MariTTT

MariEMS Train the Trainee (MariTTT) Courses on Energy Efficient Ship Operation

By

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Foreword

This book has been compiled from the summaries of full chapters produced by the partners and contains the chapter summaries as well as a set of quizzes for each chapter. The book also contains a course manual for both a full 60hrs nominal course on ship energy efficiency for Engineering and Deck cadets as well as a shorter 3-day course for updating existing seafarers on aspects relating to ship energy efficiency. Both courses are ECVET compliant and complemented by a book consisting of 14 full learning chapters; the book of full chapters is a printed book and can be purchased from the MariEMS partners' designated organisation(s). The cost of the book and the access to the online course and their learning material, quizzes and assignments are kept to a minimum and considered a necessity for updating the online system and the learning material and assessment elements. The assessment for up-dating the seafarers' knowledge about the energy efficiency is to answer the quizzes however, for cadets, it is necessary that they will have at least two assignments and one End Test. The End Test could take the form of the quizzes but a confidence evaluation of their answers will take place. They will be asked to state if they are 100% confident about their answers, if so, full mark is given; if they are 75% confident then only half mark is allocated; for 50% confidence no mark is allocated and if they are only 25% or have no confidence in their answers then -0.5 or -1 mark is granted for each question. The system described was developed by C4FF and is known as RZ's Confidence Assessment. This additional assessment will make sure that there are no guessing hence make multiple-choice type questions a valid means of knowledge assessment. A sample assignment for Cadets is provided in this Book but the institutions can develop their assignment in line with their course evaluation/accreditation guidelines. The seafarers are also encouraged to apply RZ Confidence Assessment when doing the quizzes.

The reading of all 14 chapters by Cadets, as part of the course, is mandatory but for existing seafarers is complementary. The exiting seafarers can use the content of the full chapters as a point of reference when attempting the quizzes at the end of each chapter summary. Both courses are assigned ECTS and ECVET Credit points and are in the process of being sent for accreditation to a major accrediting body with international recognition and Royal Charter as both a module and a CPD Course. This is very similar to MariFuture's previous courses such as SeaTALK (www.seatalk.pro).

The content of each full chapter is prepared to ensure they are in line or the same as the material produced by IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation with the same title for the trainers as far as possible. This is expected to help the trainers to implement the learning material without any discrepancy when teaching the cadets for existing seafarers. In turn the cadets and existing seafarers when studying any of the two MariEMS courses will be learning the same material as contained in the course for their trainers. In preparing the 14 full chapters initially the 6 Modules of IMO TTT course was transformed into 36 learning chapters and all material taken from the IMO TTT course highlighted so that both the trainers and trainees are aware where the texts are the same or very similar. Some inaccuracies in the IMO course have also been corrected in the learning chapters and in chapter summaries. A copy of all 36 chapters will also be available online and hence accessed by both trainees and trainers.

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Chairman - Centre for Factories of the Future

Contents

Shipboard Energy Manager Training Course

Course value:
Full Course: 7.5 ECTS/ECVET
Short Course: Updating for existing Officers managing energy onboard ships 3.25 CSTS
Course Level: NVQ 4
Duration of the Course:
Full Course: 60 Hrs nominal (40 Hrs of contact and 20 self-learning)
Short Course: Updating for existing Officers managing energy onboard ships: 5 days

Introduction
The purpose of this course is to develop an energy management job and training specification, and the development and implementation of an online leaning and assessment system for the new training programme so that current Cadets, as well as existing seafarers, can up-skill themselves to the new IMO regulatory requirements to fulfil several needs and requirement as outline in the next paragraph. This course manual was developed by C4FF and takes into account their finding from several major projects such as Idealship and IdealPort.

1. the need for qualified personnel to implement regulations and technologies to achieve the best results.
2. the need for Energy Efficiency of shipping companies in order to achieve through cost savings and more efficient use of fuels, etc.
3. the mobility and enhance employability in the global labour market for EU seafarers and cadets who take the qualification either as part of their initial studies or as part of a continuing VET for career development.
4. IMO SEEMP and related requirements of MET providers (METs) for them to offer courses that are relevant and comply with latest regulations and requirements of the industry and address the new skill gaps that are emerging between traditional education and the latest technologies, requirements and practices for maritime energy efficiency.
5. the integration and development of e-Learning and digital skills into the EU MET's so that they can design and deliver e-learning materials as an online learning platform for the maritime officers who can truly benefit from online access to learning and training materials.

Summary of outcomes and assessment Criteria and references to the learning material

The assessment criteria are based on the learning outcome and the learning outcomes are devised in relation to the learning material organised in 14 MariEMS chapters. The chapters are based on Ziarati et al (2017)[1] and IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation (2016)[2]**. T**he learners must complete all the outcomes fully to achieve a **Pass** grade. Assessment is based on demonstrating effective understanding and/or application of performance criteria for each outcome. The following table summarises the Learning Outcomes, references to the Learning Material and the assessment Criteria.

Outcomes	**Learning Material**	**Assessment criteria**
Learning Outcome 1 - Able to argue effectively on current arrangements for combating air pollution.	Chapter 1 - Climate System and Combating Global Warming and Air Pollution	To be able to: a. Demonstrate understanding of climate system & global warming b. Explain the requirements of combating air pollution & the role of International bodies c. Describe different shipping structures, cargo types and characteristics
Learning Outcome 2 - Able to distinguish between the roles of each of the crew members regarding ship energy efficiency operations.	Chapter 2: Ship-Board Operations and Energy Efficiency and references to Crew Responsibilities	To be able to a. Understand the importance of communication between different departments of the ship b. Explain shipboard efficiency measuring processes c. Describe the economic benefits and effects of trim optimisation d. Identify the key elements of a ballast water management plan (BWM) & trim optimisation for energy efficiency
Learning Outcome	Chapter 3 - Trim, Hull and	To be able to

3 - Able to explain the advantages of trim optimisation and how hull and propellers can be conditioned to save fuel.	Propeller Design and Optimisation	a. Demonstrate an understanding of trim optimisation b. Identify the key Propeller design parameter for fuel efficiency or increased speed c.
Learning Outcome 4 - Able to understand how e-navigation and weather routing can lead to fuel saving.	Chapter 4: E-Navigation and Weather Routing	To be able to a. Understand how e-navigation works b. Describe how weather routing is used in passage planning c. Identify key factors in e-navigation and weather routing that can save fuel
Learning Outcome 5 - Able to explain how engines and machinery load management could help a optimise power plant operation.	Chapter 5: Engines and Machinery Load and Utilisation Management	To be able to a. Explain the efficiency of engine and machinery and load utilisation management.
Learning Outcome 6 - Able to manage fuel usage through a range of methods including slow steaming.	Chapter 6: Fuel Management	To be able to a. Demonstrate fuel usage through at least six methods including slow steaming.
Learning Outcome 7 - Able to provide reasoning for technical upgrades and use of retrofits.	Chapter 7: Technical Upgrade and Retrofit	To be able to a. Provide reasoning for technical upgrade and their benefits b. Describe how retrofits help in saving fuel.
Learning Outcome 8 - Able to explain how boiler and	Chapter 8: Boilers and Steam System	To be able to a. Demonstrate the boiler energy

steam systems can be optimised to keep fuel consumption to a minimum.		efficiency measurement system b. Identify key elements in boiler system optimisation
Learning Outcome 9 - Able to identify key elements of an efficient port which is operated to keep pollution from ships and plants and other transport systems to a minimum.	Chapter 9: Port Operations, Air Emissions and Efficiency Measures	To be able to a. Identify the key factors in efficient ports b. Demonstrate port operations and how ports can improve their energy efficiency c. Describe the benefits of integrating ship, port and local transport systems
Learning Outcome 10 - Able to demonstrate that optimising loading and unloading of ships and correct management of the ballast water can help to save fuel and time as well as safety.	Chapter 10: Cargo and Ballast Management	To be able to a. Explain the operation of Ballast system b. Identify the key management of Ballast system that can help to save fuel without comprising safety
Learning Outcome 11 - Able to argue that ship maintenance plays an important role in reducing ship energy requirement.	Chapter 11: Ship Maintenance and Energy Efficiency	To be able to a. Argue that ship maintenance plays in improving ship energy efficiency b. Identifies key maintenance operations that lead to energy saving
Learning Outcome 12 - Able to explain the application of IMO SEEMP including EEDI,	Chapter 12: Energy Efficiency Management and Operational Measures	To be able to a. Explain the IMO SEEMP, EEDI and EEIO and their application in ship energy and emission

EEIO and as well as MARPOL and the significance of monitory systems with regard to IMO/EMSA rules for reducing fuel consumption and reducing emissions form Engines and other power plants.		control b. Identify key propulsion operations that can lead to improve energy efficiency.
Learning Outcome 13 - Able to explain the reasoning behind IMO responses to environmental issues and GHG emissions from shipping	Chapter 13: Environmental Concerns and IMO Response	To be able to a. Explain key environmental concerns and the international response b. Describe the reasoning behind the IMO efforts in reducing emissions of harmful pollutants into atmosphere
Learning Outcome 14 - Able to identify the key factors in ISO 150001 and ISO 19030 and how these standards are helping to initiate, introduce and maintain good practices in shipping.	Chapter 14: International Energy Management Standards	To be able to a. Explain key factors in ISO 150001 and 19030 helped in improving energy management on board vessels and in ports b. Describe aspects of good practices in energy efficiency as result of ISO standards

Assessment Strategy

Evidence may be generated through a variety of assessment methods such as assessments, tests, examinations or face-to-face interview.

Each outcome may be tested separately or integrated successfully to carry out tasks.

The length of time allocated to each outcome and the amount of time suggested for self-study and tests may be adapted by instructors to suit individual groups of trainees, depending on their previous experience, their individual learning needs, their ability to demonstrate their knowledge of technical areas. The value of tests will depend primarily on how they are used to establish test content by carefully sampling from the domain of the test. This should include a set of practical and real world tasks with particular known roles or work skills setting rather than abstract contrast.

The model answer in such cases must be clear to display what is acceptable and what is not acceptable.

The procedure for scoring is critical against which the performance will be judged. It must be clear for each outcome.

A test may be fixed for a period of time or may be a continual process to evaluate the performance of the learner.

Links

This unit is intended to integrate the skills and knowledge developed in many of the other Engineering units. In particular, it will use and develop themes of watch-keeping, emergency response and general communication.

Resources

IMO TTT and MariEMS Learning Chapters and MariEMS online course materials

Suitable classroom facilities. Notes on STCW requirements, Use of recorded messages and video tapes in listening classes.

IMO relevant Publications – Ziarati et al (2017)

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Suggested reading

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Chapter 1 - Climate System and Combating Global Warming and Air Pollution

Summary

Part 1: Air Emission – A Local and Global Concern

After the dawn of the industrial era and the extensive use of fossil fuel in all sort of transportation modes there has been a rapid decline of the environmental welfare; both air and aquatic. The most well-known causes for this decline is of course the CO_2 (carbon dioxide) and CO (carbon monoxide) as far as the air welfare is concerned and the of course the waste that ends up in the water is the major danger to the aquatic welfare.

Amongst the most famous, and well documented over the years, consequences of this increase in the environmental pollution are the greenhouse effect and the hole in the ozone layer.

While there are some natural causes that produce CO_2 and other harmful gases the cause for the majority of their production is the human factor.

Considering how necessary clean air and water is for human health not to mention the increase in the planet's temperature and ocean level, it is of utmost importance that humans do something to mitigate this damage. The negative effects that polluted air and unclean water have on human health are well known to all.

Part 2: Climate System and Global Warming

When we think of the climate we usually mean the weather conditions over a specific region. The difference between the climate and the weather is time; the climate has to do with a long period of time, usually a few months, and the weather with a short period of time, usually a few days if that.

While the climate consists of several factors e.g. atmosphere, hydrosphere, lithosphere etc. this chapter will focus on the atmosphere and the two most important layers of the atmosphere; the troposphere and the stratosphere.

The troposphere is the first major layer in the atmosphere and it is called the Earth's blanket; it reflects infrared radiation and warms the earth; unfortunately it also contains Ozone depleting substances such as man-made pollutants (FluoroCarbons, CFCs, HFCs and other cooling agents, some of them radioactive). Almost all of weather happens within this layer. The troposphere forms the lowest level of the Earth's atmosphere, extending down to the surface of the Earth.

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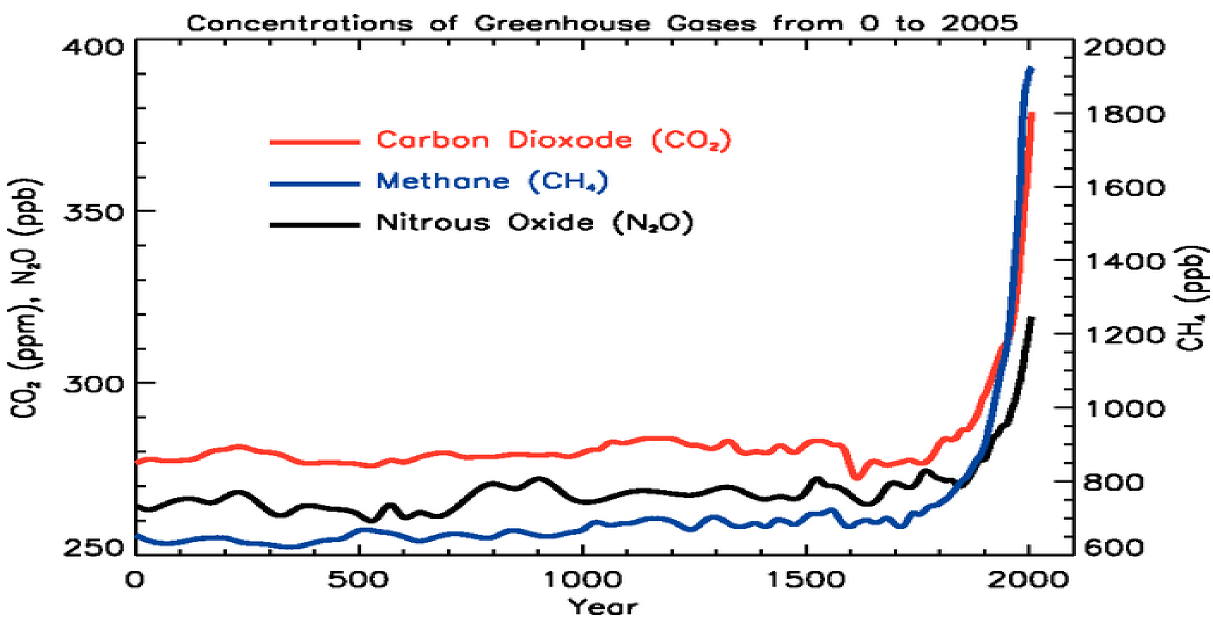
The layer just above the troposphere is the stratosphere. It is the second major layer in the atmosphere after the troposphere. It contains the ozone layer which filters the UV light coming from the sun's radiation; unfortunately the man made pollutants in the troposphere deplete the ozone in the stratosphere and are the main reason for the hole in the ozone layer. No weather happens within this layer.

