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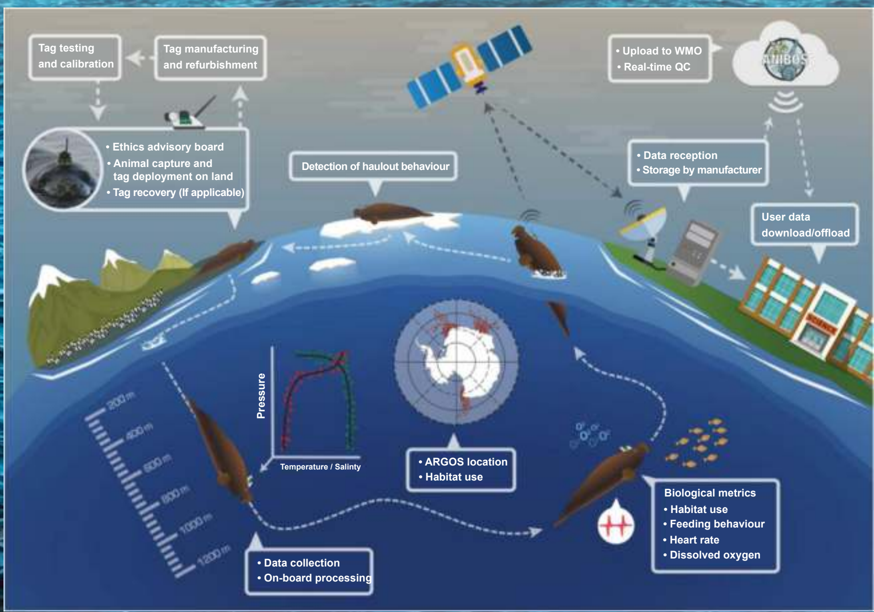

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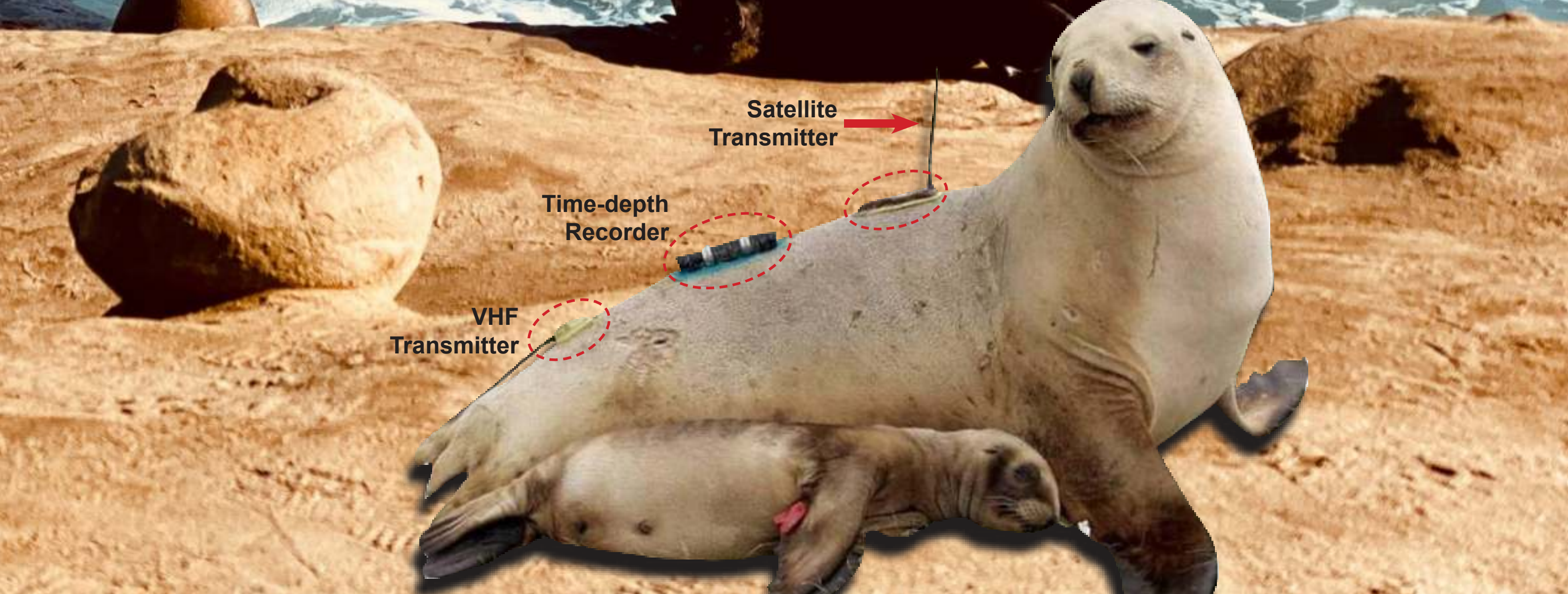

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EDITORIAL

Education to be complete, must be human, it must include not only training of intellect but refinement of the heart and discipline of the spirit. No education can be regarded as complete if it neglects heart and spirit.

- Dr. Sarvepalli Radhakrishnan

Extending our concerns of the quality of Maritime Education & Training, another important discussion would be the revision of the STCW Convention. The heart of the matter in the last sitting of the HTW was about the matters of the heart, mostly. Psychological safety, sexual assault/harassment (SASH), personal safety and social responsibilities... all featured in the deliberations. There was recognition of gaps in the cultural and generational firmaments also, which were to be additionally covered.

Psychological safety relies on self-assurance that mistakes and questioning in a workplace will not attract ridicule and reprimand. To cultivate this sense of safety, it is recommended that work be seen as part of a learning realm, rather than as a task to be executed. In workplace hierarchies, especially on board ships, a trainee is seen as equivalent to an empty receptacle, and this line of thinking will need a culture change.

Next, the present day independence in gender recognition justifies the SASH awareness, which is certain to have relevance beyond the feminine borders. And, safety and social responsibilities are good for all seasons and will prevail. So, there shall be more Model Courses and more endorsements.

The shipping industry, well invested in the idea of a regulatory Convention driving the education needs, must look at moving beyond the minimum standards of functional competence for these elements and others. The STCW should engender ideas to keep the maritime profession contemporary and importantly providing avenues for continual learning. To illustrate, Artificial Intelligence and algorithms have come to govern everyday life actions, machine processes and programs. Data analytics and Maritime Informatics are few other areas that are becoming meaningful in operations. Unless the seafarer crop is skilled in such sunrise technologies, we could be looking at an ineffectual professional. The STCW sculptors must know this. Maritime Education and Training will then be more palpable while it intends to refine the hearts and discipline the seafarers' spirits.

In this issue...

An earliest homo sapiens' database could be the knowledge capture of other living creatures, while evolving with the earth's environment. Animals and birds have been inspirations and instruments in scientific progress. We carried the inspiration part in an earlier issue of MER and Dr. Veda was the elucidator. In this discussion, Dr. Veda focusses on Animal Borne Sensors (AniBOS). Their scope for tracking and studying the creatures apart, the article highlights how ocean ambience can be observed using various sensors. Dr. Veda takes us into the sensor architecture also. This could possibly remain as one of the most interesting cover stories for 2023.

The fuel conversations follow. The Part 2 of the article on alternate fuels, Daga *et al.*, start with a short note on LNG. Methanol, Ammonia and Hydrogen get better space. E-fuels and biofuels also are discussed. The fuel discourses will continue at this understandable level.

We move on to a management article. Prabu Duplex expounds Asset Life Cycle (ALCM) of waterway canals. Prabu presents the case taking the quay walls, bollards and track rails as ponderable examples. After explaining the life cycle phases, a perspectives-cluster of Technical-Economic-Compliance-Commercial-Organisational [TECCO] is considered for all the three assets. The design phase discussion for each of the asset, maintenance interventions and exemplar failures etc., are quite simple and will be digestible for a marine engineer. This is another absorbing read from Prabu.

Under Technical Notes, Sanjiv Wazir, extends the lubrication discussion on lubrication regimes. The absorbing discussion has two takeaways: Hertzian Contact and Elasto-hydrodynamic lubrication. The brief talk on solid lubricants would leave us wanting more. Practicing marine engineers would find this month's Lube Matters interesting. MER Archives from June 1983, which has some safety talks of interest. Heritage Hourglass has Narasiah chronicling the concluding part on the decline and the rise of the Indian shipping. There will be more on this soon.

Here is the June 2023 issue for your reading pleasure.

Dr Rajoo Balaji
Honorary Editor
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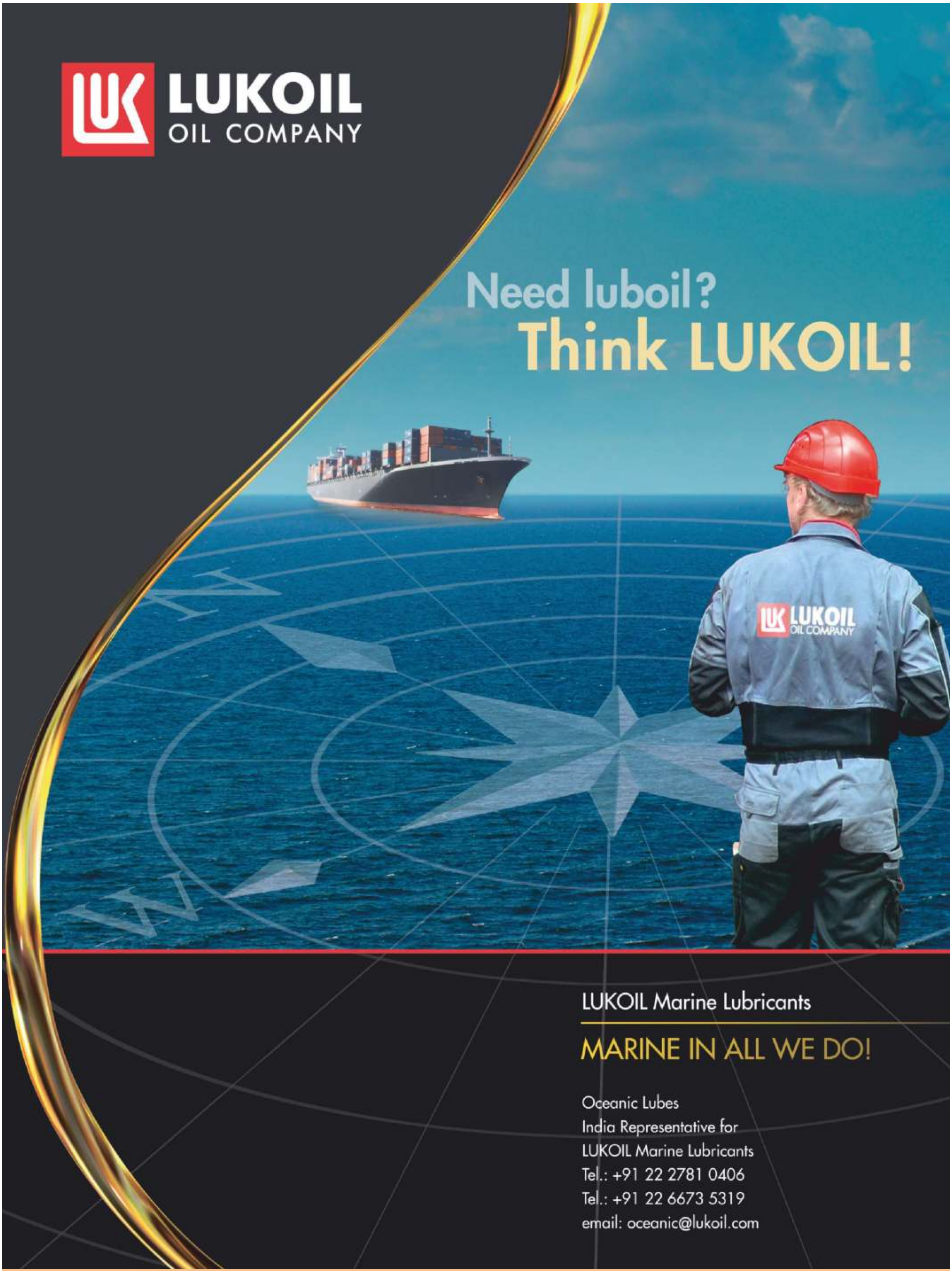
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In This Issue

ARTICLES

COLUMNS

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Animal-Borne Sensor Technologies for Monitoring The Ocean Ecosystem

N. Vedachalam

Abstract

Animal-Borne Ocean Sensor (AniBOS) technologies, recognized as a powerful tool in the global ocean observation network in 2020, helps in improving our ability to observe the ocean's structure and marine life more comprehensively, concomitantly improving our understanding of global ocean and climate processes consistent with the United Nations Sustainability Goals 13 and 14. Over the past five decades, satellite-linked AniBOS and networks of acoustic receivers allow marine animals and trans-ocean birds to be reliably monitored over scales ranging from tens of meters to thousands of kilometers, giving insight into their habitat use, home range size, phenology of migratory patterns, maternal denning, anthropogenic impacts, biotic and abiotic factors that drive their distributions. Further, AniBOS enables collection of physical environmental variables using animals as autonomous sampling platforms, increasing the spatio-temporal coverage of global oceanographic observation systems that are essential to bolster ocean ecosystem policies. The article discusses the importance and technological trends in AniBOS, animals involved in monitoring, significant global AniBOS-based tracking studies and the factors required to be considered for identifying fit-for-purpose AniBOS.

Introduction

The global ocean is our planet's largest ecosystem that stabilises climate, stores carbon, nurtures bio-diversity, directly supports human well-being through food and energy resources, as well as by providing cultural and recreational services. As the world population is expected to reach an estimated 9 billion by 2050, marine pollution, ocean acidification, loss of marine species and degradation of marine and coastal ecosystems will increase. Technology is the key for the sustained and precise spatio-temporal measurements of the physical, biological, bio-geochemical parameters essential for carrying out effective assessments of the status, variability and change in the ocean ecosystems.

The present global ocean-observational networks, comprising precision in-situ meteorological and oceanographic sensors are configured for real-time and delayed-mode coastal and offshore observations using 300 offshore and coastal-located moored surface buoys, 1500 drifting buoys, 4000 Advanced Research and Global Observation (Argo) satellite supported floats that has completed >2 million profiles till-date, water current profiler moorings, deep-ocean wave buoys, coastal wave-rider buoys, tsunami buoys for deep-sea water level measurements and ice buoys. There are a number of cabled benthic observatories that enable studies on physical, biological, and chemical processes associated with seismic, tsunami, volcanic and seafloor ecology.

> *There are a number of cabled benthic observatories that enable studies on physical, biological, and chemical processes associated with seismic, tsunami, volcanic and seafloor ecology*

Further, virtual constellations of satellites are used for measuring sea surface temperature, ocean colour, ocean surface topography, ocean surface vector winds, and ocean surface salinity. Despite Argo's global fleet of ~4000 profiling floats, the high polar seas, shallow coastal shelves and high-energy boundary currents remain under-sampled. The logistical difficulties and the expense of accessing remote regions for deployments, and the high cost of deploying and operating autonomous vehicles and systems are overcome using Animal-Borne Ocean Sensor (AniBOS) and networks, which is evident from an average of 500 near-real-time Conductivity-Temperature-Depth (CTD) profiles obtained annually/animal.

Importance of EoV & AniBOS-based Ocean Observations

Evolution of EOV

In order to avoid the decline in the health of the ocean ecosystem, the United Nations Decade of Ocean Science for Sustainable Development 2021-30 provides a time-frame to build a comprehensive, sustainable and data-based informed decision-making global ocean observing system (GOOS). This demands global-scale investigations, trans-disciplinary science, and mechanisms to integrate and distribute data that otherwise would appear to be disparate.

The Essential Ocean Variables (EOV) are a suite of parameters that have been identified by the United Nations Intergovernmental Oceanographic Commission's Global Ocean Observing System (UN-IOC-GOOS) Bio-Eco, Physics and Climate Panels that are crucial for detection and attribution of change in the marine environment relevant to the global scale **(Figure. 1).** The essential Bio-Eco EoV have been identified after evaluating their readiness, feasibility, and the need to track the variation and trends in the key biota and ecosystem processes.

Importance and Trends in AniBOS

Despite major developments in the global ocean-observational networks, some important marine regions remain under-sampled, or challenging to observe, particularly the polar seas, coastal shelves, tropical oceans and the deep-ocean. Understanding these gaps is crucial, especially in the Antarctic and Arctic high latitude oceans, which are currently affected by climate change. The Southern Ocean is the globally dominant region for heat and CO_2 exchange, and researches rely mainly on Argo float data to quantify this imbalance.

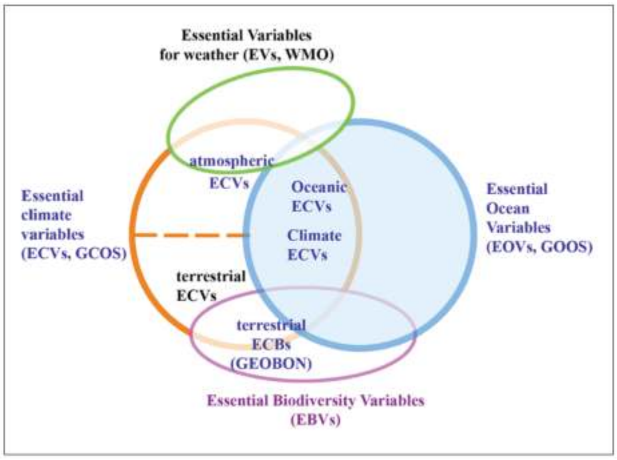

Figure 1. Ocean status monitoring priorities

In ice-covered high latitudes, in-situ observations from ice capable Argo (mainly during winter) are still relatively sparse. Deploying AniBOS are an effective way to help fill these data gaps and are hence an important component of the integrated GOOS. The observations from AniBOS Conductivity-Temperature-Depth (CTD) instruments are helping the scientific community to understand the physical processes such as sea-ice formation, Antarctic bottom water formation, ocean and ice shelf interactions, and frontal system dynamics.

