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EDITORIAL

The tragedy of life is often not in our failure, but rather in our complacency;
not in our doing too much, but rather in our doing too little;
not in our living above our ability, but rather in our living below our capacities.

- Benjamin Mays (American Civil Rights Leader)

In the din of decarbonisation, dragging recession and conflicts, one issue almost went unnoticed: The decision of European Commission's Directorate General for Mobility and Transport to continue recognising the Certificates issued by the Philippines. This is a decisive moment after a year since the EMSA (European Maritime Safety Agency) Audit outcome demanded 'serious measures' from Philippines' Administration, to comply with STCW requirements. Philippines, one of the largest provider of global seafaring force was riddled with issues of substandard training and breeding corruption in the institutions. Filipino Administrators have been in the damage control mode for over a year and after this move, have called for a serious introspection. Understandably, the non-recognition and decertification would have affected those employed in the vessels (of EU regional bloc) and the future prospects also of this big seafarer-providing nation. Realising the gravity of losing out in the maritime sector, President Ferdinand Marcos Jr., has assured to work on reforms.

The tremors of this Filipino shock should be consciously felt at India's coordinates also. The Indian stakeholders (Administration, Companies, Training Institutes) need to introspect rather than living with an insular perspective and looking at the employment metrics alone. Being a much larger economy than Philippines, India has similarities and nearness to many parameters and traditional interest in maritime domain is one of them.

India has enjoyed the fruits of having a 'well educated, hard-working, problem solver' image when it comes to global seafarer employment, especially of the officers. However, maladies of mediocrity, work place attitudes (read: on-board work attitude), absence/erosion of loyalty quotient etc., extend from the MTIs to the on-board spaces.

Philippines and many other maritime nations are already touching pre-pandemic employment levels. Though some attention has shifted favourable due to the Ru-Uk war, the paucity of ship berths persists. India cannot afford complacency or feel adequate with present capacities and capabilities. A major course correction would be on carrying and cultivating correct aptitudes for sea careers and attitude towards maritime education, while modernising the MET platforms (simulators, VR etc.).

Let us move, as the saying goes, 'With confidence, but not complacency'.

In this issue...

We have a collective focus (partly) on fuels in this issue.

We start with a discussion on Natural Gas (NG). Asim Prasad et al., pitch for NG as a viable option for inland waterways transportation. After a brief discussion on valence points on emissions, climate etc., the Authors present the case with some interesting statistics, which almost makes the option unequivocal. The metrics of information on fuels, Indian waterways etc., are brief and to the point. The NG infrastructure projections and the merits for the waterways-transportation sector to adopt this alternate fuel are interesting takeaways. This is an easily digestible read.

Following this fuel talk is a lengthy analysis of alternate fuels, which are in contention for the future energy space. Sudarshan Daga et al., juxtapose the fuels and the technologies for adaptation. We present this lengthy discourse by the IRS team as a series. In this first write-up of the series, about a dozen options are listed with some introductory information on Fatty Acid Methyl Ester (FAME) Bio-diesels. I would recommend readers to follow this analyses, which get interesting as we proceed.

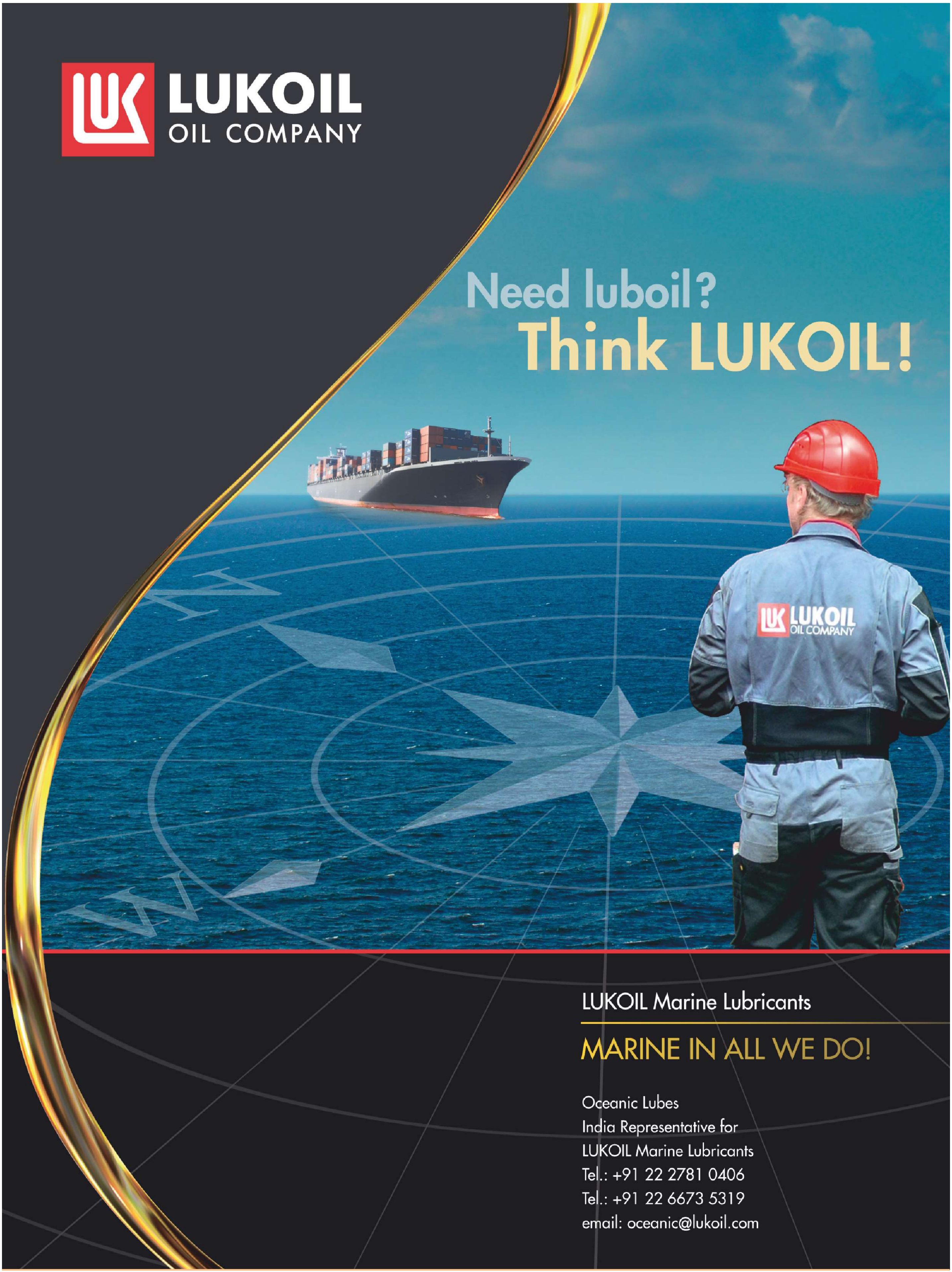
We conclude the discussion on the Subsea navigation systems with the third (Part C) part. Jyothi et al., get quite technical and discuss seven scenarios, which comprehensively provide the insights into the navigation system design and more importantly the reliability aspect of the sensor architecture. This 3-part description-analytics of the kinetics (waterborne body motion behaviour) and kinematics (motion-equations) would be of interest to the researchers. This would be worthy addition to the AUV discussions we have been hosting in the MER.

And under Technical Notes, Sanjiv continue our smooth slide with discussion on Lubrication Regimes and the tick-mark tracing of the regimes with the interesting Stribeck Curve. Elstan extends the electrical discussions explaining how to read the diagrams in the Competency Corner. MER Archives: The extracts from May 1983 has some information on few products, which many would be familiar with and worked with also.

In this issue, we have the renowned writer, Narasiah penning on the Indian shipping times through the history.

Here is the May 2023 issue for your reading pleasure.

Dr Rajoo Balaji
Honorary Editor
editormer@imare.in



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Cover Credits: **GAIL petrochemical at Pata, Auraiya. World's 1st floating CNG Station established by GAIL. This will provide CNG to 1700 boats approx. at Khidkiya Ghat, on the Ganges in Varanasi. LNG ships, Regasification plant.**

***Pictures courtesy:* Asim Prasad**

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Natural Gas as a Sustainable Option for Waterways Transportation in India

Asim Prasad, Anita Kumar, Niti Nandini Chatnani, Ranjit Deka

Abstract/Summary:

India's carbon neutrality goals are ambitious and stringent. A concept-centred literature study identifies policy reforms in the Waterways and Natural Gas Sectors that complement each other to the greatest extent possible in developing resilient infrastructure for sustainable socio-economic development. A gas-based economy is the first step, aiming to enhance the share of Natural Gas in India's primary energy consumption mix from 6% to 15% by 2030.

This article explores the potential of Natural Gas to decarbonise the Indian Waterborne Transportation System, thereby enhancing consumption. Findings indicate that access, availability, acceptability, and cost of Natural Gas are crucial for marketing this environmentally friendly fuel in waterways. Refuelling systems for closed circuit transportation for gas access, bunkering facility, technology requirements to switch to Natural Gas, operation & maintenance requirements of gas-based waterborne transport systems, policy reforms to accelerate the rapid adoption of Natural Gas in waterborne transportation, and awareness of the use of alternative fuels are the six related growth dimensions. The article has a policy and practical implications for practitioners and decision-makers to realise the Indian carbon-neutrality vision.

By 2050, nearly 40 % population is likely to face a severe water crisis, coastal cities may face severe challenges due to rising sea levels, while the risk of intense floods exists in the Ganges and Brahmaputra along with forecasts of severe draughts hampering agricultural outputs

Keywords: ***Gas-Based Economy, Decarbonisation, Net Zero, CNG, LNG***

Introduction

Global warming and climate change are major global threats to modern human society caused by rising GHG emissions adversely impacting the earth's environment. Besides impacting human health trigged by climate-sensitive diseases, lowering the average life expectancy, and deaths, these have led to increased natural disasters, like draughts, floods, changing crop patterns, wildfires, heat waves, cyclones, etc.(WHO, 2022). The United Nations has set the SDG 2030 global agenda providing a shared blueprint for enduring peace and prosperity for all people and the planet. The global target is to limit the temperature rise to 1.5^{0}C above pre-industrial levels to achieve net zero emissions by 2050(UN, 2022).

As the third largest global economy, India has struggled to decouple economic growth and climate change since its economic growth is dependent on fossil fuels, with coal and oil contributing 83% of the energy consumption mix. India is vulnerable to climate change due to its large population at the bottom of the pyramid, while its agricultural-based economy still adopts traditional farming methods. India's primary source of pollution is the construction sector, intermittent events like crop burning, industrial waste, cooking using solid biomass, coal-based power generation, and transport sector emissions. **As a result, India is the fifth most polluted country globally, having 11 cities among the 15 top polluted cities in Central and South Asia (GOLDACH, 2022), while more**

than 90% of its population resides in areas with air quality below WHO air quality standards.

By 2050, nearly 40% population is likely to face a severe water crisis, coastal cities may face severe challenges due to rising sea levels, while the risk of intense floods exists in the Ganges and Brahmaputra along with forecasts of severe draughts hampering agricultural outputs (IPCC, 2022). However, India has announced its goal to achieve net zero carbon emissions by 2070 with "panchanmrit" and also enhanced its Intended Nationally Determined Contribution (NDC) targets to limit its GDP emission intensity from 2005 levels by 45% against 33-35% by 2030 announced earlier (PIB, 2022).

With an increase in shipping operations, GHG emissions increased by 9.6 % between 2012 and 2018, accounting for 2.89 % of global emissions

Towards this effort, one goal is to gradually phase out the traditional liquid petroleum fuels with Natural Gas(NG), the global choice. The target is to increase the share of NG consumption in the country's primary energy consumption mix from 6% to 15% by 2030 to transition toward a gas-based economy. However, NG's share in the India's primary energy consumption mix is only 6.3% against 24.4% globally(BP, 2022).

Historically the power, fertilizer, refineries, petrochemicals, and other sectors have dominated the NG consumption mix in the Indian NG sector, while the City Gas Distribution (CGD), an emerging sector, is the fastest growing and accounting for nearly 20% of NG consumption share. In order to provide access to clean NG to the retail and transport segment, the supply chain for the local distribution network is being created to cover 88% of India's land area, targeting 98% Indian population (MOPNG, 2022a) with the objective to provide access to clean, modern fuel, the NG, for fulfilling the objectives of SDG 7. Concurrently, in 2016 the Ministry of Ports, Shipping and Waterways(MOPSW), GOI under its "SagarMala" Program, rolled out its plan for port-led development in the country to harness the 7,500 km long coastline potential to its economic advantage (MOPSW, 2022). The vision is to provide a competitive edge by reducing transportation costs during the export/import and domestic trade. Also, the National Waterways Act 2016 was notified to develop the national waterways to enhance shipping and navigation while promoting Inland Waterways Transport (IWT). The Indian Vessel Act 2021 emphasises pollution control and allows using Liquified Natural Gas(LNG)in special-category vessels (Inland Vessels Act 2021, 2021). Further, PM Gati Shakti unites logistics with the six transport modes for economic growth and sustainable development through a transformative approach (DPIIT, 2021). As such, the waterways transportation and the NG sector complement each other in building resilient infrastructure for economic development while promoting decarbonisation for sustainability.

In light of the above developments, this article explores the growth opportunities for NG in different forms like Compressed Natural Gas(CNG) and LNG in the Waterways transportation sector in the country, underpinning the environmental concerns, costs, infrastructure, and operational and policy considerations. The article concludes with implications and a futuristic outlook suiting Indian requirements.

Emissions from Waterborne transportation systems

The waterborne transportation system is the oldest and most popular economic mode of transport globally. Over 80% of global trade is done through shipping. Nearly 47% of China's trade is through waterways. In Europe, Bangladesh, US and Japan it is 40, 35, 34 and 12.4%, respectively, but in India, the share is only 6%. With an increase in shipping operations, GHG emissions increased by 9.6% between 2012 and 2018, accounting for 2.89% of global emissions (IMO, 2020a).

Accordingly, in its GHG strategy, the International Maritime Organisation(IMO) has set a target to reduce carbon intensity from the 2008 level by at least 40% by 2030 and 70% by 2050 (IMO, 2021). IMO 2020 emission standards effective from 1st January 2020 are enforced, limiting sulphur emissions from shipping operations to 0.5% globally and 0.1% in IMO-designated emission control areas.

The IMO regulations for sulphur emissions are in **Figure 1.** To promote effective implementation of these standards, the European Union is considering including shipping in its Emissions Trading System to offer financial incentives to transporters adhering the standards. Further, many organisations post COP 26 have committed to reducing their supply chain emissions.

Clean Fuel Options for Waterborne Transportation Systems

Due to growing pressure from end-users, and strict environmental regulations, the global quest for adopting cleaner energy options has intensified while the energy

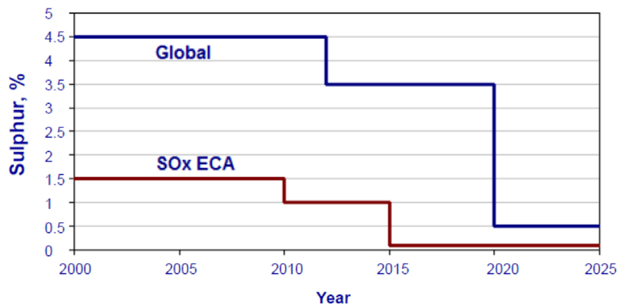

Figure 1. IMO Regulations on Sulphur emission (IMO, 2020a)

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Among various available options, NG in LNG form has emerged as a safe, reliable, ecologically positive, and economically attractive option to provide solutions to reduce GHG emissions from waterborne transportation systems

transition in water transport had advanced from coal in the 19th century, oil in the 20th, towards next-generation fuels with low GHG, carbon, and sulphur emissions (Takahiro, 2021). Alternative fuels like Ammonia, Methanol, Bio-fuels, Hydrogen, LNG, and nuclear are being considered to replace liquid fuels as a sustainable option. The details of in-service and on-order vessels on alternate fuel are in **Figure 2.**

Among various available options, NG in LNG form has emerged as a safe, reliable, ecologically positive, and economically attractive option to provide solutions to reduce GHG emissions from waterborne transportation systems.

Globally, NG adoption in the transport sector is driven by environmental, safety, reliability, and cost considerations. LNG has better calorific value and can offer the best thermodynamic yields resulting in better energy efficiency as a primary fuel. LNG's emission intensity is significantly less than traditional fuels like FO and HSD (**Table 1**).

Further, as a marine fuel, LNG can decrease GHG emissions by 80%, NOx emissions by 80%, and produce almost negligible particulate matter (PM). The presence of Sulphur in LNG and CNG is insignificant, resulting in almost negligible SOx emission. LNG-fuelled ships can integrate NOx reduction technologies such as Exhaust Gas Recirculation (EGR) or Selective Catalytic Reduction (SCR) at an additional cost to further reduce NOx emission (DNV, 2021). Even though LNG volumetric energy density is less than HSD and gasoline, it is high compared to available alternatives like compressed hydrogen, cooled hydrogen, CNG, methanol, ethanol etc. but less than HSD and gasoline. However, its energy

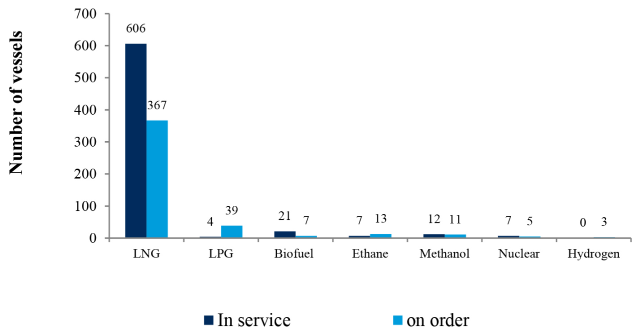

Figure 2: Alternate fuelled vessels
(Source: Drewry Maritime Research)

Table 1. Emission of various fuel types

Emission/Fuel	LNG	FO	HSD
CO_2 (Kg per MMBtu)	53.06	73.96	70.22
CH_4 (g per MMBtu)	1.0	3.0	3.0
NO_2 (g per MMBtu)	0.1	0.6	0.6

(Source: US Energy, 2014)

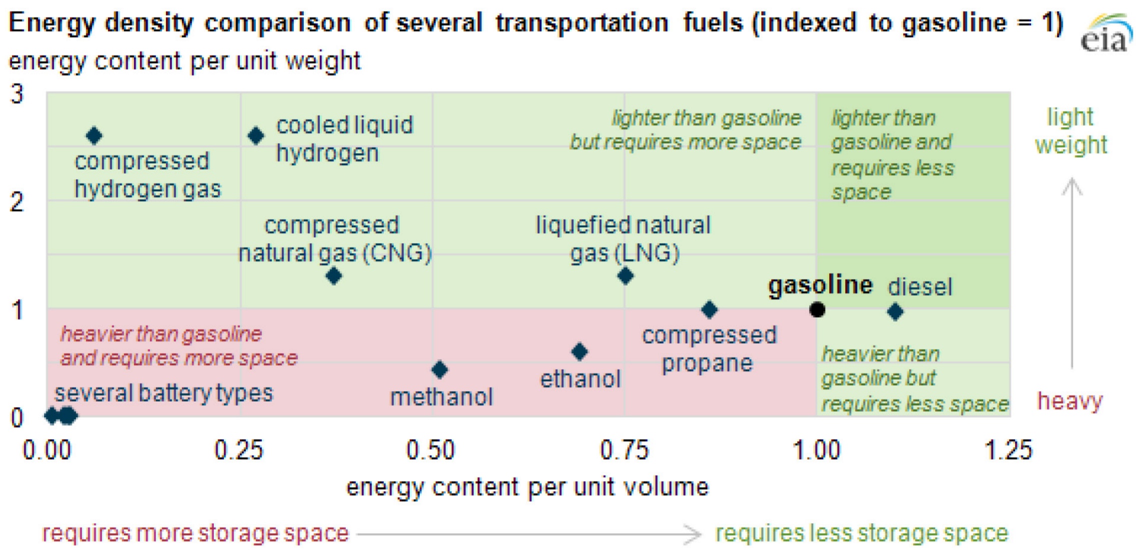

Figure 3. Energy density comparison of several transportation fuels (indexed to gasoline = 1)
(Source: U.S. Energy Information Administration, based on the National Defence University)

content per unit weight is more than gasoline and HSD (EIA, 2014). As a result, **LNG occupies less onboard space per unit volume, leaving more free space for freight or people** (**Figure 3**). These considerations provide an edge to LNG towards transitioning to this clean fuel.