The Greenhouse Gas (GHG) is a very important part of the stratosphere, because it reflects the energy of the infrared emitted by the earth's surface. What this means is that it keeps earth warm, without it the earth would be too cold for life to be sustained. The presence of the GHG in the stratosphere is not a problem in itself, in fact as mentioned above it is in fact vital.

The problem is in the quantity of it, while there are natural processes that produce GHG without causing any issues after the widespread use of chemicals likes the CFCs and HFCs the quantity of GHG in the atmosphere got larger quite fast. The man-made GHG in addition to the natural ones have resulted in steady increase of the earth's temperature over the years up to now. This is what is known as the Global Warming.

The main gases that are the causes of this phenomenon are the: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Halocarbon (CFCs, HCFCs) and other gases like Ozone (O_3) and water vapours.

In the picture below we can see the increase of the aforementioned gases from the year 0 all the way to the recent year 2005, less than a dozen years ago. It is very obvious that there was an exponential increase in the production of CO_2, CH_4 and N_2O after the mid-1850s.



The main sources of man-made GHG are the following; use of fossil fuel for energy generation, transportation, agriculture and livestock, mining, industrial farming and others.

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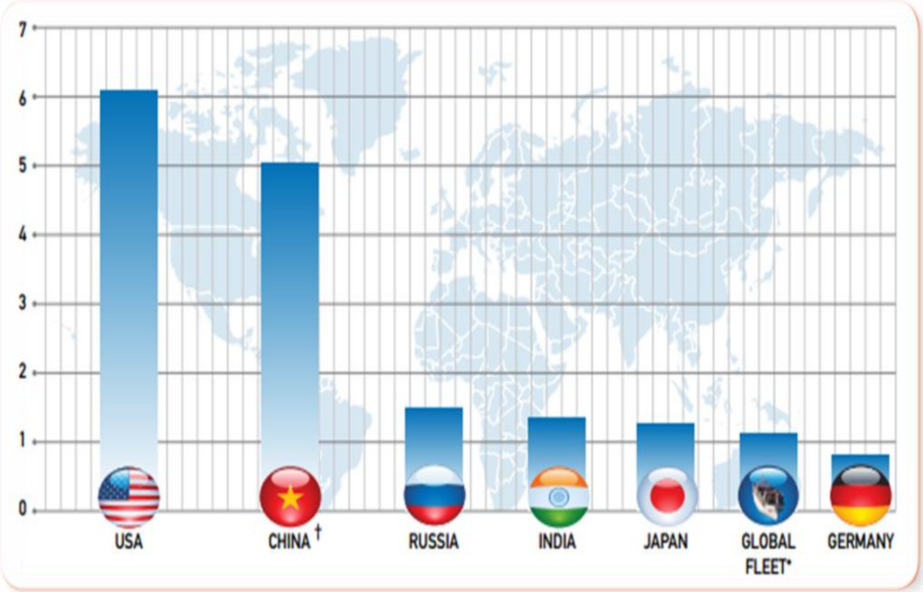
The diagram below clearly depicts that the 2 main polluters on a global scale is the USA and China.



A maybe not as well-known impact of this pollution is the acidification of the oceans. The combination of CO_2 and H_2O (water) produces H_2 CO_3 carbonic acid. The acidification of ocean has resulted in the lowering of the pH of the ocean surface by 0.1 units which may initially not seem a lot but is in fact a 25% increase in the ocean acidity since mid-1700s.

Part 3: Combating Air Pollution: The Role of International Bodies

There have been many incidents over the last century that have brought to the front the danger the environment faces if the human pollution remains unchecked. Just to name a few of those incidents; there was the great smog in the UK and USA in the 50s and the 60s, there was the acid rain in the 70s and of course everyone knows about Chernobyl in the 80s.

There have been many conventions and conferences by the UN in order to draft regulations/laws and then put them into force about the protection of the environment.

The outcome of one of these conferences was the creation of the United Nations Environment Programme (UNEP) whose main purpose is to coordinate and support the countries and developing nations in a unified response against the danger to the environment and also to help them make the current environmental situation a part of their domestic development process. Their priority areas are the climate change, environmental governance, resource efficiency and ecosystem management just to name a few. The mission statement of UNEP as found in their website is:

"To provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations."[1]

In the late 80s the combined efforts of UNEP and the World Meteorological Organisation (WMO) created the Intergovernmental Panel on Climate Change (IPCC). IPCC is an internationally recognised body for the assessment of the science behind climate change and one of its jobs is to provide policymakers with assessments about the climate changes and their impact and also suggests measures/solutions. While the IPCC has 195 members, a plethora of scientists all over the world voluntary take part in the IPCC activities to ensure that the organisation has up-to-date, reliable data with which to make decisions on.

Within a couple of years of its operation the IPCC produced its first assessment report. The assessment reports are only one part of the documents produced by IPCC and they intend to assess all the relevant data gathered (scientific, technical, socio-economic etc.) concerning climate change, its potential effects, and solutions for minimizing the damage already done.

The IPCC's latest assessment report (the fifth) was released in 2014 and it contained four principal sections:

- The Physical Science Basis (Contribution of W/G I (WGI))
- Impacts, Adaptation and Vulnerability (Contribution of W/G II (WGII))
- Mitigation of Climate Change (Contribution of W/G III (WGIII))
- The Synthesis Report (SYR) (Contribution of W/G I, II, and III)

In March 1994 the United Nations Framework Convention on Climate Change (UNFCCC) entered into force. The UNFCCC is a framework convention whose goal is to bolster the cooperation of the nations into making the necessary legal changes to their policy in order to mitigate the damage caused to the environment by human industrial activities.

One of the main objectives is to lessen the production of manmade GHG emissions so that the ecosystem will be able to stabilise itself without any disturbances to the natural order of things. The UNFCCC assigns the countries/nations involved their tasks based on their individual capabilities but with everyone still working towards the same goal; the preservation of the environment.

The leading body of the UNFCCC is the Conference of the Parties (COP) who has annual meetings in order to further promote and support its members into adopting and implementing the new directives and regulations. In 1997 during a COP in Kyoto the Kyoto Protocol was developed.

The Kyoto Protocol is, in essence, an agreement between the signatory countries for the mandatory reduction of the GHG emissions. Even though, the Kyoto Protocol was adopted in 1997, it only went into force in 2005. It is much more strict in the regulation of the GHG emissions that previous similar regulations and in particular on nations and countries with

[1] http://web.unep.org/about/who-we-are/overview

heavy industrial activities. Its first commitment period started in 2008 and ended in 2012 and the participant countries committed into reducing the GHG emissions by 5% on average compared with the levels in the 90s.

In 2012 there was an amendment to the Kyoto Protocol; the Doha Amendment in the Kyoto Protocol, which specifically referenced issues pertaining to the first commitment period and which needed to be updated for the second commitment period 2013 to 2020. The participant countries have committed to further reduce the GHG emissions by 18% at minimum compared with the levels in the 90s.

According to the Kyoto Protocol, the countries' actual emissions have to be monitored and precise records have to be kept of the trades carried out. There are several systems in place to ensure that the monitoring is done. There are registry systems to track and record the transactions, the reporting by the participant countries of the annual emissions data at regular intervals, a compliance system to make sure that the participant countries meet the specified requirements and should they have trouble doing so helping them to find solutions to them.

Another goal of the Kyoto protocol is to help the participant countries prepare and adapt to the effects of the climate change. In 2001 the Adaptation Fund was established to finance projects in developing countries whose goal was that adaptation.

In Durban, another protocol is doing to be developed by the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) which was established for this very reason. The ADP is to complete its work the soonest possible, but no later than 2015, in order to adopt this protocol at the 21st session of COP and then be implemented in 2020.

As far as the aerial and sea transportation is concerned the Kyoto Protocol has given the responsibility to the relevant specialized agencies; the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

Quizzes

True or False

- The stratosphere is the earth's blanket.
- The GHG is a product of human activity and not found in nature.
- UNEP's main purpose is to help the coordination between countries in order to be a unified response to the climate changes.
- The Kyoto Protocol is responsible for the reduction of the emissions for all kind of transportation.

Multiple Choice

1. What is the major cause for the CO_2 production?
   a. Natural causes
   b. Human activity
   c. Natural causes and human activity
   d. Sun radiation
2. What is the troposphere not consisted of?
   a. The Ozone layer
   b. Cooling agents
   c. FluoroCarbons
   d. All of the above
3. When approximately did the production of CO_2, N_2O and CH_2 started to increase exponentially?
   a. The1960s
   b. The 1970s
   c. The 1980s
   d. The 1990s
4. What country is the main polluter on a global scale?
   a. China
   b. Russia
   c. USA
   d. Germany

Fill in the Blanks

1. Without the …………… the earth would be too cold for life to be sustained.
2. A not well known impact of this pollution is the …………….of the oceans.
3. The combined efforts of UNEP and the ………………. created ………………….
4. The Doha Amendment in the Kyoto Protocol, states that in the second commitment period the participant countries have committed to further reduce the GHG emissions by …………. at minimum compared with the levels in the 90s.

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Chapter 2 - Ship-Board Operations and Energy Efficiency and references to Crew Responsibilities

Summary

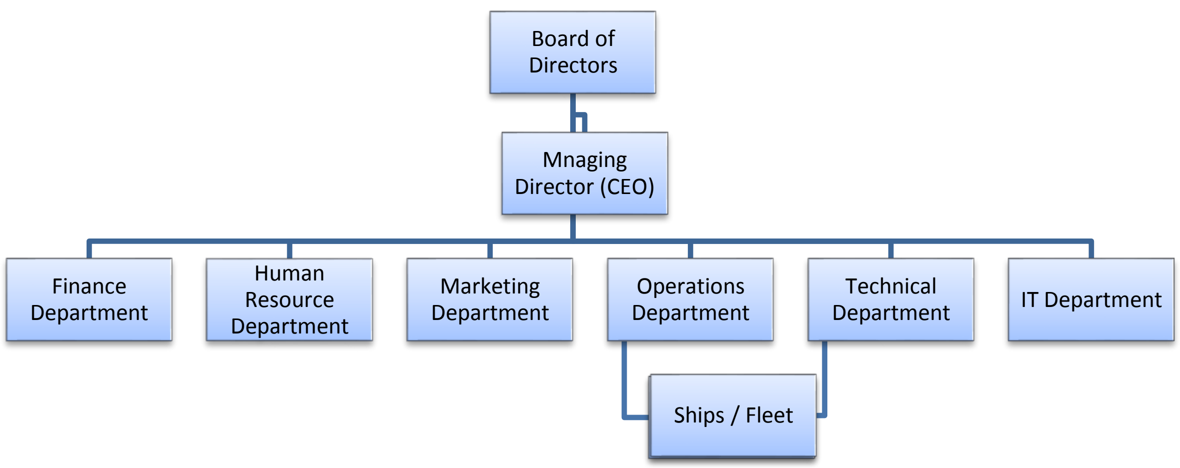
Part 1: Shipping Operations Overview

The purpose of this part is to enlighten the reader about fleet management issues and the best ways to implement best practices for a sustainable fleet with a view to environmental protection and cost reduction.

A sustainable comprehensive fleet management policy must include;

- A policy to reduce risks and costs, e.g. accidents
- A policy for the protection of the environment
- A policy for the efficient planning of trips
- A policy to increase competitiveness

A shipping company's internal structure can be seen in the diagram below;



Ships come in a variety of types and sizes. Some ship types are the following; tankers, bulk carriers, container ships, refrigerated vessels, Roll-on–Roll-off (Ro–Ro) vessels, ferries, passenger ships, fishing vessels, service/supply vessels, barges, research ships, dredgers, naval vessels, sometimes a combination vessels and other special purpose vessels. The types of ships are usually even further categorized in sub-types depending on the size of the

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ship. To measure the size of a ship we have to take into consideration its weight carrying capacity and its volume carrying capacity.

There is a large variety to the cargo carried by ships like the ships themselves. The cargo of a ship can be consumer goods, unprocessed and processed food, livestock, industrial equipment and even raw materials. All these different cargos come with a variety of packaging all to make the cargo handling more efficient.

Ships operate between ports. Ports are used for resupplying and for discharging waste. Ports impose physical limitations on the size of the ships and charge fees for their services. Port operations involve a lot of people, both at management level and at operational level. The port is a physical entity and is managed by a port authority. In addition, depending on the size of the port, any number of businesses may be found inside.

Issues of governance, control and ownership are very important to any discussion of environmental management in ports. The majority of ports are characterized by privately owned dock facilities and in these instances, control of property and operations lie with each private property owner. One of the main issues that ports are facing is local air quality. This is caused due to air pollutants; in particular the CO_2 emissions. In ports, air emissions and energy consumptions are primarily due to ships. Around 85% of emissions come from containerships and tankers but despite that the most contaminants ships in ports are the cruise ships. Containerships have short port stays, but high emissions during these stays. However, there are other facilities that contribute to air emissions and energy consumption in ports.