Bio-ecosystem conservation and sustained utilisation of ocean living resources requires precise estimation of marine animal population sizes, survival rates, and reproduction with specific populations; ranges and distribution of individuals, populations or species; growth rates; and individual foraging behaviours. Individual animals are naturally hard to identify in the vast ocean without some form of artificial marking or tagging. In the vast ocean environment, this is compounded by long home ranges, deep-diving and the visually-obscure nature of the aquatic habitats. Overcoming these challenges, AniBOS is the culmination of decades of scientific endeavour and technological development enabling a variety of biological and physical sensors to be incorporated into miniaturised data-logging/data-transmitting devices deployed on marine animals.

AniBOS has the capability to provide robust and reliable information on Eco-Bio EOV related to animal diet, phonology, abundance, foraging range, sustainable harvest rates, understanding the impacts of climate warming, delineating critical habitat and assessing potential anthropogenic impacts. Foraging range is an important Eco-Bio EOV that could be obtained by AniBOS about the distribution of prey and its effect on marine predators. Assimilating the data acquired through AniBOS into ocean circulation models can provide important ecological insights into animals' habitat preferences and home range sizes, behaviour states, physiology, timing of long-term movements and migrations, and the biotic and abiotic factors that shape their current and potential abundances and distributions, thus providing an insight into changes in the state of the oceans and their ecosystems.

The potential and importance of AniBOS-based ocean observations was mainly recognised during the Ocean-Observation Conference in 2009. The Marine Mammals Exploring Oceans Pole-to-Pole (MEOP) program is an important source of Eco-Bio EOV data in the Southern Ocean. **The parameters including foraging ranges, trip durations and habitat use obtained by tracking seals (elephant, Weddell, harp, gray, harbor), sea lions, whales (humpback, narwhals, beluga and bowhead), penguins (king, emperor, Adélie and Gentoo), turtles (loggerhead and Olive Ridley), cetaceans, large-bodied fishes, flying birds, distribution of mesopelagic fish and krill have been identified as a cost-effective and efficient way to monitor the ocean ecosystem.**

Support Transition to Zero-Emission

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

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There is a growing community of AniBOS observers in the tropical oceans, such as the Sea Turtle for Ocean Research and Monitoring (STORM) project that studies the properties and variability of the tropical Indian Ocean to improve research on ocean dynamics and climate change. **Sharks have effectively collected data on dissolved oxygen and sub-surface warming, as well as temperature profiles in Arctic waters.**

The importance and interest in AniBOS can understood from the cumulative number of ecological studies carried out per year during the period 1970-2020. **Figure. 2** (right) depicts the cumulative number of tagging effects, methodology, review, technology, and range-testing studies per year, carried out during the same period. To date, more than 0.6 million profiles have been collected by AniBOS and have been made available to the broader operational and oceanographic research communities. Since 2020, AniBOS has been launched to pursue and further the goals of MEOP on a broader scale. AniBOS is an emerging network of the GOOS endorsed by the UN Ocean Decade as one of 94 new decade actions in 2021. The locations in which AniBOS-based studies are carried out using acoustic and satellite telemetry is shown in **Figure 3.**

Animals Involved in Eco-system Monitoring

Understanding an animal response to the environment using AniBOS can help determine the impact of ecological or climate changes have on the species, which can facilitate proper conservation strategies.

Elephant seals have been the most effective of all phocids used in the collection of oceanographic data as they are deep divers, routinely diving as deep as 2000 m, as well as traverse ocean basins, spend long periods at sea and have predictable cycles on land and at sea. Southern elephant seals also provide unprecedented sampling of coastal polynyas and regions of bottom water formation and therefore help observing the dynamics of ocean ventilation. The ice-obligated Weddell Seal is deep-diver that often dives to the ocean floor along the Antarctic continental shelf. Arctic seals and bearded, ringed, hooded and harp seals exhibit a wide range of

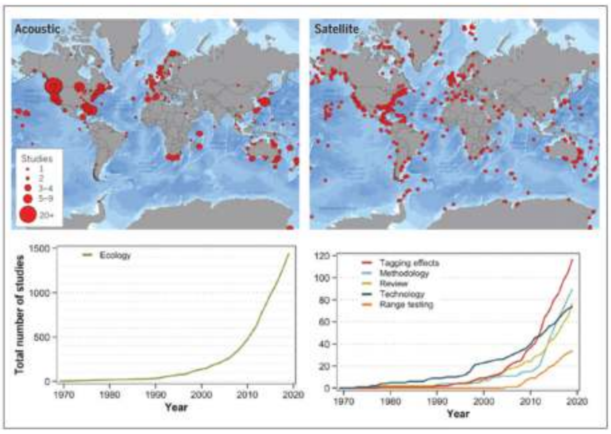

Figure 2. Trends in acoustic and satellite-based AniBOS activities

> ***Flying seabirds have provided surface measurements such as ocean currents and winds over great expanses of the tropical and temperate oceans***

dive and movement patterns, with the hooded seal being the deepest diver. Gray and harbor seals have collected oceanographic data in the temperate regions of the North Atlantic and North Pacific Oceans, as well as in the High Arctic. The northern elephant seals have provided important oceanographic data from the North Pacific Ocean.

Sea lions and fur seals are appropriate to sample temperate coastal waters, having delivered oceanographic profiles along both coasts of South America, the Galapagos Islands, Southwest Africa, West Coast of North America across the Aleutian Islands to the northern reaches of Hokkaido Japan. They are also well-suited for sampling the coastal zone of the South Island of New Zealand, the sub-Antarctic Islands and the southern coasts of Australia and the Sea of Okhotsk. Valuable sampling in the Arctic has been accomplished using narwhals, beluga, and bowhead whales. However, cetaceans include highly migratory species that cover tropical to Polar regions during their migrations having therefore a huge potential in collection of EOVs.

Seabirds can be highly effective platforms for ocean sensing. King and emperor penguins have provided temperature profiles from the Southern Ocean. Penguins and fur seals from temperate regions of the Southern Hemisphere may also hold opportunities to provide temperature and other oceanographic data, albeit primarily in the upper 100m of the water column. Flying seabirds have provided surface measurements such as ocean currents and winds over great expanses of the tropical and temperate oceans. Sea turtles, sharks and large-bodied fish can be used to obtain oceanographic data in the temperate to tropical regions. The Temperature-Depth profiles collected by loggerhead turtles were integrated in ocean nowcast/forecasts that greatly improved the representation of mesoscale eddies and front variations in the Kuroshio-Oyashio Confluence region around Japan. Moreover, Temperature-Depth profiles collected by olive Ridley turtles were assimilated into an operational seasonal prediction system of regional sea surface temperatures in the Arafura Sea.

The complex and diverse marine systems in the tropical regions support a rich diversity of life including tens of marine mammal and sea turtle species, many of which are endangered. In tropical Asia, the green turtle is listed as endangered and the Bryde's whale is listed in the International Union for Conservation of Nature's (IUCN) red list of threatened species. Tropical Asia also hosts more than a third of the 32 known important nesting areas for green turtles and more than half of the subpopulations nesting at these sites have been declining in the region. Although Bryde whales are distributed throughout the tropical Asian waters, limited population data are available and only for the upper Gulf of Thailand. Hence, studying the demographics, ecology, migrating behaviour, and the potential overlap with anthropogenic activities can improve the way ecologists manage and conserve free-ranging marine vertebrates.

Significant AniBOS-based tracking studies

The Marine Mammals Exploring Oceans Pole-to-Pole (MEOP) program is an important source of Eco-Bio EOV data in the Southern Ocean. **Figure. 3** is the map showing the distribution of CTD profiles (i.e. vertical profiles of temperature and salinity) currently available in the MEOP-CTD database. Thus, MEOP brings together several national programmes to produce a comprehensive quality-controlled database of oceanographic data obtained in Polar Regions from instrumented marine mammals. **Figure. 4** shows the multispecies aquatic telemetry studies, which involves long-term tracking of 23 apex predators across the Pacific Ocean.

With regards to long-range marine animal migrations, **Figure. 5a** shows the migrations of six satellite-tracked leather back turtles nesting at Grenada Islands (shown as green dot), spanning over the entire Northern Atlantic Ocean. It can be seen that most turtles wandered over large oceanic areas, but some (green and red track) migrated directly towards specific sites along the North America continental shelf. **Figure. 5b** shows the oceanic migrations of twelve green turtle females nesting at Ascension Islands (green dot) towards their individually-specific foraging grounds along the Brazilian coast (white squares), while most turtles migrated directly to their foraging sites, some of them (e.g. red and yellow track) first reached the coast and then moved along it until getting to their destination.

Figure. 5d shows the successive migrations of the male elephant seal tracked during its fall (yellow line) and subsequent spring (red line) journey from its Californian rookery (green squares) to the same foraging area (white square) in Western Aleutian Islands).

With reference to spectacular long-range trans-ocean bird migrations, **Figure. 5c** is a GPS data logger glued to the back of a Northern fulmar. **Figure. 5e** depicts the record-breaking bird migrations logged using light-weight tracking devices (the weights has dropped from 250 to < 20 g over the decade). The longest migration is by the Arctic tern (black-crowned seabird weighing ~100g) is an intrepid individual that covered almost 96000kms/year. The highest altitude journey is by the bar-headed goose (obtained from 38 geeses tracked using light-weight trackers). This highest flying individual reached almost 7300m above the mean sea level when crossing the Himalayas. Migratory birds are extraordinary endurance athletes, and their feats require serious preparation. Weeks before take-off, they undergo extreme physiological changes. Most obviously, they load up on fats.

In many cases, that means temporarily supersising their digestive organs to ingest as much food as possible. Immediately before departure, they shrink their digestive organs to reduce their flying weight. Several species, including the red knot are known to bulk up their heart muscles so that they can pump more oxygen-rich blood around their body. The bar-tailed godwit is found to have the most effective way to supercharge aerobic capacity. Its levels of haemoglobin increase considerably in the weeks before migration. This explains how godwit can fly >11000kms without a single rest.

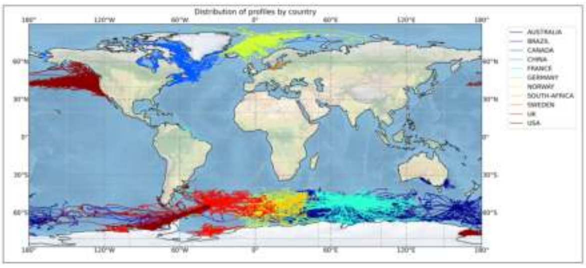

Figure 3. MEOP database of AniBOS profiles in Polar regions

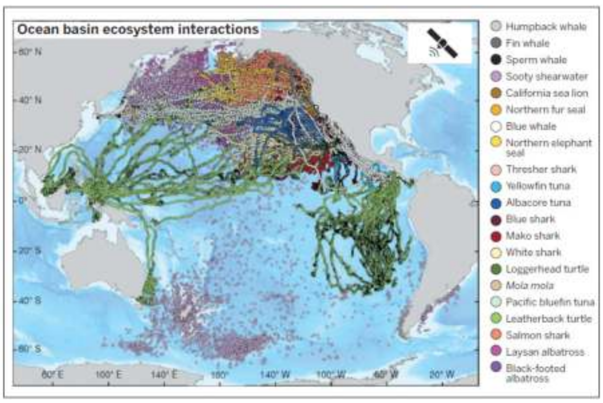

Figure 4. Satellite-AniBOS for tracking large scale movements of sea animals

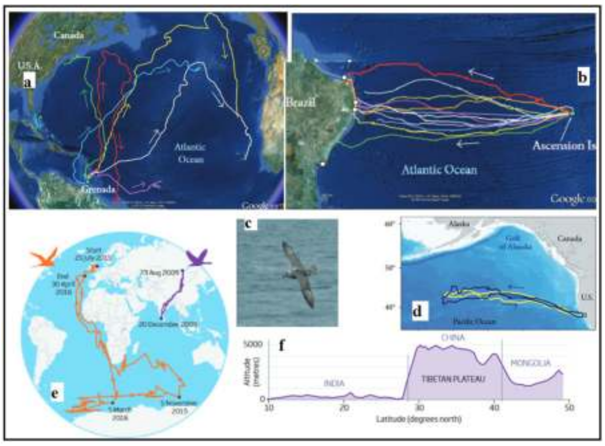

Figure 5. Satellite-AniBOS for tracking large-scale movements of cross-ocean and sea animals

Tagged experiments were conducted on yellow fin tunas in the warm and stratified northern Indian Ocean. PAT AniBOS (Model X-Tag from Microwave Telemetry Inc) with pop-up periods varying from 4 to 12 months, weighing ~40g having depth, temperature and light sensing features with ARGO satellite interface were tagged to 42 tunas with length >1m **(Figure. 6).** Overall, 31 tags had retention periods that varied from few days to 134 days. The study revealed that dissolved oxygen concentration in subsurface layer restricts tuna movement to deeper layers. Due to global/ocean warming the movement of tuna could be further restricted to the upper layer, which may lead to excessive catch. The results helped to understand the fish stock dynamics and evolve sustained spatial harvest regulations.

SAT tags accurately determine the geographical locations via Doppler shift calculations and transmit it to orbiting satellites. They are designed to be long-lasting, transmitting signals until they run out of batteries or become detached. In sharks, they are used in conjunction with SPOT tags. SPOT tags are highly accurate devices for recording small-scale movements. They track movements at near-real time, and a particularly useful for tracking horizontal movements of individuals, which can be analysed at much higher resolution than those obtained from PAT tags. They contain salt water switch, which initiates transmissions only when it surfaces. The collection of geological positioning data is dependent on the passing satellites, which may require the tagged animal to surface for longer periods of time, which is a disadvantage. Fast GPS tags provide highly accurate positional tracking using GPS and are capable of recording individual animal interactions in air-breathing animals. **Figure. 7** shows the vertical movement behaviour of blue shark and the varying dive profile patterns of Chilean devil rays which are logged using SAT tags.

Monitoring ocean surface winds is essential for understanding the ocean-atmosphere interactions which in turn are essential for weather forecasts. Such measurements are carried out using satellites and moored data buoys. However, wind measured by the satellite

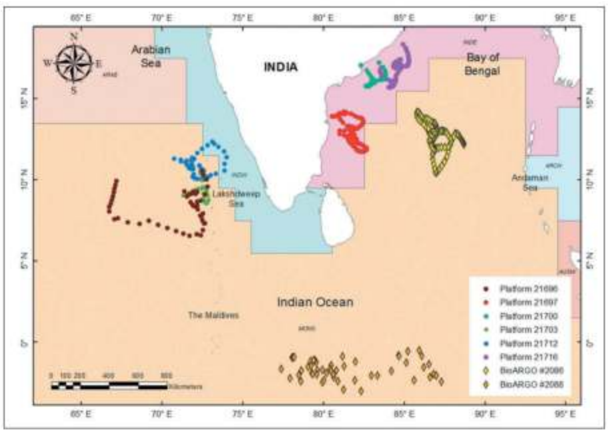

Figure. 6. Satellite-AniBOS for tuna tracking in Northern Indian Ocean

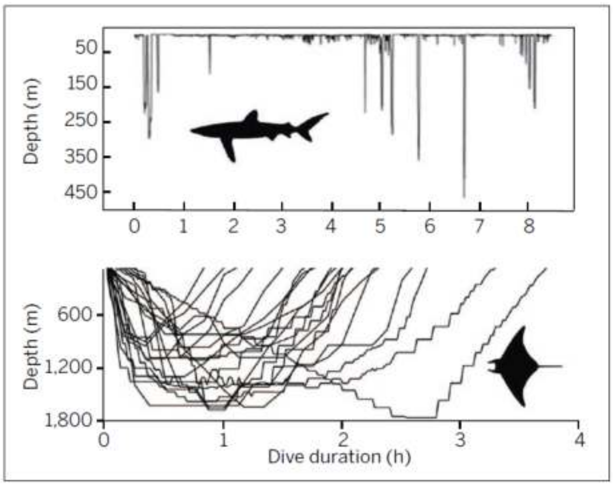

Figure 7. Satellite-AniBOS for tracking precise small-scale movements of sea animals

scatter meters and buoys are spatially and temporally coarse. Further, winds are particularly under-sampled in open ocean areas due to infrequent (twice/day) satellite observations and sparse buoy measurements, and in coastal zones where the topography is complex. The wind observed by soaring seabird's tracks complements the conventional observation gaps in terms of both time and space. This provides the possibility of using soaring birds as a living anemometer.

The development of a small motion logger that can be attached to a bird's back containing a micro-controller, GPS receiver, inertial sensor, 3-axis geomagnetic sensor, and a Li-Ion battery charger has revealed that observations of soaring seabirds, such as the Streaked Shearwater and Albatross can measure winds over the sea, surface currents and surface waves. Extensive travel distance and prolonged flight duration of soaring seabirds enable fine-scale resolution and wide geographic range estimation of wind speed and direction covering temporal and spatial gaps between the remote-sensing measurements. As an example, **Figure. 8a** shows the 5min section of the flight path of a streaked shearwater. The arrows indicate the estimated wind velocity. **Figure. 8b** indicates the enlarged view of a meandering path shown in **Figure. 8a**. **Figure. 8d** shows a 5-min section of a flight path of a streaked shearwater when the bird seemed to travel in a certain direction. **Figure. 8e** shows the enlarged

The wind observed by soaring seabird's tracks complements the conventional observation gaps in terms of both time and space. This provides the possibility of using soaring birds as a living anemometer

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Assessment, Examination and Certification of Seafarers

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view of 8d depicting repeated zig-zag movement from soaring manoeuvres. **Figure. 8c** and **Figure. 8f** shows the relationship between flight direction and ground speed of the path section in shown in **Figure. 8a.** The estimated wind speed and direction is indicated by black arrows.