> *Even though LNG volumetric energy density is less than HSD and gasoline, it is high compared to available alternatives like compressed hydrogen, cooled hydrogen, CNG, methanol, ethanol etc. but less than HSD and gasoline*

LNG bunkering infrastructure is rapidly expanding across the globe, due to which the LNG is available in major global shipping hubs. The Mediterranean Shipping Co (MSC), has invested over $2.8bn to convert its fleet to LNG to reduce emissions and comply with IMO guidelines (Irene Ang & Hine, 2022). DNV GL has considered LNG a major transition fuel for the shipping sector due to technological breakthroughs and bunkering infrastructure development. CMA CGM is working to develop LNG-based container ships for next-generation transportation. German liner Hapag-Lloyd is exploring the use of LNG in its upcoming container fleet (Jasmina Ovcina, 2020). Thus LNG choice as a clean fuel option is expected to gain further popularity.

Waterways in India

India has a widespread network of inland waterways (**Figure 3a**), but the waterborne transport share is less than 6% of the modal split. The waterways sector achieved a significant boost by enacting the National Waterways Act, 2016, wherein the GOI notified 111 Inland National Waterways (NWs) for water transport. Among them, 23 (~5200 Km) were identified for mechanised crafts, and 17 are in operation (Prasad, 2021). The government has undertaken different interventions to promote the IWT related to terminal development, vessel operations, navigational aids, fairy development, and building riverine structures. IWT in India is limited to a few selected waterways in Goa, West Bengal, Assam, and Kerala. The total cargo movement (Tons per kilometre) by the inland waterway is 0.1% compared to 21% in the US. To date, the modal share of IWT is 2% compared to 8 to 15% global share. However, the national waterways in India handled 83.6 million tons (MT) in 2020-21, registering 8.55% CAGR between 2017 to 2021. The traffic trend is in **Figure 4.**

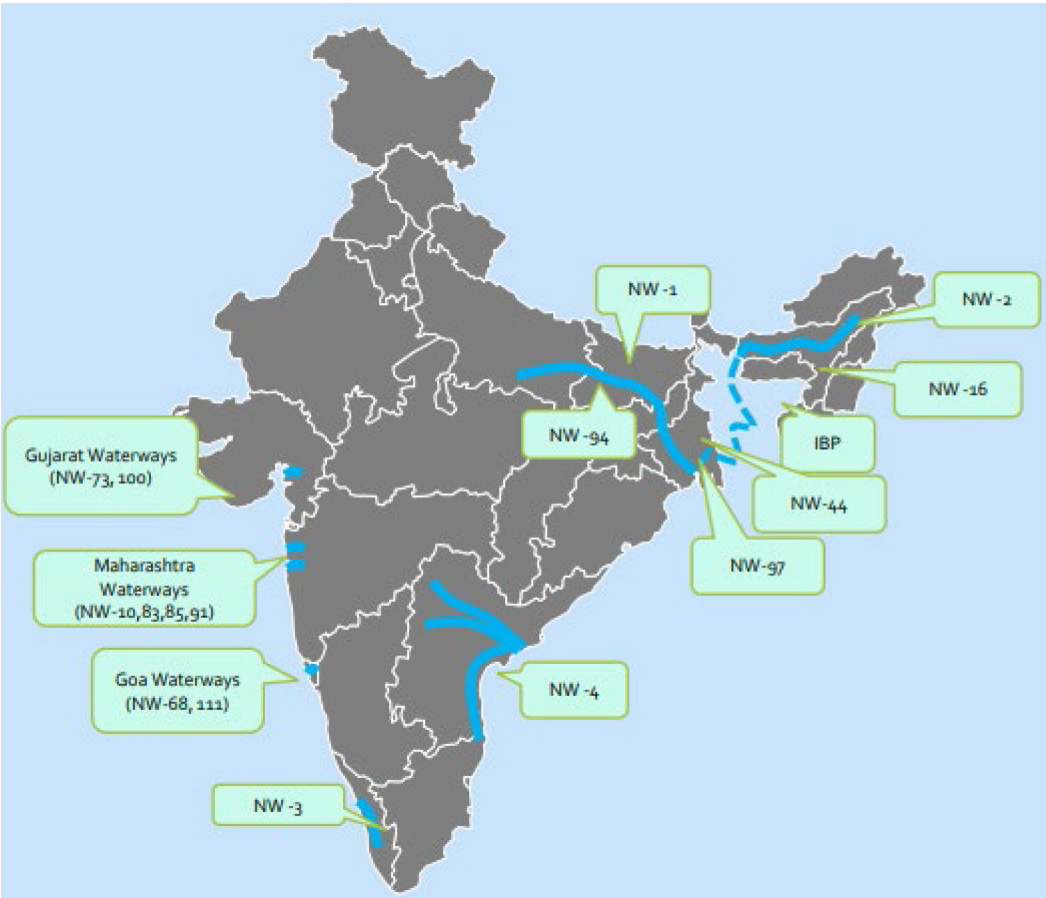

Figure 3a. Waterways in India
(Source: IWAI 2021)

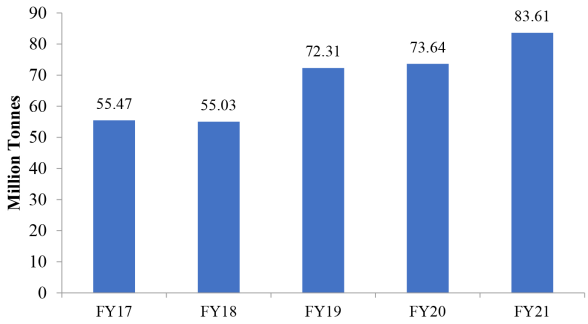

Figure 4. Traffic on National waterways in India
(Source: IWAI 2021)

The GOI has set its vision to promote waterway transportation considering cost economics and environmental merit. IWT has the potential to complement the overburdened railways and congested roadways network. Besides cargo movement, IWT promises to offer carriage for vehicles (in Roll-on-Roll-off mode of cross-ferry) and Tourism, including overnight stays and entertainment. However, IWT faces challenges like operational infrastructure, allied logistics, skilled workforce, adoption of modern technology, and lack of awareness about IWT, which may hinder India's vision to enhance traffic to 140 MMTPA by 2030.

Under its flagship "SagarMala" program, the MOPSW is committed to developing an ecosystem to promote waterway transportation in the country by implementing 574 projects at an estimated cost of Rs. 6.0 Trillion (MOPSW, 2022) to reduce logistics costs. The different components of this program provide impetus towards achieving sustainability in coastal and waterways transport, skill development, generation of livelihood, development of industrial clusters in and around ports, optimisation cost and movement time of cargo, enhancing connectivity to the hinterland, developing greenfield ports apart from expansion of existing ports with modern equipment (MOPSW, 2016). However, rising coastal and IWT traffic poses environmental challenges due to emissions caused by conventional oil-based fuels.

Recently, the world's first floating CNG station with a modular design was established by GAIL in Varanasi to promote sustainable transportation on the Kashi Vishwanath Corridor of the river Ganges. 900 diesel engine boats running in the closed circuit have been converted to mono-fuel CNG mode, while the target is to convert 1700 boats. This model promises to reduce harmful emissions, improve water quality, and better marine life in the river Ganga, promoting eco-friendly pilgrimage and tourism in Varanasi (DD News, 2022; PMO, 2022).

Natural Gas Infrastructure in India

The Indian primary energy basket is historically dominated by Coal and Oil, contributing to 83% of the primary energy consumption mix (BP, 2022). However, the GOI vision is to transform India into a gas-based economy by 2030. Target has been set to increase the NG share in the country's primary energy consumption mix from 6% to 15% by 2030 (MOPNG, 2020a). The current share is only 6.3% due to barriers that hinder the growth of the NG sector in the country, but the GOI is facilitating the gas sector to overcome these. To promote NG, an investment of 66 billion USD (MOPNG, 2020) is being made to develop the NG infrastructure in the country. This comprises LNG terminals, NG transportation, and a distribution network of buried pipelines being built under the "One-Nation-One Grid" National Gas Grid (NGG) program and the local distribution network for NG retailing under CGD projects which is spread across 88% of India's land area covering 98% to the population (MOPNG, 2022a). The NG infrastructure is shown in **Figure 5**, while the coverage of CGD projects is shown in **Figure 6**. As per the authorisations issued by the Petroleum and Natural Gas Regulatory Board(PNGRB), the development of the CGD network in the authorised Geographic Areas (GA's) is likely to be completed by 2030.

With declining domestic NG production, the dependence on imported LNG has increased to meet the rising demand-supply gap. The import dependence has increased to the extent of approximately fifty%. Six LNG terminals with a nameplate regasification capacity of 42.5 MMTPA are operational, while four LNG terminals with 20 MMTPA capacity are planned/under construction. The details of existing and planned LNG terminals are in **Tables 2** and **3**, respectively.

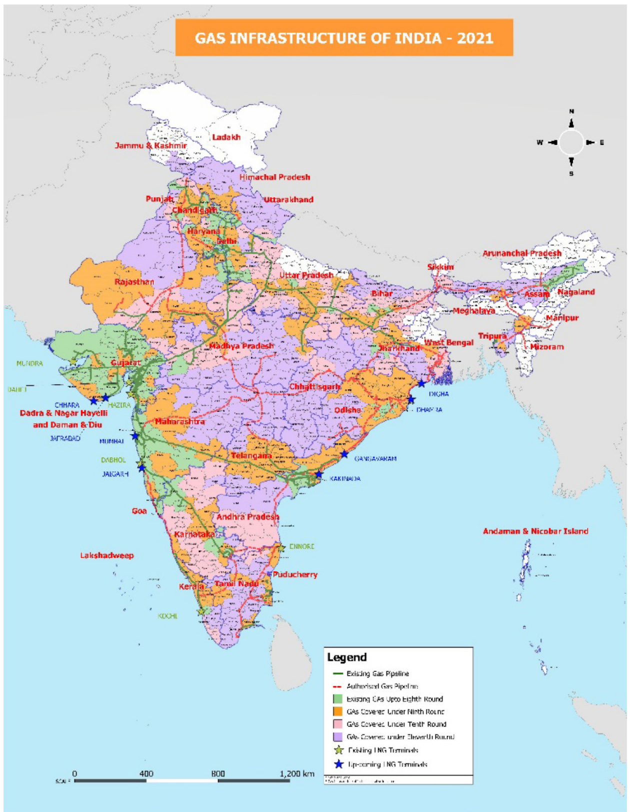

Figure 5. National Gas Grid (NGG) of India (PNGRB, 2021)

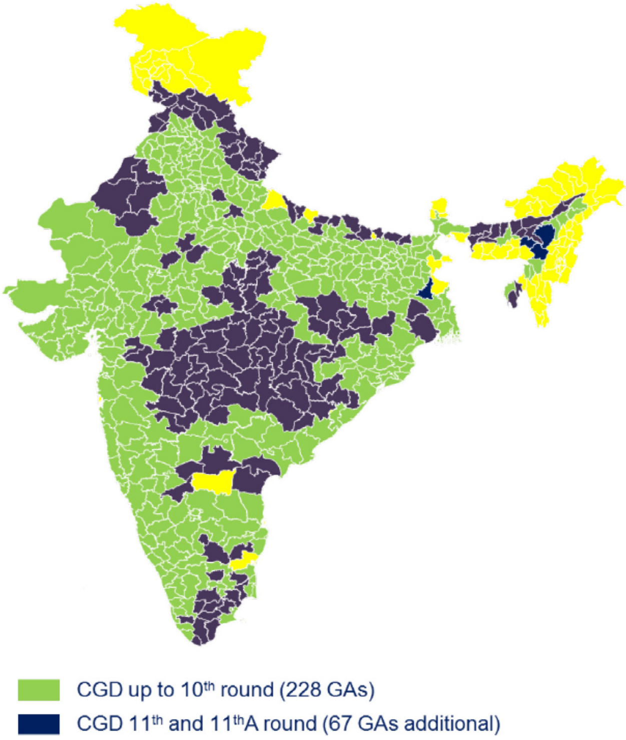

Figure 6. CGD infrastructure in India
(Source PNGRB, 2021)

Table 2. Existing LNG terminals in India

Existing LNG Terminal	Entity	Capacity (MTPA)
Dahej, Gujarat	PLL	17.5
Hazira, Gujarat	Shell	5.0
Dabhol, Maharashtra	KLL (GAIL)	5.0
Kochi, Kerala	PLL	5.0
Mundra, Gujarat	GSPC & Adani	5.0
Ennore, TN	IOCL	5.0
TOTAL (Existing)		**42.5**

(Source: MoPNG)

Table 3: Upcoming LNG terminals in India

Upcoming Terminal	Entity	Capacity (MTPA)
Jafrabad, Gujarat	Swan	5.0
Jaigarh, Maharashtra	H-Energy	4.0
Dhamra, Odisha	Adani & Total	5.0
Chhara, Gujarat	HPCL	5.0
TOTAL (Upcoming)		**19.0**

(Source: MoPNG)

In order to meet the immediate NG demand at locations not connected to any NG pipeline network, the gas supply is made in Liquid to Compressed Natural Gas(LCNG) mode, often referred to as the virtual supply chain (Cryo Equipments Private Limited, 2022). The LCNG mode

In order to meet the immediate NG demand at locations not connected to any NG pipeline network, the gas supply is made in Liquid to Compressed Natural Gas(LCNG) mode, often referred to as the virtual supply chain

finds application in non-piped areas, difficult locations, ports etc. The LNG is supplied to LCNG stations through cryogenic road tankers. After vaporisation, the LNG in gaseous form is supplied as either CNG for the transport segment or PNG through the local distribution network.

Natural Gas for Waterways Transportation

The enablers for promoting NG in waterways transportation in India are related to access, availability, acceptability, and affordability, along with related growth dimensions:

1. Refueling Systems for closed circuit transportation for gas access

(a) Natural Gas Infrastructure for dispensing CNG: 4531 CNG stations are operational in the country, while the target is to establish 8181 CNG stations under the 9th and 10th CGD bidding rounds authorisations (PNGRB, 2020)from the plasticity of plant growth and development to the nutritional control of caste determination in honeybees and the etiology of human disease (e.g., cancer. The Geographic Areas located in the vicinity of the national waterways shall benefit from the availability of CNG, which can cater to the gas requirements of different types of waterways transport running in closed circuits within city limits for passenger and freight transport.

(b) LCNG mode for dispensing LNG/CNG: Until such time, NG through pipeline mode is made available at the demand centers; LCNG mode provides solutions to supply the NG through a virtual supply chain to various types of waterways transportation systems on national and new waterways being established.

(2) LNG Bunkering for gas access: LNG bunkering facilities for LNG-fuelled vessels are offered by the PLL Kochi LNG terminal (PLL Kochi, 2016). Further, an opportunity to set up new bunkering facilities exists at the other operational LNG terminal if there is LNG demand build-up in coastal waterways transportation along peninsular India.

(3) Gas availability: The GOI is promoting domestic gas production while encouraging the import of LNG at a market-determined price. Gas consumption in the country registered a three% CAGR in the last five years. As such availability of market-driven priced LNG may not be a constraint for the waterways transport sector in India.

(4) Gas acceptability and affordability: NG in LNG or CNG forms provides environmental benefits over conventional liquid fuels commonly used by waterways in inland or marine transportation. LNG is competitively priced on an energy equivalent basis compared to the waterways fuels it will substitute. Hence acceptability and affordability may not be a constraint.

(5) Technology Requirements: The current fleet of water transportation systems' engines are designed to run on conventional liquid fuel in mono-fuel mode. However, to run on LNG or CNG, the engine may require technical adjustments, modifications, or retrofitting to operate on either dual-fuel LNG mode or mono-fuel LNG or CNG mode (Hannu Jääskeläinen, 2019). The Indian automobile sector is already accustomed to NG in CNG form with mono-fuel and dual-fuel options. Several OEM's and retrofitters dominate the Indian market with solutions for Gas. **The engine characteristics not being very different, the switchover to Gas doesn't appear challenging**.

(6) Operation & Maintenance (O&M) Requirements

(a) Vendor Development: With the growth of the gas market for the automobile segment, vendor development has happened, which can cater to the specific requirement of the waterways sector with adjustments suiting the user type.

(b) Skill Manpower for O&M: The O&M requirements of gas engines are less compared to engines running on conventional liquid fuels. The manpower already engaged in the O&M activities in the waterways sector can cater to the new requirement with hands-on training by the OEM or the retrofitter converting the engines to LNG or CNG.

(7) Policy Reforms: After the 2015 Paris agreement on climate change, the government has implemented enabling reforms for the growth of the NG and Waterways sector in the country. Various regulations and acts specifically to eliminate bottlenecks are notified. The MOPNG promotes the use of LNG in IWT and bunkering for vessels going to sea for fishing purposes, with the potential to convert 1400 vessels to LNG by 2024 (MOPNG, 2022b). The Indian vessels act 2021 emphasises the prevention of pollution, with a provision to use LNG for propulsion of special category vessels (Inland Vessels Act 2021, 2021).

Nevertheless, to curtail emissions from waterways transportation systems, policy guidelines underpinning the IMO 2020 regulations(IMO, 2020b), their GHG strategy (IMO, 2021), and India's updated NDC targets are essential to promote alternative fuels in the waterways transportation system comprising IWT and Coastal waterways in India

(8) Awareness about the use of alternate fuels: Awareness about the use of alternate fuels in waterways transport is vital to adopt clean fuels even if the environment is conducive to adaptation.

Conclusions

The GOI is committed to achieving a transition toward a low-carbon economy to contribute India's part towards achieving the shared global targets of the SDGs for 2030. The goals are already defined to achieve the shared vision quantifying objectives underpinning the people and planet to achieve peace and prosperity while promoting partnerships. The focus areas in the context of Water Transportation relate to building resilient infrastructure, promoting sustainable consumption, reducing the adverse impact of climate change, conserving the lives in sea, ocean, and water bodies, and promoting well-being and a healthy lifestyle. Leveraging the strengths of the NG sector, promoting waterborne transportation systems will provide quick solutions to limit GHG emissions in Inland Waterways and Coastal Transportation. This will simultaneously enhance NG consumption through the incremental demand from this new sector.

India has set stiff targets to achieve net zero carbon emissions by 2070, with its first step aiming to transition towards a gas-based economy by 2030 with the target to increase the share of NG in the primary energy consumption mix to 15%. The gas market is steadily expanding, while many sectors remain unexplored with the potential to use NG. Waterborne transport is one such sector where the potential to replace conventional liquid fuels with NG exists.

> *“The operating 19,398 kms gas grid infrastructure, construction of 14,417 kms pipeline networks, and new LNG terminals will facilitate the delivery of CNG/ LNG at the demand centres along coastal waterways in the vicinity of the port and also along the current and proposed inland waterways”*

The operating 19,398 kms gas grid infrastructure, construction of 14,417 kms pipeline networks, and new LNG terminals will facilitate the delivery of CNG/ LNG at the demand centres along coastal waterways in the vicinity of the port and also along the current and proposed inland waterways. On the other hand, LCNG mode with a tailored design will cater to the immediate requirement in non-piped areas. Retrofitting the operating engines to convert to Gas may be challenging in the initial years or till such time vendors specialise in engine-specific adjustments.

However, policy guidelines on alternate clean energy sources with a time bond plan for switching to low-carbon fuels and fiscal incentives are essential to promote the waterways transportation sector in India. Guidelines for mandatory switching to mono fuel CNG mode in closed circuit waterways transportation for goods and passengers to replicate the Varanasi model will promote eco-friendly tourism across the Ganges and other major waterways in India. Guidelines on emission norms for various categories of vessels operating on national waterways will provide impetus to develop the waterways sector at a fast pace in India, underpinning India's commitments for decarbonisation.