Future forecasts indicate that most of shipping emissions in ports are estimated to grow fourfold up to 2050, with Asia and Africa seeing the sharpest increases in emissions, due to strong port traffic growth and limited mitigation measures. Despite the fact that a lot of ports have developed regulations to reduce shipping emissions, they would need wider application in order to be truly successful.

While shipping can be categorized in many segments, like by ship types, another two are the segment by geography of operation and segment by operation.

Segment by geography of operation basically means that ships are categorized by where they are able to travel; deep-sea, short-sea, coastal and inland waterways. Most often larger size vessels are employed in deep-sea trades between continents whereas smaller size vessels usually operate in short-sea and coastal routes.

Segment by operation is referring to the modes of operation of commercial ships; Liner operations, tramp operations and Industrial operations. Liner operators usually control container and general cargo vessels. Tramp operators usually control part of tankers and dry bulk carriers segments. Both liner and tramp operators try to maximize their profits per time unit. Industrial operators usually own the cargoes shipped and control the vessels used to ship them either as owner or as a charterer. They aim to minimize the cost of shipping for their cargo transport but generally operate within a wider company business framework, thus their approach to ship management is probably different from those of the liner or tramp operators.

Because ships are operating under a lot of varied operational conditions, the ship/fleet planning is a particularly difficult. There are several different areas of planning included in the ship/fleet planning. There is business planning, choice of the ship size, fleet size and mix, commercial planning, routine (operation) planning, speed selection and cruising speed and voyage management. All of these categories need to be taken into account when planning the ship/fleet, which can make it particularly challenging.

Ship Maintenance is usually conducted annually but some maintenance is needed between the planned maintenance periods. This includes both routine/preventive maintenance and repair of breakdowns, sometimes only temporarily until the ship reaches the closest port. In order to facilitate the ship's maintenance, a ship usually carries some spare parts on board.

The management and operations of a ship's maintenance is of utmost importance to ensure energy efficient operation of its equipment. Because of normal wear and tear there is damage to ship and its systems and that can cause equipment downtime, energy loss etc, which in turn is the reason for extra operating costs. Therefore good and regular ship maintenance is essential for energy efficiency.

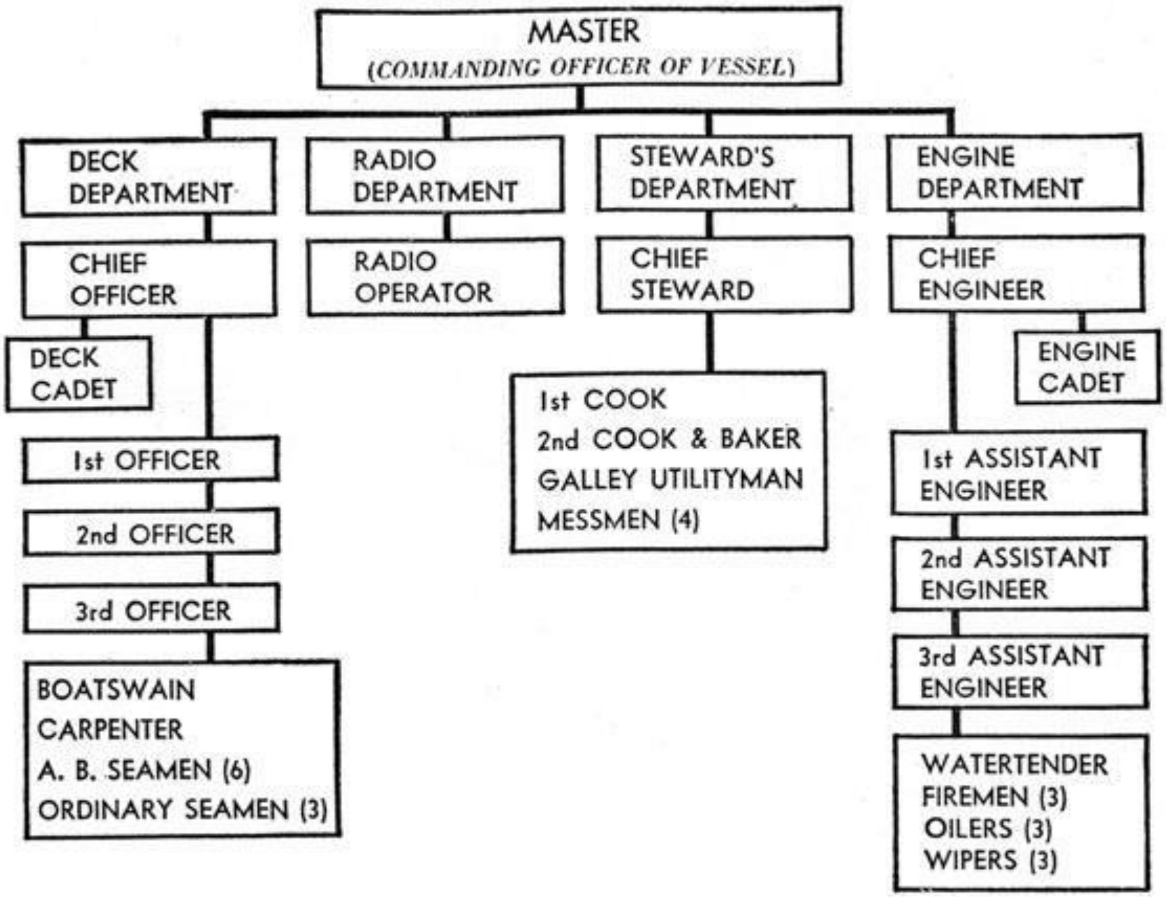
The maintenance is arranged based on the makers prescribed maintenance frequency for the ship model. An electronic database is kept both on board and in the shore office synchronised to upkeep all the maintenance info.

A ship usually consumes hundreds of tons of bunker fuel per day at sea and there may be significant differences in the cost of bunker fuel among the different bunkering ports. Occasionally it may be cost effective to divert the ship to enter a port just for loading bunker fuel. The additional cost of the ship's time has to be traded off with the savings in the cost of the fuel.

The procurement of bunker fuel involves both operational and technical considerations. Due to the increasing fuel price shipping businesses normally use Heavy Fuel Oil (HFO) that is of lowest quality and therefore cheapest in price and could be of poor quality if care is not exercised during procurement and use. The control of the quality and the quantity of the purchased fuels and also their treatment can provide significant benefits for preventing damage to the machinery but also in terms of energy efficiency.

Part 2: Introduction to Shipboard Roles and Responsibilities

A ship is like a business in that it has an organisational hierarchy among the crew members in order to have the daily operations of a ship run smoothly. That hierarchy is depicted in an organogram as seen in the figure below.



NB: This figure is the original diagram taken from IMO train the trainer Course representing a typical Shipboard Organogram with three main departments. The Radio Department is obsolete as a result of the implementation of the revised GMDSS to the Deck Officer's certification.

The Master of the ship, or as he is more commonly known the Captain, is the absolute authority of the ship acting on behalf of the owner and he is legally responsible for the daily management of the ship. Each department has a designated head who reports to the Captain. The Captain, as the highest ranking officer on-board, has important input in all ship operations. Without the Captain's cooperation and motivation, successful energy management is unlikely to be implemented on-board ships. The Captain has the authority to reroute the vessel at more convenient and cost saving way as well as he has the decision making capacity to reduce the vessel speed to complete a voyage at much lower fuel consumption but without making significant delays.

The Chief Officer is the head of the deck department and he is second-in-command after the ship's Captain. His main responsibilities are the vessel's cargo operations, its stability and supervising the deck crew and also the safety and security of the ship, as well as the welfare of the crew on board. Since the Chief Officer is the Captain's second in command he could also have significant input in the energy management of the ship.

The Chief Engineer is the head of the engine department. He is responsible for all operations and maintenance of all engineering equipment in the ship. He reports directly to the Captain on all issues related to his department. He is the person who determines the best way to get optimum energy output out of the ship's engines while using the least fuel and therefore reduce emissions. He is vital for the successful implementation of any energy management policy.

The Chief Steward is the head of the catering department. He directs and assigns personnel that prepare meals, clean and maintain the officers' quarter, and manage the stores. He also does other activities such as overtime and cost control records, and may requisition or purchase stores and equipment.

All crew members have responsibilities so that they can contribute on ship energy efficiency. Their responsibilities are different as they are tied to their ranking in the ship hierarchy.

One very common reason that causes waste of energy is miscommunication between the departments of the ship. This is why in most energy efficiency policies proper communication between departments and its improvement is considered vital. However, miscommunication is only a small part in the measures needed to have energy efficiency in a vessels operation and since those measures are not entirely controlled by the ship's staff they are still under consideration. It is obvious that in order for the energy efficiency measures to be successful, they need to be in some way controlled by the on-board staff.

Part 3: Ship-Board Energy Efficiency Measures

In order to achieve optimised ship handling 3 things need to be considered. The trim, the ballast, the use of rudder and autopilot. Optimised ship handling can help the ship be more energy efficient. The optimization of the propulsion condition is also something that needs to be taken into consideration when trying to make a ship more energy efficient. What affects the propulsion of a ship is the hull, the propeller and also the main engine. Specifically the hull needs to be maintained because of the fouling, the propeller needs to be cleaned and polished and most importantly the main engine needs to be maintained according to the manufacturers' instructions.

Another thing that needs to be taken into account when it comes to energy efficiency in ships is the steam system, as depending on the ship type it can play a medium to a major role.

The figure below from IMO 3rd GHG Study 2014 depicts the level of energy use in marine boilers for the whole of international fleet.

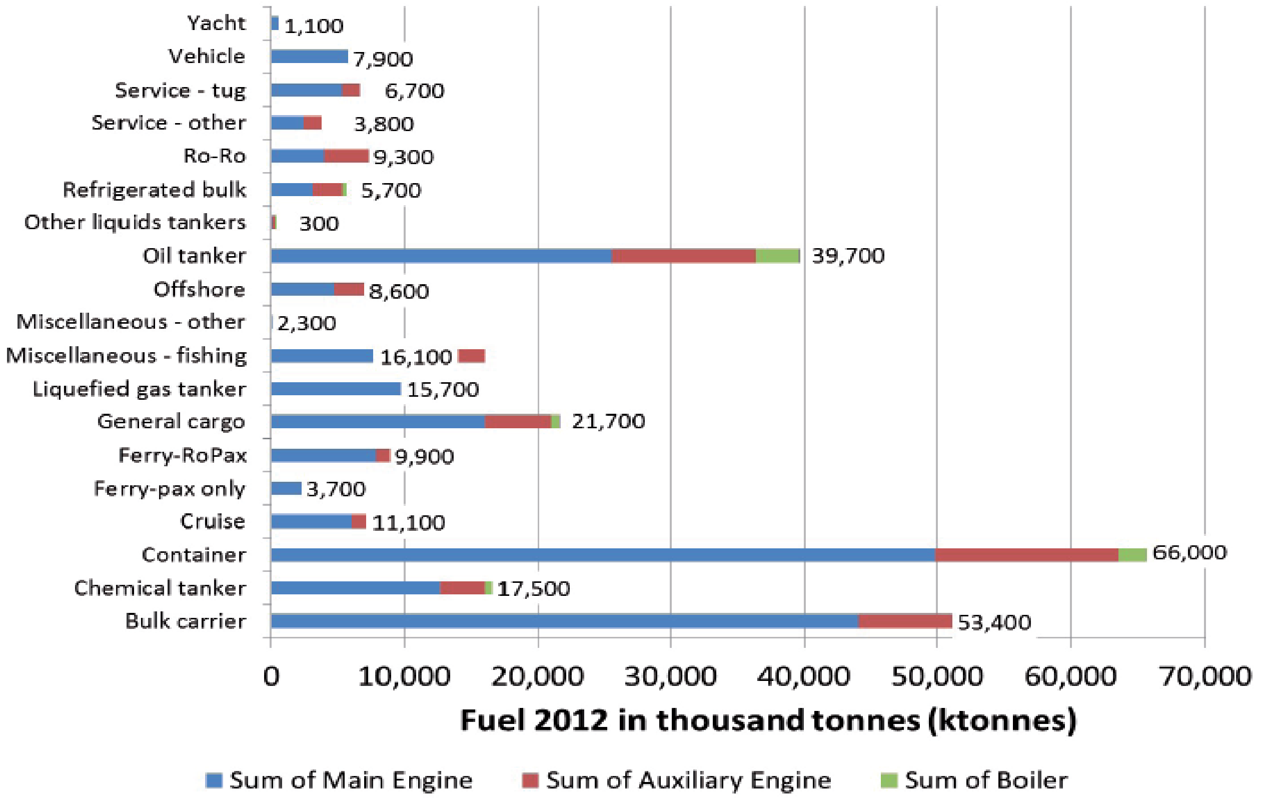


Figure - Annual shipping fuel consumption per ship type and combustion system [Third IMO GHG Study 2014]

In most cases the steam system of a ship includes the auxiliary boilers and the exhaust gas economisers. As far as efficient energy management is concerned we also have to include the steam distribution system and the steam end-use.

Several things need to be taken into consideration in order for the boiler to be kept at maximum efficiency. First of all, the fouling or scaling of the boiler tubes can cause a significant reduction in the rate of the heat transfer, therefore careful monitoring of the heat transfer areas of the boiler is essential in order to prevent or repair any fouling. Secondly, the hot well temperature needs to be monitored and kept at the level specified by the manufacturer, to avoid unnecessary energy loss and carefully done blow-downs of the boiler need to be conducted to avoid the concentration of impurities in the water. Thirdly, excessive combustion air in a boiler can cause a waste of energy, so the engineers need to monitor the O_2 and CO_2 levels in the boiler exhaust gas. The boiler's load factor is also something that can interfere with the boiler's energy efficiency.