Tri-axial accelerometer tags record detailed 3D movements of tagged animals which generate a clear picture of behavioural activities such as mating, breathing and feeding. Acoustic business card tags can be applied to free-ranging individuals, which can then emit and receive signals from other tagged animals, permitting mobile peer-to-peer (MP2P) transmission of data. The time, frequency, duration and location of the exchange is recorded and transmitted via satellites. Valuable data about interactions with conspecifics, distance travelled, timing of mating or spawning rituals and predator-prey relationships can be collected.

Progress in Marine AniBOS Technologies

The first successful use of AniBOS with NIMBUS satellite telemetry was in 1977 to track three adult female polar bears in Alaska. During 1979, four female polar bears in Lancaster Sound, Canada, and four bears in the Greenland Sea were tracked. In these studies, the satellite-linked AniBOS (weighing ~5 kg) were housed in collars and fastened with a steel-reinforced harness covered by plastic and rubber tubes. The cables were fastened by a magnesium bolt under the chest to allow for release when the bolt gets corroded.

Since 1978, Argos, was used a worldwide data collection and location and networking system for ocean-based scientific data. The Argos system hosts a network of autonomous platforms that collect data for more than 2000 projects in more than 100 countries. The low-orbiting polar satellites deliver uplinked data to Global and Regional Processing Centres (GPCs and RPCs), providing worldwide coverage. AniBOS uses this network in tracking marine animal migratory paths, understanding ocean conditions, impact of climate change and anthropogenic activities marine wildlife. Argos also uplinks data from myriad platforms, including gliders, buoys, Argos profilers tagged by the Ocean Tracking Network (OTN).

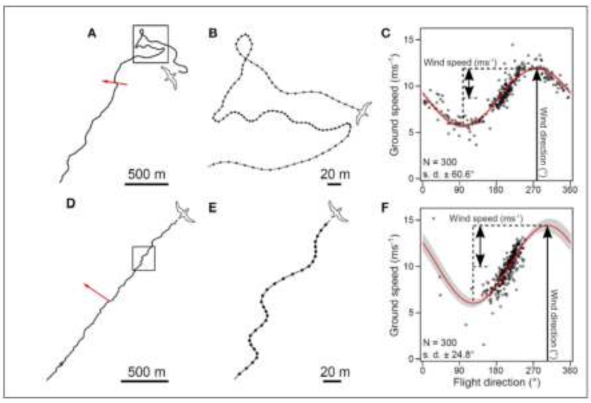

Figure 8. Satellite-AniBOS for tracking precise movements of birds

In 2011, advent of the Iridium satellite system allowed more data to be transferred at a lower cost than the Argos system and enabled two-way communication with the AniBOS. This allowed AniBOS to be programmed remotely (e.g., changing the duty cycle) and opened the possibility for release devices that could be triggered by the user. The performance of the Argos and Iridium satellite telemetry is summarised in **Table 1.**

Various attachment types for satellite transmitters, including collars, glue-to-fur, implants, and ear tags, can be used on marine mammals. There are trade-offs between retention period, operational life, data quality, and the animal's physical tolerance to different attachment types **(Figure. 9).** Collars are most frequently used because their size can accommodate a battery that provides high-quality data for> 1 year. Collars allow for the attachment of devices for monitoring behaviour, such as video cameras and activity sensors with high spatio-temporal resolution. However, low battery capacity associated with the small size of ear-mounted transmitters (< 60 g) and the propensity of animals to remove the transmitters has resulted in a mean functional life of 70 days, which is too short to evaluate seasonal patterns in movements and habitat use. The use of subcutaneous AniBOS implanted in the dorsal cervical region with a percutaneous antenna is also in practice.

Various methods of attaching the AniBOS to animals are shown in **Table 2.** In some cases, tagging will be stressful. The surgical technique that is most often used in long-term data logging experimentation is intra-coelomic implantation. Although this method provides excellent data, surgical procedures increase the probability of negatively affecting the health of the animal and can lead to an early mortality.

Figure. 9 shows a sea lion with satellite transmitter in shoulder, time-depth recorder in back, VHF transmitter on the hip and at the left is the satellite relay data logger incorporating a miniaturised CTD unit coupled with the Argos satellite transmitter that enables geolocation and data transmission. Such devices can be programmed to sample water properties at desired frequencies during the ascent phase of an animal's dive and these CTD profiles are then telemetered in a compressed form using the

Table 1. Performances of satellite systems

Parameter	Argos	Iridium
Number of Satellites	8	66
Altitude	830km	780km
Communication type	1-way	2-way
Data rate	250 bps	2.4 kbps
Latency	~hrs	< 20s

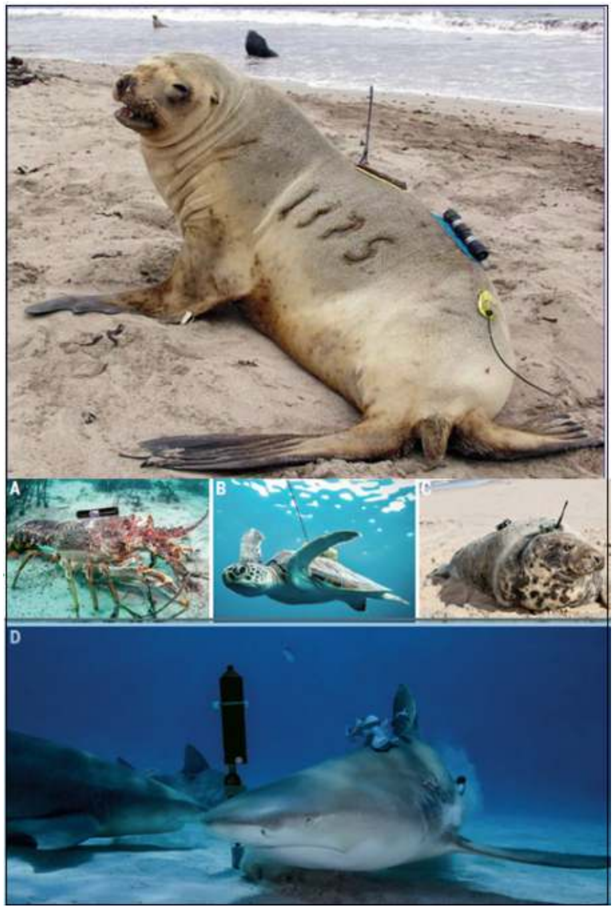

Figure 9. Satellite interfaced AniBOS fixed with marine animals

Table 2. Methods of attaching AniBOS to animals

Temporary	Semi-permanent	Permanent
Paints & dyes	Tags	Chemical branding
Adhesive tapes	Neck collars	Tatooing
Hair/Fur removal	Bands	Passive Integrated Transponders (PIT)
Radioisotope marks	Telemetry : Satellite, radio, Bio	Natural markers
	Archival data recorders	Tissue removal : ear notching, Toe removal Disc clipping, Web clippings

Argos location and data collection system, offering a life-span of several months.

Figure. 9a shows the southern rock lobster and **Figure. 9d** shows a lemon shark fitted with acoustic tags are detected and logged by moored receivers or mobile receivers attached to opportunistic platforms or carried by large animals **(Figure. 9c).** A juvenile green turtle **(Figure. 9b)** fitted with a satellite tag is monitored in real-time using satellite telemetry. A grey seal (Figure.9c) fitted with inter-communicating acoustic and satellite transmitters, transmits and receives data on animal interactions and ocean conditions.

Types of AniBOS

Depending on the research requirement, AniBOS is available various forms, sizes, and shapes. Some of the widely used tags for tracking marine vertebrae include Pop-up Archival Transmitters (PAT) tags, Satellite-linked Transmitters (SAT) and Satellite Position and Tag (SPoT). The PAT tags accurately record and store information about the water depth, temperature, ambient light levels etc. They are used for monitoring large-scale movements, having pre-programmed detachment dates, usually between 30 and 90 days. Upon floating to the surface, they transmit a data summary to the passing (ARGOS/ IRIDIUM) satellite, while raw data can be obtained upon retrieval of the tag.

Various types of commercially-off-the-shelf (COTS) satellite-based AniBOS are shown in **Figure. 10.** The Sea Mammal Research Unit (SRMU) Satellite Relay Data Logger **(Figure. 10a)** records and summaries the diving behavior and environmental data (temperature, salinity, fluorescence depending on the configuration) and can transmit a subset of those through satellite. It is usually deployed on larger animals that surface regularly. The Vemco acoustic pinger shown in **Figure. 10b** transmits unique identity codes to underwater receivers when a tagged animal passed within a range from the receiver, typically 100–2000m. It is suitable for coarse-scale tracking over large areas or fine-scale 'positional' tracking over small areas in both marine and freshwater environments. Optional sensors provide temperature, depth, or acceleration. Tags can operate for weeks to years depending on size and programming options.

The SPOT tag **(Figure. 10c)** provides locations only which is calculated by triangulation of transmissions to satellites. The recent versions can also collect and transmit behavioral and temperature data. As it is available in a variety of physical configurations, it can be deployed on many different species, ranging from fish to whales and sea lions. The PAT tag shown in **Figure. 10d** records the behavioral and environmental data as long as a corrodible link keeps it attached to the animal. When that breaks it floats to the surface and for the next

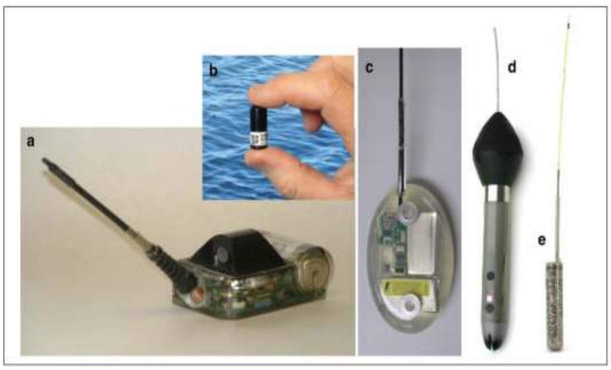

Figure 10. Commercially-off-the-shelf AniBOS

~10 days it transmits as much of the archived data as it possible. It is most frequently used on larger fish species, e.g., sharks and tuna. **Figure. 10e** is an archival tag which records depth, temperature and light level. The tag must be recovered to get the data. Most frequently used in harvested fish with rewards are offered for recovery through commercial fisheries.

However, units that transmit data from receivers over mobile phone networks, or via satellite telemetry, are becoming increasingly common, paving the way for the development of novel observation platforms especially in near-shore regions

Satellite-relay systems have limited bandwidth and often unable to transmit all of the data (large volumes) that sophisticated multiple sensor tags collect and archive. This constraint is a function of tag energy requirements, amount of time an animal spends at the surface, i.e., having access to a satellite and satellite availability. Therefore, these tags often transmit either a pre-programmed data summary. Acoustic telemetry is widely used for small marine animals that do not surface to breathe and are unlikely to be reliably recaptured. Typically, acoustic transmitters are small, light, implantable and cost-effective, facilitating large sample sizes. However, acoustic telemetry is limited by the fact that data transmission occurs through the water via acoustic data packages that can only be detected within the range of a receiver (rarely > 800 m). In most cases, receivers must also be physically recovered from the ocean to download the archived data, limiting real-time data acquisition.

However, units that transmit data from receivers over mobile phone networks, or via satellite telemetry, are becoming increasingly common, paving the way for the development of novel observation platforms especially in near-shore regions. Mobile acoustic receivers mounted on gliders or attached to free-swimming animals are also now starting to be deployed, increasing the spatial coverage of the acoustic network. Emerging coordination among research organizations with compatible receivers enables acoustic telemetry data to be linked across scales of tens of meters to thousands of kilometers.

Communication performance for marine animals typically ranges with between 70 to 97% of dives transmitted successfully for a year-long deployment, and this is higher near the poles than at the equator due to improved satellite coverage, ~ 8 passes per day. On an average ~ 450 bytes and 1700 bytes are transmitted daily at the equator and poles respectively. Depending on the number of messages received along a satellite pass, derived positions are classified into one of seven location classes (LC3, LC2, LC1, LC0, LCA, LCB, and LCZ) and have a nominal error radius. Because marine mammals and reptiles commonly only surface to breathe briefly (e.g., ~10% of the at-sea time for elephant seals), transmission opportunities are short and infrequent, typically resulting in large proportions of locations with high spatial errors (LC 0, A and B). Alternative position acquisition systems exist and can been added to instruments, but adding these systems comes at a cost in terms of energy and bandwidth consumption and as a rule both systems are not typically run on the same instrument. The most popular compliment (to Argos) positioning system is Fastloc GPS (Wild-track Telemetry Systems). Fastloc GPS offers lower power consumption and faster acquisition times (100 ms) than the traditional GPS, and computes animal location with high accuracy (95th percentile error for >6 satellites = 70 m).

The use of AniBOS EoV observation is facilitated by standardization across regional networks such as the Animal Telemetry Network (ATN, USA), Ocean Tracking Network (OTN, Canada and Global), European Telemetry Network (ETN), Acoustic Tracking Array Platform (ATAP, South Africa), and Integrated Marine Observation System Animal Tracking Facility (IMOS ATF; Australia). The adoption of common and coordinated analytical metrics by these regional facilities promotes the application of EOVs to global problems.

Selection of AniBOS

Revolutions in sensor technology has resulted in new generation AniBOS to track marine life, with significantly reduced footprints, lower power and energy power requirements, better accommodating animal anatomy and movement and containing significantly enhanced capacities for data storage. The frequency with which the sensors are interrogated decides the energy consumption (which is a linear function of sampling frequency) which determines the battery capacity, and ultimately the size. The factors that are to be considered for selection of an AniBOS is shown in depicted in **Figure. 11.**

Examples of revolutionary sensors include the "marine skin," a flexible-stretchable silicon-printed sensor system that brings the concept of wearable to marine animal

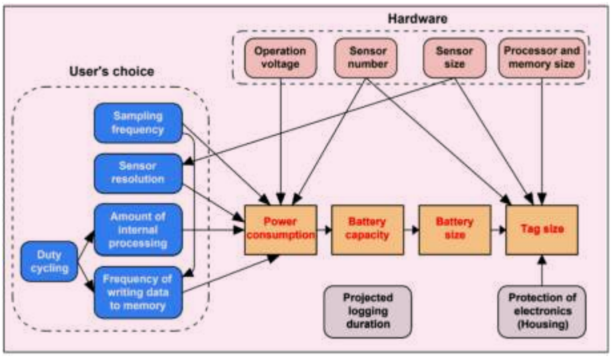

Figure. 11. Factors for selecting an AniBOS

Table 3. Summary of COTS satellite-connected AniBOS

Model	Function	Dimension (mm) & Weight	Endurance	Attachment
Cefas G5 TDR	Depth & Temp	35x12x12 & 2.5g	730 days	Invasive
CTD-SRDL	CTD	105x70x40 & 545g	91	Glue
DST-CTD	CTD, Temp	45x15x15, & 13gms	2.5	Invasive, Glue
LAT 1100	Depth, Temp	31x15x5, & 1.7g	30	Invasive
Onset HOB U20	Depth, Temp	150x25x25, 210g(air)	30	Invasive
Bio-tag, Florida Uty	CTD	100x24x24, 104g(air)	6	Glue
MiniPAT 348	Depth, Temp, Light	124x38x38, 60g(air)	10	Towed
PTT 100	Depth, Temp, Light	166x41x41, 65g (air)	2	Towed
Skin Kaust	CTD	55x55x3.5, 2.4g(w)	151	Glue

Table 4. Comparison between Argos Floats and AniBOS tags

Observing network	Core Argo float	Core AniBOS tag
Active Instruments per annum	4000	103
Observing cycle	1 every 10 days	2.5 per day
Instrument longevity	4.5 years	0.8 years (290 days)
CTD profiles per instrument/ annum	36	725
Total CTD profiles per annum	144 000	74 675
Depth range	0-2000m	0-2000m
Real time vertical resolution	2 dbar (0-2000m)	20 dbar (0-1000m)
Delayed mode (DM) vertical mode resolution	2 dbar (0-2000m)	20 dbar (0-1000m)
Recovered tag (DM) vertical mode resolution	2dbar (0-2000m)	1 dbar (0-1000m)
Temperature accuracy	±0.002°C	±0.02°C
Salinity accuracy	±0.01 psu	±0.03 psu
Pressure accuracy	±2.4bar	±2dbar
Cost per instrument (hardware, data telemetry)	USD 24 000	USD 10960
Cost per profile	USD 148	USD 20

tags, new magnetic sensors to monitor animal behaviors in detail, and graphene-based flexible, ultrathin, and light salinity sensors to acquire oceanographic information. **Table. 3** summarises the COTS satellite-linked AniBOS sensors, their features, dimension, weight, endurance and method of attachment.

The performance of Argo floats compared against the AniBOS tags are summarized in **Table. 4.** It clearly indicates that the temperature and salinity resolutions of the fast emerging AniBOS network have to increase further so as to complement the matured observing networks such as Argo.