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Alternative Fuels and Technologies for Decarbonisation in Maritime Field – A Preliminary Analysis (Part A)

S. Daga, K.M. Doshi, S. Gupta, D.R. Sonawane

Abstract:

Global efforts in maritime field towards decarbonisation require transition to zero carbon or net zero fuels to reduce the CO_2 emissions. Comparison is made of the relative benefits and limitations of alternative fuels and technologies with regard to their application on-board seagoing ships. A well to wake approach is kept in consideration while examining the merits/demerits of each fuel and technology. An analysis of the present worldwide seagoing fleet, which would be impacted by the decarbonisation efforts is also presented.

Key Words:

Alternative Fuels, Decarbonisation, International Maritime Organization, GHG emissions.

INTRODUCTION:

Alternative fuels are being considered popularly in the present scenario of the maritime industry to support the de-carbonisation goals adopted by IMO for achieving the carbon dioxide and other greenhouse gases (GHG) emissions targets. The GHG may be carbon dioxide (CO_2), methane (CH_4) and/or Nitrous Oxides (N_2O). These targets are set for achievement with a short and a medium term time ranges viz., 2030 and 2050 respectively. The target is to reduce the maritime transport work related CO_2 emissions (tonnes CO_2/tonne nautical mile) by at least 40% by 2030 and 70% by 2050 when compared to the base year of 2008. Another goal is to reduce GHG emissions by 50% by 2050 when compared to the year 2008.

To achieve the decarbonisation goals mentioned above, use of alternative fuels and/or technologies will be needed.

The choice of some of the fuels may incur near zero GHG emissions when used for generating power on-board the ship. However, GHG emissions would also result prior to the use of these fuels owing due to reasons such as:

a. During production/extraction of raw materials (e.g. methane is a typical input for production of ammonia, methanol etc.)

b. During processing of raw materials to produce the final fuel.

c. During storage and transportation of the produced fuel to the berth where it will be bunkered.

The GHG emissions ensuing due to the above processes are termed collectively as "Well to Tank" emissions. The GHG emissions due to the use of the fuel on-board the ship is termed as "Tank to Wake" emissions. It is important to gauge the total level of emissions to understand the utility of a given fuel, i.e. the "Well to Wake" emissions. The goal is to reduce the total lifecycle emissions rather than only the "tank to wake" emissions which has been the approach till date.

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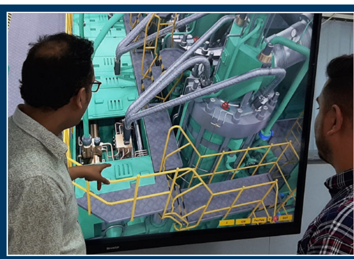

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An important aspect to be noted herein is the variability possible within the calculation of the Well-to-Tank emissions. The amount of GHG emissions would depend upon the power sources used to produce, process and refine the fuels and also whether there is a system to capture the CO_2 released during such processes. If the power generation is from renewable energy sources such as wind, solar, nuclear etc. sources, then the GHG emissions for the Well-to-Tank component are reduced.

Likewise, there may be utilisation of a CO_2 capture system (CCS). Such systems are being considered for trial on-board seagoing merchant vessels. As a result, the Tank-to-Wake emission components may also depend upon the availability and installation of such systems on-board.

The present paper aims to consider the following fuels and technologies which can contribute to maritime decarbonisation:

a. Biodiesel – FAME (Fatty Acid Methyl Ester)
b. Biodiesel – Hydro treated Vegetable Oils (HVO)
c. Methanol
d. Ethanol
e. Liquefied Natural Gas (LNG)
f. Ammonia
g. Hydrogen
h. Synthetic Fuels
i. Fuel Cell Technology
j. Electric Battery Technology
k. On-board Carbon Capture & Storage Systems
l. Nuclear Fuel Technology

The following factors are important for consideration during assessment of the preliminary feasibility of a fuel:

a. Availability (current and future forecast)
- **a.** Feedstock
- **b.** Availability of feedstock for production of the fuel
- **c.** Power Sources used in the production
- **d.** Production process for the fuel
- **e.** GHG emissions for the production and transportation of fuel to ship (i.e. Well-to-Tank)

b. Physical and Chemical properties
- **a.** Storage temperature and pressure
- **b.** Density at storage
- **c.** Lower Heating value (LHV)
- **d.** Flashpoint
- **e.** Lower and Upper Flammability Limits (LFL and UFL)

c. Special conditions (if any required for storage)

d. Safety of handling the fuel

e. Safety requirements for using the fuel for on-board generation of power

f. CO_2, NOx, SOx, Particulate Matter (PM) emissions-Tank-to-Wake

g. Present and future costs of the fuel

> **"The GHG emissions ensuing due to the above processes are termed collectively as "Well to Tank" emissions. The GHG emissions due to the use of the fuel on-board the ship is termed as "Tank to Wake" emissions"**

For HVO, Oils of Rapeseeds, Sunflower, Soyabean, Palm, Waste Cooking Oil etc. Jatropha and algal oils can also be used. Animal fats also may be used.

It can be noted that FAME and HVO Biodiesels can use feedstock from agricultural origin or crops as well as from bio-waste.

Table 1. Properties of Alternative Fuel Candidates

	FAME	HVO	Methanol	Ethanol	Ammonia	Hydrogen	LNG
Storage Temperature (°C)	Amb	Amb	Amb	Amb	-33/25	-253	-163
Storage Pressure (bar)	Amb	Amb	Amb	Amb	1/9	1	1
Density (kg/m³)	880	780	796	792	600	70	430-470
Lower Heating Value (MJ/kg)	37	43	20	29	21.2	120	50
Flashpoint (°C)	>149	>149	12	17	132		-188
Auto ignition Temperature (°C)	-	-	464	363	651	571	537
LFL (%)	-	-	6	3.3	15	4	5
UFL (%)	-	-	36	19	27	75	15
Cetane Number	>47	80-99	3	8	-	-	--
Octane Number	-	-	110	110	110-130	130	120

FAME Biodiesel production is accomplished using trans-esterification process requires the fatty acid from plant or animal sources along with an alcohol (typically methanol) and presence of a catalyst which a strong alkaline base (for biodiesels derived from algae, an acidic base is used) (catalysts depend upon the feedstock used). After the process, the FAME Biodiesel is filtered from the by-products glycerol and water.

HVO Biodiesel production involves two major steps. In the first step, feedstock is deoxygenated to form alkanes. Hydrogen is added to the feedstock for this purpose. The reaction temperatures range between 300°C – 390°C. The addition of hydrogen leads to saturation of the double bonds of the unsaturated triglycerides contained within the vegetable oils. By further addition of hydrogen, these are cleaved to remove propane and the remainder is fatty acids. By further hydrogen addition, these fatty acids are broken down in alkanes with release of CO_2 and water. In the second step, alkanes undergo isomerisation and cracking to reduce alkyl chain length and increase hydrocarbon branching. It is remarked that HVO could have a lower production cost as compared to FAME because it uses existing hydro treatment process equipment in petroleum refineries (McGill et al, 2013; Moirangthem, 2016; Hsieh & Felby, 2017).

FAME and HVO Biodiesels have densities and energy content which are typically less as compared to the conventional marine fuels (typically LHV 48 MJ/kg and density 900 kg/m^3). (See Table 1 for a detailed comparison). However, HVO is considered to be a 'drop-in' fuel. This implies that HVO can be used on-board within existing engines with very less or no modifications required. The lower density of HVO should however be considered during its use on-board.

On the other hand, FAME Biodiesels need special consideration when stored on-board in terms of the following.

a. Due to their tendency for self-oxidation (because of higher oxygen content), these fuels are not very stable (Hsieh & Felby, 2017). These are not amenable to storage for a long duration. For storage exceeding a period of 2 months, the fuel may become unstable and needs to be monitored to ensure it meets the specification (Moirangthem, 2016, Grijpma, 2018).

b. Long storage may lead to corrosion of the tank, clogging of the fuel filters, pipes and injection systems (Moirangthem, 2016).

c. Hygroscopic nature of FAME – This can further increase the rate of corrosion. This is also exacerbated by the acidity of FAME which can cause damage to fuel supply system components and the main engines (fuel pumps, injectors and piston rings) (Moirangthem, 2016; Grijpma, 2018).

d. For long term storage, microbial growth can take place which can again contaminate the fuel tank and the fuel supply system (Moirangthem, 2016).

e. Degraded Low Temperature Flow properties (Moirangthem, 2016)

f. Wax deposition and Fuel solidification for storage over long periods and aggravated by lower temperatures.

g. This is also characterised by the high cold point of the fuel (32°C) and can lead to clogging of engine filters and fuel flow properties (Grijpma, 2018). However, mixing of additives in the fuel can help alleviate this problem (Opdal & Hojem, 2007; Winnes et al, 2019)

h. FAME forms an emulsion with water and it is difficult to separate the fuel from water (McGill et al, 2013; Hsieh & Felby, 2017; Winnes et al, 2019). This is particularly important taking into account the hygroscopic nature and the instability of FAME.

i. The outcome when biodiesels from two different sources are mixed may also not be easily predictable (e.g. refuelling with FAME developed from a different type of feedstock) (Winnes et al, 2019)

When used within the engines, the FAME Biodiesels would not present major issues if blended with distillate fuels (not more than 20%). It may be noted here that ISO

8217 permits blends not beyond 7%. For higher blends, the following issues would need to be considered.

a. Presence of peroxides and acids from oxidation may lead to increase corrosion of the fuel supply system (Opdal & Hojem, 2007; Moirangthem, 2016; Hsieh & Felby, 2017).

b. FAME may not be compatible with certain non-metallic and metallic materials and would usually require modification of current engines and shipboard systems (McGill et al, 2013; Winnes et al, 2019). FAME with concentrations in large quantities may dissolve seals, rubber hoses and gaskets (Tyrovola et al, 2017).

c. Over time, the lubrication properties of the FAME may deteriorate leading to increase in engine wear

d. FAME is not compatible for blending with Residual Fuels. Before switchover, proper flushing is required

e. FAME material decomposition on exposed surfaces including filter elements (Moirangthem, 2016)

f. FAME blends can wash out deposits from the fuel supply system lining and therefore lead to clogging of the filters (Winnes et al, 2019)

g. At high local temperatures, FAME can polymerize making the fuel similar to a plastic mass (Opdal and Hojem, 2007). Temperature control is thus essential which may call for extra heaters, coolers, trace heating (and of course sensors)

h. Most frequently reported issues occur during the start-up phase when there is a switchover from HFO to Biodiesel. Thoroughly cleaning the storage tanks is recommended as solution. In addition, it is also recommended to schedule three-four additional filter changes during the cleansing period if prior cleaning is not feasible at berth (Opdal and Hojem, 2007).

All References shall be provided in the last part of the series.

[This paper was presented at INMARCO (November, 2022)]

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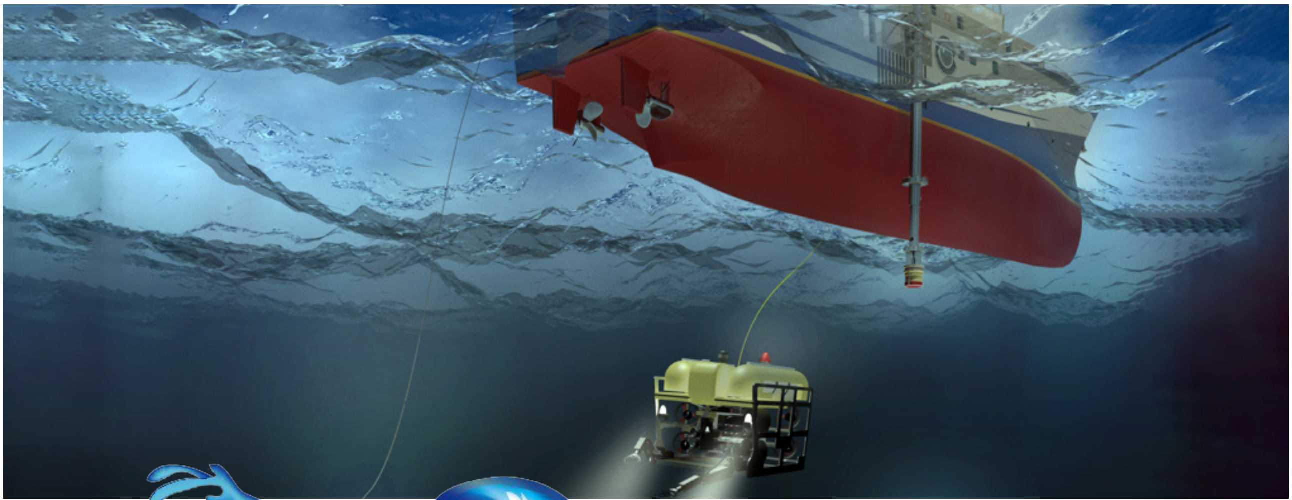
Assessment of Maturity of Subsea Navigation & Positioning Systems - Part C



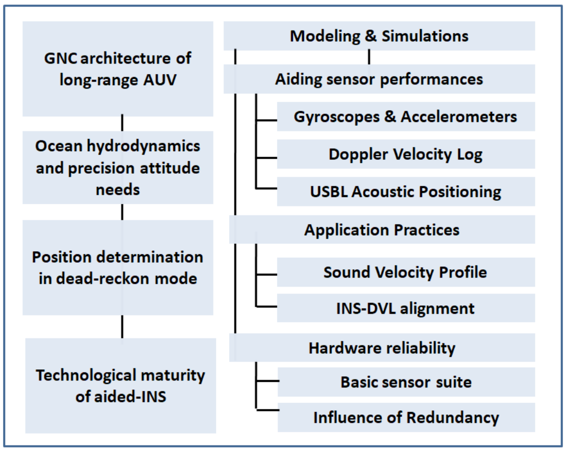
V B N Jyothi, R Ramesh, N. Vedachalam

Abstract

Effective manoeuvrability, precise navigation and position determination are the key requirements for effective operations of deep-water and long-endurance autonomous under water vehicles (AUV). The article is published in three parts. The first part detailed the kinetics and kinematics involved in AUV attitude control when operated in hydrodynamic environments, principles of underwater real-time position determination based on dead-reckoning technique and the technological maturity of the state-of-the-art Inertial Navigation System.

The second part described the maturity of acoustic sensors/systems, principle of acoustic positioning systems and their performance in various water depths and sea states using Bellhop numerical simulations.

This part (last) describes the importance of aiding sensor performances and best field application practices in achieving the desired position accuracies. Modelling and simulation case studies presented for seven important scenarios shall help in understanding the intricacies in subsea guidance and navigation system design, identification of mission-specific sensor suite for achieving the desired performance and reliability.



Index terms: AUV, Guidance, MATLAB, Navigation.

A-INS field Performance- Modelling and Simulations

Based on the navigation and positioning methodologies and the sensor error models (inertial and acoustic) described in previous parts, numerical models of A-INS subsystems/components are developed and interfaced in MATLAB software (**Figure 1**). The models are simulated resembling seven important real-time scenarios to obtain accurate position estimates. (**Table 1**)

Case B: Assessment of importance of INS aiding sensor performance (without APoS)

The specification of the AUV dead-reckoning (DR) navigation and positioning sensor suite are mission-specific, importantly the mission duration. The sensors

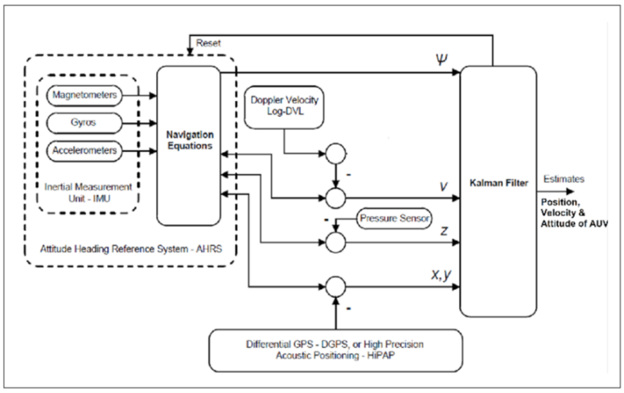


Figure 1. AUV's Aided-Inertial Navigation System (A-INS)

include AHRS and DVL. In order to determine the importance of sensor performance with time, an algorithm is developed using MATLAB R2021b (**Figure 2**) to estimate the position based on DR mode (the principle of DR is explained in the first part) with an update interval of 1s. The sensor suite includes six cases involving a combination of DVL and heading sensors with various accuracies and bias stabilities (**Table 2**).

The DR position determination performances for three grades of sensors suite (Type 1, 2 and 3) are plotted in **Figure 3**. The DR position computed by Type 5 sensor-suite when operated in NIOT's inspection class underwater vehicle is plotted in **Figure 4**, in which the underwater vehicle is deployed from and retrieved back on the anchored barge. It is observed that the position error observed is ~5% of the total distance travelled, matches closely to the simulation results.

Case C: Position error for AUV during descent and ascent in gliding and spiral trajectories without APoS aid

During a deep ocean mission, AUVs are programmed to reach the subsea target and back to the deployment vessel either in gliding or spiralling trajectories. The modes are decided based on mission objective, operational conveniences, time available to reach the subsea target, energy management strategies, ocean state and position drifts that could be encountered by the INS. The kinematics of the spiral and gliding descent/ascent spiralling radius/gliding angle depends on the thruster capacity, lift producing area and angle of the control surfaces including the fin and rudder.

The DVL operates in the bottom track mode up to 200m from the seafloor and in water track mode at water depths >200m (more details in Part A). During the descent/ascent phase, when the DVL is operating in the water track mode, in addition to the vehicle velocity, it measures the water velocity in the X-Y plane. For calculating the INS position drift when operating in water track mode, the water current profile logged in the Central Indian Ocean Basin up to 5500m using a submersible mounted upward-looking Acoustic Doppler Current Profiler (ADCP) on board NIOT Technology Demonstration Vessel Sagar Nidhi in April 2019 (**Figure 5**) is used. The water velocity measured in NED frame is converted to body frame using the Win ADCP software and used as an input to the simulations.

Based on the real-time position determination methodology and the INS sensor error models described in the first part, a mathematical model (with the algorithm shown in **Figure 6**) is developed in MATLAB2015b software for estimating the position error for an AUV with A-INS operating without APoS aid.