Furthermore, the temperature and also the cleanliness of the exhaust gas economiser is something to keep in mind when trying to achieve energy efficiency in ships. A regularly scheduled maintenance program for the ship's steam distribution system is also something that every ship needs to have in place in order to have a successful energy efficiency strategy and also some steam end-use efficiency measures so that the need for extra generations of steam would lessen.

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Moreover, the cargo’s temperature is also something important that needs to be considered as different cargo have different temperature requirements and may require continuous heating/cooling during transport. There is also the connection between the cargo discharge and the ballast water operation that needs to be included in any energy efficiency plan as ships that need large ballast pumps need more boilers in order to be able to operate smoothly. Something that must not be forgotten is the inert gas generation which is important for safety and saving energy.

To conclude there are several things that need to be carefully monitored and maintained in order to operate the boiler at maximum efficiency with minimum cost. All of are important to any good energy efficiency policy that a ship/company need to have in place.

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Quizzes

True or False

- The Chief Engineer is the second-in-command after the Captain.
- The trim of the ship is important when it comes to optimised ship handling.
- Around 85% of emissions come from containerships and tankers; however the most contaminants ships in ports are the cruise ships.
- Miscommunication between the departments of the ship is very uncommon.

Multiple Choice

1. What needs to be considered for optimised ship handling?
   a. The ship's trim
   b. The ballast
   c. The use if rudder and autopilot
   d. All of the above
2. What type of ship uses their boiler the most?
   a. An oil tanker
   b. A container ship
   c. A bulk carrier
   d. A cruise ship
3. Who is the second-in-command after the Captain?
   a. The Chief Officer
   b. The Chief Steward
   c. The Chief Engineer
   d. None of the above
4. What do we take into consideration to measure the size of a ship?
   a. The type of the ship
   b. The height of the ship
   c. The weight of the ship
   d. None of the above

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Fill in the Blanks

1. While shipping can be categorized in many segments, like by ship types, another two are the segment by ………………….. and segment by ………………
2. The ……………..and also the ……………… of the exhaust gas economiser is something to keep in mind when trying to achieve energy efficiency in ships.
3. The maintenance is arranged based on the ………………prescribed maintenance frequency for the ship model.
4. The port is a physical entity and is managed by a ………………

Chapter 3 -Trim optimisation, Hull and propeller condition

Summary

Mariners are used to know the best possible trim for their vessel using her sea worthiness as the main and only criteria. Often the best trim is one feet astern.

Shallow fairways may set as well criteria for her trim. Even keel loading in the port is quite common especially with the small ships operating from small harbours. Today more important criteria is energy efficiency and if these two criteria result to the same time trim it is excellent result.

Trim is normally defined as the difference between the aft draft and the forward draft. When the trim is positive, it means that the stern is more inside the water than the forward. Accordingly, positive trim means trim to aft and negative values of trim means trim to forward. Optimum trim is trim where required propulsive power is minimal. Optimum trim is achieved via the proper planning and ship ballasting plan. when the ship is fully loaded, transferring ballast water and extent fuel from tank to other can be used to achieve the optimum trim. A ship's resistances and trim are closely related to each other. Trim affects to hulls wetted surface area and therefore increases or decreases forces that is slowing the ship.

The possible explanations for the relatively large dependencies of ship performance on the trim could be attributed to the following impacts of trim.

- Changes to wave resistance
- Changes to wetted surfaces and thereby the frictional resistance.
- Changes to form resistance due to transom submergence
- Changes to various propulsion coefficients including:
- Resistance coefficients
- Thrust deduction
- Wake fraction
- Changes to propulsive efficiencies including:
- Relative rotative efficiency.
- Propeller efficiency

Using optimum trim, it can have 2% to 4% reduction on fuel consumption. However, this reduction can be higher or lower depending on the vessels type and operation draft. And when there are ways to save environment and money all possible measures should be taken care of. When trim changes, wetted surface of the hull and therefore hull resistance will be

affected. Therefore even 5 to 10 centimetres difference on trim can cause higher fuel consumption. However, it is difficult to measure the exact fuel saving levels due to trim while vessel is underway because of all variables are never exactly the same. (Speed, draft, weather and sea impacts).

There are different methods of determining the vessels optimum trim. The best results are obtained from self-propulsion tests using a scale model. In this method, not only the changes in hull resistance are investigated and the choice of propeller is examined but also the propulsion coefficients are normally measured. when these tests are made with different draft and speed the optimum trim, for different operating conditions, can be found.

Nowadays the accuracy has improved so much that, trim tables based on use of Computational Fluid Dynamics (CFD) software tool calculations can be comparable to the results from resistance model test. However, both resistance test and CFD methods tend to ignore the impact of the propeller: this may have significant impact on evaluations of vessel with light drafts. Normally when Trim is being calculated the test are made at both forward and aft trims. Often forward trim is not even possible for the lighter drafts due to restriction in the propeller's submergence.

The recent studies show that, currently on great majority of cases, even keel (zero trim) is normal practice. This can be the optimum trim for large and slowly moving vessels, like bulkers and tankers. However, Vessels like container ships and RoRo car carriers, with slimmer body and higher operating speed are more sensitive to trim and for that reason more care should be taken to optimise the trim.

Because of the recent energy efficiency regulation, more shipping companies have chosen to do trim optimisation calculations using the CFD software. The issue, however, is that all the calculations are based on analytical forecast. These calculations combined with feedback from the master on their judgement on trim tables and its impact on ship powering requirements, can give relatively accurate trim tables.

There are few problems that might affect to the trim optimisation. When loading the vessel, the weight distribution should be determined to allow trim optimisation. Therefore, there need to be good communication between ship and port. Also, transferring bunker and water on-board changes the vessels trim. This highlight the need of communication between deck department and engine department. Crew changeover is also one thing can cause problems with trim optimisation, if there is lack of communication between the crews. The above barriers are possible to remove by understanding the subject and training of shipboard crew, but it also needs crew's dedication on the best practice.

When talking about energy efficiency on ships, the trim isn't the only factor that affects to ship's propulsion fuel consumption. One almost as big thing to keep on mind is hull and propeller cleaning and maintaining.

As stated earlier, the vessels resistances due wetted surface areas are composed of frictional and wave making resistances. Frictional resistance is the main component that slows down the vessel. The frictional resistance is caused by the water flow along the hull.

For that reason, the hull should be as smooth as possible so the water could flow fast and smoothly. each 10μm to 30μm additional roughness causes the total hull resistance to increase by 1%, and as discussed earlier increasing resistance increase fuel consumption as well. Normally new ship is delivered with hull roughness of 75μm and later when ship comes to dry-dock the hull roughness can be 250μm. even with good maintenance, the hull roughness can increase 10 to 25μm per year, depending on the hull coating system.

Hull surface roughness can be divided to two categories, physical and biological. These two categories are normally divided to two subcategories micro roughness (less than 1mm) and macro roughness (more than 1mm). The physical micro-roughness is normally human made mistakes or mechanical failures like, mechanical damage, failure of the applied coating and even improper preparation of the surface and/or improper application of a new coating. Biological roughness (fouling) comes when some organic growth sticks on the hull of the vessel (slime, algae, barnacle etc.). Even micro level biological

roughness has significant impact on resistance. Light slim covering the entire wetted surface can increase total resistance by 7 to 9 percent. Heavy slime increases resistance by 15 to 18 percent, and small barnacles and weed can push up to 20 to 30 percent increase in total resistance.

Biological fouling depends on many things such as:

- Initial roughness of the hull
- Quality of hull coating
- Robustness of the coating with respect to mechanical damage
- The areas of the hull where there is sunlight, along the sides of the hull and near the waterline.
- Temperature of water (colder water generally means less fouling)
- The salinity of the water (performance coating will be a function of salinity of water)
- Amount of algae in the water
- Ship speed and its operation profile (hull moving, speed, at berth, at anchor, layby, etc. or static)
- Hull maintenance

Surface roughness can increase during the operation due to damage on the coating as well as due to corrosion, all physical roughness on hull surface also attract marine growth. using antifouling paints is possible to reduce the growth of slime and other species. Antifouling paints last for 3-5 years, but its performance is reduced gradually over time. Therefore, hull need to be cleaned time to time even when using antifouling paints, Cleaning can be done by divers or automatically. Keeping coating in good condition reduce energy consumption. Cleaning the coating costs but saving from the decreased fuel consumption and extended time to need of renewing the coating outweighs those costs. The renewing of the coating need to be done in dry-dock and that is very expensive.

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Minimising hull roughness can be done by using smoother surface finish, more appropriate paint, more appropriate maintenance of the hull and propeller, also avoiding excessive anchoring and port time reduce fouling. Care should also be taken to make sure cleaning technologies used are appropriate to the coating, using wrong cleaning methods can damage the coating and every excessive roughness on the surface of coating make it easier to organic species to hold on the surface and therefore fouling increases faster.

Currently there are three different coating types in common usage and all of them have different resistance to fouling, different impact on hull roughness and have different cleaning intervals. These methods are:

· Controlled Depletion Polymer (CDP)

o Typical life before recoating is 3 years, but green slime or weeds can become a problem in less than two years. The average hull roughness increase is estimated at about 40 µm per year in surface profile, but this can vary greatly.

· Self-Polishing Copolymer (SPC)

o Five years of service for high quality systems can be achieved. Average hull roughness increase is estimated at about 20 µm per year.

· Foul-release Coating

o For slower vessels (less than 15 knots) this is a challenge for even the best coatings so some ‘soft’ cleaning is usually required to remove the micro fouling. If the vessel is stationary for some time, barnacles and other macro-size biota can become attached. The coating gains some of its effectiveness from its extremely smooth surface and this must be maintained for best performance. Roughness in a foul-release coating will reduce its ability to discourage adhesion and slime/ micro fouling can take hold. Mechanical damage from example from tugs is especially critical for these types of coatings requiring special care in operations as the damaged parts has no fouling protection. Average hull roughness increase is estimated at 5 μm per year.

When choosing hull coating things that needs to be observed:

1. Cost: The more effective the coating is the more expensive it is
2. Speed of vessel: Ships using higher operating speeds need harder coating
3. Operating environment: Is the ship going to operate in salt-water or fresh-water area.
4. Compatibility: Some coatings cannot be used on top of other due to chemical interactions
5. National regulations: Some of the coatings are banned in certain countries
6. Area of operation: Severity of fouling in area vessel is trading, some sea areas are much worse than others.

When searching for the best hull coating, best opinions are coatings that provides smooth surface and can be reasonably, maintained in its smooth state, that prevents the fouling organism. high- quality coatings can save up to 4% in propulsion fuel consumption. Cleaning the hull and changing the hull coating to better working coating can save 10- 12 percent on fuel consumption. However, removing the roughness and application prime, anti-corrosive and advanced antifouling painting can cost about US $10/m², and on VLCC that makes about $300,000. since the banning of TBT(Tributyltin), most antifouling coatings are self-polishing copper and tin based paints, but many countries have banned or planning to ban copper based products in certain areas. The ''foul-release'' coatings have so smooth surface that it is difficult to most organic growth to hold. new studies show that it is equally as effective as TBT-based products, but because of its relatively high price and its smooth surface is not lasting as long in higher operating speeds it is not in vide use. if ship is getting fouled up faster with one product, it is worth considering the change to another product. If fouling is getting very big problem, talking to other ship owners in the same area and asking what product works for them, as they can give unbiased advice which one may not get from an original vendor.

Cleaning the coating is always clearly beneficial if it is done correctly and without harming the coating and therefore made the surface rougher. The savings on fuel consumption overweight the costs of hull cleaning so it is always recommended. When cleaning is done on regular intervals it is also often cost effective. The need of hull cleaning can be determined from performance indicators (like power versus speed) or with regular pre-cleaning inspections. Cleaning should be taken care of when the fouling is on micro level because removing macro level fouling is difficult without harming the original coating. Cleaning light slime can reduce fuel consumption 7-9 percent, heavy slime 15-18 percent and macro

heavy fouling 20-30 percent. Cleaning the hull cost about US $1,5 to $2,5/m² in the far east. This could convert ton US $50,000 for a full hull cleaning for VLCC.

It should be kept in mind that if ship is operating at fresh water or brackish water the fouling is increased, also operating in warm water increases fouling. if vessel is operating at fresh water for some time it should be considered to extend the cleaning intervals or changing to anti fouling paint specially designed for those areas.

Like the hull roughness, Propellers suffer also decreased performance due to surface roughness. The absolute reduction in ship energy efficiency due to propeller roughness is less than those seen on hull roughness, but propeller roughness can increase propulsion fuel consumption up to 6 percent. Propellers suffer physical surface roughness created by corrosion, cavitation erosion and impingement attack. These damages can be cleaned and polished which will reduce the propellers frictional and rotational losses.

In the last 15 years, there have created new coatings to the propellers that can have even better surface properties than the polished propeller surface. Coatings can be damaged by cavitation erosion, but the force that caused the damage also prevents fouling so that damage doesn't affect performance in any significant way. The propeller coating also gives protection against roughness caused by corrosion and fouling. Most damages to the propeller is caused by cavitation pitting which is caused by poor cathodic protection or by allowing the propeller to operate too close to the surface.

Fouling is not problem on propellers that are constantly moving, therefore vessels that are anchored or in harbour for extended periods should rotate their propellers for short period once a day to prevent fouling on the propellers. in a long run the fuel saving that have gained by preventing the fouling by rotating propeller outweighs the fuel consumption that is used to do so. Polishing roughened propeller can decrease fuel consumption by 3 percent, Cleaning and polishing the propeller can give 6 percent improvement on fuel consumption. Divers can clean a 5 blade 10m diameter propeller in about 3-4 hours and that costs about US $3,000 in Far East and about double of that in Europe.