Discussion and Conclusion

Presently, AniBOS using satellite telemetry and networks of acoustic receivers allow animals to be reliably monitored over scales of tens of meters to thousands of kilometres giving insight into their habitat use, home range size, the phenology of migratory patterns and the biotic and abiotic factors that drive their distributions, concomitantly improving our understanding of global ocean and climate processes based on the oceanographic measurements. Many streams of AniBOS telemetry data are now routinely included in online data portals that are available to researchers in a broad range of scientific fields. By the advances in tag technology, including miniaturisation, improvements in battery efficiency, application of AniBOS has further matured, and the use of animal telemetry continues to grow exponentially. However, temperature and salinity resolutions of the fast emerging AniBOS have to increase further so as to complement the matured observing networks such as Argo.In terms of satellite telemetry, the recent ICARUS (International Cooperation for Animal Research Using Space) initiative is working to mount a new animal tracking antenna on the International Space Station (ISS) that would allow smaller tags to send data back through the low-orbit satellite. The Sensor Gnome Network is currently managing ~1600 very high frequency (VHF) tracking tags on one standard frequency, reporting the detection of tags at hundreds of locations across North America.

Advanced AniBOS capabilities would augment our knowledge and understanding of ocean ecosystems and our ability to engage in science-based decision-making and ecosystem-based management. The data is being made accessible for analysis and assimilation by computer models and to improve our ability to provide accurate forecasts and inform eco-system based coastal and marine spatial planning.

Promoting development of cost-effective AniBOS technologies and investments in new sensors for oxygen and acidity measurement to understand the growing concerns on the potential impacts of ocean acidification and hypoxia on marine biological resources and the health of the ocean ecosystems are essential. Coordinated deployments of receivers and tags to reduce costs and expansion of the animal-tagged ocean observation sensors are required for increased outreach and to foster the public understanding. Animal distribution and migration data obtained from AniBOS are to be overlaid on oceanographic data to develop predictive mapping tools that shall help to protect endangered species, minimize bycatch of protected species and understand the impacts of climate change on life in the global ocean.

In addition to the vital contribution AniBOS makes to GOOS, AniBOS are also ideal platforms for education and outreach activities and for more general communication of science to society, from children in classrooms to interested citizens. The "Follow the Glider" initiative is a nice example of how to reach the public with ocean science. Like ARGONIMAUX in which AniBOS is an active participant, "Follow the Glider" is a web-based educational tool aimed at students and teachers. AniBOS is currently working with the COVERAGE project and collaborators at the NASA Jet Propulsion Laboratory to develop an interactive web platform to visualise and interact with animal borne CTD data sets. These are valuable forums to raise awareness in the broader community about the marine environment, climate change, the interaction between animal performance and climate and the conservation of biodiversity using these data collected by marine animals equipped with sensors. Thus AniBOS is a valuable component in the domains of ocean science, operational oceanography, weather forecasting, marine conservation, living resource management, blue economy, climate change research, policy decisions and education.

ABBREVIATIONS

AniBOS	Animal Borne Ocean Sensors
ARGO	Advanced Research and Global Observation
ATAP	Acoustic Tracking Array Platform
ATN	Animal telemetry Network
ATF	Animal Tracking Facility
COTS	Commercially-off-the-shelf
CTD	Conductivity-Temperature-Depth
COVERAGE	Committee on Earth Observation Satellites- Ocean Variables Enabling Research and Applications for GEO
EOV	Essential Ocean Variables
ETN	European Telemetry Network
MEOP	Marine Mammals Exploring Oceans Pole-to-Pole
GOOS	Global Ocean Observing system
GPC	Global Processing Centers
GPS	Global Positioning System
ICARUS	International Cooperation for Animal Research Using Space
IMOS	Integrated Marine Observation System
IOC	Intergovernmental Oceanographic Commission
ISS	International Space Station
IUCN	International Union for Conservation of Nature
MP2P	Mobile Peer to Peer
NIO	Northern Indian Ocean
OTN	Ocean Tracking Network
PAT	Pop-up Archival Transmitters
RPC	Regional Processing Centers
SAT	Satellite-linked Transmitters
SDG	Sustainable Development Goal
SPOT	Satellite Position and Tag
SRMU	Sea Mammal Research Unit
STORM	Sea Turtle for Ocean Research and Monitoring
UN	United Nations
VHF	Very High Frequency

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

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

LIQUEFIED NATURAL GAS (LNG):

LNG is a popular fuel containing principally the simple saturated hydrocarbon Methane. At room temperature and atmospheric pressure, methane is a gas. It can be compressed up to 600 times in liquid form. The boiling point of methane is -163°C at atmospheric pressure, hence it is stored and transported at cryogenic temperatures in bulk.

Feedstocks include Coal, Natural Gas from land/offshore fields, Syngas (H_2+CO mixtures), Biomass etc. From offshore and onshore oil fields, the gas is extracted from the condensate and compressed. This is pumped to onshore facilities via pipelines, where it may be liquefied further and made ready for transport in bulk. Coal based methane is also growing popular as a useful source of natural gas.

Biomass can be used to produce methane via fermentation, anaerobic digestion or gasification. Production can be also via gasification of ligno-cellulosic biomass. This is a more sustainable option as it does not require food crops as feedstock. Biogas consists between 45-75% of methane. The methane so obtained would have to be refined and liquefied so as to make it useful as marine fuel (Florentinus, et al., 2012).

In terms of hazards to persons, LNG can lead to cryogenic shock, frostbite to a person coming upon contact. There is extensive experience of handling LNG as cargo on ships. This is regulated by the IGC code. For use of LNG as fuel, requirements are provided within the IGF Code. These regulations ensure that the applicable hazards are accounted for.

CO_2, NO_x, SO_x, PM emissions would be reduced as compared to conventional marine fuels. However, the emission of Methane by leakage (methane slip) has to be taken carefully into account as methane is 84 times as potent as of CO_2 in terms of GHG emissions (considering Global Warming Potential over 20 years).

METHANOL AND ETHANOL:

Methanol or Methyl alcohol is also gaining popularity as an alternative marine fuel. Methanol can also be used as a hydrogen carrier within a fuel cell. Ethanol or Ethyl alcohol is also gaining popularity as an alternative marine fuel.

Natural gas, Coal and Naphtha are major feedstocks for production of methanol. These are used to produce industrial methanol. Biomass can also be used to generate methanol which is also known as **green methanol**. Glycerine has also been used as feedstock to produce biomethanol (Moirangthem, 2016). Biomass or biomethane may also be used to generate the Syngas used for generation of methanol (Grijpma, 2018; Thepsithar et al., 2020). The methanol so produced is also known as biomethanol.

> *Natural gas, Coal and Naphtha are major feedstocks for production of methanol. These are used to produce industrial methanol*

Bio-methanol can also be produced from oxidation of biogas (oxidation of bio-methane), however this process is not viable (Hsieh & Felby, 2017). Another potential way of methanol production is via the use of black liquor from pulp and paper industry. However, for this additional amounts of biomass are required (Brynolf, 2014; Moirangthem, 2016; Hsieh & Felby, 2017). It is reported that this process can have a conversion efficiency of 66% (Brynolf, 2014). Biomass to methanol is seen as the most energy efficient pathway for producing transportation energy by 2050 (McGill et al., 2013). Methanol can also be produced by electrolysis process. This is possible using the CO_2 capture from air or recovered from industrial processes and the H_2 generated using electrolysis of water and combining these two gases (Grijpma, 2018; Thepsithar et al, 2020). This is also known as E-Methanol or RFNBO (Renewable Fuels of Non-Biological Origin (Grijpma, 2018).

Crops rich in sugars or starch are the typical feedstocks for production of ethanol. Corn and Sugarcane are the most popular feedstocks. Beetroot, Wheat, Wheat straw, Waster wood etc. (basically lignocellulosic material) are some other feedstocks which can be used (Winnes et al., 2019).

Methanol is comparatively less energy rich as well as lower in density as compared to conventional marine fuels. It also has a low flashpoint which necessitates precautions while handling and using methanol on-board. Methanol is also toxic to persons. Since its vapour is heavier than air, it increases the risk of inhalation of the vapour by the on-board crew. Methanol, being a toxic substance, is to be handled carefully if spilled or leaked in confined spaces or on deck. At high vapour concentrations, methanol can also cause asphyxiation.

Requirements (interim) for safe use of methanol as fuel on-board ships have been developed at IMO (IMO, 2020).

Methanol can be used as a fuel in existing two and four stroke engines but these would require adjustments in the fuel injection and fuel supply system (Winnes et al., 2019). The following issues should be also considered:

a. Methanol is corrosive to certain materials, and the use of methanol as a marine fuel may require the redesign of some combustion engine parts (Ellis & Tanneberger, 2015; Thepsithar et al., 2020). Corrosion-inhibiting additives or special coatings could also be an option to reduce methanol corrosion.

b. The conductivity of methanol increases its corrosiveness in the presence of certain metallic materials such as aluminium and titanium alloys. These materials are commonly used in natural gas and distillate fuel systems but may not be used for pipes or fittings intended for methanol fuel or methanol fuel blends.

c. Methanol can be used in spark ignition, dual spark ignition and compression ignition engines. However, its reduced ability to self-ignite (compared to diesel) require modifications in design of the ignition system and redesign of parts of engine (Grijpma, 2018)

d. Methanol has a low cetane number and thus will not ignite favourably within a diesel engine (Brynolf, 2014; Andersson & Salazar, 2015). It has to be hence used in a dual fuel gas engine with diesel as the pilot fuel. The gas valve is replaced or the engine is fitted with a methanol injector. Modifications in terms of the ignition energy or preheating of the combustion air will be required because of the higher heat of vaporisation of methane (Brynolf, 2014). Potential concerns are the presence of formaldehyde gas in the exhaust, corrosion of fuel inlet and cylinder liner surface (Brynolf, 2014). Methanol can also be used in a methanol-diesel dual fuel engine, where methanol is injected at high pressure and ignited using small amount of pilot diesel. Emissions of formaldehyde, carbon monoxide are expected to be lesser compared to the dual fuel engine (Brynolf, 2014).

Ethanol on the contrary does not pose hazards to humans. material compatibility of the fuel storage tank and the supply system has to be checked to ensure that materials do not react with ethanol. Some Aluminium alloys may be sensitive to degradation. Mild steels and stainless steels have acceptable resistance to corrosion (Ellis & Tanneberger, 2015). Ethanol like methanol has a low flashpoint which is below the normal ambient temperatures. Hence measures have to be taken against possible ignition and explosion. Ethanol and Methanol are classified as Class 3 flammable liquids and share similarities with other gasoline and petroleum fuels (Ellis & Tanneberger, 2015). Hence, the storage and handling procedures can be considered from these fuels.

Ethanol being an alcohol would require considerations similar to methanol for use in propulsion systems. Engines using ethanol as fuel have been used for land-based transport (e.g. cars, trucks) however marine engines are not yet commercialised. It is remarked that Ethanol is not amenable to be directly used in diesel engines due to its low cetane number, energy content and lubrication properties. There is however onshore experience of using it as a neat fuel on land. A glow plug ignition and ignition improver would be necessary in the engine on-board. Use of ethanol could be more amenable as a fuel within the on-board auxiliary engines (Florentinus et al., 2012)

AMMONIA:

Ammonia has zero carbon content as it is a compound composed of Nitrogen and Hydrogen. At room temperature and atmospheric pressure, ammonia is a colourless gas with a distinguishable odour. The boiling point of ammonia is -34°C at 1 bar.

Methane, Coal, Biomass, Nitrogen (from air) are the main feedstocks required for production of ammonia.

Hydrogen is produced from natural gas using steam reforming and then combined with Nitrogen (N_2) using Haber Bosch process. If the CO_2 from the first step is released into the atmosphere, then ammonia so produced is termed as grey ammonia. If CO_2 is captured using carbon capture techniques, then it termed as blue ammonia (Alfa Laval et al, 2020).

> *Ammonia is incompatible with various industrial materials, and in the presence of moisture reacts with and corrodes copper, brass, zinc and various alloys forming a greenish/blue colour*

Other approach would be to electrolyse water to produce Oxygen (O_2) and H_2 and then combine H_2 with N_2 using Haber Bosch Process. The process can be used with renewable energy in which case this will be pure green ammonia (Alfa Laval et al., 2020).

It is remarked that significant production overcapacity exists on date to sustain the initial request of ammonia (estimated as 30% of the total global marine fuel demand) for marine propulsion making the smooth introduction of this fuel in the marine markets possible (Alfa Laval et al., 2020).

Ammonia has a lower energy content as well as lower density as compared to the conventional marine fuels.

In low concentrations, ammonia can be irritating to the eyes, lungs, and skin and at high concentrations or through direct contact it is immediately life threatening. Symptoms include difficulty breathing, chest pain, bronchospasms, and at its worst, pulmonary edema, where fluid fills the lungs and can result in respiratory failure. Skin contact with high concentrations of anhydrous ammonia may cause severe chemical burns. Exposure to the eyes can cause pain and excessive tearing, in addition to injury to the corneas. Acute exposure to anhydrous ammonia in its liquid form can cause redness, swelling, ulcers on the skin, and frostbite. If it comes in contact with the eyes it can cause pain, redness, swelling of the conjunctiva, damage to the iris and cornea, glaucoma, and cataracts.

There is extensive experience of handling Ammonia as cargo on ships. The requirements for this are provided within the IMO IGC code. Ammonia is incompatible with various industrial materials, and in the presence of moisture reacts with and corrodes copper, brass, zinc and various alloys forming a greenish/blue colour (Alfa Laval, et al., 2020). Ammonia is an alkaline reducing agent and reacts with acids, halogens and oxidising agents. Materials are to be carefully selected when ammonia is used on-board a vessel. Iron, steel and specific non-ferrous alloys resistant to ammonia should be used for tanks, pipelines and structural components where ammonia is used. Stress corrosion cracking is induced and proceeds rapidly at high temperatures in steel when oxygen levels of more than a few ppm in liquid ammonia are introduced.

It is possible to store Ammonia by pressurising it in a Type C tank or an independent/membrane tank if it is to be stored at atmospheric pressure (Alfa Laval et al., 2020)

Due to its toxicity and flammability, double-walled piping must be used as secondary containment whenever pipes are inside enclosed spaces. Double-walled pipes can also be relevant when pipes are located in open air to ensure efficient detection of leakages and to keep hazardous zones to a minimum. Detectors are expected to detect any leakage and contain the fuel within the secondary containment before it reaches areas where humans and ignition sources are present. Safe release of ammonia during emergency scenario will also need consideration (Alfa Laval et al., 2020).

Ammonia has high auto ignition temperature, low flame speed and limited flammability limits (Klussmann et al., 2020). For self-ignition, it requires use of very high compression ratios and temperatures which may lead to higher quantities of NOx formation. A possible solution to address this problem is to mix ammonia with hydrogen gas (this can be produced on-board from ammonia by cracking). As an alternative, pilot fuel can also be used to facilitate ignition of the fuel (Alfa Laval et al., 2020). Jansson et al., (2020b), and Taruishi (2020) remark that significant amounts of pilot fuel would be required for engines using ammonia as fuel. The pilot fuel would be required for both SI (spark ignition) and CI (compression ignition) engines.

It is remarked that up to 20% pilot fuel may be necessary. (Kokarakis, 2020) which is a significant quantity. As a result, there remain issues at present as to the suitability of ammonia as fuel. It is anticipated that dual fuel engine configurations would have to be used at least for the initial stages so as to gain experience with Ammonia as fuel while also avoiding loss of propulsion.

Nitrogen generators would also be required on-board to purge the engine after dual fuel operation, gas freeing, tightness testing etc. (MAN Energy Solutions, 2020). A dispersion analysis study would also be necessary in case there is an accidental ammonia leak (Alfa Laval et al., 2020). Ventilation systems and gas detection systems would also need to be studied for their readiness for application (Palmer, 2020)

Fuel supply system may be liquid based or gas based. For gas based systems, the problem arises of maintaining fuel supply during transient or zero demand so as to avoid the shutdown of the system. For liquid fuel systems, such problems are not typically encountered. Liquid fuel systems are also being studied to be used in actual designs (Kwon, 2019).

Having the above in view, it is also acknowledged that marine engines which can use ammonia as fuel are yet under development as on date of developing this paper.

A hazard identification exercise will be necessary for handling, storage and use of ammonia on-board as fuel (till sufficient experience is gained on use of ammonia as fuel enabling development of prescriptive regulations).

HYDROGEN:

Like ammonia, liquid hydrogen is a clean fuel as it is carbon free. Hydrogen is a gas at room temperature and atmospheric pressure and its boiling point is -250°C. The critical temperature of hydrogen is -240°C and the critical pressure 13 bars (IMO, 2016). Hydrogen can be used within fuel cells or within internal combustion engines or as a mixture gas (e.g. with ammonia) to generate energy.