Simulations are carried out with sensor data update rate of one second for gliding and spiral trajectories of descent and ascent up to 6000m water depth. Four case

Table 1. Modelling and simulation case studies

Case	Description
B	Importance of aiding sensor performance (with INS and DVL) and without APoS in AUV Navigation & Positioning
C	INS position error when descend/ascend of AUV without APoS to/from 6000m water depth in spiralling and gliding trajectories in the presence of ambient ocean currents
D	Influence of AUV mounted gyroscope-DVL misalignment
E	Positioning error without sound velocity profile inputs to APoS
F	Relative position error of the AUV without ship attitude real-time correction
G	Position error with APoS aid with varying transceiver beam angle coverage

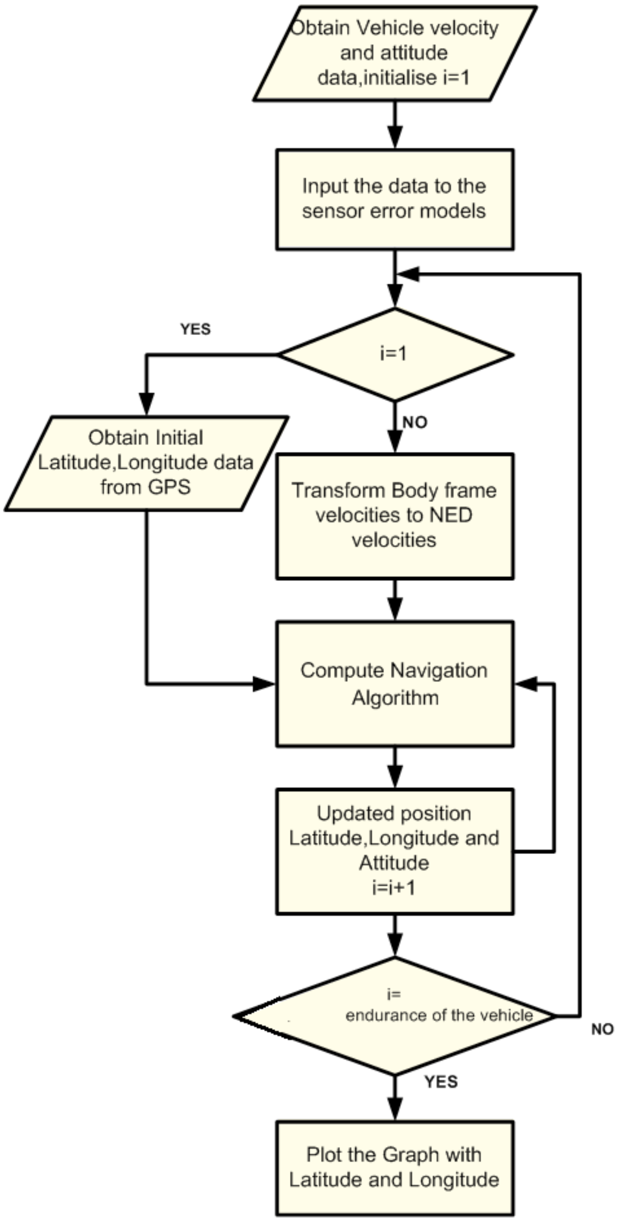


Figure 2. Algorithm for DR position computation

studies are carried out, two for each mode of descent and ascent (**Table 3**). For spiralling trajectory, AUV with 7m length, turning radius of 25m and 50m, with down/up gliding angle of 30° is considered. For gliding case, down/up gliding angle of 30° & 45° and an appropriate starting range is given as input. As an example, the results for Case 1 are plotted in **Figure 7**.

For Case 1, after estimating the position drift for the AUV in descent/ ascent phase with DVL aid only (without APoS), exhaustive Monte Carlo (MC) simulations are carried out to analyse the influence of sensor errors for obtaining the maximum possible position drift with a Circular Error Probability (CEP) over the two extremes sensor error ranges. The CEP50 is computed to analyse the probable position error with 50% confidence level. The CEP is defined as the square root of mean square error that includes 50% probable position outputs from mean as centre, which is also defined as the median error radius. It is identified (**Figure 8**) that the INS position drift shall be 1±0.125km.

Case D: Position error due to Gyroscope-DVL misalignment

The INS performance, in addition to the precision and quality of the individual inertial sensors (especially the gyroscopes bias stability that determines the heading accuracy) also depend on their alignment when strapped down on-board the AUV. This demands calibration and compensation of these parameters before operation. The recently introduced aided INS-DVL (integrated and tightly-coupled) system reduces the misalignment errors. The model equations used for computing the same is shown below.

The DVL error model in water track is based on equation:

Table 2. DR performance for a combination of navigation sensor suites

Suite	DVL	Attitude sensor	Drift from Lat after 30min	Drift from Lon after 30 min
	Accuracy (cm/s)	Bias stability (°/hr)	(m)	(m)
Type 1		0.01	0.9	0.9
Type 2	0.3±0.2	0.8	2.2	2.22
Type 3		5.0	10.51	4.35
Type 4		0.01	1.5	1.5
Type 5	1.1±1.0	0.8	5.1	5.15
Type 6		5.0	11.52	8.23

$$V_b = (1 + S_f)(V_i + SC) + b(t)$$

The DVL error model in bottom track is

$$V_b = (1 + S_f)(V_i) + b(t)$$

The misalignment error between the DVL and INS is given as

$$V_e = C_b^e C_b^d\, V_i$$

where 'Vi' is the simulated velocity input data from the DVL sensor, 'SC' is the sea current measured by the DVL in the water track mode, 'Vb' is the velocity output from the model measured in the body frame, Sf is scale factor, and b(t)is the white Gaussian noise. 'C_b^d'is the alignment matrix [3].

Based on the position estimation methodology and the model equations the position drift, in terms of % of the distance travel for INS-DVL misalignment errors of 1°, 2° and 5° for the simulated trajectory which is straight line

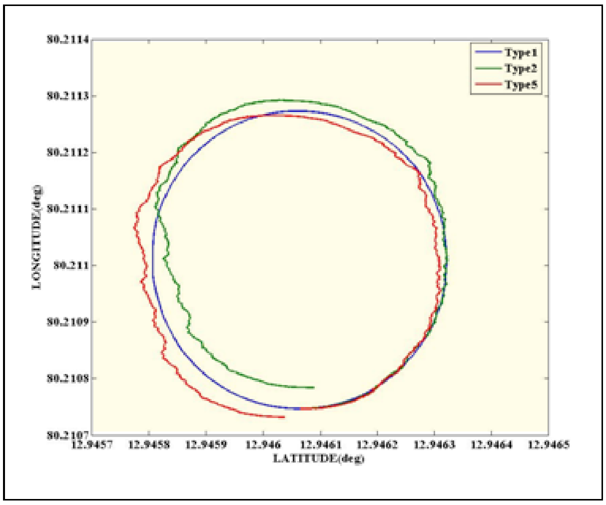


Figure 3. DR position performance for a combination of sensor characteristics

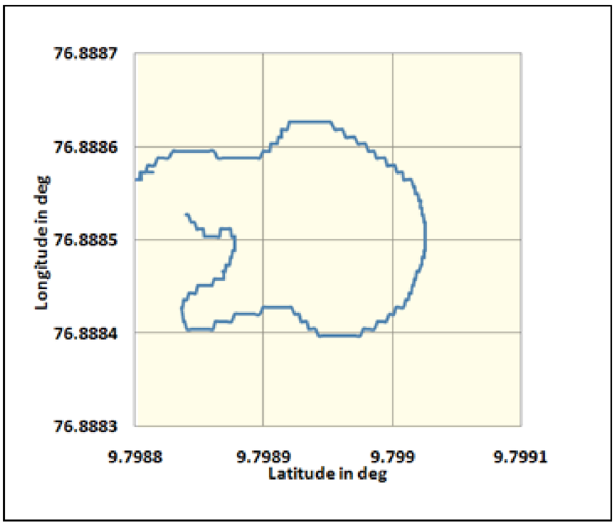


Figure 4. DR position computed by Type 5 sensor suite when operated in NIOT's inspection class underwater vehicle [1]

during the sea bed survey with 3 knots AUV speed for 4h, and the total distance travelled is 21.6 km) are shown in **Table 4**.

Case E: Position error without sound velocity profile inputs

The location-specific sound velocity profile (SVP) is an important input required for precise position determination by the APoS. Based on the real-time position determination methodology described in the second part, a mathematical model is developed in MATLAB2015b for estimating the position error. The probable position error in the APoS position without SVP (actual SVP at the location shown in **Figure 8** of Part B) input are computed and plotted in **Figure 9**. It is found that, without SVP inputs the position error could be up to 150m at 5500m water depths (2.7% of the range) in the Indian Ocean.

Case F: Relative position error of AUV without real-time ship attitude inputs to APoS

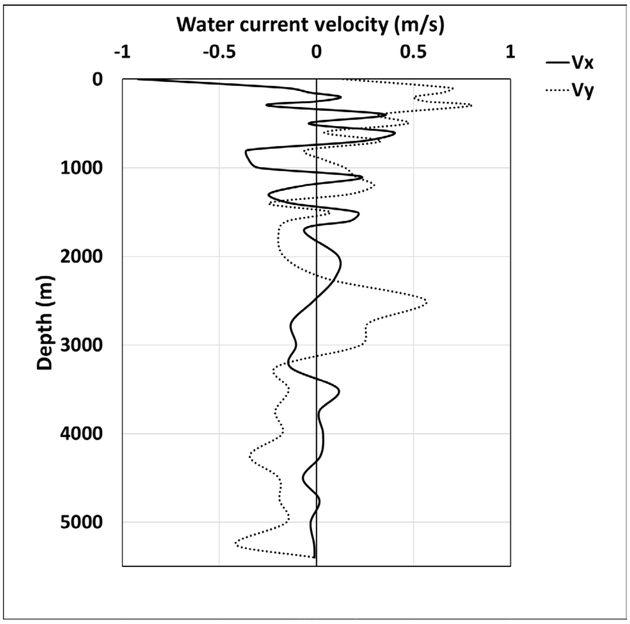


Figure 5. Water current profile in the Central Indian Ocean [2].

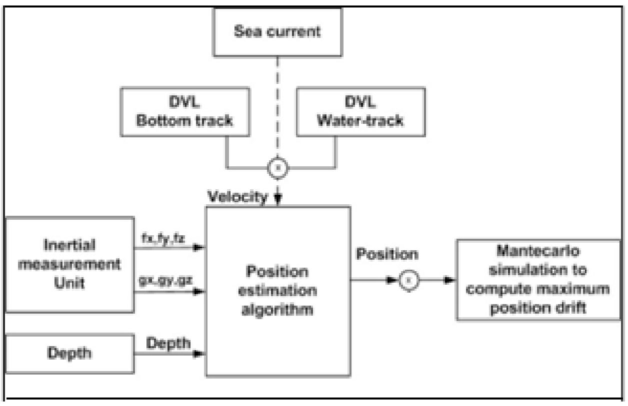


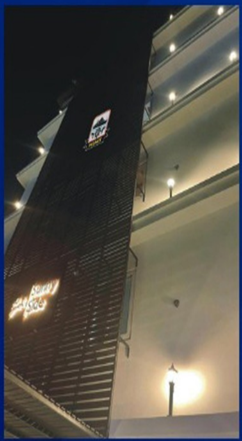
Figure 6. Algorithm for position computation without APoS aid

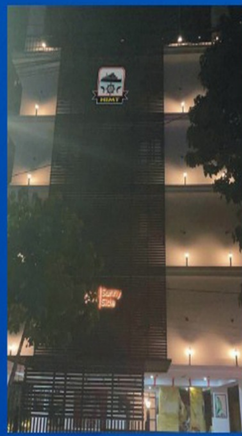
The USBL APoS on-board the deploying ship is used for tracking the AUV in real-time and for providing position updates for correcting the drifts in the AUVs on-board INS (if there is a communication link). During operations, the deployment vessel undergoes attitude changes in 6 DoF including pitch, roll and heading in angular orientation, and surge, sway and heave in the linear orientation. The ship USBL transceiver also undergoes attitude changes in all DoFs. The ship attitude changes are measured using a Motion Reference Unit (MRU) and the 6-DoF attitude parameters are provided as real-time inputs to the transceiver unit for motion compensation.

Based on the principle of bearing computation (described in **Figure 2** and **3** of Part B), the time of arrival (ToA) of the pressure wave-front between the transducers is used for computing the bearing angle. The attitude changes introduce an increase/decrease in the wave-front travel distance **Δx** and this introduces errors in the position computation. The magnitude of the error depends on the number of transducer elements in the transceiver and its internal arrangement. **Figure 10** depicts the true bearing (with attitude compensation) and relative bearing (without attitude compensation). Based on the APoS manufacturers experiences, a roll or pitch error of 0.25° will result in an error of ~5m at 1000m water depth and 13m at 3000m water depth. A roll and

Table 3. Results of simulations for descent/ascent without APoS

Case	Simulation results
Case 1: Spiral mode Turning radius 25m Body frame velocity 5 kn (Fig.14)	Spiral height 202 m, Number of spirals 30 Flight Duration 7200s INS Position drift: Latitude – 12.9461,12.9462 Longitude - 80.21091,80.22054 Drift in north -22 m; East -1069 m **Total position drift (CEP50) 1.07 km**
Case 2: Spiral mode Turning radius 50 m Body frame velocity 5 kn	Spiral height 202 m, Number of spirals 20 Duration 7200s INS Position drift Latitude – 12.946,12.9461 Longitude - 80.2108,80.2135 Drift in north -10 m; East -299.9 m **Total position drift (CEP50) 300.6 km**
Case 3: Gliding mode Angle: 30° Body frame velocity 5 kn	Duration 7200s INS Position drift Latitude – 12.9461,12.9462 Longitude - 80.21081,80.2218 Drift in north -92 m; East -1204 m **Total position drift (CEP50) 1.208 km**
Case 4: Gliding mode Angle: 40° Body frame velocity 5 kn	Duration 7200s INS Position drift Latitude – 12.9463,12.947 Longitude - 80.21091,80.22054 Drift in north -28 m; East -1073m **Total position drift (CEP50) 1.12 km**





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pitch error of 0.05° will result in position error of ~1 and 3 m, at 1000 and 3000m water depths, respectively.

Case G: Position error with APoS of varying transceiver beam angle coverage

The deep-water low frequency USBL having a transceiver operational beam width of 120° and 12km range is considered for the analysis. The ship-based positioning system with a range accuracy of 0.2 % of the slant range and angular accuracy is 0.1° is considered with the technology-matured USBL. The USBL system is programmed to include the SVP of the specific location.

The USBL system computes the position in spherical co-ordinates (range and bearing angle). The position of the USBL is converted to NED frame using the equation.

$$P^{N}_{USBL} = P^{N}_{U} + R^{N}_{U}\begin{bmatrix}(ru+\delta ru)\sin(\psi u+\delta\psi u)\cos(\varphi u+\delta\varphi u)\\(ru+\delta ru)\sin(\psi u+\delta\psi u)\sin(\varphi u+\delta\varphi u)\\(ru+\delta ru)\cos(\psi u+\delta\psi u)\end{bmatrix}$$

Where:

P^{N}_{U}, is the initial position of the USBL in NED frame

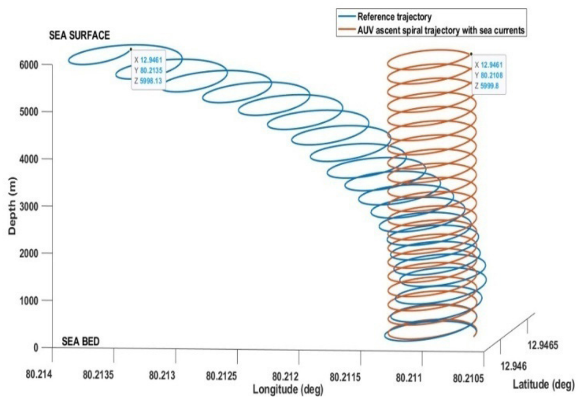

Figure 7. AUV in spiral ascent mode with a turning radius of 25m

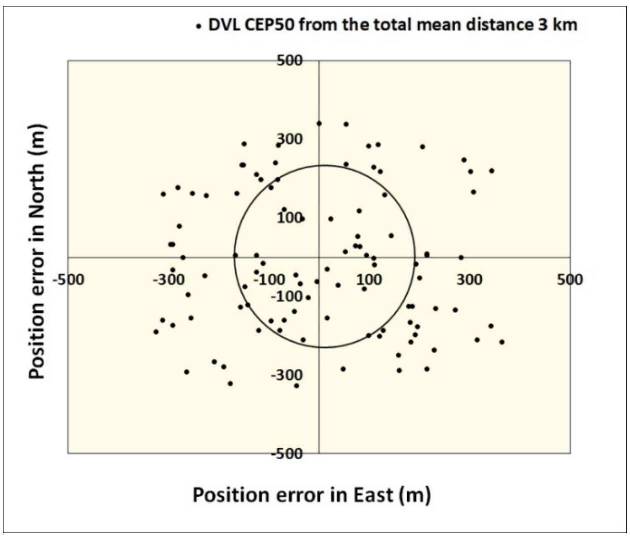

Figure 8. CEP50 position plot of AUV during ascent/descent with DVL aid

R^{N}_{U}, is the rotation/orientation matrix of the USBL w.r.t NED frame

ψu, is the elevation angle in deg.

Φu, is the azimuth/bearing angle in deg.

δru, is the range accuracy of the USBL system

$\delta\phi u$, is the angular accuracy of the USBL system

The horizontal drift is estimated based on the angular error of the USBL modem and depth (equation 23& 24).

X = Depth * tan ψ_x

Range = X/Sin ψ_x

ψ_x is the elevation angle in degrees

Based on the equations of USBL sensor model, simulations are performed for position estimation with INS aided by the USBL for different beam angles. The horizontal shift, range due to the USBL transceiver with 0.1°angle accuracy is estimated to be ~21m (**Table 5**).

Based on the simulation results, the uncertainty in the position estimation is performed using MC simulations for 100 iterations and the results for a circular error probability CEP50 are represented in **Figure 11**. The position error aided by USBL in North and East are +/- 10m, +/-5m for the beam angle 5° from the mean position (9.53 m, **Table 9**).

A-INS Hardware reliability- Modelling & Simulations

Reliability estimations of the A-INS done using numerical methods based on field failure-in-time (FIT)

Table 4. Position error due to gyroscope-DVL misalignment

Misalignment (deg)	Actual distance travelled	Position Error (m)	% Error of total distance travelled
1º	21.6 km	43	0.2%
2º		129	0.6%
5º		281	1.3 %

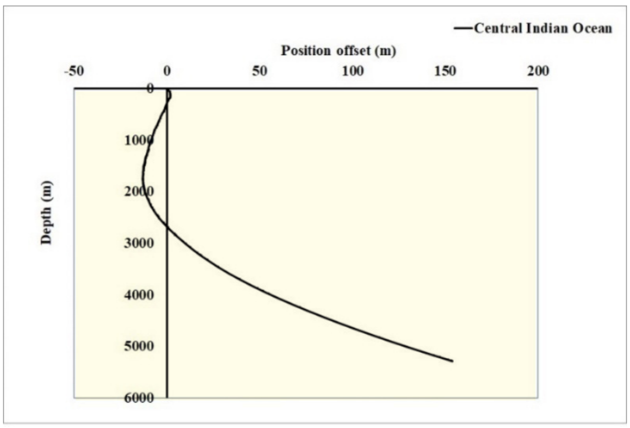

Figure 9. AUV Position error without SVP inputs for APoS

data and published failure models serve as a yardstick for comparing alternate technologies, continuous improvements, and maintenance planning. The reliability of a system is defined in FIT, is usually represented as λ, and expressed in failures per billion hours. Given the number of failure and the cumulative operating period, λ is calculated as (Number of failures/ Total operating time in hours) x 10^9. [4]

For the system/component with a failure rate of λ, the probability of failure (PoF), Q(t) in % in a period t is computed based on the following relationship,

$$Q(t)=1-e^{-\lambda t}$$

The failure rate of the subcomponents/subsystems used for AUV navigation and positioning are shown in Table.6.

Based on the functional bottom-top approach, Failure trees (FT) are modelled and simulated using TOTAL GRIF reliability analysis software for computing the PoF of the A-INS (**Figure 12**). The exponential law is used for defining the degradation pattern over the simulated period. The results of the analysis taking into consideration possible redundancies are shown in **Table 7**.

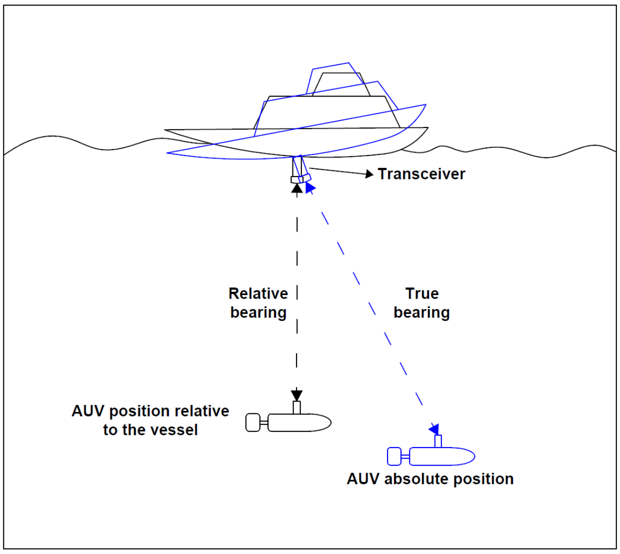

Figure 10. AUV Position error without SVP inputs for APoS

Table 5. Range and position error with different beam angles of USBL system

Beam angle (deg)	Horizontal shift X 'm'		Slant Range Sr 'm'		Position Error from initial to final lat & long (m)
	Ideal	USBL	Ideal	USBL	USBL
1	104.5	114.9	6000.9	6013.1	9.42
5	521.9	532.3	6022.9	6035.8	9.53
15	155.1	156.1	6211.5	6226.9	10.47
30	302.2	303.1	6927.8	6948.7	13.92
60	595.0	598.0	11996	12056	42.2

CONCLUSION

The performances of autonomous underwater vehicle navigation and positioning systems have reached unprecedented levels. The article series described the kinetics and kinematics involved in AUV attitude control when operated in hydrodynamic environments, principles of underwater real-time position determination based on dead-reckoning and the technological maturity of the underwater Aided-Inertial Navigation System. The importance of systematic system engineering and best application practices in reducing the position inaccuracies in the aided inertial navigation system is described using seven case studies with the aid of numerical models. Modelling simulations are performed using Bellhop ocean sound propagation modelling software for determining the transmission losses in Indian Ocean conditions and the results were used to determine the range and acoustic power requirements for base line positioning systems when operated under varying ambient noise conditions.