When determining the need of hull and propeller cleaning, there are two ways to do so. First way is to use divers in port, who measures the roughness of hull and propeller and compare them to the baseline values. This method gives very accurate result and therefore it is easy to the ship owner to decide when the cleaning is needed. The second way is to comparing the vessels performance indication and do calculations that way. However, it is very difficult to get accurate results on that way because all the variables (weather conditions, trim etc.) are never the same, so determining what increase comes from what source is difficult. Doing performance monitoring for long time and comparing these results to earlier performance it gives good overview of the condition of hull and propeller.

Quizzes

1. Normally on RoRo car carriers the optimum trim is

    a. Positive trim
    b. Zero trim
    c. Negative trim

2. Fouling is problem on propellers that

    a. are operating too close to surface
    b. are constantly rotating
    c. have damaged coating
    d. are stationary for long time

3. Biological fouling is not depending on

    a. Quality of hull coating
    b. Amount of algae in the water
    c. Trim of the ship
    d. Ship speed and its operation profile

4. The most accurate way to determine the need of hull cleaning is

    a. using divers
    b. Performance monitoring
    c. There are regular cleaning intervals
    d. Hull doesn’t need cleaning

5. what is not explanation for the trims effect to fuel consumption

    a. Changes to wave resistance
    b. Changes to wind resistance
    c. Changes to propulsive efficiency
    d. Changes to wetted surfaces

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Chapter 4 –e-Navigation and Weather Routing

Summary

There is a clear need to provide the master of ships and those responsible for the safety of the vessels ashore with modern proven tools to make marine navigation and communication more reliable and hence reduce errors, especially those with the potential for loss of life, injury, environmental damage and undue commercial costs. Navigational errors and failures have been significant in overall incidents that require a full investigation. This has inspired the development of new technologies such as Automatic Identification System (AIS), Electronic Chart and Information System (ECDIS) Integrated Bridge and Navigation Systems, Automatic Radar Plotting Aids (ARPA), Long Range Identification and Tracking (LRIT) systems, Vessel Traffic Services (VTS) and the Global Maritime Distress Safety System (GMDSS). A strategic vision for the utilization of navigational tools, in particular electronic tools, in a holistic and systematic manner is called e-navigation. Five solutions were agreed at IMO to provide a basis for this purpose:

- Improved, harmonization and user friendly bridge design;
- Means for standardised and automatic reporting;
- Improved reliability, resilience and integrity of bridge equipment and navigational information;
- Integration and presentation of available information in graphical displays received via communication equipment; and
- Improved communication of VTS service portfolio.

IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities)defines the e-navigation as “e-navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment”. The implementation of e-navigation involves the development of onboard navigation systems that integrate all relevant ships sensors and supporting information. ECDIS is the main item of the broader e-navigation initiative that has evolved as a result of IMO activities. IMO considers the implementation of e-navigation in the world’s fleet as a long term objective.

E-navigation implements also many other shipboard and shore side management elements than just navigation with the aim of ensuring the highest standard in environmental protection and safety. The system may combine measures like passage planning with dynamic real time monitoring to ensure that the pre-planned under-keel clearance is maintained during the whole passage. Also the ships' route can be analysed in real-time in relation to GHG emissions to look for ways to reduce fuel consumption and cost. The system may have a built-in decision support system to assist both the masters and officers on navigational watch.

It is clear that any reduction in collision and grounding will lead to the reduction of ship generated pollution. E-navigation could be used also to reduce carbon, sulphur and nitrogen emissions from ships. It has also been proposed to use e-navigation data to audit the measurement of emissions data if and when they need to be reported. The introduction of e-navigation will enable closer relation between the “officer of the watch” on the bridge and the assistance provided from shore based stations in carrying out the safe navigation of the ship.

There are, however, legal problems with regard to who will be responsible for the navigation of the ship if directed by shore side, particularly in a collision avoidance situation in open sea. Centralized shore-based traffic organizations that would have the authority to modifying voyage plans and make dynamic route changes from ashore for the purpose of safety and efficiency of the overall traffic, are the subject of research and development projects. Although e-navigation provides many new opportunities for optimizing navigation actions in favour of safety and environmental protection, the potential to reduce GHG emissions are still difficult to estimate.

The international convention for safety of life at sea (SOLAS) will soon require that the paper charts shall be replaced by approved electronic charts and an approved Electronic Chart Display and Information System (ECDIS). Paper charts will only be able to be used as a backup or on small ships of less than 500 GT. The ECDIS takes the information from the approved electronic chart and reproduce an image on a display system. The ECDIS can however do much more as it also has, as a minimum, the speed, water depth and position input from sensors so these other ship’s information are accessible by it and can be seen at all times. Many ECDISs also have the capability of showing radar, ARPA and AIS data so other ships can also be seen on the ships ECDIS display unit but this in not mandatory. The ECDIS is used to include the ships passage plan on and it has the ability to analyse the ships route and provide alerts for better ship course control. The ECDIS will also alert the “officer of the watch” of deviations from any pre-programs safety zones set by the officer or master. The above capabilities are relevant to energy efficiency measures such as weather routing and route planning.

The main advantage of ECDIS is that it is capable of accurately plotting and monitoring the ships position in real time to ensure that the ship follows the optimum course to the destination. An ECDIS fitted to the ship has the ability to be linked to a track pilot that can improve the vessels ability to keep on track and alter course at just the right time to minimise the distance travelled. This will ensure that the ship take the minimum distance between the departure and destination port, thus reducing GHG emissions.

An ECDIS can also give a quick method of calculating estimated time of arrivals (ETAs) at the port of arrival taking into account the current position of the ship, the distance to go and the tidal rates and directions without doing a complicated calculation. This information gives the information to accurately adjust the speed of the vessel so that it arrives at the pilot station or start of the pilotage passage at exactly the right time when on coastal passages or approaching the port. This can be used to adjust the speed for better fuel efficiency and for more convenient time of arrival.

The ECDIS has the potential to improve the fuel efficiency of a vessel on an ocean passage also when the ship is operating at her full service speed. The ECDIS can follow a Great Circle curved track that requires the ship to constantly alter the ship's course, as the ship follows a circular path to take the shortest route between two points on the earth's surface.

The passage plan is the most important part of the voyage plan. Careful planning and execution of the passage plan can achieve an optimum route and improved efficiency. The ECDIS can be an important part of any passage planning and implementation. The stages of a passage plan are*:*

1. **Appraisal:** An overall assessment of the intended voyage, made by the master, in consultation with the navigating officer and other deck officers who will be involved

2. **Planning:** The navigating officer carries out the planning process. The detailed plan would cover the whole voyage, from berth to berth, and includes all waters where a pilot will be on board.

3. **Execution:** The execution of the finalised voyage plan.

4. **Monitoring:** Monitoring of the vessel's progress along the pre-planned, which is a continuous process.

For energy saving purposes, the route planning needs to take extra dimensions such as avoiding shallow waters, avoiding sea currents, etc. combined with overall voyage planning. Thus, a fuel-efficient operation should be part of the 'passage planning' and taken into consideration at the appraisal stage above.

When operating in areas of high traffic density, it may be necessary to deviate substantially from the intended track by an alteration of course to comply with the collision regulations. In such cases, any considerations to reduce CO_2 emissions are outweighed by an international obligation to comply with the international regulations for the prevention of collision at sea. The international regulations for prevention of collision at sea require all ships to comply with its regulations. It may be necessary to ignore energy saving measures when operating in such areas. Navigational safety and good seamanship must always take priority. Ships may operate in an area of restricted visibility for several days which may require them to reduce speed significantly or even wait with subsequent need for over steaming that overall will result is a significant increase in fuel consumption but yet again navigational safety must take priority.

In shallow water both frictional and wave making resistances increase. Because of this, shallow water can have a significant impact on ship resistances.

In shallow water, the deep draft vessels can experience "squat" which, depending on the hull form of the vessel will generally increase ship draft and increase the trim either by the head or the stern. This can result in the ship virtually dragging itself along the bottom. Squat can seriously increase fuel consumption. The solution to the problem is simply slow down where possible. With the increased planned accuracy of satellite navigational systems, improved tidal information the ships will have the capability of resolving the issue in a better way. If a ship is operating on a trade where tide heights and depth of water in the channel or on berth is a major consideration, the use of ECDIS capability plus weather routing services could provide savings via avoiding inappropriate operations in shallow water, restricted areas and narrow channels.

Weather routing has been around for a long time and was originally developed by the shipmasters in the time of sailing ships that often develop their own weather charts. It was not until the late 60s and early 70s that weather routing as we know it today was developed. This major change was happened because of the increased accuracy of weather information that could be provided by the various met offices using satellite technology viewing from space in real time on various aspects of weather developments.

The fuel consumption for a ship not only depends on speed, but also on water depth and weather conditions. The impact of shallow water operation on fuel consumption was discussed earlier. The weather condition includes wind and wave. A one Beaufort increase in sea state could result in 4% increase in fuel consumption due to the head wind. Waves may also have a significant impact on route selection. In order to take waves into account one has to know their height and direction along the route. Such knowledge may allow selection of the route and of power setting for optimal fuel consumption and transit time.

In most oceans, there are regular currents that ships may be able to exploit. Ocean currents are not constant but change over time. An appropriate satellite service could provide reliable estimates of dynamic current patterns that are necessary for routing a vessel through such currents. The major question is, however, whether there is a sufficient market to justify development of a system for collection of the necessary data.

Based on the above, the ship speed and route is best not only to be decided by commercial and contractual considerations but also using data on sea condition, sea currents, water depth and wind characteristics. The optimal speed distribution along the route can be calculated in advance, if a weather forecast is available. These techniques are used by weather routing service providers as part of their ship modelling and analysis. The advantages of including weather routing in a ships passage plan is that a ship on an ocean passage can significantly reduce its fuel used by reducing the time taken for a particular voyage, even if the route taken is longer. Some weather routing services provide advance and accurate current and tidal predictions which can be used on coastal routes. There are many weather routing providers throughout the world so there is plenty to choose from.

If a ship is operating in a sea area which has a high occurrence of bad weather, the owner may consider using weather routing services to reduce fuel cost and ship and cargo damage. Weather routing service can direct the ship away from sea areas where such weather conditions exist with the likelihood of damage and increased fuel costs. Heavy rolling with a beam sea can result in significant damage to both the ship (racking stresses) and the cargo, particularly if it is carried on deck so it may be necessary to alter course lengthening the distance. Weather routing service can use long-range weather forecasts to route the ship away from these heavy beam sea conditions, optimising the distance and time travelled. In some cases the weather routing service may advise delaying the ships departure until the weather improves by either staying in port or finding a safe anchorage until a storm passes.

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Weather routing services can also help to optimise the route a ship takes under any prevailing weather conditions. Weather routing can be effectively used for a reduction in travel time and a reduction of fuel consumption. The owner or in some case charterer of the ship may choose one of the following routes, as examples:

- Fastest route.
- Fastest route least fuel.
- Fastest route least damage
- Fastest route least fuel and least damage

The route that the owner requests from a weather routing provider will depend on a number of factors including the type of cargo, the type of ship, the area of operation, the conditions of the charter party. If for example the ship is carrying an expensive cargo that is very susceptible to damage from heavy rolling and pitching, the owner may decide to ask for he least damage route and accept that the ship may take longer and use possibly more fuel to reach its destination. If there is no time constrains because the port of discharge or loading is blocked with traffic the owner or charterer may choose the least fuel route. If there are no such constraints and it is of utmost importance that the ship arrives at the port in time the owner or charter may decide to ask for the fastest route.

However, it should be recognised that the navigation of the ship is ultimately the master's decision and he can at any time ignore the advice given by the weather routing services if he believes that following that particular advice would threaten the ship, its cargo or crew.

Weather routing service providers would normally build a computer-based ship model in their system. The weather routing service provider can also visit the ship and collect the ship data from the master. They would look in particular for characteristics of the vessel so that it can be built into their model for best route planning. When putting together a plan for ship on a particular voyage the weather routing service provider uses ship specific information and takes into consideration additional data, such as historic data on currents, wind, pressure, temperature, water temperature, paths of depressions, tropical storms and wave heights as well as the latest information on wind, waves, wave heights, temperature, pressure, cloud cover and type provided by national and private weather meteorological data suppliers.

The weather routing services provider can use advanced computer-modelling tools to predict the weather pattern and how this will affect the ship at a particular course and speed. From this information, the model then produces a voyage route or routes that will reduce the fuel consumption or voyage time for these conditions taking into account the safe navigation aspects.

Quizzes

Question 1: E-navigation may include on-line monitoring of ships' route to look for ways to reduce GHG emissions, fuel consumption and cost.

Question 2: One important goal of the implementation of e-navigation is to reduce the amount of ship/shore information exchange.

Question 3: "raster chart" is a copy of the paper chart and cannot be scaled up in too much without losing definition

Question 4: Which of the following equipment is NOT connected to the ship's ECDIS?

Options:

1. radar
2. AIS
3. GMDSS
4. echo sounder
5. compass

Question 5: The fuel consumption of a ship is higher in 100 m deep water than in 30 m deep water if the speed of the ship remains constant

Chapter 5 - Engines and Machinery Load and Utilisation Management

Summary

In this chapter are described all operations that are made on board of the ships. Independent of its specialty to carried out the marine adventure of carry goods from a port to another and vice versa, and they need the use of equipment's and systems of the ship. The use of the before mentioned equipment imply an energy consumption which one must be made in the most efficiency way.

The first equipment that is analyzed are the diesel engines and its load during the performance of the same.

Engine Load Management

The index that better define the quality of the engines is the specific fuel oil consumption, SFOC, this index give the quantity of fuel is uptake for each power unit in a time unit, kg/kWh, i.e. is the minimum quantity of fuel that engine consumption for each kW per hour is transformed.

However, the specific fuel oil consumption is not fix for the diesel engines; it is variable and depend of the load of the engines. It is due that the engines are design and constructed for a minimum specific fuel oil consumption at the 80% of the nominal power, or what is the same, at the 80% of the Maximum continuous rating, MCR, and when the engines are working with a load lower that the 80% to MCR, the SFOC will rise and the thermal efficiency of the engines be lower.