Thus, the ideal pathway would be the production of hydrogen from electrolysis of water using renewable energy (also termed as green hydrogen)

Coal, Natural Gas, Waste wood are the typical feedstocks which may be used to produce hydrogen. Hydrogen is produced from natural gas via steam reforming followed by CO-shift. The hydrogen-rich gas, including CO_2 is then commonly routed to a pressure swing adsorption (PSA) plant to separate the bulk of the hydrogen. The same scheme applies to coal, replacing steam reforming by partial oxidation (gasification). 96% of the global supply of hydrogen is from fossil fuel based sources (Thepsithar et al., 2020)

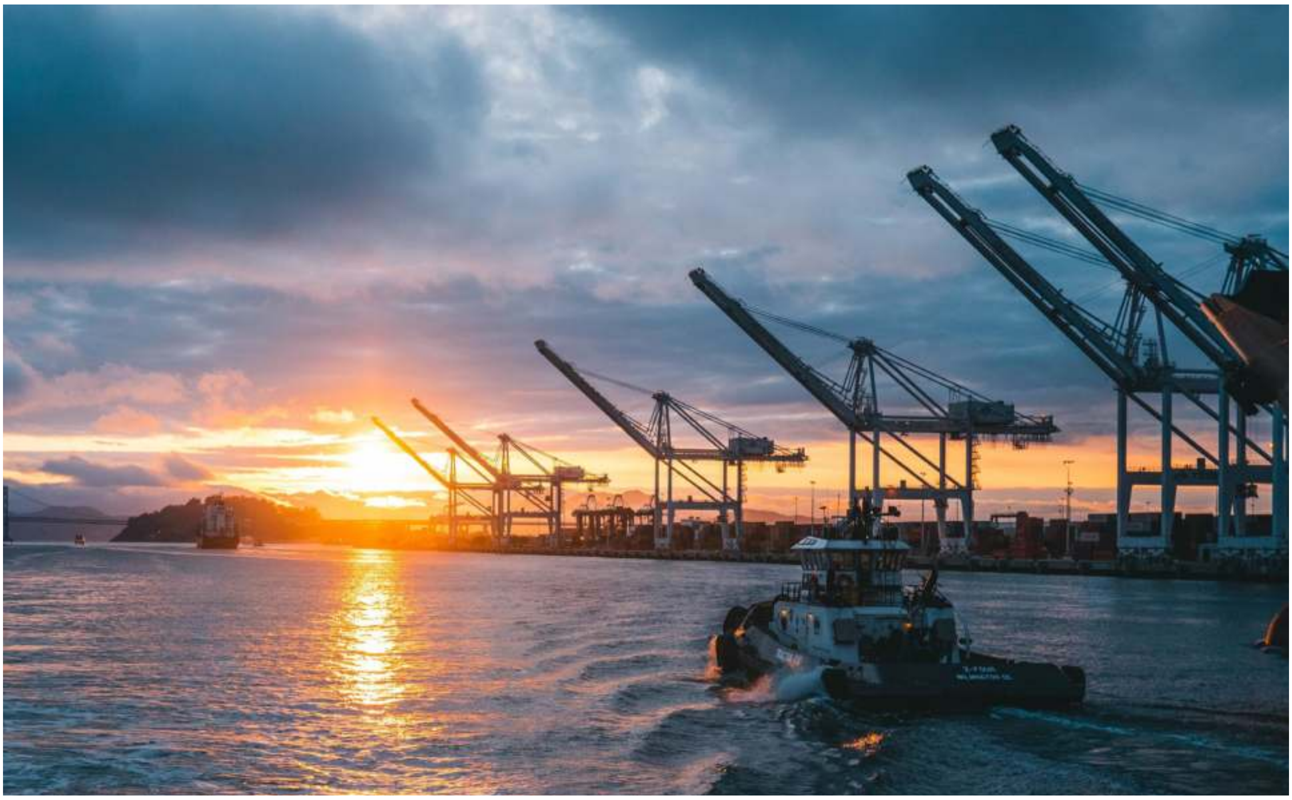
Hydrogen can also be produced from electrolysis of water. It was reported in 2019 that 2% of the hydrogen production was derived from electrolysis (IEA, 2019). Production of hydrogen by electrolysis is viewed as an efficient way of stabilizing the output of wind and solar power plants by diverting the surplus energy into production and storage of Hydrogen which can later be reused to retrieve back the same energy.

It should be however recognized that these would lead to higher well to tank emissions. Thus, the ideal pathway would be the production of hydrogen from electrolysis of water using renewable energy (also termed as green hydrogen).

Hydrogen has excellent energy content which is the highest amongst all fuels. However, the density of hydrogen is quite low making storage of hydrogen an issue (as more storage capacity would be required).

Hydrogen storage is envisaged to be at cryogenic temperatures to maximise its carriage (ratio of volumes between gas to liquid is 1:775). Exposure to liquid hydrogen would cause thermal shock, frostbite, asphyxiation etc. For storage of hydrogen as liquid at cryogenic temperatures, tanks would require to be cryogenic. The boil-off rate could be significant considering the differential temperature of boiling point of hydrogen and the ambient environmental conditions. Efficient insulation which minimizes the heat input within the tank would be necessary. Hydrogen can also diffuse easily within metals & materials since its molecules are smaller than metals or any other compounds. This may lead to embrittlement of the material. ISO TR/15916 provides guidelines for use and storage of hydrogen in gaseous or liquid form. Interim Guidelines (IMO, 2016) have also been developed on carriage of liquid hydrogen in bulk.

Hydrogen may be used as a fuel within the Fuel Cell systems or Internal combustion engines. It may be that internal combustion engines using hydrogen as fuel for ships are under development. The wide range of flammability limits for hydrogen coupled with the very low energy of ignition pose issues, which must be carefully considered when considering use of Hydrogen on-board as fuel.



It would be inevitable to perform a hazard identification exercise to prevent and mitigate hazards posed by the storage, handling and use of hydrogen as fuel on-board.

As of present, engines using hydrogen as fuel in the maritime field are under development. A mixture of 3% hydrogen can be used in marine engines. It is expected that engines using 100% hydrogen may take time to develop (MAN Energy Solutions, 2022).

Electro fuels or E-fuels is a general term to imply carbon-based fuels produced from using electricity as the primary source of energy

The electro fuels may hence be produced during periods of excess energy surpluses for use later. Electro fuels offer feedstock flexibility and potential high-efficiency synthesis of fuels directly from renewable energy resources without competition for arable land and scarce water resources (Brynolf, 2014). However, the production of electro fuels is still in its infancy – mainly the generation of renewable energy has to pick up speed for these fuels to be available on commercial and industrial scales.

OTHER PROSPECTIVE FUELS:

Synthetic biofuels are fuels produced from syngas produced by cleaned and modified gas from thermal gasification (partial oxidation) of biomass (The Royal Society, 2008). There are three major pathways followed:

1. Synthetic fuels from Fischer Tropsch Process
2. Methanol to Gasoline (MtG) or Methanol to olefins, gasoline and diesel (MOGD)
3. Fast Pyrolysis to produce liquid bio oil
4. Solvolysis

Electro fuels or E-fuels is a general term to imply carbon-based fuels produced from using electricity as the primary source of energy. It is envisaged that this electricity is generated from renewable sources such as Solar, Wind, Tidal, Geothermal, Hydro etc. The Carbon within the fuel is derived from CO2 which may be obtained from capture from air, sea and exhaust gases from industrial plants. Electro fuels offer an excellent advantage of energy storage considering fluctuation of electricity generation especially from renewable sources (for example, generation of electricity from wind power can be maximum during the night-time, however at this time the demand from public use may comparatively less and this energy could be harnessed if it were used for generation of electro fuels).

Biofuels can be produced extracting oil from Algae as feedstock (Opdal & Hojem, 2007). Algae have fats within their cells and are able to grow rapidly (Opdal & Hojem, 2007; Macgill et al., 2013; Moirangthem, 2016). The fuel production potential of algae is reported to be much superior as compared to food crops in terms of production per unit square metres of land (Macgill et al., 2013; Opdal & Hojem (2007) report a comparative ratio of 30 when comparing production from algae to oilseeds; Zhang and Cooke (2008) report that more than 300 times the oil can be produced as compared to soyabean per acre or 24 times as compared to palm oil).

Algae can be cultivated even in desert lands and other non-productive sites (Opdal & Hojem, 2007). It is reported that 200-400 tonnes/hectare/year of oil can be produced from algae (Opdal & Hojem, 2007). It is common to build algae biodiesel plants close to energy production units as these can help perform carbon capture (Zhang & Cooke, 2008). The algae being discussed herein refer to micro algae which are quite simple in form. Microalgae are also referred to as a third-generation biofuel feedstock. These may also be genetically modified for better yield (Thepsithar, 2020).

The only major drawback of using algae fuel at present is the limited availability as the cost of production is too high (Macgill et al, 2013; Moirangthem, 2016; Hsieh & Felby, 2017). Other technical reasons are well described by Zhang & Cooke (2008) and Wang (2013) (These are mainly concerned with capital investments, high cost of extraction of lipids from algae, water extraction and its treatment etc.). Hence its' use is reported so far only within US naval ships. However, considering futuristic vision and the fact that algae can be cultivated virtually anywhere and to any desired extent, this has the potential to be a very useful feedstock in the future (Zhang & Cooke, 2008). Pilot projects in several continents are ongoing which may help in improving the scalability of production of this fuel (UNCTAD, 2016).

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

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Design for Maintenance and Operations: Asset Life Cycle Management (ALCM) of Waterway Canals

Prabu Duplex

Introduction

As physical assets have long lifetimes – often amounting to several decades – it is important to effectively manage these assets over their complete life cycle. In the context of Asset Life Cycle Management (ALCM) a number of important aspects has to be taken in consideration. First, it is important to understand the breadth and depth of ALCM. **ALCM has 5 main characteristics: it is 1. a multidisciplinary practice; in which 2. the whole life cycle of a physical asset is taken into account; aiming 3. to achieve certain objectives; 4. limited by risk and relevant regimes; and it considers 5. the allocation of resources. Second, different life cycle phases have different implications for the design of an asset.**

To illustrate, for the maintenance phase, it is important that maintenance can be carried out in an easy, safe and effective way. Finally, the 5 TECCO-perspectives can be considered: Technological, Economic, Compliance, Commercial and Organizational. In each of these perspectives on the asset, changes may happen with an important impact on the asset: lifetime impacts. The timely identification of lifetime impacts allows the Asset Manager to prepare measures to prevent the negative impacts and to exploit the full potential of the positive ones. This work aims to demonstrate the above mentioned aspects to practice, in an application to the management of an inland water way canal. The main objectives of this work is to:

- Propose **three** changes to the design and management of canal, based on a thorough analysis of the asset, using
  - the different life cycle phases
  - the five TECCO perspectives

Life cycle management of inland water way canal

(Location for discussion: The Netherlands).

The inland water canal is a kilometre-long nautical infrastructure that connects harbours and is used as a mode of transportation and also for recreation functions. It generally connects major cities to the national network of rivers and canals of a nation. The canal is expected to be widened and deepened regularly to cope with traffic growth. Currently the canals are being used for the transport of sand, gravel, salt, animal feed and containers.

Figure 1 shows, the Twente canal composed by the nautical channel and eight harbours. Thus the canal plays a significant role in enabling transportation of goods and hence it is important to have an effective and efficient asset lifecycle management (ALCM) strategy in place.

"The taxonomy of a canal generally consists of six main classes that are roadway, underground infrastructure, quay infrastructure, railway, vegetation infrastructure and city furniture"

The canal governing body will outsource the management responsibilities to a third party or sometimes they maintain them self. The contract will initially be signed for a prescribed period. To maximise the value creation from the assets, the managers usually considers making changes in the maintenance approach of the asset. Therefore, this work analyses potential maintenance concepts and improvement strategies for three prominent assets in a canal.

The taxonomy of a canal generally consists of six main classes that are roadway, underground infrastructure, quay infrastructure, railway, vegetation infrastructure and city furniture. Each of these classes then compromises of various elements.

The assets taken into consideration in this work are **quay walls, marine bollards and track rails**. The whole asset is narrowed down to these three parts to propose a more detailed design and operational change. Quay walls and bollards as subsystems are the most substantial and long-term investment goods and thus maintenance has a major impact on the performance of the asset. Furthermore, information about maintenance on these assets is widespread and easily accessible in literature. Additionally, maintenance on rail tracks is assessed to broaden the view on the asset and including the surrounding infrastructure. To have an effective and efficient asset lifecycle management, a total of three changes in operation, design of new assets and redesign aspects are discussed in this work. For a better value creation, the following are discussed in detail in line with the guidelines mentioned in [18].

- an introduction of the asset and the main characteristics of its design (e.g. materials used, main components, facilities)
- a discussion of the different life cycle phases of the asset
- an analysis of the asset (its complete life) using the TECCO perspectives [17]
- propose three changes to the assets design and operation that address (some of) the problems identified
- problems are solved by the changes
- discussion

Marine Bollards

Bollards are short vertical posts used to moor vessels. They are distinguished from other mooring options. For canals those are: rings, hooks and pins [3]. These posts are

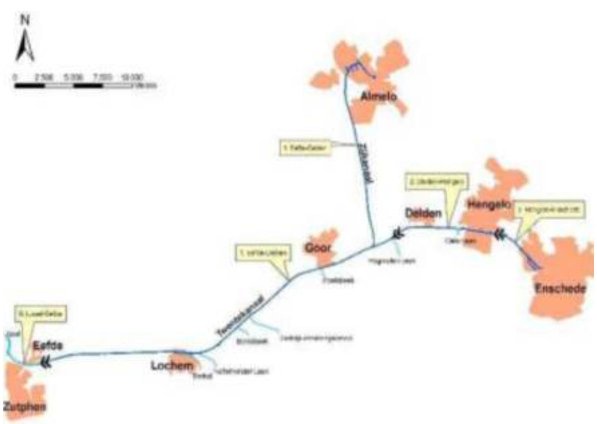

Figure 1. The Twente canal and its harbours

"The life cycle of a bollard can be divided in the four phases such as design, installation, operation and decommission"

usually made of spheroidal graphite but also cast steel, and especially in the past cast iron are used. The shape varies from type and size but consists of a hollow body and a base which is screwed on several bolts. The mainly used material spheroidal graphite has several benefits compared to the alternatives (higher strength, lower service life costs and higher corrosion resistance) but is also costlier [4].

Life cycle phases

The life cycle of a bollard can be divided in the four phases such as design, installation, operation and decommission.

Design phase

During the design phase the right bollard is chosen based on ship tonnage, mooring patterns, changes in draft, wind forces, swell, wave and tidal forces, mooring line types, sizes and angles and ice forces. The bollards are designed with a safety factor of 3 [4].

Installation Phase

Bollards are installed during the construction of the whole asset. In general, bolts or "anchors" are moulded in concrete and bollards are screwed on with nuts. Mastic is additionally applied on exposed threads for easy removal in future [4].

Operation Phase

Bollards are operated for several decades. During this time the asset may be damaged by corrosion, wrong installation, mooring ropes, excessively or inadequate tightened fixings, unauthorised modifications, grinding and other works near bollards, spillage of paint and solvents, bird guano or overloads and impacts [4, 5]. Possible effect of disregarding proper installation and maintenance has become visible in a mooring accident at BAE Systems shipyard, Mobile River, Alabama, USA in April 2013. During storm cruise ship "Carnival Triumph" broke free from moorings resulting in a collision with a moored dredge whereby a worker's life has been lost and an overall damage of 2.9 million USD was caused, excluding several penalty charges for violation of laws that this incident revealed. Assessment showed that poor bollard condition caused the accident. Loosened bolts, corroded bolts and high forces lead to brittle fracture and ductile rupture that made the bollards fail **(Figure 2).** Therefore, mainly preventive maintenance of the steel structure, paint system, anchors and fixings need to be carried out, in addition to the periodical visual inspections. Preventive maintenance includes, full inspection after 15 years for steel structure, anchors and fixings, and for the paint systems inspection in a span of 10 years is required [5]. Also, corrective maintenance is carried out as per

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Figure 2. Failed Bollard with failed bolt and damaged concrete base

interim inspection findings, and repair activities after incidents (e.g. overload, impacts).

Decommissioning

After full maintenance, refurbishment or replacement is decided. Also, replacement of the asset due to changing requirements by higher class vessels must be considered. The recycling of the used material is not problematic. However, if obsolete structures need to be removed, their heavy duty concrete bases require heavy machinery to fully remove them from the ground. In case of failure, the bollards are usually ripped into waters where they either remain or being salvaged for the inspection of causes [6].

TECCO Perspectives

During the lifetime of the asset, it is desired to be agile for its changing environment [16]. Therefore, the bollards will be further analysed regarding the five TECCO agility drivers and TECCO life time impacts. During the life cycle analysis, the following issues can be encountered.

Technical Perspective

Considering technical agility drivers, bollards require a certain strength and maintainability to withstand different conditions of weather and wear. Corrosion and loosened fixings are the main lifetime impacts.

Economical Perspective

Privatisation leads in the whole asset to an increase of cost efficient investment. In a severe case, economic factors have suppressed proper maintenance and lead to shortened lifespan of the bollards.

Compliance Perspective

Government renews its perspectives on the waterway usage, resulting in a change of waterway classification. Assume for a certain classification [1], if twice as much tonnage for a vessel than before is allowed, then the existing bollards (say 10 t load capacity) will become obsolete.

Commercial Perspective

Commercial shipping changes with its ability to ship the canal demanding for appropriate mooring.

Organisational perspective

A changing private operator of the canal brings his own organisation, however known technical issues can be disregarded by the organisation leading to failure with severe consequences.

Life Cycle Interventions

Due to their exposure to environmental factors and their long lifetime, failure and thus the right period of maintenance is highly unpredictable. However, failure leads to severe damage and must be avoided in any case by the organisation. Further, faster changing compliance issues during the whole lifespan of the asset require adjustment by replacing the asset. Thus, changes in design regard a longer lifespan by choice of higher quality material and over dimensioning. Larger vessels may be able to use the asset in the coming future. To tackle this and lay a basis for long term operation bollards may be changed towards a more durable design. Changes in organisation include, adaptive visual inspection, checks based on questionnaires that are directly forwarded to repair and maintenance team, regular repainting and exchange of bolts.

Proposed Design Change

A replacement of the asset is vital due to the new positioning and obsolescence of the old asset regarding maximum load (say 20 tons to be upgraded to 25 tons for new bollards). The decision for safe working load to be decided based on the expected higher capacity/ stringent class notation vessels in the prescribed period. It will be beneficial, to change the installation of bollards from rested to mounted by through bolting **(Figure 3).** In one hand this eases installation and maintenance. On the other, it eases decommissioning and replacement for further changes to the whole asset. Also, choosing spheroidal graphite cast iron makes the asset more

> *"The decision for safe working load to be decided based on the expected higher capacity/ stringent class notation vessels in the prescribed period"*

resistant to wear and corrosion. Reduction of corrosion of the bolts is achieved by covering the bolt ends with mastic. If the canal be deepened and broadened during the coming years, landing stages can be installed for installation and inspection of the painting system or other inspection activities.