The importance of inertial navigation system aiding sensor performance is demonstrated using MATLAB models and simulations for a range of sensor grades. It is identified that the mechanical misalignment errors between the strap-down gyroscope and the Doppler Velocity Log, if not accounted during calibration, could result in position inaccuracies of up to 1% of the distance travelled. By means of MATLAB numerical model and field measured water current data it is identified that the unavailability of the acoustic positioning aid to the AUV leads to position drift of ~1.5 km when descends/ ascends in spiralling trajectory from 5500m water depth in the Indian Ocean, and the drift could be 3.2 km when descends /ascends in gliding trajectory. By modelling and simulations, it is also identified that sound velocity profile inputs could improve the acoustic system positioning accuracy by 2.7% of the slant range at 5500m water depths. The importance of providing ship attitude inputs is real time to ship USBL transceiver for precise position computation is also described.

The hardware reliability of the aided inertial navigation system is computed using reliability modelling and

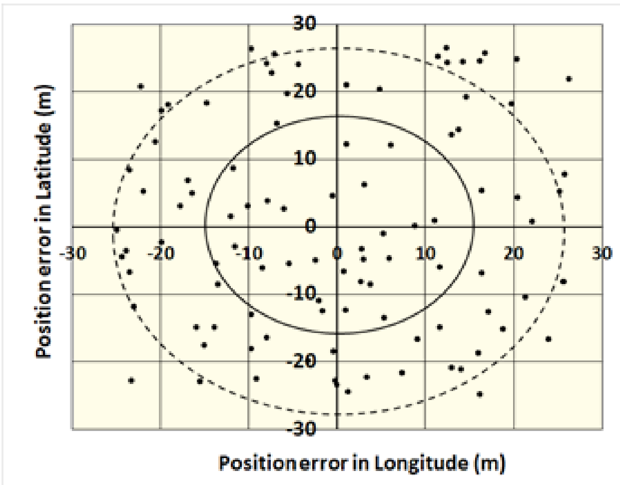

Figure 11. MC plot of USBL position drift with CEP50

simulations software and it is found that the Mean Time to Fail period could be increased from ~5 to ~10 years by using a redundant depth sensor and ultra-short baseline acoustic positioning systems. The results presented shall help in understanding the intricacies in subsea guidance and navigation system design, identification of mission-specific sensor suite for desired performance and the importance of reliability-centred hardware design.

Table 6. Failure rates of the AUV Nav-Pos systems

Component	Failure rate(failures/ billion hrs)	Source of data
INS-DVL	12500	(Vedachalam., et al., [6][7][8])
APoS-USBL	22831	(Kebkal,V.,2015, [5])
Depth sensor	2500	(Vedachalam., et al., [6][7][8])
Cable harness	244	
AUV control system	13333	
Ethernet switch	759	
Serial to Ethernet converter	365	

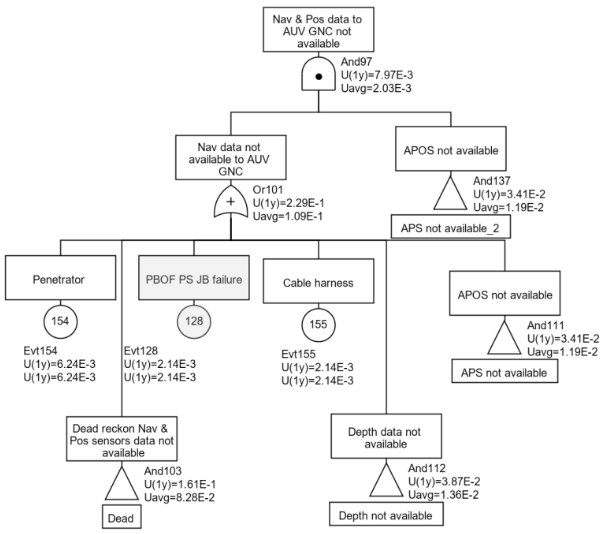

Figure 12. Fault tree analysis for A-INS without redundancy

Table 7. PoF of the A-INS with and without redundancy

Configuration	PoF %	MTBF
INS with aid of DVL and depth sensor	17.8	5 years
INS with redundant DVL and depth sensors	9.9	10 years
INS with redundant DVL and depth sensors and USBL aid	10.9	8.5 years

ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
AHRS	Attitude Heading Reference System
A-INS	Aided-Inertial Navigation System
APoS	Acoustic Positioning System
AUV	Autonomous Underwater Vehicle
CEP	Circular Error Probability
DoF	Degree of Freedom
DR	Dead Reckoning
DVL	Doppler Velocity Log
FIT	Failure-In-Time
FT	Fault Trees
GRIF	Graphical Representation of Fiability
INS	Inertial Navigation System
MATLAB	Matrix Laboratory
MC	Monte Carlo
MTBF	Mean Time Between Failures
MRU	Motion Reference Unit
NED	North East Depth
NIOT	National Institute of Ocean Technology
PoF	Probability of failure
SVP	Sound Velocity Profile
ToA	Time of Arrival
USBL	Ultra-Short Base Line

ACKNOWLEDGEMENTS

We thank the Ministry of Earth Sciences, Govt. of India for motivating this study.

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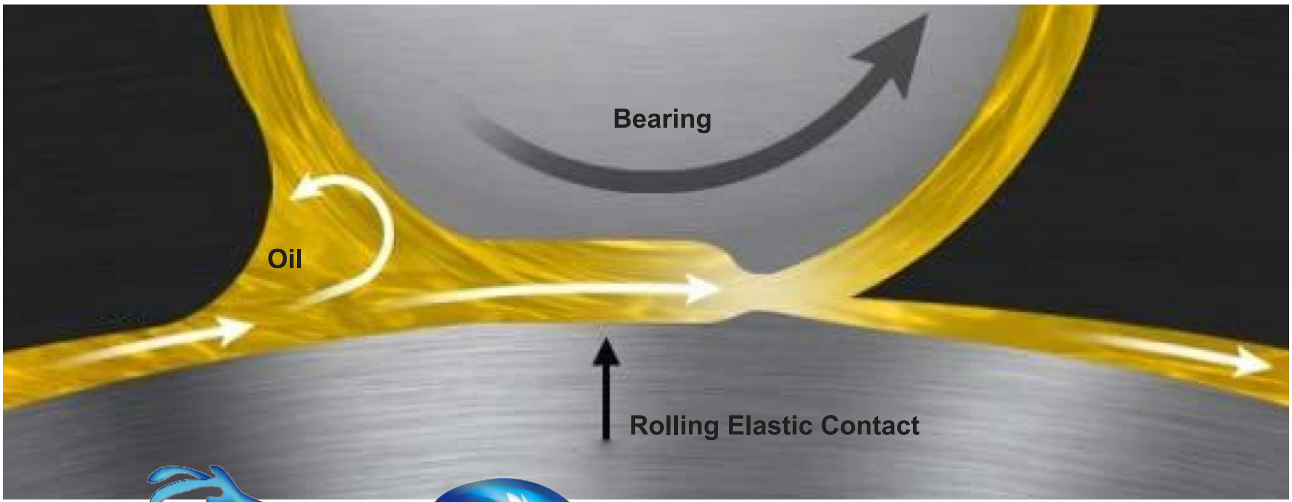
TECHNICAL NOTES

LUBE MATTERS # 22
LUBRICATION REGIMES (PART I)



Sanjiv Wazir

Introduction

The primary purpose of lubrication of machine components is to reduce friction, prevent or minimise wear, and carry away heat. This is usually achieved by the formation of a lubricant film between the surfaces in contact.

Lubricants can be of gaseous, liquid, or solid origin. Lubrication by liquids and solids is described below. Lubrication by gas bears many similarities to liquid lubrication, both being fluids.

Liquid Lubrication

Formation of liquid lubricant film depends on physical/chemical properties of the liquid, most importantly viscosity and wettability. Liquid lubricants can be brought into a converging contact due to the rotation/relative motion and pressure generation between bodies.

Viscosity (refer to LUBE MATTERS # 9: VISCOSITY)

Viscosity is a measure of the force required to slide one flat body along another with liquid in between. Many properties of a lubricant film are closely related to the fluid viscosity.

Wettability

Wettability refers to the ability of a liquid to form contact with a solid surface due to intermolecular interactions when the two are brought together. Wettability is defined in terms of the contact angle. It is dependent on the surface tension of the fluid and the surface energy of the surface.

For a given solid, a liquid with low surface tension will produce more wetness than a liquid with high surface tension.

Surface free energy is a measure of the excess energy present at the surface of a material, in comparison to that present in its bulk. A high surface energy surface, will allow the liquid to spread, whereas a low surface energy surface will not.

Stribeck Curve

The lubrication of shafts in sleeve or journal bearings has been well studied over the last two centuries, because these components are so widely used in machinery and railroad equipment. In 1886, Osborne Reynolds developed some equations for the case of the flooded (i.e., adequate lubricant supply) bearing with no flow of lubricant out the end of the bearing. He described the action of lubrication using the idea that the rotating shaft “drags” fluid into the contact region between itself and the bearing, building up a fluid pressure that carries the applied load. He combined these variables into a mathematical formulation based on the Navier–Stokes equations for fluid flow. Many later authors and researchers used variations of the Reynolds equations for their analysis of bearing behaviour for other cases such as narrow bearings (considerable side leakage), high loading, and variations on conditions prevailing in the entrance wedge.

Richard Stribeck presented the results of studies of friction of hydrodynamic bearings graphically. He

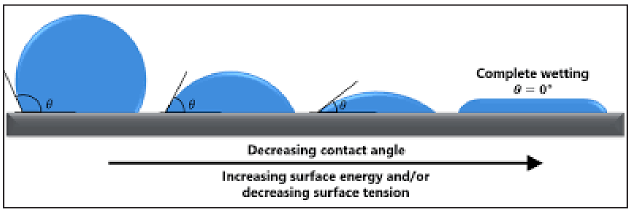


Figure 1. Relationship between Wettability (contact angle), Surface tension & Surface free energy (1)

confirmed a minimum point in friction for varying conditions. Hersey realised a convenient relationship between friction and shaft speed (rpm), N, viscosity Z and load P.

A high surface energy surface, will allow the liquid to spread, whereas a low surface energy surface will not

ZN/P is commonly used quantity found on the x-axis on the Stribeck curves (it is sometimes referred to as the Hersey number). The Stribeck curve graphically shows three distinct ranges along the x-axis in which the change in coefficient of friction (COF), on the y-axis, is distinctly different. These distinct ranges have since been identified as the three lubrication regimes of boundary, mixed and hydrodynamic lubrication.

Superimposed with film thickness curve (blue), Lambda (λ *) ratios and EHD region**

The Stribeck curve is often used as tool to evaluate the effect of changes in lubricant's viscosity or additive composition, speed, load, and surface roughness on friction.

Static Friction (refer LUBE MATTERS # 19: ON FRICTION)

Before the journal begins to rotate in the bearing, static friction is to be overcome. Static friction is higher than kinetic friction. If the Stribeck curve were to start at the "zero" mark along the x-axis, where the rotational speed is zero, the COF (static) would be significantly higher than what is observed in the boundary lubrication regime. Usually, static friction is not shown on the Stribeck curve.

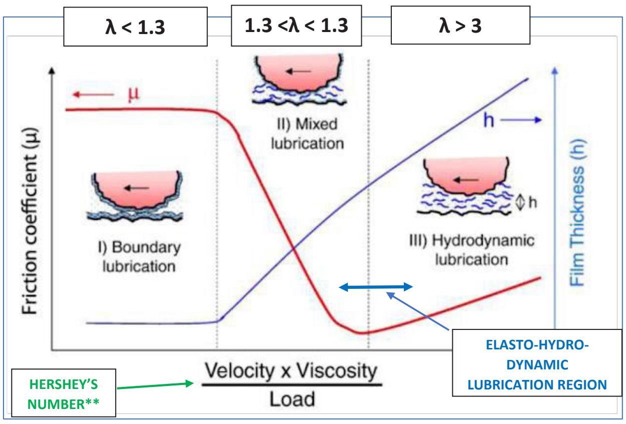


Figure 2. The Stribeck curve* (red line) (2)

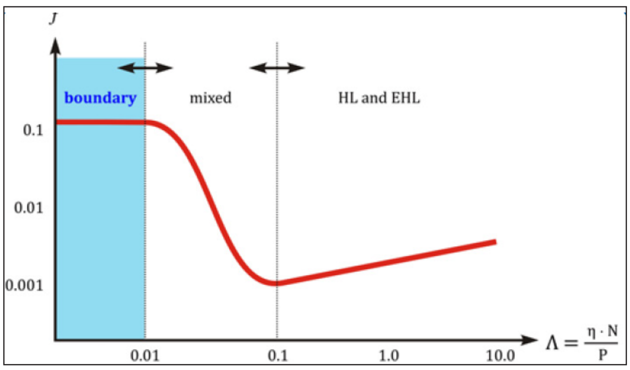


Figure 3. "Boundary" Stribeck curve (4)

Boundary Lubrication

Although both the journal and bearing have macroscopically polished surfaces, at microscopic levels the surfaces comprise of asperities and valleys. The solid surfaces are so close that most of the load is supported by the peaks of the asperities. In addition, surface interactions between monomolecular or multi-molecular films of lubricants trapped in the asperity valleys supports the rest of the load. This combination of large surface contact and little lubricant film in the interface results in high friction and is termed the boundary lubrication regime. When the journal begins to rotate, a combination of low speed, low viscosity, and high load (low Hershey's Number) will result in high COF.

In boundary lubrication regime, the bulk properties of the lubricant (such as viscosity) play little role. The chemistry of the lubricant and the surface material properties dominates the friction and wear behaviour of lubricated surfaces. Sacrificial additives, such as friction modifiers & antiwear additives, are required to reduce friction and wear before a lubricant film is developed by the rotation of the journal. Such additives form sacrificial (easily sheared) films on the bearing surfaces, so that the asperities can slide over/past each other without welding/gouging, thereby minimising wear (refer to LUBE MATTERS 12: FILM FORMING ADDITIVES). Boundary lubrication is typically prevalent at start-up & shut down of machinery (low speed, thin film). Highest friction and

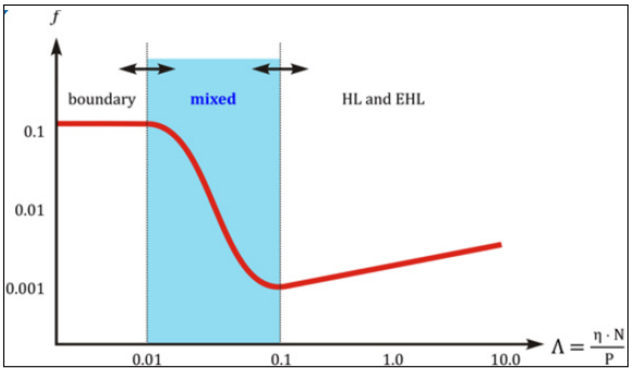


Figure 4. "Mixed" Stribeck curve (4)

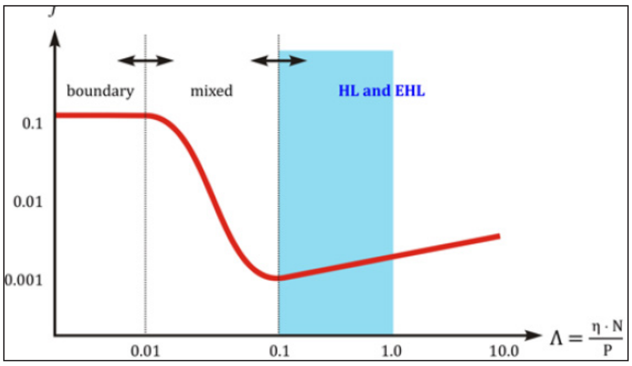


Figure 5. "Hydrodynamic" Stribeck curve (4)

wear are usually experienced under these conditions.

The Stribeck curve graphically shows three distinct ranges along the x-axis in which the change in coefficient of friction (COF), on the y-axis, is distinctly different. These distinct ranges have since been identified as the three lubrication regimes of boundary, mixed and hydrodynamic lubrication

Mixed Lubrication

As the speed and/or viscosity increases and/or load decreases, more fluid gets dragged between the rubbing surfaces. A lubricant film begins to form and separate the surfaces reducing their contact, and friction. The film is still thin but continues to grow and brings about a sharp decrease in COF, as relatively small changes in rotational speed results in fewer and fewer asperities of the rubbing surfaces contacting each other, as indicated by the steep slope in the Stribeck curve, **Figure 4**. This is the mixed lubrication regime.

Hydrodynamic Lubrication (HL)

As speed and/or viscosity continues to increase and/or load continues to reduce, the film thickness increases to a stage where opposing asperities are no longer in contact with each other. The interface has now transitioned to HL, also is known as "full fluid film lubrication", because the load is carried entirely by the lubricant film and there is no solid-solid contact. COF is at its lowest, and there is no wear, **Figure 5**. This usually occurs when the lambda ratio > 3.

HL does not depend on the introduction of the lubricant under pressure. Inlet pressure is required to deliver the lubricant to the wedge forming area. The pressure in the lubricant film is created by the relative motion of the surfaces. In this regime friction arises entirely from the oil viscosity and is directly dependent on the area of the film, the rate of shear and the viscosity of the lubricant. Coefficients of friction can be as low as 0.001 - 0.003 and wear is negligible.

In the HL regime, when speed increases beyond the point of lowest COF, the COF begins to increase. This is due to the lubricant's viscosity. Viscosity is a measure of the lubricant's internal resistance to flow. With the higher speed resulting in thicker film the oil provides more resistance or friction. Higher viscosity fluid would also result in similar increase in COF. Hence choosing the right fluid viscosity is of critical importance in achieving low COF. Changes in surface roughness (e.g., running-in) also effect Stribeck curve.

The mere introduction of a film of fluid between components in relative motion resolves a lot of tribological problems. In many cases the viscosity of the fluid and the geometry and relative motion of the surfaces, can be used to generate sufficient pressure to prevent solid contact. This is the principle of hydrodynamic lubrication, a mechanism which essentially drives modern industry.

Although usually beneficial, hydrodynamic films can sometimes be dangerous. For example, care has to be taken to prevent the formation of a film of water between the tyres of a vehicle and the road surface in wet weather, to prevent "hydroplaning", resulting in a loss of grip.