For the above, the main engines of the vessel should always work at the 80% of MCR to get the best thermal efficiency of the engines. However, whether the ship only has one main engine this will work on demand power, but in the case that the ship has two or more main engines, the engines should work at maximum power to get the maximum thermal efficiency, and never must be working two engines at the 50% per cent of MCR.

Another important conclusion is that due to the last economic global crisis and the very high prices of the fuel the owners has been forced to reduce the speed of the ship and therefore the output power of the main engines to reduce the consumption of the fuel.

The above measure to reduce the consumption of fuel is contrary to the principle of running of engines to the 80% of MCR to get maximum thermal efficiency, because the specific fuel oil consumption is increased. In the case of the ships, the speed increase the output power of main engines exponentially to the cubic, and in this case if the speed is reduce the output power and the fuel consumption is also reduced in the same quantity.

The reduction of the speed of the ship generally called slow steaming and the main engines is going working with at reduced output power, to reduce the consumption of fuel. Obviously, when the ship is going to slow steaming the fuel consumption is reduced exponentially at the third power. But in the case that the ship sailing to slow steaming for a long period, the running of the engines has a perverse consequences that provoke an abnormally running of the elements of the engines like turbocharges, injections systems, etc. and for this cases it is necessary to do a derating in the engines.

As has been mentioned before, the consumption of fuel of the main engines are penalized for the speed of the ship at the third power. It can also be conclude that if it is consider the fuel consumption of the main engines as function of the navigated distance, the fuel consumption is going penalized for the speed at the second power.

Load Management for Auxiliary Engines

In the case of the Auxiliary Engines for electricity generation of the ship, it is recommended to have running only one auxiliary engine generating all electricity demanded. This planning of the work of the auxiliary engines allow to work close or inside of the 80% of MCR, and therefore with the lower specific fuel oil consumption and high efficiency.

It is not recommended that be working simultaneous two auxiliary engines with sharing the electricity load and working both below the 80% MCR, with a SFOC high and therefore a bigger fuel oil consumption.

Electrical Load Reduction

For reduce the electrical consume of the ship, all equipment and machinery of the ship must be stopped when are not been used. It is necessary to avoid that the machinery and equipment be running not load.

The running of HVAC equipment has to be optimized, and it must only work when be necessary in accordance with the weather conditions. In the case of cruise ships, the HVAC has a very high uptake of electricity energy, and therefore it is very important that be working in the optimum condition. The environmental temperature of all spaces inhabited of the cruise ships must be not less the 24 ºC degrees.

The departments of deck and engine must be coordinated in the planning of the equipment and machinery that are not necessary during the passage or in port, must be switch off.

Auxiliary Machinery Use Reduction via System Planning

Regarding to the flow machinery like, pumps, fans, compressors, etc. it is necessary check aspects like size of the same, that must be calculated in accordance with the needs of the ship, and this machinery should not be oversized or undersize, in both cases they will rise the consumption of electric energy, therefore of fuel. To avoid oversize or undersize of this equipment, a factor of capacity has been defined that is the ratio between operational capacity and nominal capacity. El optimum factor of capacity ratio is when near the unit.

Generally, the fluid machinery does not work continuously at the same work load, and mainly are driven by an electric motor without regulation control of flow, therefore, the electric motor is working always at the same power output independent of the load, and the electric motor consumption the same electrical power at lower or higher work load. The

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above, permit that this equipment work with a low efficiency when are working with low flow load.

When the electric motor that are drive the pumps, fans or compressors, has not flow control regulation, the control of the flow load, are make opening or closing the suction or discharge valves.

To avoid that the electric motors that drive the pumps, fans, compressors, etc. be working consumption the same electric output power for the different flows work load, is proposal that the mentioned electric motors be of variable speed, and of this way adjust the electric power consumed to the flow fluid load required, and therefore to have a better efficiency.

The aspects to have account in the fluid machinery, is the clean of this equipment, avoid the running idle time, the flow fluid control through the suction and discharge valves, to use electric motors with variable speed, adjust the flow to the needed demand and not more, avoid any kind of loss and to have a very good maintenance.

Electric Motors

The electric motors that drive pumps, fans, compressors, etc. consumption about the 60% of the electricity generated on board, therefore, it is very important, with the target to reduce the consumption of the electricity, that the electric motors be working in the optimum conditions and with the maximum efficiency. For that it is necessary to have account its dimensions avoiding oversize it that provoke a high consumption of electricity, they must work, if it is possible, above of the 40% of its nominal power, from this load the electric motors work with the maximum efficiency.

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Quizzes

1.- Question text: Efficiency concept is?

ANSWERS:

Choice 1: To get the desirable effect.

Choice 2: To get the optimal desirable effect.

Choice 3: To get that engine operate.

Choice 4: To get that the engine operate as we desirable.

Choice 5: To make that the engine running.

2.- Question text: The specific fuel consumption of the engines is lower when it is working at low power output.

Choice 1: TRUE

Choice 2: FALSE

3.- Question text: The specific fuel consumption of the engines is lower when it is working at high power output.

Choice 1: TRUE

Choice 2: FALSE

4.- Question text: What are the responsible of the reduction of consumption fuel on board of the ship?

ANSWERS:

Choice 1: The Master.

Choice 2:The Chief Engineer.

Choice 3:The Donkeyman.

Choice 4:The Greaser.

Choice 5: All of above.

5.- Question text: What are the responsible of the reduction of consumption fuel on board of the ship?

ANSWERS:

Choice 1: The Master.

Choice 2:The Chief Engineer.

Choice 3:The Chief Mate.

Choice 4:The Boatswain.

Choice 5: All of above.

6.- Question text: What are the responsible of the reduction of consumption fuel on board of the ship?

ANSWERS:

Choice 1: The Master.

Choice 2:The Chief Engineer.

Choice 3:The DPA.

Choice 4:The owner.

Choice 5: All of above.

7.- Question text: The reduction of consumptions of fuel on board, depend only of the technology.

Choice 1: TRUE

Choice 2: FALSE

8.- Question text: The engines of medium speed has a highest fuel consumption that the engines of low speed

Choice 1: TRUE

Choice 2: FALSE

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9.- Question text: The engines of low speed has a highest fuel consumption that the engines of high speed.

Choice 1: TRUE

Choice 2: FALSE

10.- Question text: The speed of the engines of low speed is between 40 and 120 rpm.

Choice 1: TRUE

Choice 2: FALSE

11.- Question text: The speed of the engines of high speed is between 121 and 399 rpm.

Choice 1: TRUE

Choice 2: FALSE

12.- Question text: The speed of the engines of high speed is between 400 and 1000 rpm.

Choice 1: TRUE

Choice 2: FALSE

13.- Question text: The low speed engines operate according two stroke cycle.

Choice 1: TRUE

Choice 2: FALSE

14.- Question text: The medium speed engines operate according two stroke cycle.

Choice 1: TRUE

Choice 2: FALSE

15.- Question text: The high speed engines operate according four stroke cycle.

Choice 1: TRUE

Choice 2: FALSE

16.- Question text: The medium speed engines operate according four stroke cycle.

Choice 1: TRUE

Choice 2: FALSE

17.- Question text: What means MCR?

ANSWERS:

Choice 1: Maximum Charge Rating

Choice 2: Minimum Continuous Rating.

Choice 3: Maximum Continuous Rating.

Choice 4: .Minimum Continuous Rating

Choice 5: All of above.

18.- Question text: The operating power of the propulsion engines will be between?

ANSWERS:

Choice 1: 20 or 30% of the MCR

Choice 2: 30 or 40% of the MCR

Choice 3: 40 or 50% of the MCR

Choice 4: 50 or 70% of the MCR

Choice 5: 80 or 90% of the MCR

19.- Question text: The load of the auxiliary engines depending of?

ANSWERS:

Choice 1: Displacement of the ship.

Choice 2: Speed of the ship.

Choice 3:Electrical needs of the equipment.

Choice 4: Frequency of the electric current.

Choice 5: Displacement and speed.

20.- Question text: The revolutions of the auxiliary engines are constant for?

ANSWERS:

Choice 1:To maintain the output power.

Choice 2: To maintain the voltage.

Choice 3:To maintain the frequency.

Choice 4: To maintain the electric current.

Choice 5: To reduce the wear of the bearings.

21.- Question text: The environmental temperature of all spaces inhabited of the cruise ship must be not less of?

ANSWERS:

Choice 1: 18 ºC degrees.

Choice 2: 20ºC degrees.

Choice 3: 21 ºC degrees.

Choice 4: 23 ºC degrees

Choice 5: 24 ºC degrees

22.- Question text: Has the electric motors with variable speed less consumptions of electricity?

Choice 1: TRUE

Choice 2: FALSE

23.- Question text: The electric motors with variable speed are less efficient.

Choice 1: TRUE

Choice 2: FALSE

24.- Question text: The electric motors must work above of the 40% of load to get the maximum efficiency.

Choice 1: TRUE

Choice 2: FALSE

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25.- Question text: The consumption of the fuel of auxiliary engines is lower working two auxiliary engines with sharing the load than only one auxiliary engine working with all load?

Choice 1: TRUE

Choice 2: FALSE

26.- Question text: For safety reasons, all the redundant essential services like lubrication or refrigeration must be operating continuously?

Choice 1: TRUE

Choice 2: FALSE

27.- Question text: The regulation of the flow in a pump of constant flow, through opening the suction valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

28.- Question text: The regulation of the flow in a pump of constant flow, through closing the suction valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

29.- Question text: The regulation of the flow in a pump of constant flow, through opening the discharge valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

30.- Question text: The regulation of the flow in a pump of constant flow, through closing the discharge valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

31.- Question text: The regulation of the flow in a compressor of constant flow, through opening the suction valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

32.- Question text: The regulation of the flow in a compressor of constant flow, through closing the suction valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

33.- Question text: The regulation of the flow in a compressor of constant flow, through opening the discharge valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

34.- Question text: The regulation of the flow in a compressor of constant flow, through closing the discharge valve reduce the energy consumption.

Choice 1: TRUE

Choice 2: FALSE

35.- Question text: In general, the fluid machinery fitted on board are oversizing

Choice 1: TRUE

Choice 2: FALSE

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Chapter 6 - Fuel Management

Summary

The quality of the fuel used by the main and auxiliary engines of the ships is very important for the good or bad running of the engines as will depend of it.

The quality of the fuel is standardized under the standard ISO 8217.

Fuel Oil Procurement and Bunkering

In the fuel is necessary to have account the impurities that it contain, like sulfur that after combustion will produce the undesirable SOx that can provoke the acid rain, the solids and water . The solids and the water contents must be eliminated on aboard before burning the fuel in the engines and boilers to avoid abnormal running of the engines and damages.

The fuel used on board must be bought to high reputation and reliability companies of bunker suppliers, to avoid boarding fuel of low quality that provoke damage in the engines. When the ships receive the fuel, a sample of the same is taken to analysis in the case to get problems when the fuel is burned in the engines. Due to the short time that the ship is in port, ir is not possible to do an analysis of the fuel to check the quality of the same.

During the bunker operation it must be taken all safety measures.

The new fuel boarding in the ship must be loaded in the empty tanks avoiding to blend the new fuel with other fuel even being of the same quality.

The quantity of fuel boarding must be checked by a flow meter or by sounding the tanks to be filled.

The fuel used in the engines must compliance with the IMO standard in force about the sulfur content.

Fuel Quality and Quantity Assurance

The fuel received on board can be from crude oil fractional distillation or from the cracking process, in this last case the fuel be able to have a high level of abrasive elements like aluminum or silicon which one provoke wear and damage in the pistons and cylinders liners of the engines.

Fuel Storage and Transfer

The storage of the fuel on board must be made in the empty tanks avoiding to blend two incompatible fuels that can clogged pipes and the filters.

If it is necessary to blend two or more fuels on board, the first thing to do is a compatibility test of the fuels before the blend.

The fuels storage on board must be consumed as soon as possible and avoid its storage for a long time. The risk of a long time storage of the fuel on board can permit the stratification of the fuel and losing its properties.

Everyday must be measured the quantity of burning fuels by the main and auxiliary engines and boilers with the purpose to have a very good control of the consumption of fuel. The control of the fuel consumed on board can be made by flow measurer or sounding the tanks.

Fuel Oil Treatment – Settling and Purification

Before use the fuel storage on board, it is necessary to be treated to remove the solids and the water contents in the fuel.

The steps to treat the fuel are to heat to between 60-70 ºC degrees in the settling tank with the purpose to remove some parts of water and solids in suspension. From the settling tank, the purifiers removing the water and the solids content remaining clean the fuel. When the fuel is completely clean from impurities can be used in the injections and combustions systems.

A previous step to use the fuel in the injections and combustions systems is to heat it to the get a low viscosity to spray it in the combustion chambers of the engines and boilers. The viscosity of the fuel is controlled by a heating system.

Due to the low quality of the fuel used on board, it is necessary to use additives that bettering the efficiency of the combustion reducing the particulate matter PM, the growing of ash in the exhaust , reduce the solids deposits on the pistons, cylinders liners, valves, etc.

Energy Efficiency Measures

As conclusion, the measures that can be taken to bettering the energy efficiency regarding to the management the fuels used on board are as follow: Carry the fuel needed for each trip, avoiding the carrying unnecessary weight and the possible stratification of the same. Maintain the fuel storage to the minimum temperature possible inside of the tank. Avoid the contamination of the fuel in the storage tanks. Control of the good performance of the viscometer.

Quizzes

1.- Question text: Is the NOx a GHG?

Choice 1: TRUE

Choice2: FALSE

2.- Question text: Is the SOx a GHG?

Choice 1: TRUE

Choice2: FALSE

3.- Question text: Is the CO_2 a GHG?

Choice 1: TRUE

Choice2: FALSE

4.- Question text: What mean IFO?

