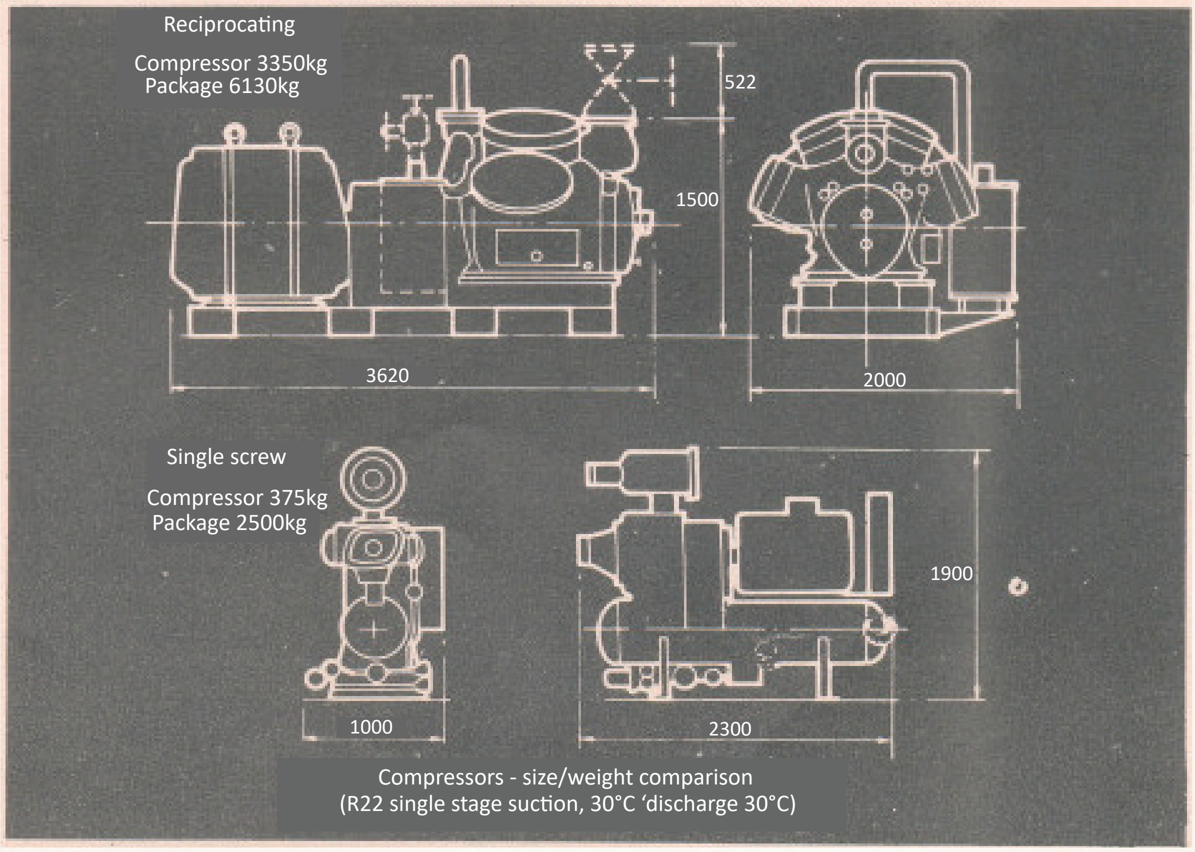
The first technical article is an informative one on reefer ships and the marine refrigerating compressors. The descriptions cover fishing reefer spaces and arrangements. Fish apart, fruits are also included in the cargoes (50% of refrigerated cargoes are fruit, it observes). The importance of air refreshing due to the carbon di oxide and ethylene generation from the ageing fruits is discussed. The comparison of screw type compressors with piston ones is interesting. (See few extracted figures of compressor comparison, vertical air ducts and module coolers in cargo holds).