Discussion

The proposed design changes require a full investment for a new asset. However, by comparing with the conventional method in use, several maintenance benefits may be achieved. Also by choosing the less corrosive spheroidal graphite cast iron even a full maintenance of the painting system can be avoided and leading to only interim maintenance which is needed after obvious incidents. The lack of scheduled full maintenance could also bring the risk of ignoring unforeseeable defects of the asset. A combination of visual inspection, use of questionnaires [5] for these visual inspections and report of incidents may lead to an optimum of monitoring while maintenance and decommissioning costs are lowered.

Quay Walls

After investigating the bollards as part of the quay structure, the maintainability of the quay walls themselves is assessed in order to propose a design change for a newly designed canal. A quay wall divides the water from the land. It is the most important and largest structural part of the canal. The quay walls are present everywhere alongside the canal, including the harbours and parts of the shut locks. It consists of bare steel sheet piles that are pushed in the ground. Usually, corrosion protection is used. The sheet piles are held in place by a steel quay wall anchor, embedded in the supporting dyke. A cross section is shown in **Figure 4.** The quay walls have a simple design, are labour and resource intensive to construct but do not endure a lot of changing conditions during their lifetime. However, there are several conditions that need to be monitored to keep the risks acceptable.

Lifecycle Phases of the Quay Walls

In the following paragraphs the lifecycle phases of quay walls are discussed.

Design Phase

The design and function of a quay wall has been the same for a long time. It is a proven concept and only must be customised to the actual surroundings. During this process reliability, availability, maintainability aspects (or even RAMSHEEP) needs to be considered [15]. Reliability centred maintenance (RCM) perspective (based on a FMECA analysis) or a combination of other maintenance strategies can be considered at this stage. This is feasible, since inputs can be learned from other canal projects or publications. For example, the necessary design input such as the pressure the quay walls need to withstand, the type of water (brackish, salt or fresh), the amount of tidal change and size of the ships passing through, the types of vessels using it (pleasure, professional) the lifespan it needs to have etc. can be determined from engineering calculations/ simulations or historic data available. From this analysis, the required lifespan, walls dimensions, anchor and dyke sizing can be determined. Advanced corrosion protection systems need to be considered in the beginning.

Operation Phase

This is the most important phase of this asset's lifecycle, since it is designed to last for a very long time (many existing canals already in service over decades). Over time, it is likely that surroundings change. Such as the demand for bigger ships, the corrosion of the quay walls or use of other kind of vessels (pleasure craft). During the operational phase, general maintenance, refurbishments and updates are executed as required. To prevent excessive costs, eliminate breakdown risks and reduce the operation down time, a maintenance plan must be in place based on the company's objectives.

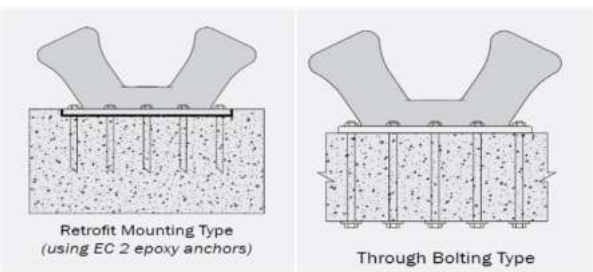

Figure 3. Change in installation from rested in concrete to through bolting [4]

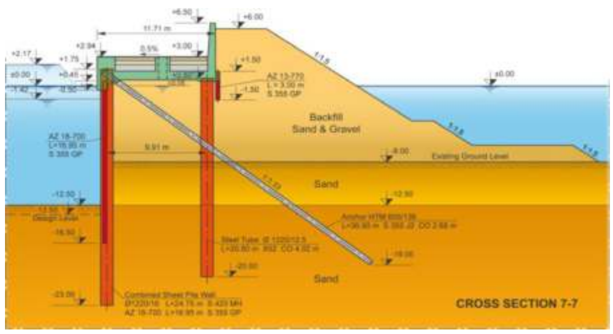

Figure 4. Quay wall cross section [7]

Decommissioning and Disposal Phase

The decommissioning and disposal phases for infrastructure this large and long lasting are usually not well considered. However, for the quay walls itself a decommissioning and or disposal plan can be in place. After a refurbishment or update, a large quantity of materials will be available for recycling (Steel from the walls).

TECCO Perspective

During the review of the lifecycle phases, the functional aspects are considered. During the TECCO perspective, future external influences will be analysed

Technical Perspective

Generally, quay walls are constructed considering bigger ships will sail through as a mean of cargo transport in the future for it to stay economical interesting [9]. Bigger ships will increase the structural demand on the quay walls. It needs to withstand higher pressure and the larger waves create a larger wet area that will corrode faster. Also, materials with enhanced metallurgical properties might be available in the future. This can be an interesting alternative since it might not need as much maintenance. These future impacts must be considered.

Economic and Commercial Perspective

If the canal is to keep adding value for ship-owners and adjacent companies in the future, it must be widened and deepened. Bigger ships can enter the ports in future. Otherwise it may lose transport to the road ways. If the canal is not widened and deepened in the future, it will lose its commercial perspective for ship owners and adjacent companies and thereby its economic perspective for the maintenance agency.

Compliance Perspective

The canals must be compliant with the maritime safety regulations (operational safety, structural safety etc.). The structural integrity of canals is critical and regularly monitored. Furthermore, with the rising sea level due to global climate change it is likely that regulations change in the future. These changes must be considered and new regulations must be anticipated in advance. For countries like the Netherlands which has a large surface area beneath sea level, the structural integrity of canals is well defined and regularly monitored [8].

Organisational Perspective

Companies who build quay walls are specialised in earth moving operations and civil construction. The basic quay walls design has been the same for a very long time. And there is no technical perspective that this will change. When the canal would become wider and deeper scaling up may be sufficient. What could be recommended though is there might be circumstances to increase the size of the canal and harbours in future. If scaling up of quay walls needs to be done, resource allocations or design additions needs to be planned accordingly.

Lifecycle Interventions

Well known problems with current quay walls are shown in **Table 1.**

A FMECA analysis including criticality and risk priority numbers will rank the most important problems. This is an excellent starting point for an asset lifecycle plan (ALCP) for the coming years (say 15 years). It will show which risks must be reduced or mitigated. What to do with the risks must be assessed/ determined with the complete lifecycle and TECCO perspectives in mind.

Where are the assets in its current lifecycle and what needs to be done?

Proposed Design Change

As stated before, one of the largest issues with steel quay walls is corrosion and corrosion prevention can be done with advanced paint coatings, anodes (sacrificial, electrochemical based etc.). Another possibility is to over dimension the thickness of the walls. These would all elongate the overall lifetime/time between maintenance. In case of widening / deepening the canals design change would be easy and scaling up activities can be done in design offices. Standard quay walls are anchored with a fixed anchor. When these anchors could be made adjustable and would be attached at multiple heights to the quay wall, adjustments can be made during their lifetime. For instance, when misalignment or failures in sheet interlocks occur, they can be solved by adjusting the tension on the anchors. When the tension is adjusted to

Table 1. Problems with quay walls [11]

Distress	Brief description
Misalignment	Horizontal or vertical deviation from the design alignment
Corrosion	Loss of steel due to interaction with environment
Settlement	Vertical movement of material behind sheet pile
Cavity formation	Loss of fill material behind or within sheet pile interlock separation
Failure of sheet interlocks	Holes broad opening in sheet dents depression in sheet without rupture
Cracks narrow	Break in sheet
Low soil level	Vessel's propeller remove solid from sheet pile edges

its standard value regularly, it might even prevent cavity formation and settlement. For the monitoring of the pressure, sensors should be incorporated in the anchors and walls to measure the local strain.

Discussion about the Proposed Changes

The proposed change can be very preventive for failures. However, it is very labour and resource intensive to construct and carry out. Therefore, the financial pros and cons must be considered before implementing. Areas that support the quay walls with softer (clay) soil might be interesting to apply this to.

Track Rails

The two previous assets focused on the design of waterway asset while the overall asset that is maintained by any supporting organisation includes infrastructure such as track rails. In the following paragraphs, the operation management of track rails is discussed.

Rail infrastructure as shown in **Figure 5,** consists of assets such as rails, track ballast, sleeper, crib and shoulder. In general, most of the assets in the rail infrastructure have a high initial cost for construction. These assets are regularly maintained to ensure a safe and smooth running of rail vehicle. The life of the some of the assets of the rail infrastructure for example rails can last up to 30 years. Rails are the members of the track laid in two parallel lines to provide an unchanging, continuous, and level surface for the movement of trains. To be able to withstand stresses, they are made of high carbon steel alloy consisting of materials like manganese, silicon, sulphur, phosphorus and aluminium. Some grades of steel also contain chromium, niobium and vanadium. Rail is the steel section that has been rolled into an I-section with hardened head and a flat bottom. The flat bottom cross section enables the rail to be fixed directly to the sleepers with the help of spikes. Track ballast comprises of crushed gravel with specific physical characteristics such as hardness and size it reduces noise and absorbs vibrations that result from the running of the railway, and degrades with time due to the contamination of oil because of frequent railway traffic. Lately, gravel track is being changed to concrete track in the railway industry because of easy maintenance and high economics. Track rails are the most essential asset in the rail infrastructure,

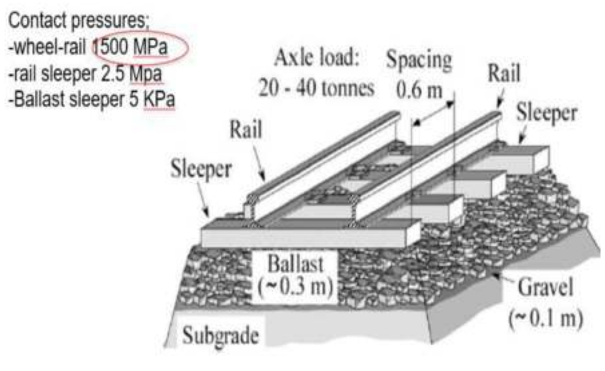

Figure 5. Track rail structure [13]

a smooth running of the railway can only be ensured by performing a complete asset lifecycle management.

Lifecycle Phases of the Track Rails

Track rails are the most expensive asset in the rail infrastructure. In order to maximise the rail infrastructure value, the organisation needs to track the activities related to the asset throughout its life cycles. The activities should align with the organisation's RAMSSHEEP (reliability, availability, maintainability, security, safety, health, environment, economics and politics) and TECCO (Technical, economical, commercial, compliance and organisational) goals. Successful implementation of these goals is only possible if they are implemented over the complete life cycle of the asset. The rails have a high initial investment cost and they can last up to 30 years if maintained properly.

Design Phase

Once the desire is made to construct rail infrastructure it needs to follow a thorough process of problem analysis, conceptual design, layout (system) design, detail design, refinement and testing and production ramp up before it can be manufactured. During the above-mentioned design phases, all the relevant question regarding the nature of traffic, rules and regulations and the relevant RAMSSHEEP and TECCO goals of the organisation regarding tracks rails must be answered.

Operation Phase

Once the steel rail tracks that manufactured they are mounted on the sleepers. During the operation phase the rails need to be continuously inspected against failure modes like fretting corrosion, surface fatigue, forced fracture, case crushing, flaking, spalling, scoring and brittle fracture. To ensure proper functioning and prolonged life a maintenance strategy need to be implemented.

Decommissioning and Disposal Phase

When the rails reach their end of life stage and are no longer able to fulfil their intended function they must be reused or recycled. Damaged crossing, switch blades and manganese inserts removed due to wear and damaged must not be scrapped. They should be recycled and returned to service as new crossing or other useful applications. It is worth mentioning here that rebuilt crossings have roughly the same magnitude of service life as new ones.

Analysis of the Asset in TECCO Perspective

The life time impacts that can be encountered in a TECCO perspective is shown in **Table 2.**

Lifecycle Interventions

To maximise the value of the asset there is need to highlight areas of improvement. There are several types of wear and damage present in the failed rails. Some

Table 2. TECCO perspectives	
Technical perspective	The company should be equipped with the staff and equipment required for implementation of the maintenance policy.
Economic perspective	The maintenance policy should consider the economical limitations of the company. It depends on how much company is willing to spend on the maintenance to reach up to required level of availability.
Compliance perspective	The rail tracks should comply with all the rules and regulations set by the government and the maintenance policy must facilitate it to be made possible.
Commercial perspective	The proposed changes must help the company in meeting its commercial goals.
Organisational perspective	The maintenance policy should be aligned with the organisational goals.

of the common examples are damaged crossing (Metal flow), Broken flow, piece fallen out, head damage, surface and subsurface cracks, extreme wear, broken switch tip, wheel burns, transverse defect, cracks in crossing nose, wheel burns and squat repairs [10]. Some of the damaged rails can be seen in the **Figure 6.** Currently most of the above-mentioned failures are dealt by replacing the rail.

This is a costly and labour intensive method. Most of these failures can now be permanently repaired and the repaired rails are not only fit to be in service again but at times can also improve the wear characteristics. In the past repair methodologies were not so successful and thus the rails needed to be replaced. The welded sample in the past showed cracks and inclusions and were unreliable. Based on the new developments and repair techniques some design and operation changes will be purposed and a maintenance policy will also be presented in a desire to maximise the asset's value.

Proposed Operational Change

The proposed operational change is as follows. To repair the failed rails with failures such as damaged crossing (metal flow), broken flow, piece fallen out, head damage, surface and subsurface cracks, extreme wear, broken switch tip, wheel burns, transverse defect, cracks in crossing nose, wheel burns and squat, instead of replacing the damaged the rails with a new one, the company should facilitate the transformation towards this new strategy of repairing the damaged rails as shown in the **Figure 7.** The presented maintenance plan incorporates and addresses failure mechanisms of the rails. To identify, prevent, repair the mentioned failure mechanism of the track rail the following maintenance activities are recommended. A team of qualified track inspectors should perform the inspections based on the scheduled timings as mentioned in **Table 3.**

The purpose of the above-mentioned maintenance activities is to identify and repair the damaged rails. For example, wear on wing and small defect on nose, head damage on wing rail should be repaired by grinding wing rail and doing a heat treatment if

Figure 6. Damaged rails [13]

Table 3. Proposed new maintenance activities

Maintenance Activity		Duration
A.	baseline track inspection	Twice a year
B.	routine track inspections	Once a month
C.	scheduled maintenance program	Twice or thrice a year is based on failure rate
D.	emergency response	In case of emergency
E.	track geometry testing	Twice a year
F.	track rehabilitation and construction services	Twice a year

Figure 7. Methods of operational change [14]

required. Furthermore, failed rails should be repaired by rebuilding the damaged rail section for example by rebuilding wing rails and then coarse grinding and post grinding them. Larger failed steel crossing for example switch blade with broken tip, swing nose crossing with head defects should also be repaired and put back in service. Before repair of such large scale of failed components manganese components must be removed from track before rebuilding. Workers should be protected from fumes and dust and other harmful effects of manganese. It can take about one to two hours to remove the damaged manganese insert out of the track and replace the new or repaired one in the track. Larger cracks that need to repaired for welding must be welded following the global standards present for welding. Inserts have a normal service life of 9-12 months and it can be extended to 31 months if repaired and maintained properly. It is possible to rebuild inserts up to four times giving making a remarkable difference in service life and performance.

Furthermore, a sensitivity analysis should be performed by the team of experts to identify critical area of failures. For example, areas, close to canals, harbours and or rail stations where trains frequently change lines. Once the potential areas of failure have been highlighted sensors can be installed to detect and monitor misalignment and corrosion for instance.

Discussion about the Proposed Changes

The proposed operation change in maintenance approach is a very cost efficient maintenance approach. It does not require lifting equipment or cutting of rail and the repaired rails will possess same hardness as original rails. It is a green process and fill help the company's transformation towards sustainable solutions to the faced challenges.

Conclusion

The three proposed design or maintenance changes have been suggested one for each asset. The changes are expected to maximise the overall asset value of the canal. For the marine bollards and quay walls a bigger investment is required but once the change has been made the failure rate will be low and very few maintenance activities are required. However, the change proposed for the track rail maintenance will see a significant decrease in investment costs but the failure rate will not be highly affected. For an optimum in asset life cycle management more than a single proposed design or operational changes is required. The optimum may be reached by combining multiple changes in design as well as in operation.

Twente Canal

Acknowledgement

This is an academic group work for, design for maintenance course, performed during the first year of Professional Doctorate in Engineering (PDEng) program at the University of Twente. The course was coordinated by Prof. Alberto Martinetti who held position in Design Production and Management (DPM) research group. I thank him for his valuable support. As this PDEng is also an industrial project I also express my gratitude to Prof. Tiedo Tinga who headed Dynamics based maintenance (DBM), for

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:

SCHEDULE

- Notice of the entire process of election shall be intimated through electronic media ONLY.
- Soft copy of the Nomination forms will be sent through mass e-Mail and can also be downloaded from the IME(I) website and returned to the Election Officer.
- Soft copy of the Nomination papers for Council elections will be mailed by **15th 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 **15th June 2023** to the email id: ***electionofficer@imare.in***
- Last date for withdrawing nomination is **30th June 2023**.
- The scrutiny of nomination papers for the Council to be completed by the Election Committee by the **5th July 2023**.
- 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**.

E-VOTING

As a corporate member you can exercise your franchise at the forthcoming elections at IME(I), using the standard Ballot **through e-Voting ONLY**.