Correct answers (at least one):

International Fuel Oil

Intermediate Fuel Oil

Indicated Fuel Oil

Indispensable Fuel Oil

5.- Question text: What mean the number after IFO-380?

Correct answers (at least one):

Density

Viscosity

Quality

Ignition temperature

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6.- Question text: What is the Intermediate Fuel Oil?

ANSWERS:

Choice 1: Gasoline.

Choice 2: Marine diesel oil.

Choice 3: Diesel oil.

Choice 4: Marine fuel oil.

Choice 5: Marine diesel oil plus marine fuel.

7.- Question text: For what is taking a sample in each fuel supply during bunker operation?

ANSWERS:

Choice 1: To send to the owner.

Choice 2: To keep in the engine room.

Choice 3:To know the quality of the fuel in the case of problems in the operation of the engines.

Choice 4: To know the quality of fuel.

8.- Question text: For the year 2020 the maximum sulphur content in the international maritime transport will be 0,5% m/m

Choice 1: TRUE

Choice2: FALSE

9.- Question text: The maximum sulphur content in EU ports is 0,1% m/m

Choice 1: TRUE

Choice2: FALSE

10.- Question text: The maximum sulphur content in the SECAs is 0,1% m/m

Choice 1: TRUE

Choice2: FALSE

11.- Question text: The sedimentation tanks are used exclusively for heating the fuel.

Choice 1: TRUE

Choice2: FALSE

12.- Question text: The sedimentation tanks are used for remove, though natural process the water and solid waste and heating the fuel.

Choice 1: TRUE

Choice2: FALSE

13.- Question text: The fuel pass directly from the sedimentation tanks to daily tank.

Choice 1: TRUE

Choice2: FALSE

14.- Question text: The fuel is heated to reduce its viscosity.

Choice 1: TRUE

Choice2: FALSE

Chapter 7 - Technical Upgrade and Retrofit

Summary

The implementation of the new technologies on board of the ships of new building, that bettering the energy efficiency, should be consider for the owner and the maritime administration. In the case of ships in service also should be consider the implementation of the new technologies, previous economic study for the amortization of the new equipment to the remain operative live of the ship.

Devices forward of Propeller

A new element to reduce the propulsion power is the MEWIS DUCT, that is a duct fitted forward of the propeller, and this duct drive to the flow of water to the propeller so reduce the power propulsion through of the wake field equalization, reduction of propeller hub vortex and contra rotating swirl, increasing the thrust and reducing the loss of rotational flow. With the fitted of this element it is possible to reduce the propulsion power till 8%.

The MEWIS DUCT are elements suitable to fitted on board of the biggest ships like tankers and bulk carrier that sailing to speeds lower 19 knots.

Another elements to reduce the propulsion power are fitted aft the propeller with the target to reduce the friction losses, axial and rotational, increasing the exploitation of energy and bettering the efficiency.

Devices Aft of Propeller

The elements fitted aft the propellers are the Boss cap fin that recapture some of the rotational energy losses. This element is easy to fit and suitable for ships with low speed. With this element can be increasing the propulsive efficiency till 5% and reduce till a 2% the consumption of fuel.

The unit of **integrated propeller and rudder**, is a device that are design like a conjunct unit, that sailing at design speed of the ship can be get a reduction of the required power of till 5%. This kind of device is optimum to fitted in ships of general cargo, RoPax and containers.

Ducted propeller

The **duct propeller** is a nozzle where the propeller is placed and permit a higher and better supply of water inside of propeller, bettering the running of the same and the efficiency between 5-20% and reducing the power propulsion and the consumption of fuel.

The only one inconvenience of the **duct propeller** it is an added device that increase the friction and the resistance to the flow. Other problem is the fouling of the nozzle and the propeller what oblige to higher to clean and maintenance.

This nozzle is ideal for ships that working to high propeller loads, like tankers, bulk carriers and tugs.

fore-Body Optimization and Bulbous Bow

Another devices to reduce the propulsion power and therefore the fuel consumption are the fore-body that are forward bulbous that are generators of waves that Override the waves that are formed in the forward of the ship and increase the resistance to advance.

Fitting this kind of device, it is possible to get till a 5% of reduction of fuel consumption.

The retrofit of a bulbous is simple and can be made during a mandatory docking survey.

Waste Heat Recovery

The main and auxiliary engines exhaust to the atmosphere a big quantity of exhaust gases at high temperature, between 300-450 ºC degrees, losing a lot quantity of thermal energy. Part of this thermal energy can be recaptured and used in a waste heat recovery to produce hot water for heating of the ship, and steam for move a steam turbine that move a AC alternator to generate electricity.

Auxiliary Machinery and Systems

High efficiency electric motors

In general the electric motors has a high efficiency, nowadays this efficiency is been bettering, and therefore, it is necessary in the new building ships to select the electric motors of higher efficiency and lower consumption. In the case of the ships in service, all electric motors that need should be replaced should be changed by a new and with higher efficiency.

Fuel oil homogenisers

To take advantage of the fuel should be used a fuel homogenizer that reduce the quantity of sludge of the fuel, and therefore, to burn much more fuel in the boilers and engines.

Other technologies

Currently new technologies are been proposals to reduce the consumptions of fuel on board of the ships, between the new technologies proposals are: the use of LED´s, speed regulators for pumps, fans and compressors, advanced system of HVAC, etc.

Quizzes

1.- Question text: What is the most efficiency way to generate electricity on board of the ship?

ANSWERS:

Choice 1: Through a genset diesel.

Choice 2: Through a PTO from the main engine.

Choice 3: Through a PTI coupled to the main engine.

Choice 4: Through a genset gas turbine.

2.- Question text: The load of the propulsion engines of the ship depending of?

ANSWERS:

Choice 1: Displacement of the ship.

Choice 2: Speed of the ship.

Choice 3: Ballast of the ship.

Choice 4: Cargoes of the ship.

Choice 5: Displacement and speed.

3.- Question text: The devices like MEWIS DUCT fitted forward of the propeller reduce the power propulsion.

Choice 1 : TRUE

Choice 2: FALSE

4.- Question text: The efficiency of MEWIS DUCT suitable in vessel sailing to speeds lower 19 knots.

Choice 1 : TRUE

Choice 2: FALSE

5.- Question text: The devices fitted aft the propeller reduce the friction losses.

Choice 1 : TRUE

Choice 2: FALSE

6.- Question text: The duct propeller reduce the propulsion power.

Choice 1 : TRUE

Choice 2: FALSE

7.- Question text: The duct propeller reduce the fuel consumption.

Choice 1 : TRUE

Choice 2: FALSE

8.- Question text: The forward bulbous reduce the propulsion power.

Choice 1 : TRUE

Choice 2: FALSE

9.- Question text: The waste heat recovery reduce the atmosphere contamination.

Choice 1 : TRUE

Choice 2: FALSE

10.- Question text: The waste heat recovery reduce the fuel consumption.

Choice 1 : TRUE

Choice 2: FALSE

11.- Question text: The output power of the propulsion engines depend of the V^3 of the ship.

Choice 1 : TRUE

Choice 2: FALSE

12.- Question text: The consumption of fuel of the propulsion engines depend of the V^3 of the ship.

Choice 1 : TRUE

Choice 2: FALSE

Chapter 8 - Boilers and Steam System

Summary

The use of the steam on board of the ships is very important. This use can be for the propulsion, in the case of the ships with steam turbines as propulsion, case of the LNG ships, to generate electricity, and to heat the cargo carried, the fuel used by the engines or for heating of the ship.

Overview of A Ship's Steam System

A boiler, or a waste heat recovery or both jointly, generate the steam on board of the ship. The consumption of fuel by the boilers in the world fleet is about the 6% of the total consumption; therefore, it is very important to do operate the boilers at condition optimum and low consumption. Further, use the maximum quantity of heat of the exhaust gases and of this way saving an important quantity of fuel.

In the auxiliary boilers, that use fuel to produce steam, is very important, the cleaning of the steam and water pipes and the maintenance of the same, to have the best heat transmission and therefore, the higher efficiency.

In the boilers of waste heat recovery that use the heat of the exhaust gases from the auxiliary and main engines of the ship, to produce hot water and steam, must work in the best conditions of cleaning of the water and steam pipes to get the better heat transmission and the higher efficiency

In the distribution system of steam, the pipes must be have a very good insulated to avoid loss of heat.

All systems that use steam, like turbines, heat exchange, water generators, etc. must have a high-level cleanness and maintenance to get the higher efficiency.

The water and steam pipes must be clean in the fireside and the waterside, to have the best heat transmission. To maintain clean the steam pipes in both sides, it is necessary to do several soot blowing every day, and to use water treated chemically without any kind of salts that can adhere to the pipes walls.

The control of the temperature of the exhaust gases will inform us of the cleanness state of the pipes. An increase of the temperature of the exhaust gases is an indicator of a bad transmission of the heat and therefore a fouling of the pipes in the fireside or in the waterside or both.

The hot well temperature of the feed water of boiler must be maintained between 80-85 ºC to avoid a higher consumption of fuel.

After each chemical analysis of the boiler water, it is necessary to do the corresponding surface or bottom water extractions to eliminate the salts and solids contented in the water.

The combustion in the boiler must be made with the air excess index fixed by the manufacturer. An air excess index upper to the specified will provoke loss of heat to outside and lower efficiency.

The optimum air excess index can be determine in accordance concentration of the O_2 or the CO_2, if the concentration of O_2 is high and the CO_2 low, it is an indication that the combustion is been made with a high air excess index.

Boiler Energy Efficiency Measures

The efficiency of the boilers depend of the workload, the maximum efficiency of boilers is when are working with a workload upper 80% of the nominal power. In the case that the ship has two auxiliary boilers and the workload demand be low, should be working only one boiler with all workload demanded.

In the distributions system of steam all kinds of measures must be taken to avoid steam loss in the by-pass valves, filters, etc. It is convenient to maintain a very good insulation of the pipes and equipment.

The heating of the cargo in the ships tankers should be made through a planning to know the best condition of heating and maintenance of the temperature of the cargo, and avoid an excess consumption of fuel.

As conclusion of the aforementioned, it is very important to follow the code of good practice, in the boilers operations, and boilers waste heat recovery, to bettering the efficiency and reduce the fuel consumption and between them are: A very good insulation of the pipes and boilers, to check the running of the steam traps, remove the steam loss, maintain constant the pressure of the boiler.

Quizzes

1.- Question text: What is the most efficiency way to generate steam on board of the ship?

ANSWERS:

Choice 1: Through a fuel steam boiler.

Choice 2: Through a waste heat recovery steam generator.

Choice 3: Through a waste heat recovery steam generator plus fuel.

Choice 4: Through a diesel engine.

Choice 5: Through a gas turbine.

2.- Question text: The boilers on board of the ships produce steam only for heating the fuel used by the engines.

Choice 1 : TRUE

Choice 2 : FALSE

3.- Question text: The auxiliary boilers on board of the ships produce steam for heat the cargo carried, heating the ship, generate electricity and heating the fuel used by the engines.

Choice 1 : TRUE

Choice 2 : FALSE

4.- Question text: The insulation of the steam pipes reduce the heat loss and the consumption of fuel.

Choice 1 : TRUE

Choice 2 : FALSE

5.- Question text: The boilers on board of the ships produce steam only for heating the fuel used by the engines.

Choice 1 : TRUE

Choice 2 : FALSE

6.- Question text: The temperature of the exhaust gases inform us the cleaning state of the steam and water pipes.

Choice 1 : TRUE

Choice 2 : FALSE

7.- Question text: An increasing of the temperature of the exhaust gases of the auxiliary boilers is indicating a bad transmission of heat and, therefore, a fouling of the pipes.

Choice 1 : TRUE

Choice 2 : FALSE

8.- Question text: The surface and bottom water extractions of the boilers are made to eliminate the salts and solids contented in the water.

Choice 1 : TRUE

Choice 2 : FALSE

9.- Question text: The surface and bottom water extractions of the boilers are made to eliminate only the salts contented in the water.

Choice 1 : TRUE

Choice 2 : FALSE

10.- Question text: The maximum efficiency of the boilers is when are working with a workload upper 80%.

Choice 1 : TRUE

Choice 2 : FALSE

Chapter 9 - Port Operations, Air Emissions and Efficiency Measures

Summary

International shipping is the most energy efficient mode of cargo transport in world trade but unfortunately is also a major producer of NOx, SOx and CO_2 emissions. The existing measures being EEDI (Energy Efficiency Design Index) for new ships and SEEMP (Ship Energy Efficiency Management Plan) for all ships. With the current debates on further measures and fuel consumption measurement and reporting, new regulations in this area are forthcoming.

Ports are part of a wider international and national network of transport and logistics. They significantly contribute to the cargo logistic network. The success of ports in the logistics chain depends on their strengths as well as the strength of other players in that chain including shipping. A similar reasoning applies to the other maritime transport players including ship owners, port operators and the land-based transport service providers. Accordingly, the function of a port like other major maritime stakeholders (e.g. ship owner) does not depend exclusively on its own facilities and management processes but also affected by a variety of other stakeholders.

When it comes to ports, there have been limited studies on port operation / management and its contribution to ship energy efficiency. The main reason for this may be the lack of IMO's regulatory authorities on ports because the IMO's main focus is on ships and international shipping rather than ports that are mainly regarded as national entities. Despite this lack of regulatory focus, marine ports are important for shipping energy efficiency and in particular they play a major role in delivering an energy efficient ship operation. Thus, their roles and responsibilities and what they could do need to be understood.

Port operations involves not only ship operation but a lot of other activities such as cargo loading and unloading, ground-level port related transportations and activities of harbour crafts for provision of various services to ports or ships (e.g. dredging, tugs, bunkering, etc.). The main prime mover for most of these vessels, vehicles, cargo handling equipment are diesel engines although move to electrification and use of other technologies are underway. In this section, technological solutions for port area emissions reduction and GHG emissions reductions are discussed.