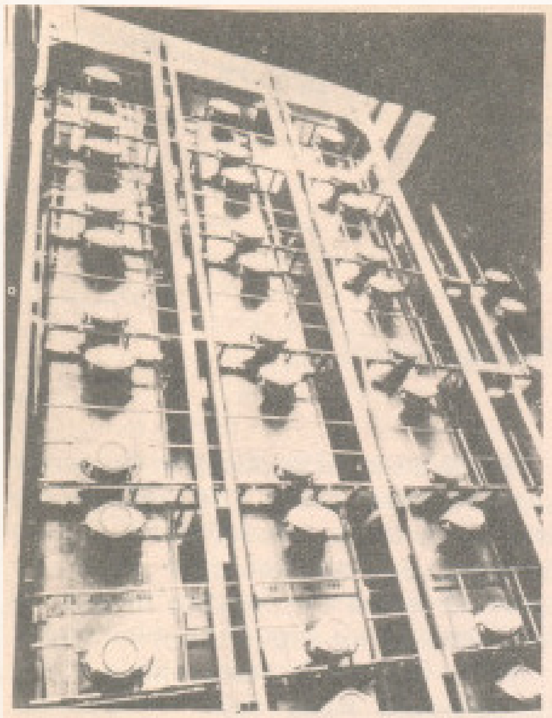
In line with the topic, the following one is on reefer containers.

From refrigeration, the issue stays topically cool with short write-ups on air conditioners and HVAC systems. The modular arrangements, insulation and the variable volume concepts make these interesting reads.

This is followed by vane wheel arrangement on propellers to capture the wake field energies. Then there is one on HFO usage with maintenance cost projections etc. This could be one of interest to many Superintendents. Other technical briefs include waste heat recoveries, offshore hook-up, RO plant (treating 1500t of SW/day) etc.

Fig 2: Comparison (size and weight) of reciprocating and single-screw compressors.





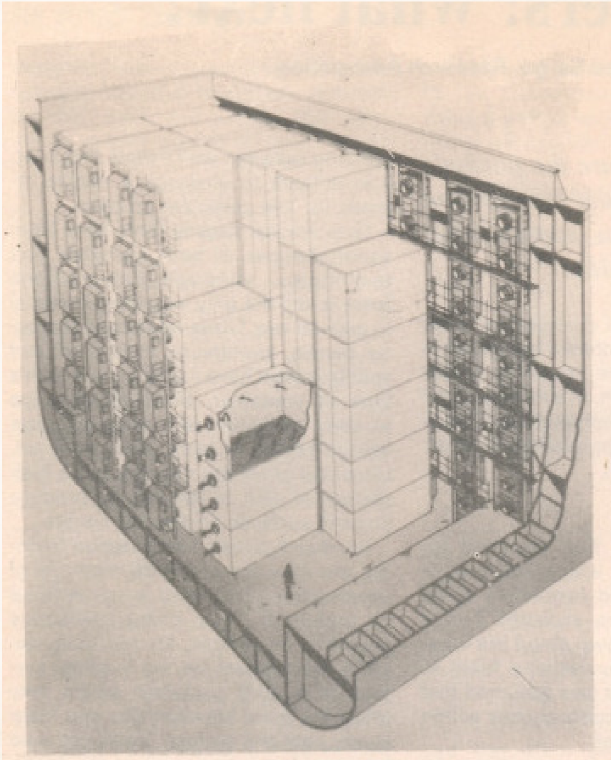


Fig 3: Vertical air ducts.

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One which drew our attention was the report on a survey pertaining to ship design (pg. 31/ scan page 33). The survey amongst shipboard personnel had drawn comments on a number of ship operations: valve design (SD globe valve instead of butterfly) to avoid oil surges during COW, providing two lines for inerting on board product tankers, better scrubber designs, flame arrestor inadequacies, manifold crossover lines to be placed higher than main lines (for easier drainage), location of fire extinguishers/remote control units, narrow alleyways preventing movement of FFE etc. This one is recommended as an easy read.