Two options would be available for both the elections i.e. for Head Office (HO) as well as the Branch Level (if the election takes place for the Branch level). Overseas Members will get Option only for elections at HO level.

Members will get the e-Voting Link **ONLY on** their e-Mail registered in the records of IME(I) as on **15th May 2023**. Members may update their e-Mail ID / contact details by writing to the HGS at ***membership@imare.in*** latest by **15th May 2023**.

USE OF WORKPLACE / OFFICIAL MAIL IDS

- Given that we have, in the past, had mass emails blocked at certain receiving (Organization) mail domain(s), treated as spam and, in some cases the blacklisting of the IME(I) domain, we would strongly recommend the use of personal email ids ONLY.
- The use of your personal mail would ensure that you do not miss any important communication relative to the election process.

Election officer
electionofficer@imare.in

his guidance to choose this coursework and to sustain funding from industrial partners to support this work.

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LUBE MATTERS # 23
LUBRICATION REGIMES (PART II)

TECHNICAL NOTES

Sanjiv Wazir

Conformal and Non-Conformal Contacts

Conformal Contacts

Contacting surfaces can generally be divided into two types: **conformal** and **non-conformal**.

Contacts where the surface curvature of one surface closely matches the surface curvature of the other are called conformal contacts. For example in a journal bearing the inner radius of the bearing and outer radius of the journal are so similar that the two fit snugly with each other. The two bodies are in contact at multiple points before any deformation takes place.

In lubricated conformal contacts the applied load is supported over a relatively large area. In a journal bearing the load is carried over the length of the bearing and approximately half of the circumference.

The unit load at any point is relatively low, and the pressure generated during the bearing operation is usually less than 60 Bar. Relative motion is sliding. The film thickness separating the surfaces *ranges from a few microns to under 100 microns, and the COF is about 0.001 to 0.003.*

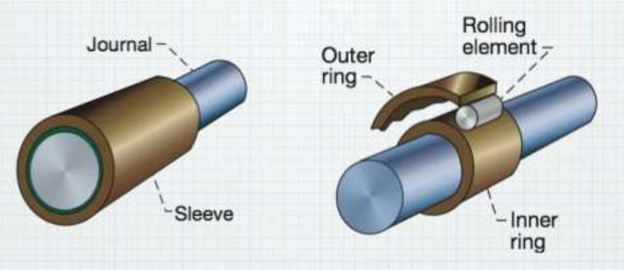

Figure. 1: Conformal and Non-Conformal Contacts (1)

Under normal conditions the bearing is not expected to experience fatigue failure (2).

Non-Conformal Contact

Non-conformal contacts refer to contacting surfaces that do not conform to one another, i.e. the radii of curvature of the two surfaces are very different, forming Hertzian contacts, e.g. ball on raceway of a rolling element bearing. The shapes of the bodies are so dissimilar that under zero load, they only touch at a point (or, in the case of a roller, along a line). In the non-conforming case, the contact area is small compared to the sizes of the objects and the stresses are highly concentrated in this area (6).

The minimum film thickness separating the surfaces is usually less than a micron. The load is supported by an extremely small, lubricated contact area, and hence the unit load in the contact area is very high. The pressure generated in this small contact area can range from 5000 bar to over 50000 bar with a COF between 0.001 to 0.01. Relative motion in such contacts is typically rolling. Fatigue can be a major concern (2).

Hertzian Contact Stress

Contact mechanics theory dates to 1881 when Heinrich Hertz published the paper "On the contact of elastic solids". Hertzian contact stress refers to the extremely high localised stresses that develop as two curved surfaces come in contact and deform slightly under the imposed loads (6).

The amount of deformation is dependent on the modulus of elasticity of the material in contact. It gives the contact stress as a function of the normal contact force, the radii of curvature of both bodies and the modulus of elasticity of both bodies (6). Hertzian contact stress forms the foundation for the mathematical analysis by FEM (finite element method) of load bearing capabilities and fatigue life in bearings, gears, and any other bodies where two surfaces are in hertzian contact.

Elasto-Hydrodynamic Lubrication (EHL)

HL theories and analysis were based on certain assumptions such as conforming, non-parallel & rigid bearing surfaces forming a converging wedge; Newtonian fluids, laminar flow of lubricant with no change in lubricant viscosity within the film; centrifugal forces due to the curvature of the bearing surface are negligibly small; inertial forces play little role, etc.

> *In lubricated conformal contacts the applied load is supported over a relatively large area. In a journal bearing the load is carried over the length of the bearing and approximately half of the circumference*

The limitations of HL theory and analysis were not worrisome to most machinery designers, since the conservative results obtained offset the poor dimensional tolerances to which many mechanical parts were made. However, under extremely heavy loading such as in non-conformal (Hertzian) contacts, e.g. between gear teeth, the divergence between theory and reality could not be ignored (3).

It was apparent that the film thickness predicted by conventional HL theory for non-conformal gear contacts was considerably smaller than the surface roughness and thus could not explain the effective lubrication and operation of gears. In 1949, A.M. Ertel showed the importance of considering elastic deformation in the region of contact. When a load is applied there is some elastic deformation of the surfaces, which increases conformity between the surfaces, and increases the area of contact. The contact pressure is therefore lower, and an escaping fluid must traverse a greater distance than in the case of a purely nonconforming contact, so the fluid film is thicker. Ertel also incorporated the influence of pressure on dramatically increasing the viscosity of oil in his analysis (Refer to Viscosity-Pressure Coefficient **α**, in LM 9: Viscosity). Ertel's equation produced a film thickness that was about 10 times what conventional HL analysis predicted and was widely accepted. This formed the basis of Elasto-hydrodynamic Lubrication (3).

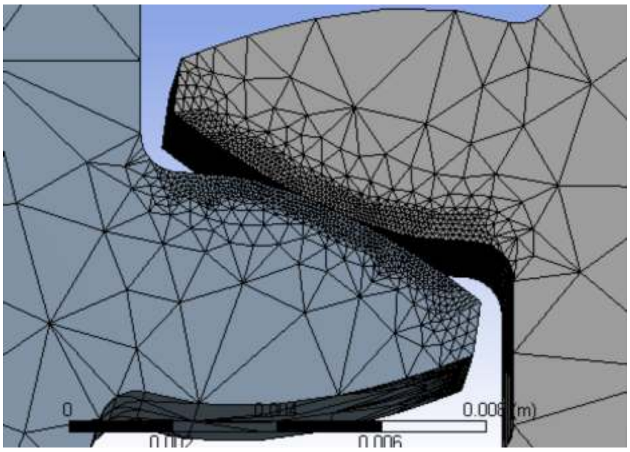

Figure. 2: Stress analysis of a Hertzian Contact by FEM (Finite Element Method) (2)

The thin EHL film is able to separate the surfaces, as, at the instant of supporting the load, the lubricant (whose viscosity has risen considerably) acts as non-compressing film at that point (like a semi-solid), while the bearing surfaces elastically deform and then revert to their original shape after the load moves on. While the oil film is extremely thin (< 1 **μ**), EHL is considered to be a kind of full film lubrication since surface roughness asperities, typically 0.4 **μ** to 0.8 **μ** are accommodated by the film. While friction is reduced and wear prevented, surfaces subject to EHL have a relatively lower fatigue life, but this life is still considerably longer than what would have been the life had the contact been poorly lubricated.

The understanding of EHL dramatically improved machine component design and performance. The thin film of lubricant separating the rolling/sliding

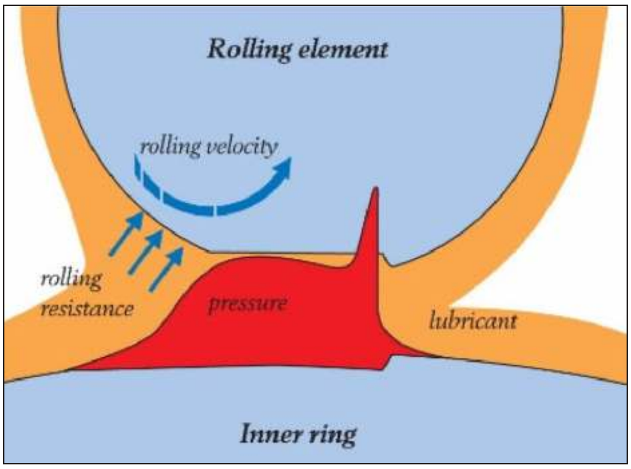

Figure.3: Depiction of EHL in rolling element bearing (4)

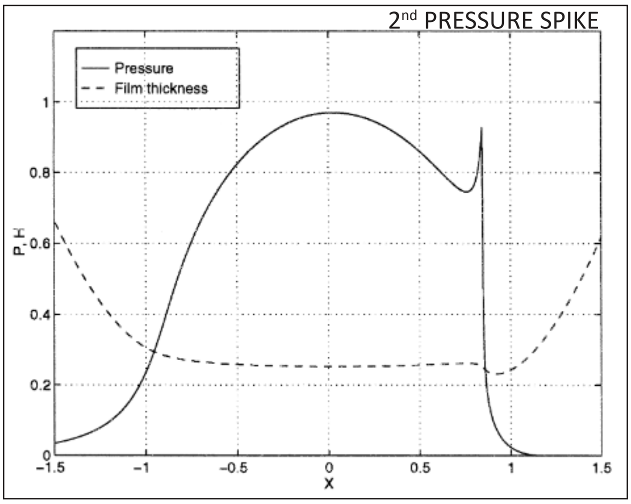

Figure. 4: EHL film pressure and thickness (4)

non-conformal surfaces successfully predicted by the EHL theory provided the explanation for effective lubrication and satisfactory operation of many machine components (e.g. ball and rolling element bearings, gears, cams and followers, etc) (7).

EHL theories and analytical models and supporting experimental results have continued to develop to include: density variation with pressure to account for the compressibility of the lubricant; formulae for minimum and central film thicknesses; thermal effects in EHL ; the effects of non-Newtonian lubricants in EHL; effects of bumps and cracks in EHL contacts, etc. With advances in computational methods, EHL investigators have been able to extend their efforts and develop models for mixed lubrication, from the condition of direct asperity contact in the early (boundary) stages, to the fully lubricated condition (HL) as the interface moves toward the final operating velocity (3).

> *Solid film lubricants are particularly useful where slow sliding movements are involved*

Parallel to the theoretical developments of EHL, there have been significant efforts in experimental investigation of EHL problems as well. Using ultra-thin film interferometry techniques, Glovnea and Spikes measured EHL film thickness down to a few nanometres. In addition, these techniques have been used to study the behaviour of EHL contacts subjected to sudden reduction in speed as happens during the shutdown stages of EHL operation; EHL film pressure and temperature. Their pressure measurements have confirmed the occurrence of the second spike in the EHL pressure profile (see Fig. 4), as predicted by the EHL theories (3).

Equations that combine both elastic and hydrodynamic considerations are known as elastohydrodynamic (EHD) equations. There are many forms of EHD equations, depending on the variations in various geometries and assumptions in analysis for mathematical convenience. They can only be solved accurately by numerical methods (3)

Squeeze Film Lubrication

When a journal stops sliding in the bearing, its velocity becomes zero. HL theory would suggest lubricant film thickness reduces to zero immediately. But there is a slight time delay, of the order of a few milli-seconds, while the fluid gets squeezed out of the contact region.

The squeeze film phenomenon arises when two lubricating surfaces move towards each other in the normal direction, generate a positive pressure, and hence supports a load. This is due to the fact that the viscous lubricant present between the two surfaces cannot be instantaneously squeezed out when the two surfaces move towards each other and this action provides a cushioning effect in between the surfaces. The time required to squeeze out the lubricant depends upon surface configuration, fluid properties and the load applied. Squeeze film lubrication phenomenon is observed in several applications such as gears, bearings, machine tools, rolling elements and bearings (3).

Lubrication by Solids

Using liquids for lubrication have some chemical limitations such as: degradation of a lubricant due to temperature and operating environment; non availability of suitable additives for certain metal combinations, or extreme temperature conditions, etc. They also have physical limitations such as: low volatility & evaporation; and inability to function in environments such as vacuum, radiation, and in space applications.

In such cases, solid lubricants can be used. Solid lubricants are solids applied to contacting surfaces to reduce friction and wear. Solid lubricants have a lamellar structure, with low shear strength bonds between some layers, that slip easily, preventing direct contact between the two surfaces coming in contact even under extreme conditions. Molybdenum Disulphide (MoS_2, or Moly), Graphite, PTFE are commonly used solid lubricants. They may be used in the form of powders, films, composite materials, or added to oils and greases as additives. They can also be added or alloyed into the surface when the component is being manufactured. Their self-lubrication properties provide low-friction coefficients (8).

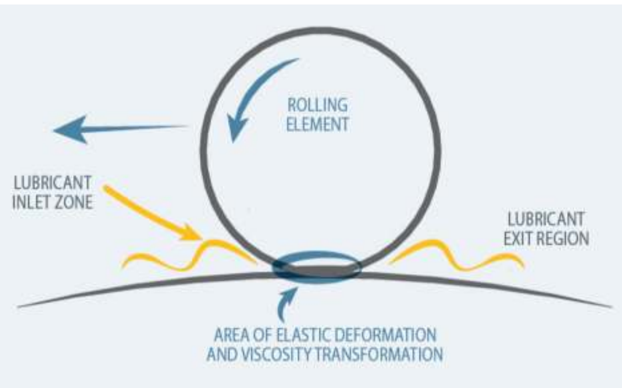

Figure. 5: EHL in rolling Element bearing (7)

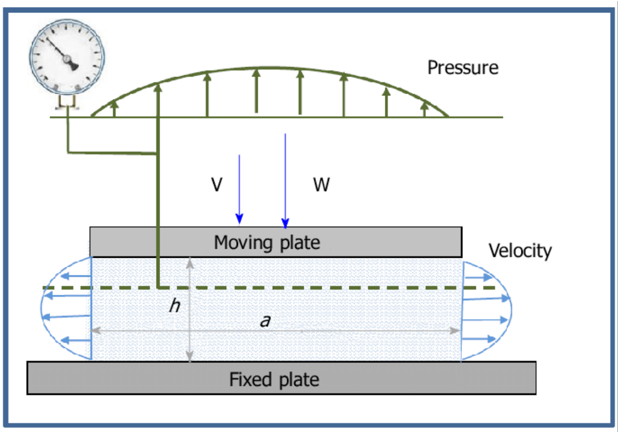

Figure. 6: Development of Squeeze film in sliding contact

Solid Film Lubrication

Select solid lubricants, dispersed in suitable solvents along with binders when are applied to contact surfaces. After drying and curing, a dry lubricant film of a few microns, strongly adhering to the base material is formed. This film acts as a separating and lubricating layer, reducing friction and wear between the contacting surfaces.

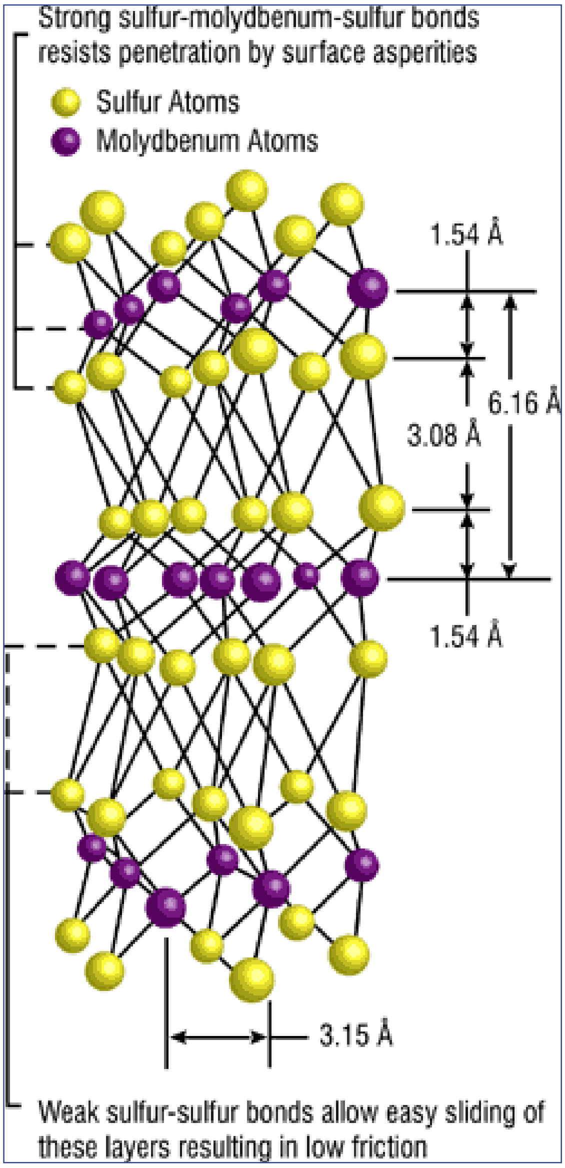

Figure. 7: Structure of MoS2 (8)

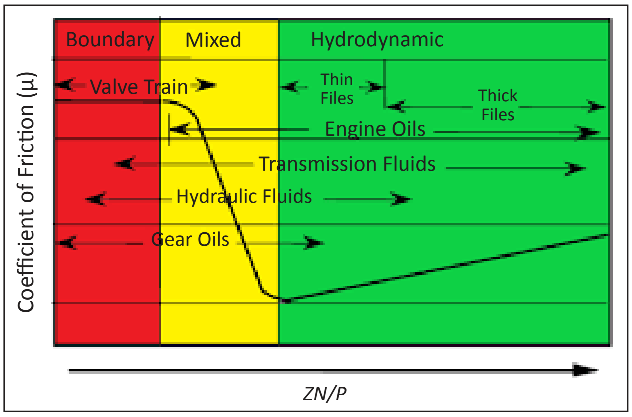

Figure. 8: Stribeck curve indicating COF behaviour in IC engines and systems

A smoothening of the surface of the solid film lubricant initially takes place because of the relative movement of the contact partners. Partial separation of lubricating components from the solid film form so-called transfer film on the counter surface. This build-up of a lubricating film between the sliding surface leads to a reduction of the coefficient of friction.