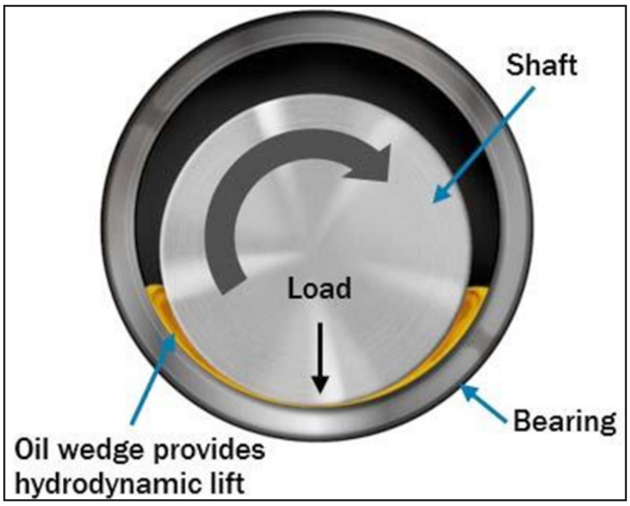


Figure 6. Hydrodynamically lubricated Journal Bearing (5)

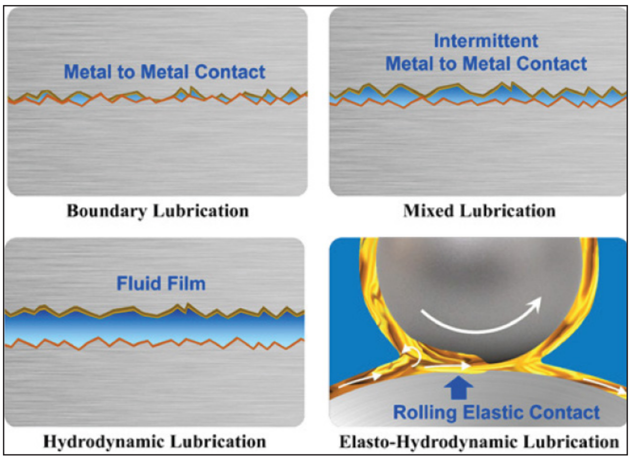


Figure 7. Main Lubrication Regimes (5)

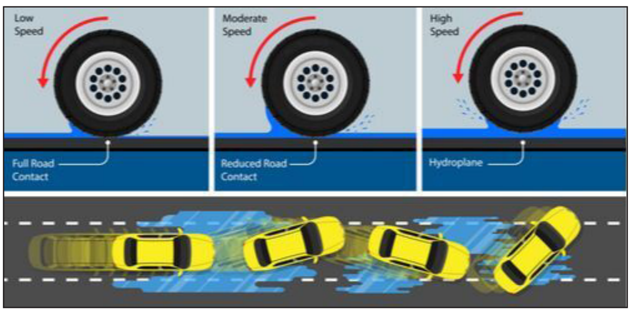
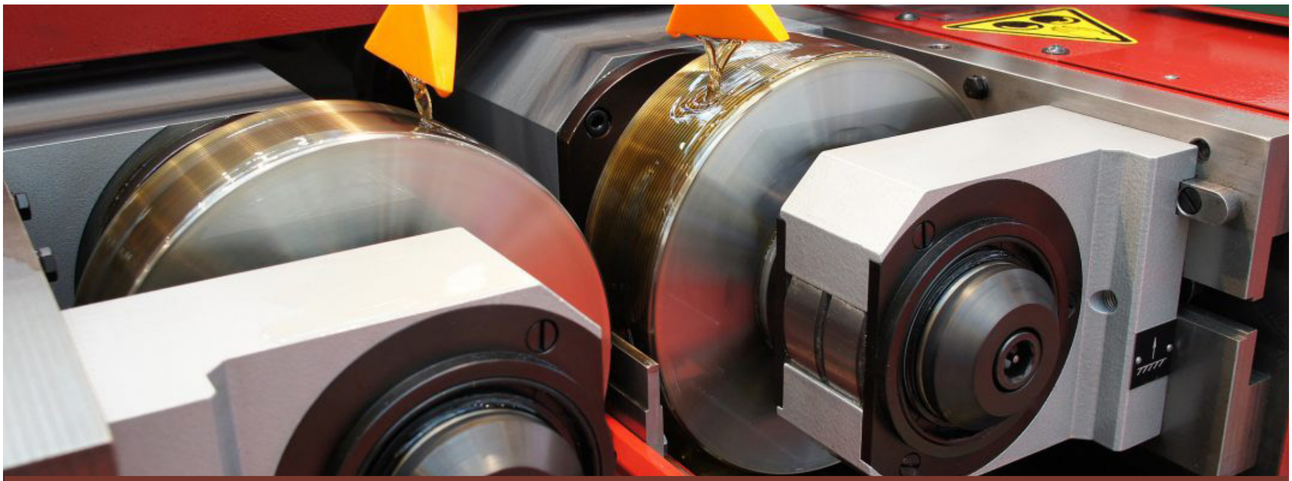


Figure 8. Hydroplaning (6)



In many cases the viscosity of the fluid and the geometry and relative motion of the surfaces, can be used to generate sufficient pressure to prevent solid contact. This is the principle of hydrodynamic lubrication, a mechanism which essentially drives modern industry

NOTES

***Stribeck Curve:**

In its simplest form, the Stribeck curve graphically shows how the coefficient of friction of a journal bearing is affected by the speed of the shaft rotation. Lubricant viscosity, load and surface roughness are held relatively constant while changing the speed of the journal rotation only. In its more complete form, the Stribeck curve incorporates the Hersey number (7).

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****Hershey's Number**, named after Mayo Hersey, whose studies enhanced the Stribeck curve. The Hersey number is essentially the lubricant viscosity (Z) times the Speed (N) divided by the load (P) (7). Some form of Hershey's number usually forms the y-axis of the Stribeck curve.

*****Lambda Ratio**, sometimes just called lambda (λ), is a parameter sometimes used to distinguish the lubrication regimes (7). Lambda is the ratio of the lubricant film thickness to the combined root mean square of the surface roughness of the journal and bearing surfaces

Other types of Lubrication regimes and films will be covered in the next article.

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IME (I) GOVERNING COUNCIL, BRANCH AND CHAPTER COMMITTEE ELECTIONS 2023-25

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

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- Notice of the entire process of election shall be intimated through electronic media ONLY.
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- Soft copy of the Nomination papers for Council elections will be mailed by **15^{th} May 2023** to the Members email id which is registered in the records of the IME(I).
- Nomination papers for the Council are to be received in the Institute's office by **15^{th} June 2023** to the email id: ***electionofficer@imare.in***
- Last date for withdrawing nomination is **30^{th} June 2023**.
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- Election Officer after scrutiny will publish the CVs of the eligible candidates on IME(I) website.
- The election window for eVoting will remain open from **15th July 2023 to 31st August. 2023**.

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- The use of your personal mail would ensure that you do not miss any important communication relative to the election process.

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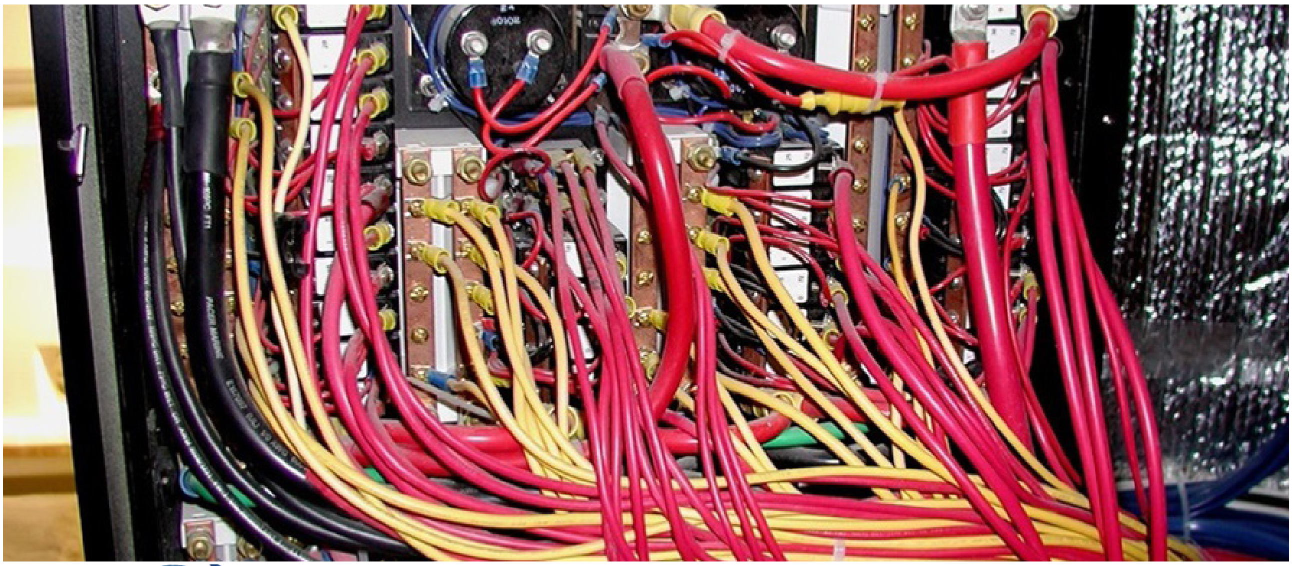
Troubleshooting Marine Electrical Equipment: Reading Diagrams



Elstan A. Fernandez

Abstract/Summary

This article is a sequel to the previous article, 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 on-board 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

Shipboard equipment can malfunction for a variety of reasons. Mechanical contacts and parts can wear out; wires can overheat and burn out; parts can be damaged by impact or abrasion; etc. Typically, whenever any equipment fails, there is a sense of urgency to get it fixed and working again. In the shipping industry, defective equipment could also cause unexpected loss of revenue and unprecedented loss of time.

It is thus essential for an ETO and Marine Engineer to be able to read Electrical diagrams as fast as possible and to find a solution as fast as possible.

Reading Diagrams

The tracing of engineering drawings like electrical circuits, requires a keen understanding of schematics, symbols and other details used to represent components. Continual practice and a habit of reading the starter, control panel and other electrical drawings before attempting to troubleshoot them is the key to comprehending the operation of shipboard systems that are growing in complexity with each passing year.

The bibliography of starter panels and other equipment on board generally contains vital information with regard to how the maker has represented various components.

1. Diagrams are always drawn with the assumption that the system is in a state of rest i.e., without power – also known as the de-energised state. However, there could be exceptions to this rule.
2. They are read from left to right.
3. Generally, devices at the same power level are drawn at the same horizontal level.
4. The inter-relation of components is generally achieved by a line diagram.

5. If the diagram runs into a few pages, then reference to a page and an alpha-numeric matrix on that page is made near the component. This is also called the Cartesian coordinate or Co-planar system.

1. *Cable and Wire-Marking Systems*

Cables and wires are marked to give the engineer a means of tracing them when troubleshooting and repairing electrical and electronic systems. Numerous cable and wire-marking systems are used in ships' equipment. For a specific system or equipment, the applicable technical manual should be referred.

Metal tags embossed with the cable markings are used to identify all permanently installed shipboard electrical cables. These cable tags are placed on cables close to each point of connection, on both sides of decks, bulkheads, and other barriers to identify the cables. The markings on the cable tags identify cables for maintenance and circuit repairs. The tags show (1) the service letter, which identifies a particular electrical system, (2) the circuit letter or letters, which identify a specific circuit within a particular system and (3) the cable number, which identifies an individual cable in a specific circuit.

2. *Shipboard Electronic Equipment Wire-marking Systems*

The following explanation is an example of the type of conductor marking used in shipboard electronic equipment. These conductors may be contained in cables within the equipment. Cables within equipment are usually numbered by the manufacturer; these numbers will be found in the technical manual for the equipment.

If the cables connect equipment between compartments on a ship, they will be marked by the shipboard cable-numbering system. On the conductor lead, at the end near the point of connection to a terminal post, spaghetti sleeving is used as a marking material and an insulator. The sleeving is marked with identifying numbers and letters and then slid over the conductor. The marking on the sleeving identifies the conductor's connections both "to" and "from" by giving the following information:

The terminal "from"

The terminal board "to"

The terminal "to"

These designations on the sleeving are separated by a dash. The order of the markings is such that the first set of numbers and letters reading from left to right is the designation corresponding to the terminal "from" which the conductor runs. Following this is the number of the terminal board "to" which the conductor runs. ("TB" is omitted when the sleeve is marked). The third designation is the terminal to which the conductor runs. For example, the conductor is attached to terminal 2A of terminal board 101 (terminal 'from' 2A on the spaghetti sleeving). The next designation on the sleeving is 401, indicating it is going "to" terminal board 401.

The last designation is 7B, indicating it is attached "to" terminal 7B of TB 401. The spaghetti marking on the other end of the conductor is read the same way. The conductor is going "from" terminal 7B on terminal board 401 "to" terminal 2A on terminal board 101. Sometimes it may be necessary to run conductors to units that have no terminal board numbers; for example, a junction box. In this case, an easily recognizable abbreviation may be used in place of the terminal board number on the spaghetti sleeving.

The designation "JB3" indicates that the conductor is connected to junction box No. 3. In the same manner, a plug would be identified as "P." This P number would be substituted for the terminal board number marking on the sleeving.

3. *Multi Page Diagram – e.g., a DG Monitoring and Control Circuit*

Multi-page electrical diagrams adopt the Cartesian coordinate method and are drawn in such a way that various operations are referred to by the current path and mainly alpha-numeric codes for the purpose of cross-referencing as shown in **Figures. 1 (a)** to **(e)**.

Multipage diagrams like those for boilers and diesel generators which consist of many simultaneous operations or in a pre-determined sequence, are drawn in many pages with current paths as shown in the **Figures 1(a)** to **(e)**.

With reference to **Figure 1(a)**, there are 13 current paths on Sheet No.4; hence the paths are numbered from 4.1–4.13.

Each relay contact is marked with a current path. For example, 4-11 has 4 NC contacts which have current paths on pages 3 and 5 namely 5.5, 5.7, 3.9 and 5.11. In order to trace the functions of these contacts, we have to go to the currents paths as marked under each relay.

The Speed Relay (SR) is a microprocessor-based relay that gets its speed signal input from the pick-up mounted on top of the flywheel.

It has 3 speed outputs namely 4-3 if the speed is less than 110 r.p.m., 4-4 and 4-5 (in parallel) if the speed is 710 r.p.m. and 4-6 for over speed which is set at 815 r.p.m.

In case of over speed i.e., at 815 RPM, speed relay 4-6 will energise and its contact will energise 5-4 which in turn will energise the common shut down relay 6K10 and finally energise the stop solenoid SV2 (3.10).

Relay 5-4 makes its own retaining contact so that the starting of the DG is possible only if the circuit is reset by relay 4-11.

A similar trip circuit will be operated by relay 5K6 in case of Low Lubricating Oil Pressure and 5K8 for High Water Temperature.

With reference to **Figure 1 (b)**, if the start signal is transmitted from the remote location, then relays 3-2 and timer 3-3 will get energised.

The "Start" solenoid valve SV1 will be energised through speed relay 4-3 and the Turning Bar interlock relay 7-3. Now when the engine attains its speed of 710 r.p.m., then speed relay 4-3 will be off and so SV1 cuts-off the starting air; relays 3K2 and Timer 3-3 will also be off.

If the engine starting has not taken place satisfactorily, then the timer 3-3 will energise 5K1 which in turn will energise stop solenoid SV2 and then relay 3-7 which will cut-off Start solenoid SV1 and activate a "Start Failure" alarm.

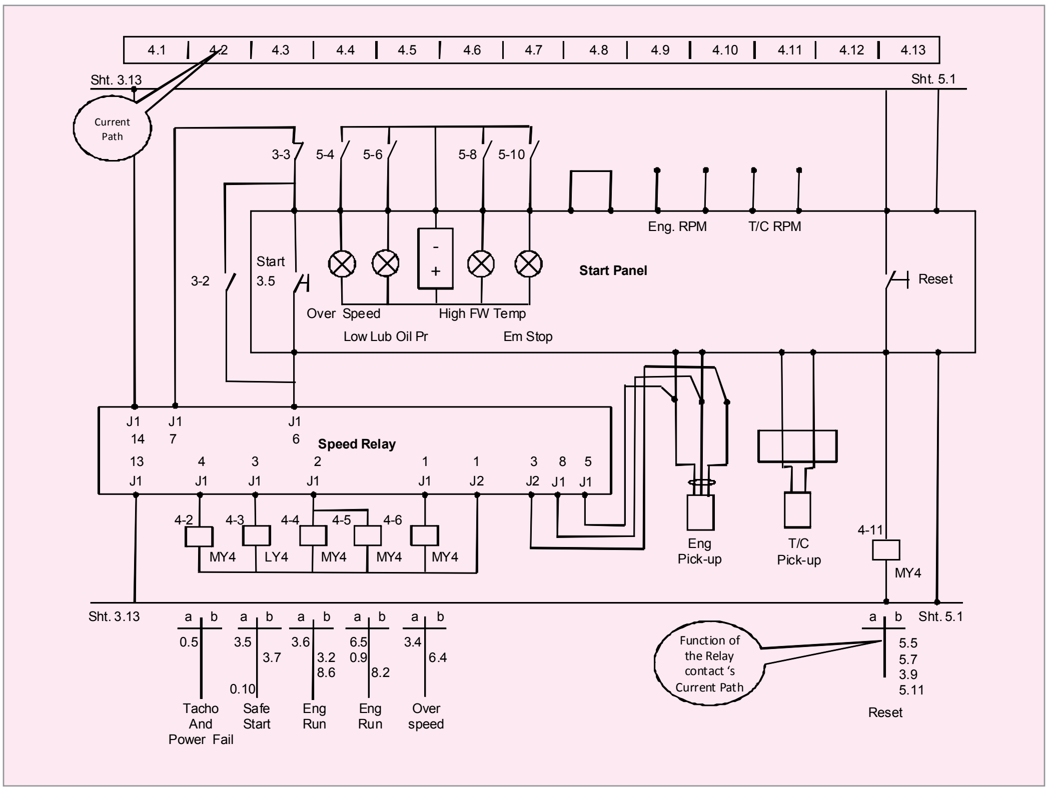


Figure 1(a) – A DG Monitoring and Control Circuit

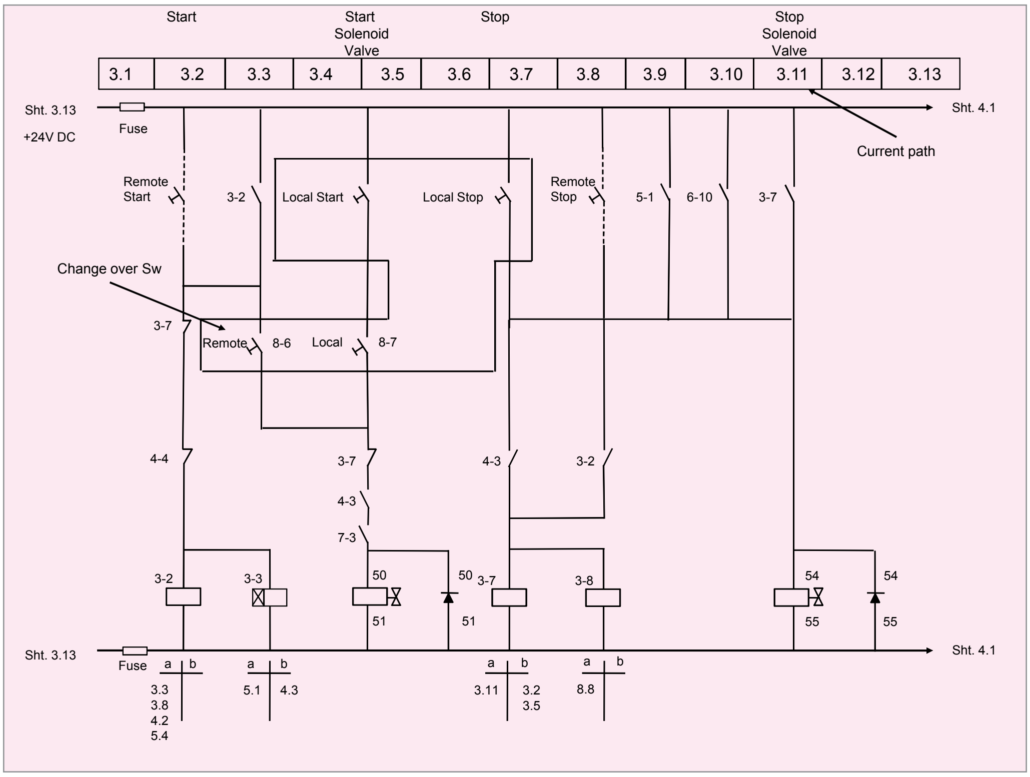


Figure 1(b) – A DG Monitoring and Control Circuit (Continued)