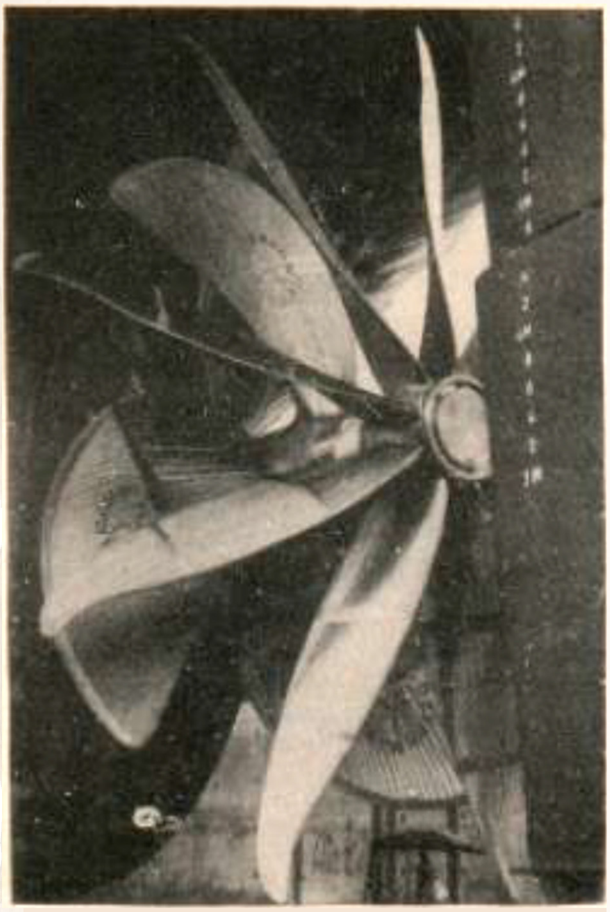

Fig 1: Appearance of the vane wheel.

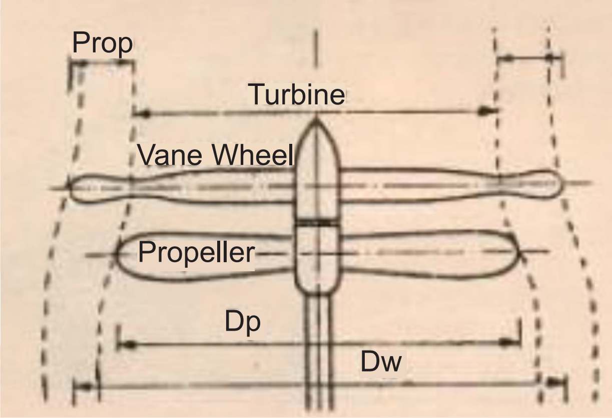

Fig 2: Wheel and propeller wakes.

Survey of sea farers highlights inadequacies in ship design

Designing a ship to achieve every conceivable objective is virtually impossible but there are many, and often minor, details that could easily be designed to achieve improvements in the seafarers' workload and safety. To try and find ways to improve the quality of design from the seafarers' point of view, the Nautical Institute has conducted a survey amongst ships' staff and analysed the results. The problems and solutions are contained in a report, from which the following is abstracted.

With regard to crude oil washing, damage can be caused to equipment when oil surges occur due to butterfly valves being either fully open or closed. The remedy would be to site individual supply valves close to the washing main to allow free drainage direct to the tanks of as much of the supply oil as possible, on completion of COW. Screw-down globe valves which allow power control should be fitted instead of butterfly valves, and indicators should be fitted to show their position.

For inerting, some ships are fitted with only one line. Fitting a minimum of two lines for products tankers and the fitting of purge lines at the top and bottom for inerting and gas freeing on gas carriers, is suggested. IG scrubbers should be better designed.

Fears were expressed regarding flame arrestors, in that the 'heat sink' on the majority of tanker flame arrestors was not adequate enough to prevent flames passing through. Further research should be conducted into this.

Inaccessibility of piping was a common criticism. Therefore, piping arrangements must be designed with maintenance in mind and mock-ups should be made of complicated areas.