Solid film lubricants are particularly useful where slow sliding movements are involved. In many cases they can replace fluid lubricants and greases and provide dry, clean lubrication. In addition, solid film lubricants can be used in combination with fluid lubricants (5). In such cases they improve the running-in lubrication during initial operation and ensure separation of the metallic friction partners in solid body contact at very low speeds or during shutdown.

Conclusion

The quest to understand lubrication grew out of early man's efforts to combat friction. From vehicles to machine tools to household appliances to aircraft to ships to engines, to pumps to gearboxes to hip joints, everything that moves, relies on lubrication for efficient and trouble-free long life.

Plotting the COF as a function of the Hersey number gives a unique curve that characterises the lubrication regimes known as boundary, mixed, hydrodynamic and elastohydrodynamic lubrication. These conventional regimes are now bolstered by the understanding of squeeze film effects and new developments in solid film lubrication.

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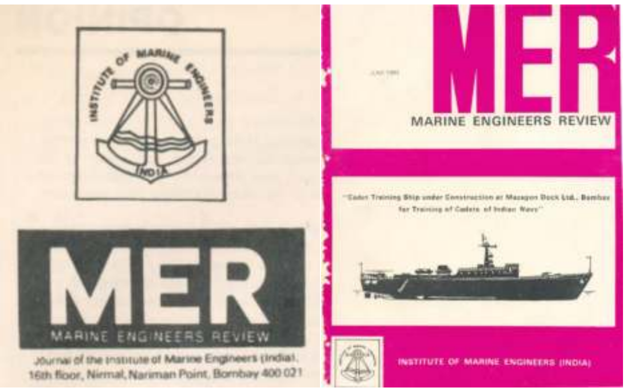
GOING ASTERN INTO MER ARCHIVES



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

This issue has a recurrent topic of Safety filling up much space. The first article on shipboard fires illustrates a 'possible' scenario of an accommodation fire which has validity in current times also.

I will present the case in a cryptic fashion.

Cargo ship; Vessel at full speed; ER unmanned; early morning accommodation fire; crew starts fighting the fire without sounding the alarm (OOW sounds the alarm when he sees smoke from the vents! does not start the fire pumps). 2E goes to ER to stop engines; starts fire pumps, comes up (fear of getting trapped in ER).

Mishap getting to greater proportions: wind from bow fanning the fire; BA inaccessible; 2O manages to get into Safety Centre; Pushes all Emergency buttons to stop vent fans (thereby stops the generators, fire pump etc.) [Action attributed to lack of knowledge]. Crew abandons ship, uses lifeboats/life rafts.

No one knows why the Emergency Fire Pump was not started.

Damages: Loss of lives in double figures; accommodation burnt out;

Lessons learnt extract is inserted. **Anyone has encountered similar situations?**

The next article discusses electrostatic hazards on oil tankers followed by IGS operations. These are followed by a discussion on Halon 1301 as an alternative FF medium.

[This should attract some knowledge sharing from the readers].

We come to a familiar fire areas next... Boiler Uptake fires. I leave it to the readers to reflect.

From safety we move to optimal harvesting of energy... we see another familiar talk on waste heat recovery. The discussions are quite digestible and many of us would have/still working on (better) systems. An interesting observation is the range of exhaust gas temperatures. The ranges might have gotten lesser (or the same) but the arguments will be from the SOx and NOx perspectives, one may say. One extract is inserted for your comparison of SULZER and the B&W engines' range.

Lessons

The vital lessons to be learned from this 'tragedy' are numerous. They include the following:

- The need for a high standard of training in fire prevention.
- The need for all crew members to learn the correct initial response procedures in any type of emergency—in particular, raising the alarm and reporting the details of the emergency.
- When machinery is controlled from the bridge (UMS), the officer of the watch must realise that he has full control of the ship, including the ability to start fire pumps and stop ventilation.
- Firemen's outfits and breathing apparatus should- preferably not be located where they can become isolated by smoke or flames. Alternatively, there should be adequate back-up equipment in other locations.
- Emergency stops should be clearly labelled and officers should know exactly what their function is.

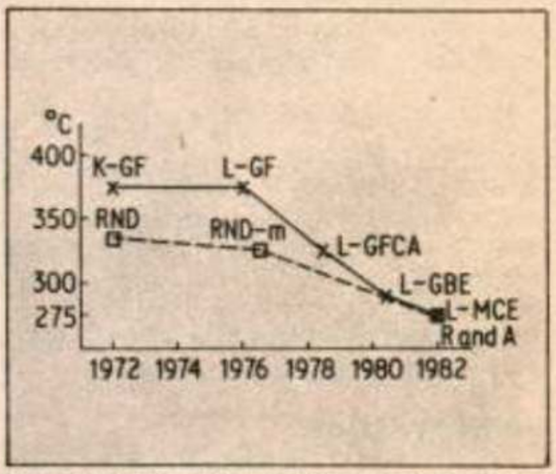


Fig 1: Diesel engine exhaust gas temperature trends.

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We dig out the POSTBAG as usual which has one interesting discussion on thrusters. One news item of significance: STCW coming into force from 28 April 1984.

POSTBAG

Whose success?

Sir,
In the April MER, Mr E F Kirton commented on my book *The Marine Turbine*, throwing some doubt as to the person who should be credited with designing the first successful impulse turbine, the design of which depended on a sound understanding of the steam nozzle. He goes on to state that Sir Charles Parsons, who paid tribute to Gustaf de Laval on several occasions, attributed the correct understanding of the convergent-divergent nozzle to John Perry in 1887.

In 1957, the de Laval Company of Sweden organised a conference to celebrate the 75th anniversary of Gustaf de Laval's first successful tests with his single-wheel high-speed reaction turbine and I was asked to write an introduction on 'Dr de Laval and his early work on the steam turbine'.

To do this I studied de Laval's diaries, early drawings and patent applications; in his diary of 1888 I found a sketch with notes dated 30 June which definitely showed that he had a very clear knowledge of how the overcritical convergent-divergent nozzle worked and how impulse blades should be designed for optimum efficiency. This information is also described in Swedish patent 1902/88, Fig 6.

Tables 1 and 2 in my book give the milestones in the development of steam turbines for land and marine use, and show that in 1884, Parsons with his reaction multi-stage turbine was some years ahead of de Laval. At this time de Laval only had experience with his single-wheel high-speed 100% reaction turbines. He used an improved Hero's Sphere to drive his cream separators but found that the 100% reaction turbine design was at a dead end. In 1890 his prototype small geared impulse turbine was running.

By 1892 both inventors had started serious production of small steam turbines for driving generators and machinery, but the Parsons multi-stage reaction turbine had two major advantages. Firstly, it did not require reduction gearing and, secondly, there were no power restrictions, as with the de Laval geared design.

However, recently I received a copy of an article from the Mechanics Journal No 637, dated 1835, describing the Avery Rotary Steam Engine in the USA which was in use on a railway carriage, printing works, and in saw mills. Avery's turbine was similar to de Laval's 100% reaction turbine and was an improved version of Hero's Sphere. It consisted of a rotating arm with nozzles rotating at 1500 rev/min with a velocity of 190 m/s driving slow-speed machines via a belt drive, which gave some trouble due to its high speed. About 50 machines were built and William Avery deserves a place among the early turbine inventors. Although their efficiency was similar to that of a contemporary steam engine they were unreliable.

Mr Kirton also asked about the advantages of the original de Laval single-wheel reaction design over the reaction turbine Hero of Alexandria, designed in 1 AD, which resembled a garden sprinkler, sprinkling steam instead of water. De Laval used a higher peripheral speed (200 m/s) and realised that the peripheral speed of a rotating nozzle should be high and, if possible, the same as the velocity of the steam leaving the nozzle.

Ingvar Jung

Swe

Thrust = Density x Thrust Area x (exit velocity)²

Power = ½ x density x jet exit area x (jet exit speed)²

C

Sir,
I wr
May
reci
S
reciprocating engined vessel, as Mr Davidson asks. I was, however, apprentice trained during a period when the colleges were full of steam-reciprocating machinery of every description. My training and experience in these areas I have yet to put to practical use!

The basic advantages of this steam engine are its simplicity of construction, maintenance and operation. It is therefore ideally suited to small feeder vessels operating in under-developed countries in the Far East. The steam turbine, with its many advantages, is a precise piece of machinery requiring skilled operation and maintenance.

I agree with Mr Snell that, currently, coal-firing is by mechanical means but this will not always be so. Hopefully the fluidised bed boiler is not far off as a practical sea-going item of equipment. The disposal of ash and clinker is no longer mechanical and I have seen the new pneumatic dense-phase equipment operating, as used on the new generation coal-fired vessels. The transfer of fuel to hoppers can likewise be done pneumatically, although conveyors are in use on some new coal-fired ships.

The high rev/min of the steam engine provides for compactness but not exceptional wear. Within the crankcase all moving parts are pressure lubricated, while within the cylinders the mean piston speeds are 3·5 and 4·2 m/s. These low speeds will ensure that cylinder liner wear is minimal.

D A Taylor

Hong Kong Polytechnic

Thrusters

Sir,
I read with great interest your article on thruster manoeuvring systems in the January issue of MER and wish to take issue with statements made by the author, Mr Aker of Omnithruster Inc.

The diagram Fig 7 in his article is a ... on of the efficiency of various ... ring devices. The comparison ... is inadmissable since, for man- ... and propulsion units, only specific ... absolute thrust can be compared. ... well-known fact that a transverse ... has a high absolute thrust of ... ately 11 kg/hp. This thrust, ... decreasing with higher ship ... still more effective than the thrust of a pump.

The Omnithruster contains a pump and, according to the physical law, a pump can only obtain a maximum thrust calculated as follows:

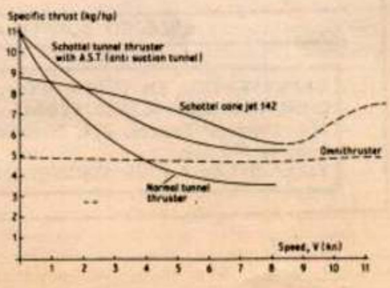
Thrust = density × thrust area × (exit velocity)². The power required by the pump is ½ × density × the jet exit area × (the jet exit speed)³. The exit velocity of the jet, as given by Omnithruster, was 18–21 m/s. The pump efficiency including the suction, the deflection (twist effect) and the discharge losses, must be calculated at an approximate value of 0·7 (this value is generous). Using these values for the above formulae, the maximum thrust of the Omnithruster under the most ideal conditions would be 4·9 kg/hp.

This value, and the obtained values of a Schottel transverse thruster with and without an AST (anti-suction tunnel), as well as the measured thrust values of a Schottel cone jet, have been compiled in the diagram shown. The thrust values of the Schottel cone jet, as well as the Schottel transverse with AST, are always above the Omnithruster values, even assuming a horizontal curve.

It should be mentioned, however, that the use of a transverse thruster is only beneficial for a speed of approximately 4 to 5 knots since, above these speeds, the rudder forces of the vessel are larger than the producible forces of a transverse thruster.

P Jacobs

Schottel of America Inc



Comparison of the specific thrusts of different types of thruster at various speeds (compiled by Schottel).

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

HERITAGE HOURGLASS:

INDIAN SHIPPING - TRAUMATIC THREE CENTURIES UNDER COLONIAL REGIME

THE DEMOLITION AND EFFORTS FOR RESURRECTION (Part 2)

K R A Narasiah

THE DECLINE OF INDIAN SHIPS

The number of Indian ships in 1857 was 34,286, and in 1898, by the designed deeds of the English, the number came down to 2302 and in the beginning of 20th century the number was only 1676. The slow but steady killing of Indian marine started in 1875 with the forming of the first Shipping Conference that helped BISN to monopolise. 1877 B I S N adopted ***deferred rebate system*** to ensure their monopoly.

Between 1860 and 1925, 102 Indian shipping companies went into liquidation by the new system. Sir Alfred Watson editor of the Statesman said, "*Indian Company after Indian Company which endeavoured to develop a coastal service has been financially shattered by the competition of British Interests*".

It was now time to realise the earlier glory of Indian Shipping and a visionary Jamsetji Nusserwanji Tata, fighting all odds, started a shipping company in 1894.It was a period of rise and soon in south V. O. Chidambaram Pillai started Swadeshi Shipping

> *Sir Alfred Watson editor of the Statesman said, "Indian Company after Indian Company which endeavoured to develop a coastal service has been financially shattered by the competition of British Interests"*

Company in 1906 followed by Jyotindranath Tagore, brother of Rabindranath in Bengal who started BSC in 1907. (About V O Chidambaram Pillai, we shall see later in detail).

Due to the cutthroat policy, the British the empire disallowed when Tata wanted P&O to reduce rates for the yarn. So, Tata tried to run his own ships; P&O played underhand tricks and thwarted the attempt. Sir Thomas Sutherland Chairman of P&O said, "We carry raw cotton from Bombay to Japan in order that Japan may cut the throat of Bombay and we carry cotton twist from Bombay to China in order that Bombay may cut the throat of Japan" To fight the competition English tried all unfair methods; first P & O spread a rumour that Tata ships were not seaworthy affecting the Insurance. To win the trade, P & O reduced the rates below that of Tatas and when Tata was compelled to suspend operation, P&O promptly raised the freight higher than Tatas'.

V. Olaganathan Chidambaram Pillai, born on 5 September 1872 was a lawyer and pleaded free of charge for the poor. Among his notable cases, he proved corruption charges on three sub magistrates. V.O.C., inspired by Ramakrishnananda, a disciple of Sri Ramakrishna, resorted to Swadeshi effort. On 12 November 1906, V.O.C. launched Swadeshi Steamship Company, by purchasing two steamships 'S.S. Gaelia' and 'S.S. Lawoe'. He was assisted in this effort by the great freedom fighters, B G Tilak and Aurobindo Ghose. At that point of time, the commerce between Tuticorin and Colombo was a monopoly enjoyed by the BISN.

"The flags of the ships of Swadeshi Shipping Company bore the legend VANDE MATHARAM"

The flags of the ships of Swadeshi Shipping Company bore the legend *VANDE MATHARAM*. This was a red rag to the English Bull and soon a two-pronged offence was launched by the English. One by freight and the second by control of passengers with presents and false promises and soon the Swadeshi Shipping Company collapsed. To make things worse, for a public speech that he made, Chidambaram Pillai was charged with sedition and sent to prison to serve 40 years. Naturally, the company was liquidated in 1911, and the ships auctioned to their competitors. To add insult to injury, the company's first ship, the *S.S. Gallio* was sold to the British Shipping Company.

NOW COME THE UNDAUNTED SCINDIAS

Walchand Hirachand was from a family engaged in trading and money lending. By a strange turn of events, he was accidentally introduced to shipping.

On February, 16, 1919, while travelling from Delhi to Bombay in train he met an English engineer, Watson who told him that a ship "LOYALTY" owned by the Maharaja Scindia of Gwalior was for sale. The Maharaja had purchased this ship during the war from Canadian Pacific Line and converted it into a hospital ship and put it into service for the army at his own cost. When the war ended, he priced the ship at 25 lakhs, with half the amount as down payment for the first bidder. Being a shrewd businessman, as the train reached Bombay VT, Walchand proceeded straight to the dock to see the ship. Though he had no knowledge of ships, he liked the ship and went to see Narottam Morarjee, a leading textile magnate who had the means and as both were visionaries immediately formed a joint venture and bought the ship to run as a passenger cum cargo vessel between India and England.

"The British also ensured that there was no purchaser for the Loyalty. On Feb 23 1923, after just four years of its life, she had to be scrapped. She was sold to the butchers for 1,35,250/- rupees. Though it met with a sad end its name remains etched in the history of the country"

The first sailing of the ship Loyalty was from Bombay to Europe on April 5, 1919 and as National Shipping was reborn on this day, the free India later declared this day as the NATIONAL MARITIME DAY which is celebrated every year from 1964.

The ship left on the 5th April and reached Tilbury Docks in London after a stop in Marseilles in France on 14th May. In London the British wanted to foil this effort of an Indian and so declared through surveyors that the ship had to undergo a survey for 100 A1 class as a passenger ship and ensured that no reputable shipyard would undertake the repairs as it was an Indian ship. This was the beginning of troubles for the ship and the British continued every possible way to stop the ship from sailing; braving the odds the ship could manage only a few sailings and found to be no more economical and had to be laid off.

The British also ensured that there was no purchaser for the Loyalty. On Feb 23 1923, after just four years of its life, she had to be scrapped. She was sold to the butchers for 1,35,250/- rupees. Though it met with a sad end its name remains etched in the history of the country.

However, this gave the first push to the resurrection 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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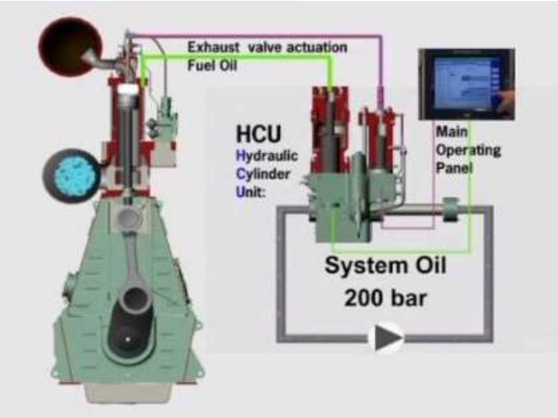

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