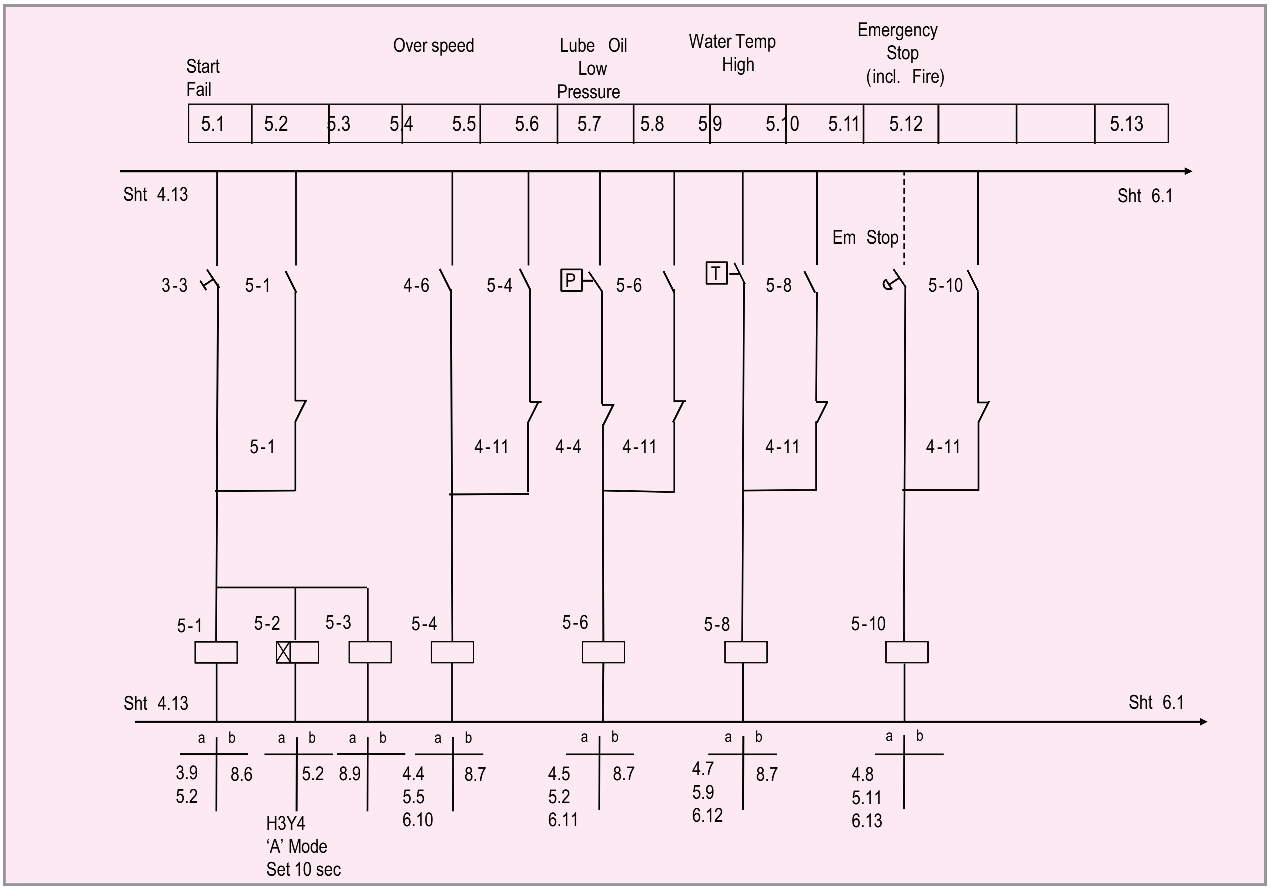


Figure 1(c) – A DG Monitoring and Control Circuit (Continued)

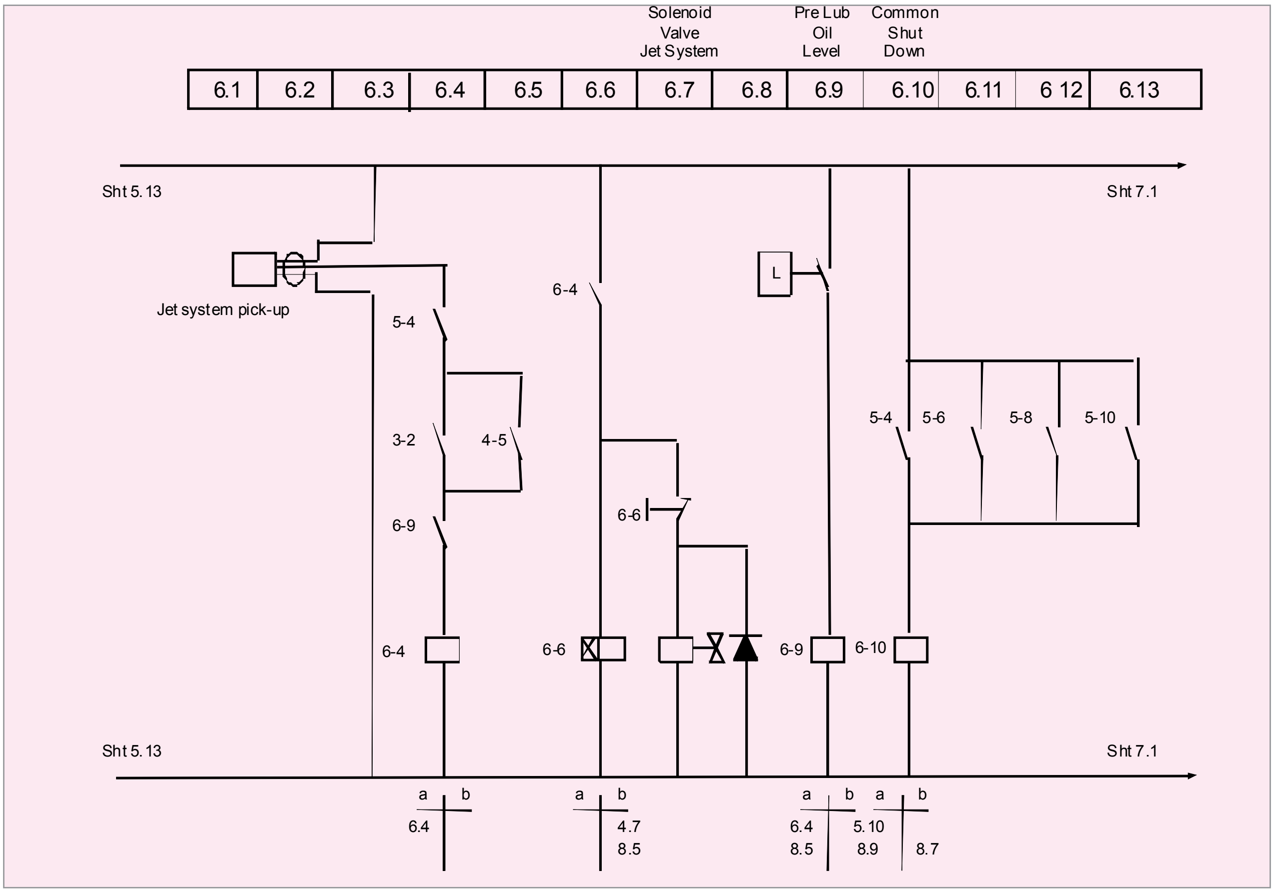


Figure 1(d) – A DG Monitoring and Control Circuit (Continued)

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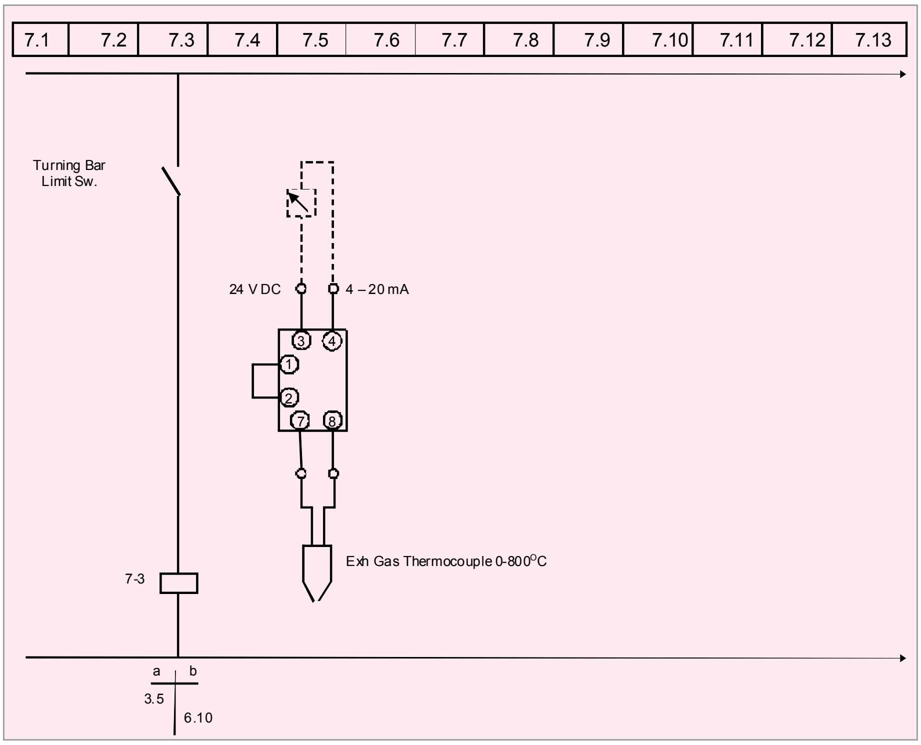


Figure 1(e) – A DG Monitoring and Control Circuit (Continued)

4. Various Symbols in Circuit Diagrams

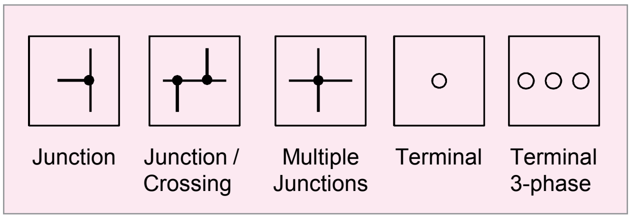


Figure 2 – Wire Connections

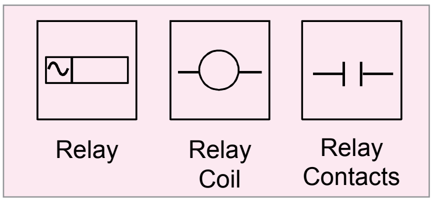


Figure 6(a) – AC Relay, Relay Coil and an "a" Contact

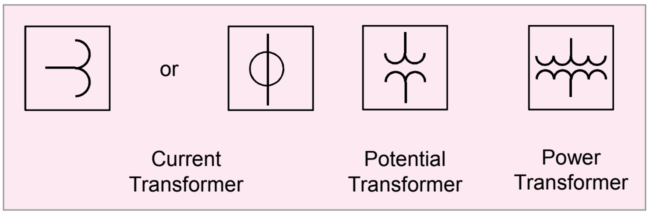


Figure 3 – Transformers

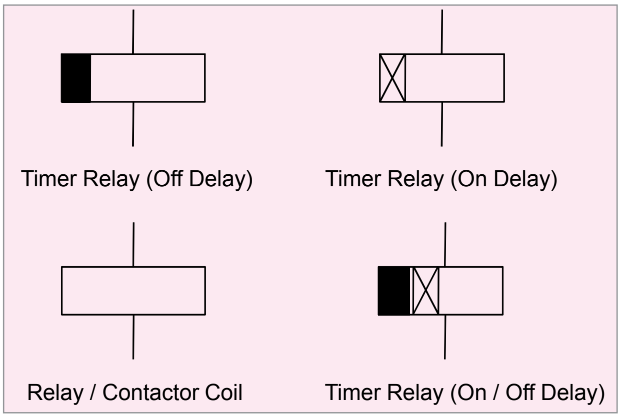


Figure 6(b) – Relays

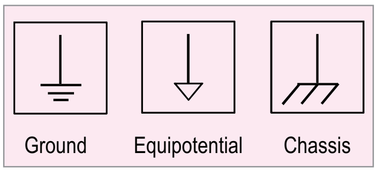


Figure 4 – Ground Connections

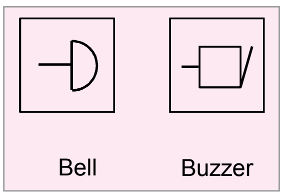


Figure 5 – Bells and Buzzers

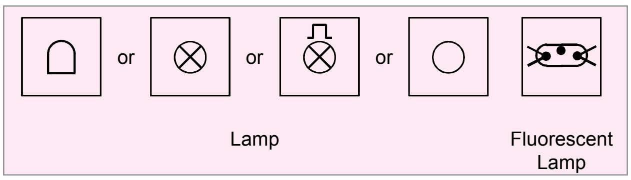


Figure 7 – Lamps

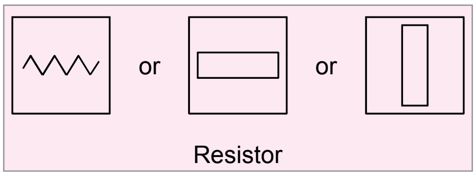


Figure 8 – Resistors

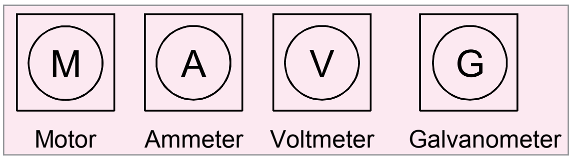


Figure 9 – Motor, Ammeter, Voltmeter

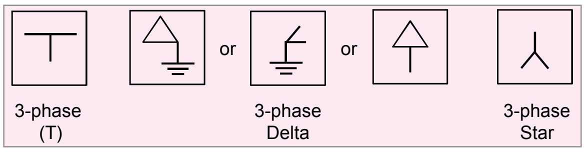


Figure 10 – Phase Connections

About the author

Elstan A. Fernandez has 43 years of experience in the Maritime and Energy Indutries; Author / Co-author of 80 Books; Chartered Eng., FIE, MIET (UK), MLE℠ Harvard Square (USA); Joint Inventor with a Patent for Supervised BNWAS; Promising Indian of the Year in 2017; LinkedIn Profile: https://www.linkedin.com/in/elstan/

Email: elstan.a.fernandez@gmail.com

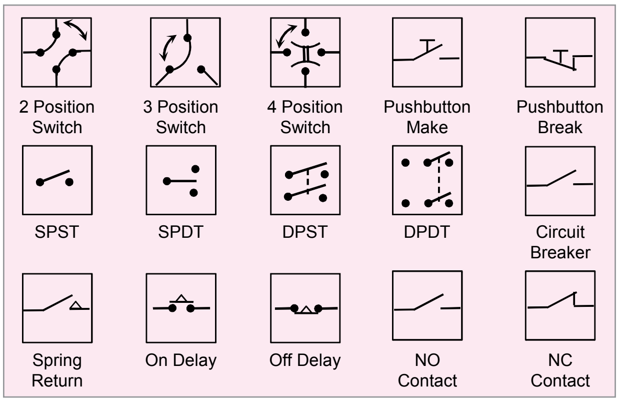


Figure 11(a) – Switches and Contacts

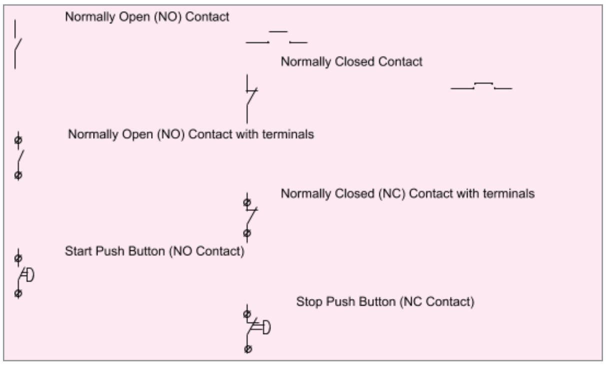
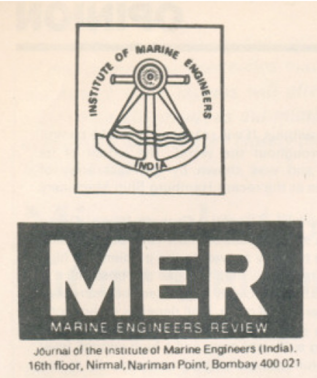
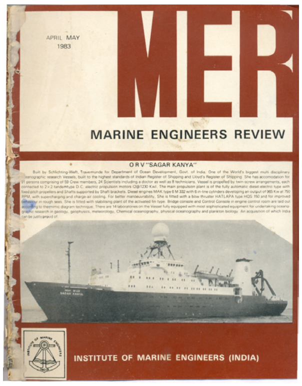


Figure 11(b) – Switches and Contacts

GOING ASTERN INTO MER ARCHIVES





MER... Four decades back... The May 1983 Issue

The issue starts with an interesting editorial on the declining British fleet. A couple of remarks by the UK Government representative are worth looking at: Ship owners must analyse the market and make the British fleet competitive in the global field (no operating subsidies for the fleet); and no form of protectionism (no controls to be imposed on UK shippers to use UK ships etc.).

Protectionism is relevant in current times and we had carried a brief discussion on this in one of our earlier issues. India's approach to tariffs, cabotage laws and ship building are areas which may need a closer study.

Following this, the first interesting article is on optimal ship speed. This is a short, easily digestible write-up with significant insights for a Superintendent. Just as an example, one figure is inserted (Fig 1. Income/Expenditure effects of ship's speed). A simple takeaway from the graphical representation is that the greatest vertical distance (curves separation highest; y axis measure) will give the optimal speed. Of course there is more analyses in the article.

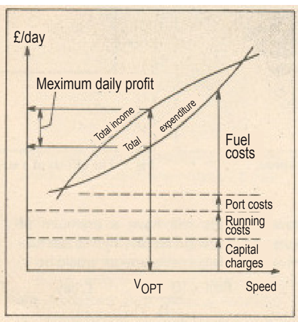


Fig 1: Income/expenditure effects of ship speed.

There are discussions on Battery provisions on submarines etc., self-polishing hull coating, multi-mil application for repairs etc. We come to another interesting discussion on bacterial infection lubricating oil and microbial degradation etc. This will be useful for the sailing engineers.

There is an article on (sunrise technology, decades back) computer technology being put into use for offshore structure designing etc. Then there is a discussion on ship design featuring multi-purpose ships (can carry containers), which some old times would have certainly worked on (about 17000dwt; SULZER RTA or MAN B&W LMCE engines; 2x diesel alternator + shaft generator etc.).

We look into the 'Postbag' as always...

There is a defensive response from Texaco on requirement for hull cleaning (scrubbing) of SPC coated hulls. There is another one wondering how Titanium might fare as a material to reckon with.

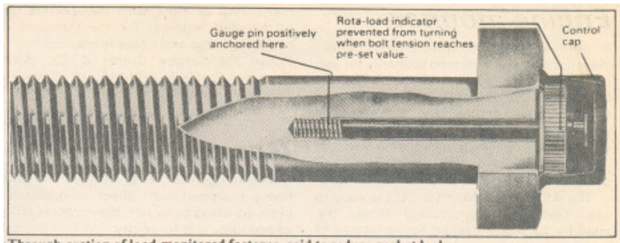
But going back to a couple of letters suggesting solutions for better operational efficiencies, it makes one wonder why such discussions are not happening anymore (even outside of MER in the WA forums) where one can deliberate on alternate ideas for improvement.

One item that could be of interest is the load-monitored fastener which provides indication of reaching the set tightening torque. Many of us would have seen such arrangements... the advantages: overtightening avoided; even tightening achieved; so gasket leaks are reduced.

Another one worth looking at is the 'Intracore' fitting on the boilers which clears soot etc., with 20Hz frequency sound (infra sound).