It is suggested that manifold crossover lines should be the same height or higher than the main deck lines from the pumproom to allow for easier drainage back to the slop tank and for final stripping. Furthermore, difficulties in marrying up manifolds with shore couplings should be overcome if OCIMF standards were complied with and lifting arrangements were provided with reducers.

More efficient cargo operations could be conducted if remote control units were sited on deck with indicators showing the valves in an open or closed position and with gauges for pressure and temperature at the manifold.

The section on fire-fighting makes some very salient points. Alleyways are often too narrow to carry fire-fighting gear or stretchers up or down; the engine room and some others have only one access, usually internal. The solutions here are obvious.

The tripod for tank rescues is said to be too time-consuming to rig and instead a permanently rigged block and tackle should be located in specific places.

Fire alarms have often been confused with navigational and engine room alarms because all panels are frequently sited in the wheelhouse. Fire alarms often cannot be heard on deck. The report suggests that a fire alarm HQ should be set up and sited in a separate room in the wheelhouse. It should incorporate the fire detection system for the whole ship and alarms should be sited on a central panel.

Each alarm should show a flashing light for easy location and repeaters should be sited throughout the accommodation and engine room with alarm cancellation only from the HQ. A flashing light would be provided on the outside of the HQ and alarm bells should sound throughout the entire ship. Smoke detectors and heat sensors should also be more widespread.

As regards portable extinguishers, they are often sited in awkward places and can often be found inside, not outside, the areas they protect. Some areas lack portable extinguishers and large mobile units, often found in the engine room, may be too heavy and cumbersome to move. It was suggested that portable extinguishers should be more widespread and recessed into the bulkhead so that they do not jut out.

Within the accommodation, decks divided by bulkheads without fire doors cause an avoidable fire hazard.

Fire pumps have been found to be difficult and time-consuming to start. The report suggests that a pump should be designed for unskilled operators with remote starting from the fire HQ or wheelhouse.

The report also covers inadequacies of life-saving appliances and includes sections on navigation, communication, stores, dry cargo work, arrival in port and other matters. Reader ref. E262

Automated docking

NEI Clarke Chapman has designed a complete mooring system, incorporating the latest developments in automatic and remote control. It consists of the automated mooring winches and windlasses, remote plug-in controllers for mooring operations, and an automatic anchor brake-release.

Using this arrangement, fore and aft mooring teams of only two men are said to be necessary for docking/undocking. Existing mooring arrangements can be updated with this new system.

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

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The Institute of Marine Engineers (India)

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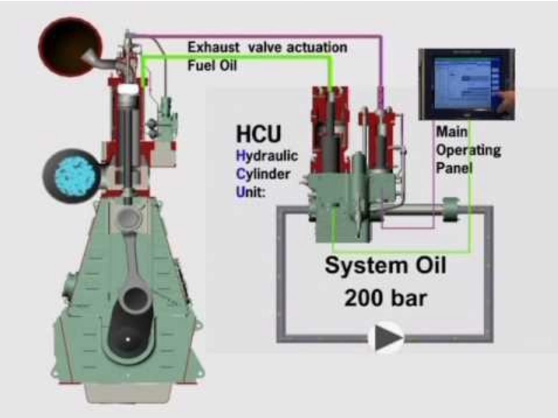

This 3 days course is designed for all Ship's Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. This course consists of technical lessons and practical instructions on the design, principles, operating procedures and maintenance activities for the safe, efficient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

Course Aims and Objectives:

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

Coverage / Program Focus:

This course deals with the following training areas:

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

Entry Requirement / Target Group:

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

DATE & TIMING : **6th - 8th Feb 2024/ 27th – 29th Feb 2024/ 26th – 28th Mar 2024/ 23rd – 25th Apr 2024/ 28th – 30th May 2024/ 25th – 27th June 2024/ 29th – 31st July 2024/ 27th – 29th Aug 2024/ 24th – 26th Sep 2024/ 28th – 30th Oct 2024/ 26th – 28th Nov 2024/ 17th – 19th Dec 2024**
8:00 am - 4:00 pm IST

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

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

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