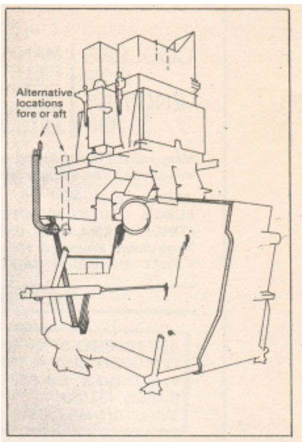
And one more for our repair repertoire: 'detnaplugging' by detonation for heat exchanger tubes. (See the extracted pictures of the above three products).

Any experience on these products would be good to discuss in these pages.

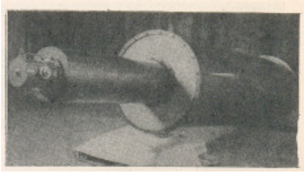


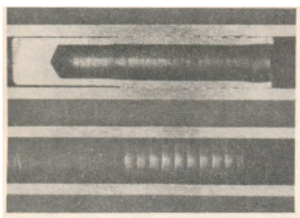
Through-section of load-monitored fastener, said to reduce gasket leaks.

But going back to a couple of letters suggesting solutions for better operational efficiencies, it makes one wonder why such discussions are not happening anymore (even outside of MER in the WA forums) where one can deliberate on alternate ideas for improvement



Alternative locations of the Infrafone. The view below shows a large Infrafone used for industrial applications.





The plug expanded in a tube and (below) with plug removed. The rings become embedded in the tube to lock the plug in place.

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Sails option: Mention of 'Open umbrella', spinnaker condition & weathercock designs

POSTBAG

Sail, not nuclear . . .

Sir,
The Commission of the European Communities is right to be concerned about the sad state of affairs of Europe's marine industries, as reported in your "Opinion" column (MER February). It is interesting that they have set a three-year time limit for allocation and use of their new R&D funds.

What is strange is that sail, coal-firing and nuclear power should be lumped together in one phrase. Nuclear power has already had not three but thirty years of the most lavish funding ever accorded to a new technology but has still failed to provide a safe, reliable and economic option. Modern computerised sail power, on the other hand, despite almost complete lack of support from our government, can already produce far greater savings.

While Japanese shipbuilders have enjoyed considerable official help in getting several sail-assisted ships to sea, a British invention of demonstrably superior characteristics has been struggling on with quite inadequate funding but is nevertheless now ready for commercial application. Not only is this British invention aerodynamically superior in wind-tunnel testing but it also has an important intrinsic safety feature. On loss of control power, the Japanese units tend to swing downwind into an 'open umbrella' or spinnaker condition, whereas the British design will, in the same event, revert to a streamlined weathercock form and present no more windage than typical tophamper such as cargo masts and derricks.

You ask whether 1990 will see Europe's new world-beating ship. Given reasonable encouragement it could see Britain's new world-beater but not if the limited marine research funding is let into the grasp of the ever greedy but ever disappointing nuclear industry.

Owen W Dumpleton

Harrow, Middx

. . . or coal firing . . .

Sir,
As a former Chief Engineer of coal-fired steamships, I have been most interested in the proposals put forward regarding a return to coal burning.

Whatever boiler is decided upon this must, of course, be fired mechanically, and the firing of the Yarrow boilers in the pre-war *Beaver* class vessels could be considered. Disposal of ash, and clinker, must be by conveyor, as must the trimming of fuel to boiler hoppers.

Referring to Mr D A Taylor's article (MER February 1983), I see no advantage in using a motor with so many moving parts turning at such high speed that a clutch and expensive reduction gear have to be included in the transmission.

Just prior to the war, North Eastern Marine brought out their superheat-reheat engine, a three-cylinder triple expansion engine with LP at centre, poppet valves at HP and IP at either end and a re-heater for HP exhaust. This proved very economical.

I would propose a modification of this engine, perhaps with closed crankcase and forced lubrication. It would be practical with direct reversing and direct drive or a non-reversing version and cp propeller. Steam generators for sea and a diesel for port use would be advisable. Some means of distilling feed-water must be provided and presumably a closed-feed system would be incorporated, using air ejectors and extraction pump; which suggests the adoption of an exhaust-driven turbo-alternator for sea service. Other auxiliary equipment, main circulating pump, ballast pump, bilge pump and domestic services could be electric motor-driven with steam-driven main feed pumps for the boilers.

R L Snell

La Lucia, S Africa

. . . but use a turbine

Sir,
The article on the coal-burning steamship in MER February 1983 made interesting rea-ing. I wonder, however, if Mr D A Tay- ever sailed with steam reciprocati- engines.

This engine is most durable and reliab- when adequately maintained. Even lacking this, it will still limp on, although demanding ever more fuel; a doubling of consumption could well occur.

The combination of a steam reciprocator and a water-tube boiler is especially sensitive to neglect. Boilers do not like oil in their steam spaces, but reciprocating engines cannot run without it. This oil must be removed completely before it reaches the boiler.

Why should a clutch be needed in this proposal? The beauty of an external combustion engine is that it can develop torque at zero speed. A clutch would seem to be a needless complication.

The turbine has several advantages over the steam reciprocating engine, which must tend to favour it. It needs less attention; it can be designed to work over a large pressure range and with a lower exhaust pressure; it needs no oil in its steam supply; and it needs less space. Thus, although it will probably cost more, it should still show an overall saving, needing perhaps only half as much fuel and significantly fewer man-hours of maintenance.

I admit to basing the foregoing on experience of the 1950s. I also have a great liking for the steam reciprocating engine. It is a pleasant machine to live with, being quiet, docile and reliable. If these good qualities can be combined with the main virtues of the turbine, there may still be a future for it in a new steam age at sea.

G A Davidson

Renfrewshire

Please note: the Editor reserves the right to edit and shorten letters.

Hull cleaning

Sir,
I wish to express our concern at certain statements about Texaco Overseas Tankship Limited on page 20 of your February issue.

In your article on the 'Economics of hull maintenance' you state that the Texaco vessel, coated with conventional, as compared to SPC paint, has to dock every three months for hull cleaning. This statement is incorrect.

No owner that we know of—and certainly not Texaco—could afford or need to dock a ship every three months. It is indeed the case that conventionally coated hulls could possibly need scrubbing after three months—or not, as the case may be. Such a scrubbing would be carried out in service, not in dock. And the fact is that the only conventionally coated Texaco hull has not even needed scrubbing since its last scheduled shipyarding in July 1982.

S Walkington

Steam support: Turbo-alternators for sea and Diesel driven AE for ports

Sir,
The item on materials in the Opinion column (MER February 1983) contains a statement that is potentially misleading and should not, I believe, go unchallenged.

It is one of the *disadvantages* of titanium that it is susceptible to marine fouling. The only commonly used materials that have inherent anti-fouling properties are the copper-base alloys.

Because of the combination of resistance to marine fouling as well as to corrosion, the 90/10 copper-nickel alloy has become the standard material for seawater piping systems in many applications. It is, moreover, under serious consideration for sheathing of ships' hulls.

P T Gilbert

Ilkley, Yorks

● *Dr T H Webster of Titanium International comments as follows:*

Dr Gilbert is quite right in questioning the resistance of titanium to marine fouling as this is a matter of some debate. However, as I understand the present situation, although fouling can occur at velocities less than 4 ft/s, above this level the problem is minimised. Indeed, it is reported that high-velocity water can kill small barnacles already attached to a titanium heat exchanger surface. Fouling is encouraged by corrosion-roughened surfaces and titanium, with its high corrosion resistance, may be expected to be less susceptible to this problem.

The proof of the pudding is in the eating. Many power station condensors successfully use titanium tubes with seawater cooling and titanium heat exchangers have been installed on board ships. Time will tell if titanium is to grow as a marine engineering material.

T H Webster

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

INDIAN SHIPPING - TRAUMATIC THREE CENTURIES UNDER COLONIAL REGIME

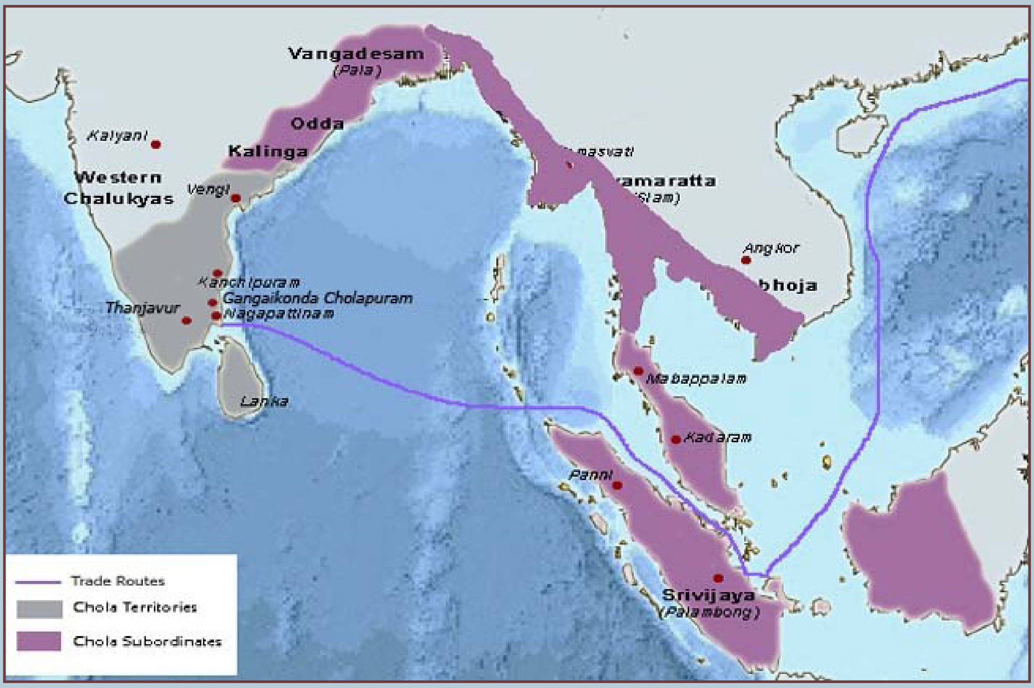
THE DEMOLITION AND EFFORTS FOR RESURRECTION (Part 1)

K R A Narasiah

It is understood that Indian maritime history began in the 3rd millennium BC when people of the Indus valley, initiated maritime trading contact with Mesopotamia. Several evidences are available to show that Indians were present in Alexandria, through recent studies and excavations in the Middle East. It is also known that the Roman traders continued to live in India long after the fall of the Roman Empire. Sangam literature in Tamil records that the foreigners stayed in Tamil Nadu.

Later, the Indian commercial connection with South East Asia proved vital to the merchants of Arabia and Persia during the 7th–8th century and a seamless trade existed between India and other countries.

Centuries later, emperors Rajaraja Chola, (985-1014) and Rajendra Chola (1012-1044) extended the Chola kingdom towards the east. Chola navies invaded and conquered Srivijaya (7th - 13th century) in the Malay Archipelago. Cholas extended their influence to China and Southeast Asia and by the end of the 9th century, had developed extensive maritime and commercial activity.



The Sea Command of the Cholas

Sea trade flourished by the efficient organisational structure maintained by the Indian overseas merchants and their guilds were autonomous with absolute control over the trade. The state took charge of the infrastructure and security, though voluntary contributions were available to provide a security cover for the trade through the guilds as well. The merchant guilds took charge of trading and logistics activities. These guilds were known by various names such as, *Pathinen vishayaththaar, Manigramam, Nanadesis,* and *Ainurruvar.*

Naturally, the question arises as to how and what changed and how India lost its control over the sea routes and their superior sea power.

An important turning point of history was the fall of Constantinople in 1453. This severed European trade links by land with Asia and the Europeans had to seek routes east by sea and this effort spurred the age of exploration. Historians often refer to this period as the *Age of Discovery*.

The Age of Discovery (also known as the Age of Exploration) was from early 15th century and continued to the 17th century. During this period Europeans explored Africa, the Americas, Asia and the Pacific islands. When there was a severe sea route competition between Portuguese and the Spanish, and as both were Catholics, the religious head of the Christianity had to intervene and a papal bull issued by Pope Alexander VI known as *Inter Caetera* (among other) on May 4, 1493, that granted to the Catholic king of Portugal all lands to the "west and south" of a pole-to-pole line through the island of Azores. The west of the line was granted to Spain.

The Catholic Monarchs signed the **Treaty of Tordesillas** with the Portuguese crown in 1494, which established the line dividing the globe between Spain and Portugal for colonisation purposes. This especially affected the Portuguese and Spanish colonisation of the Americas, and

placed the name *Tordesillas* worldwide into history's use since. Thus, this treaty can be said to be the first treaty in the world about sea and trade. Thus, the world was divided between Spain and Portugal and the Portuguese explored the East.

Kozhicode (Calicut) became the entry port for the Westerners in India and on 20th May 1498 Vasco da Gama arrived in Calicut and was received by Zamorin. THE WORLD WAS NEVER THE SAME AGAIN!

Vasco de Gama landing at Kozhikode

Watching the huge profits earned by the Portuguese, the English in 1611 the Danes in 1620, the French in 1668 and the Dutch in 1670 followed to explore the East. The main trade of spice, textile and diamond lured them mainly to the Southern Peninsula.

Though started an establishment in Surat earlier, to have a foot hold in south, Capt. Hippon came sailing in GLOBE looking for a port to establish trade in the coromandel coast. When he came near Pulicat he was chased away by the Dutch. From there he arrived at a place called Peththapalli later known as Nizampatam and on August 20, 1611 he landed there and this was virtually the first place where the English started to have a trading post.

The English tried at Armagon a village in the coast; named so as it was purchased from one Arumuga Mudaliar (in Telugu Durgaraya Pattianam) and it was a miserable place for a port and they had to scout for another place and they went looking south.

In 1637 Francis Day went up to Puducherry looking for a better place. But the Portuguese did not allow them anywhere near Santhome and so he went north. At that time the coromandel coast was under Nayaks and one Damarala Venkatadri was representing Nayaks, who on 22nd August 1639 gave Day a firman granting trading rights to the British East India Company to trade from Madras.

In 1690, Job Charnock, an agent of the East India Company, who started his career in Madras and sent to Calcutta to scout for a trading location. He a site that was protected by the Hooghly River on the west, a creek to the north, and by salt lakes about two and a half miles to the east. There were three large villages along the east bank of the river Ganges, Sutanuti, Gobindapur and Kalikata which were bought by the British from the local land lords. On application to the Mughal emperor East India Company was granted freedom of trade from that location in return for a yearly payment of 3,000 rupees.

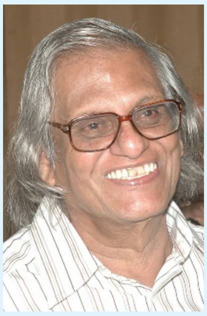
The **Battle of Plassey** was a decisive victory of the British East India Company over the Nawab of Bengal on 23 June 1757. The battle established the Company rule in Bengal which expanded for the next hundred years, over other parts of India. The Company then started harassing Indian shipbuilders and shipping companies and during its regime in Calcutta, Indian artificers and carpenters were banned from shipbuilding and ship-repairing activities and the English thus killed the shipping Industry; first by curtailing craftsmen and then by introducing new regime on tariff.

First was the draconian Navigation Act of 1646 that became tougher in 1650. Oliver Cromwell in England brought yet another restriction in 1651 specially aimed to annihilate the shipping activities of Indians. This provided that no goods produced in Asia, can be imported into England in any ship that was not built in England and did not have at least 75% of English sailors. After thus restricting the Indians in trade, in 1811 another cruel discriminatory order on tariff was introduced. Calcutta promulgated separate rates of import duties on goods carried by Indian and Company's ships and it was 7.5% for the company vessels and 15% for non-British ships. Madras followed this in 1812 and Bombay in 1813.

The 1814 act was, yet another, passed as British shippers wanted full protection; according to this, *"even though Indian sailors are British subjects, they shall not be deemed as British Mariners"* and Ships not having an English captain and/or ¾ of its crew as British mariners shall not be allowed to enter English Ports.

In 1928 Mahatma Gandhi said, "The tragic history of the national village industry of cotton manufacture is also the history of the ruin of Indian Shipping. The rise of Lancashire on the ruin of the chief industry of India almost required ***the destruction of Indian Shipping."***

About the author



K R A Narasiah is a well-read writer in Tamil and English and a recipient of Awards (four instances) by Tamil Nadu State Government for Tamil literature. He did his marine engineering training in the Naval Training centre, I N S Shivaji (1949-1953) and sailed on board naval ships for 10 years. While in Navy he was deputed to Harland & Wolff Shipyard in Belfast to standby during the construction of the India's first Aircraft Carrier I N S Vikrant and later, took over as its first Indian Flight Deck Chief.

Selected through the UPSC, he joined Vizag Port in 1965 as a marine engineer, where he rose to the position of the Chief Mechanical Engineer in 1986 and retired in 1991.He was called by the Indian Navy during the liberation struggle of Bangladesh and served under the Eastern Naval Command. He also worked as a Consultant for Indian Ports Association.

He was also a visiting faculty for the NIPM, IIPM, AMET University and other marine Institutes. In 1994 The World Bank invited him to join as a marine consultant (ports) for a mission for Emergency rehabilitation programme of Cambodia where he served with distinction from 1994 to 1996. He was also a consultant to Asian Development Bank for port development. He contributes to The Hindu regularly as a reviewer of Books and to the Times of India for its South Pole columns. His main area of research continues to be the colonial and maritime history.

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Sir William Digby was an English journalist who sympathised with India and in May 1888 he set up the Indian Political and General Agency in London for raising awareness about Indian grievances in the British Parliament and Press. A strong advocate of constitutional reform he acted as an unofficial guide to Indian National Congress leaders visiting London. He wrote, "The ancient occupations on sea and land have been destroyed. The ships which now carry India's coastwise trade are steamers built in Britain, the officers are Britons and the profits derivable from trade go to Britain. We are literally draining India dry – *bleeding* was Lord Salisbury's term in 1875 - It is more accurate than my own."

Adding insult to injury, the parliamentary committee while recommending the restrictive measures said: *The native sailors of India to the disgrace of our national morals, on their arrival here, are led into scenes which soon divest them of the respect and awe they had entertained in India for the British character and the effects of it may prove extremely detrimental.*

In 1862, the British India Steam Navigation Company (BI) was floated and by carrying troops from Ceylon to India from 1857 to 1859, and through influential contacts, English company got contracts to carry mail around the Indian coast with extensions to the Persian Gulf and Singapore.

Here it is worthy of note to see how a single English businessman caused maximum damage to Indian shipping. Born in 1852, son of a shipmaster, James Lyle Mackay left Scotland at the age of 20 and worked in the Customs department of Gellatly, Hankey and Sewell, leading shipbrokers in London for many lines including BI. Mackay joined MMC's Calcutta office in 1874 and through great diligence and flair, took over as president after the death of Mackinnon in 1893. In 1889 he became the President of the Bengal Chamber of Commerce. He was instrumental in causing the downfall of Indian shipping companies.

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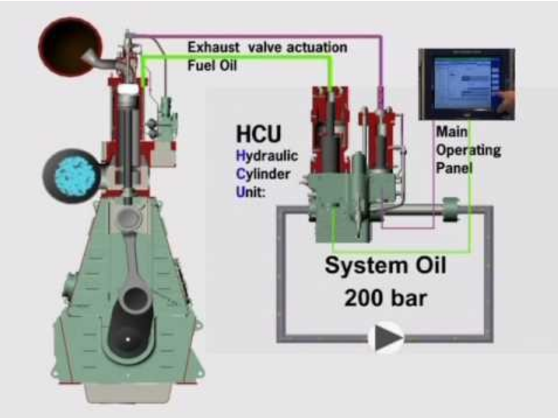

This 3 days course is designed for all Ship's Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. This course consists of technical lessons and practical instructions on the design, principles, operating procedures and maintenance activities for the safe, efficient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

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- **Engine Control System (ECS)**
- **Main Operating Panel (MOP)**
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Entry is open to all Ship's Engineers and Electro Technical Officers with basic knowledge of diesel engines.

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

REGISTRATION & PAYMENT : Rs. 15,000/- /- per participant – inclusive of taxes.
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