A port encompasses more than the port authority as the top governing body but also other players such as shipping companies as its principal customer and terminal operating companies as the main suppliers of services. There are numerous other, often smaller players to take into account and typical examples of such players are fuel trading and dredging. The former plays a big role in ship operations, whereas the latter has its role in the construction of shipping and port facilities. The availability of efficient fuel provision can convince a shipping company to call at the port and even make a longer stay, in both cases

resulting in more cargo loading and unloading capacity. Dredging activities are an important element of capacity creation and maintenance.

Port operations involve a great many players, both at management level and at operational level. The management of ports also varies from one country to the other. The port as a physical entity is managed by a port authority in which the public authorities may or may not be a stakeholder. In addition, depending on the size of the port, any number of enterprises may be located within its perimeter. Many shipping companies rely on services provided by third parties (e.g. pilots, towage services, ship repairers, provisioning, waste reception facilities, and bunkering companies) that are somehow but not fully associated with a port.

From a different perspective, port management is a complex process as this is normally made up of a variety of links. Often different part of the chain are controlled or managed by different players, but some activities are also integrated across links. So, ports could have a relatively complex management and decision making structure.

In port areas, air emissions and energy consumptions are primarily due to ships. However, there are other equipment and facilities that use energy or contribute to air emissions to port areas. For example cargo loading devices, trucks and other transportation units, buildings and energy needed for these buildings and harbour crafts that provide additional services to port and shipping companies.

For example, when it comes to the energy efficient ship operations, reduced ship speed at sea is closely related to the minimisation of a ship's time in port. A ship's time in port will be referred to here as ship's "port time". Reduction in port time through the high quality port operations allows shipping lines to improve the operational efficiency via reduced ship speed and thus fuel consumption. This calls for examination of all aspects of port operation in order to find practical ways to cut down on ship port time.

The amount and level of such emissions will depend on not only technologies used but also operational aspects of ships, the time they stay in port and other energy using machinery and facilities in port itself. Emission reductions in the port area are typically focused on PM, SOx and NOx due to air quality health impacts. Controlling NOx, PM and SOx is the central focus for most national and regional regulatory agencies and therefore the same applies for ports as does to the shipping industry. GHGs emissions have recently been seriously addressed by regulatory agencies such as IMO, although in the port area, health effects and thus pollutants typically take the priority over GHG emissions.

One possible way is to make a ship to operate Just-in-Time that involves getting rid of the waiting times in port. This will not only help shipping lines to get the maximum notice of berth availability, but also facilitate the use of optimum ship speed at sea. The emission sources directly associated with ship operations in port include those due to propulsion engines, auxiliary engines and auxiliary boilers. Further, reduction of berth time by improved cargo handling could be another way to reduce ship time in port. Few studies, however, have been done to identify the relationship between ship time in port and efficient ship operation at sea. The reduction of port time, or minimization of waiting time through just-in-time arrival and departure, improvement of berth productivity and simplification of the administration process, lead not only to the reduction of the operating cost but also to the improvement of the environmental performance of the shipping industry.

When the ship arrives at a port, there are some limited scope for the ship to reduce its fuel consumption while at anchor or at berth. Despite the fact that such reduction in fuel consumption may not have significant impact on a ship's overall annual fuel consumption; the impact on port air quality could be significant. Therefore, the question "if ship-board staff could do anything to support a more efficient ship-in-port operation" is main topic of this section.

A number of measures could be identified that if implemented would reduce fuel consumption for the benefit of ship's energy efficiency and port air quality. These measures are analysed by assuming that ship will not be connected to shore power or a major switch in terms of fuel type will not take place as these changes may make some of the arguments put forward herein redundant.

The aspects covered in this section are simple day to day ship-board operational measures that can be undertaken by all ships. In fact, some of them could be implemented also by harbour and port support vessels. The main ship-board systems working when ship is at anchor or at berth include auxiliary machinery and equipment, diesel generators and boilers.

As an alternative to on-board power generation, vessels can be hooked up to an onshore power supply, i.e. connected to the local electricity grid. In this way ships' operations can proceed uninterrupted, while eliminating negative side-effects. The amount of power generated and fuel consumed is dependent on type of ships and could be anything from a few hundred kW to several MW of electric power. The operation of auxiliary engines is a major source of SOx, NOx and Particulate Matters (PM) emissions to ports. The amount of emissions is generally proportional to the amount of fuel used. The longer the ship stays at berth or at anchor, the higher the ship fuel consumption will be and thereby the more the exhaust pollutants emitted to the port.

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Quizzes

1. What is the most effective system for reducing ship in-port air pollutants?
    - Using existing engine technology
    - Using alternative fuels
    - Using On-Shore Power Supply
    - Using after treatment technologies

2. Just In Time (JIT) normally refers to process Improvements that...
    - Reduce Unnecessary auxiliary engine loads and boiler burnings
    - Reduce Unnecessary waiting and the idle periods of ship operations
    - Reduce Unnecessary towage services
    - Reduce ship crews working hours

3. In port areas, air emissions and energy consumptions are primarily due to...
    - Ships
    - Cargo loading and unloading devices
    - Buildings and energy needed for these building
    - Harbour crafts that provide additional services to port and shipping companies

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Chapter 10 - Cargo and Ballast Management

Summary

This Chapter concerns issues relating to ship loading, use of ballast water, use of loading or unloading equipment and their impacts on ship energy efficiency.

Cargo ships setting sail in the 1860s were very likely to be unseaworthy, both badly maintained and overloaded. In same year, after increased loss of ships due to overloading a member of the British Parliament, Samual Plimsoll advocated the creation of legislation about load line. The idea was a level of maximum ship submergence based on the tonnage of the ship that would give a minimum freeboard to which the ship could load. This idea was finally implemented worldwide by the International Load Line Convention.

The Plimsoll Line or Load Line is placed mid-way between the forward and after perpendiculars of the ship and give the draft of the ship that is the legal limit to which a ship may be loaded for specific water density and temperature. Temperature can influence the draft of a ship because warm water provides less buoyancy as it is less dense than cold water but this factor is not really taken into account in cargo calculations except by the use of Load Line Zones of areas that have been defined in the International Load Line Convention as outlined in the following paragraph.

International Load Lines Convention applies to all commercial vessels of over 24m length and requires that every ship is surveyed and issued with a Loadline certificate every 5 years. If the ship does not have its certificate up-to-date then it can be detained by the Flag State or Port State inspectors. The survey mainly consists of checking the vessel to ensure that the watertight integrity of the structure as a whole has been maintained. Cargo capacity is normally decided on most ships by it load-lines which are placed on each side of a ship to show the ships maximum true mean draught that must not be exceeded. The measured load-lines on a ship are defined as the measurement from the uppermost continuous watertight deck to the ships waterline at its mid-point.

It is pertinent to note that as regard to loading aspects, trim and ballasting, ships such as bulk carriers do not have much scope for changing trim without shutting out cargo and reducing the load factor as the holds are often full. So it is very important in the design stage of the vessel that this is taken into account with regard to the placement of the engines, fuel tanks and fresh water tanks as well as the shape of the hull.

Container ships and general cargo ships will generally have a good deal of scope for improving stability and changing trim using ballast tanks. It is also very important to make sure that the propeller and rudder are adequately submerged during the voyage for ship steering and safety purposes, particularly on ballast voyages as well as reducing fuel costs and GHG emissions. In addition to wasting fuel as the propeller may be out of the out of the water, if the wind force increases, the ship can start to roll violently putting the safety of the

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crew at risk and make it extremely difficult to berth unless tugs are available; thus delaying the vessel and also wasting fuel and increasing GHG. It should also be taken into account that over the life of a ship, the light ship displacement will increase due to a build-up of paint and bio growth on the hull and mud in the ballast tanks, thus leading to a reduced the cargo load capacity.

Ships are designed to carry a certain amount of cargo at a certain speed for a certain fuel consumption that generally results in a particular trim for the vessel when fully loaded and in ballast. Trim has a significant influence on the resistance of the ship through water and of the effectiveness of the rudder and propeller. Optimized trim can give significant fuel savings and for any draft there is a trim condition which will give minimum resistance and increase the efficiency of the engine. There are two main factors that affect the trim of the ship; one is the shape of the underwater form of hull/water plane area at particular draft and the other is the distribution of weighs such as ballast water, cargo and fuel in the vessel. The optimum trim for a particular ship at a particular draft will be computed at the design stage and the ship builder should make reference to the ship design data provided. In some ships it may be possible to access and apply optimum trim condition for fuel efficiency throughout the voyage. Trim can be adjusted and improved by arranging bunkers, by positioning cargo or by varying the amount of ballast water but taking extra ballast more than needed can lead to an increased displacement and therefore increased fuel consumption.

The ship may need to take on ballast either when loaded to take out a list and change the trim, or in ballast to submerge the propeller and rudder. The position and weight of all cargo should be included in the cargo and lashing plan before the ship sails from any port to ensure that adequate stability is maintained. Some other environmental restriction to ballasting or de-ballasting that will apply will be contained in the ship's ballast water management plan. The need to keep the ship seaworthy in the open sea, protected waters and when berthing; must always be considered when both loading and ballasting a ship takes place.

When a ship is on a ballast voyage, there is generally no problem with pumping and transferring ballast as long as the ship remains upright with no list and the correct trim is maintained. This is because ships in ballast tend to be very stiff anyway and any free-surface effect will have no or very little impact on the ships minimum stability requirements.

It is very important to be fully aware of the cargo to be loaded and discharged so that the route, cargo and ballast plan can be defined and calculated accurately before the ship sails. A container will normally be packed in a warehouse some miles from the port and transported to the dock by a truck. In order to avoid the inaccurate weight declarations; According to the provisions of SOLAS Chapter VI - Amendment to Part 2 of Part A , from 1 July 2016, it was stipulated that the gross weight of the containers should be verified and confirmed and forwarded by exporter to the port facility representative and the ship's captain or his representative in advance.

Reefer containers can be stored on deck or inside the cargo holds and a large amount of heat from their condensers is removed from the inside of the container .When reefer

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containers are stored on deck , heat from the condensers can be discharged into the atmosphere. The ship's cargo hold ventilation system should be designed to allow the required amount of air changes to maintain the temperature inside the hold within the pre-set limits. Reefer containers are usually equipped by default with air-cooled condensers, some are designed to run as water-cooled units. Water cooled reefer plants have a much lower energy consumption so can lead to substantial reduction in the production of GHGs emissions than current systems.

One of the key tasks for ship's master is to pre-calculate weight of the cargo for stability and trim. In this regard the ships master must rely on the ship loading computers and ships final drafts to ensure that stability is maintained throughout the intended voyage, taking into account the consumption of fuel oil and any international load-line requirements. The master will then ballast the ship to get the optimum trim for the actual draft.

In recent years there has been considerable effort to upgrade cargo Equipment for Energy Efficiency. The ship operator should consider all ships in the fleet when considering the upgrade of the ships' cargo handling and stowage equipment to reduce GHG emissions but the methods that can be used will depend on the type of ship, where it is operating and the cargo it intends to carry.

In some cases it is possible to improve the energy efficiency of the operation by upgrade the shipboard or ashore cargo equipment. This will require the development and installation of more advanced equipment and cost. However, this cost will be offset by the acceleration of the loading and unloading functions, as well as the improve the energy efficiency of the operation..

The overall efficiency of the ship is a function of the ship's size. As the ship grows, a lower fuel consumption and lower CO2 production per cargo will be achieved. Operationally, energy efficiency can be increased by concentrating the transportation of cargo on larger ships that can reduce the energy consumption of the shipping industry as a whole. These smaller feeder ships will be less efficient anyway than the large ships and there will also be some extra GHG emissions penalties in the additional discharging and loading operation for trans-shipment. So, the use of economies of scale is as effective as it can be, but it is a good idea to make a lot of money. This means that the overall energy efficiency may also be improved for smaller vessels with access to more ports and cargo types and able to fill cargo holds to full capacity.

Another key factor is the Ballast water (BW) Management. BW is essential to control trim, list, draught, stability and stresses of a ship. Ballast water activities are largely regulated not only because of the above ship's safety implications but also since they have been recognized to be a pathway for the movement of undesirable and alien bio-species from their natural habitat to other ecosystems . According to Ballast Water Management Convention, two main methods are highlighted: ballast water exchange (Regulation D-1) and achievement of ballast water standards (Regulation D-2). The impact of Ballast Water Management (BWM) on a ship's fuel consumptions is not normally considered despite the evidence that, regardless of the management method established, the overall energy efficiency of a ship is affected by ballast water because The ballast exchange requires the additional use of the ballast water handling equipment and in particular pumps. Ballast water impacts the ship's energy efficiency in two additional ways:

- The change in ship displacement; thus wetted surfaces and ship resistance.
- The change in ship trim.

The amount of ballast water discharge/uptake in a port depends on type of vessel, amount cargo loaded/un-loaded and ship loading planning. The need to counterbalance the detrimental effects of weight distribution during and after loading/unloading must be addressed in ports. . Therefore, the port and ship responsible persons must develop plans and procedures to optimize the ballast water intake through the establishment of the cargo loading/unloading process and the final cargo plan.

In addition to the anticipated ballast plan, the dynamics of the voyage should be taken into account especially when ballast water exchange has to be carried out. Ballast water and trim optimisation and adjustments while in passage should be pre-planned relative to the port operations that normally give and even-keel no trim. Sediment uptake and removal should be controlled as part of voyage planning to ensure the minimal level of sediments. The voyage should be planned taking into account when ballast water exchange or adjustments are to be carried out. Also, trim optimisation and adjustments, while in passage, should be pre-planned relative to the port even keel operation.

One key development is the requirement of a Ballast Water Management Plan (BWMP). According to Ballast Water Management Convention entered into force, the 8th of September 2017, it is a requirement for each applicable ship to have a BWMP. The following are normally included in the BWMP:

- Acceptable methods for ballast exchange and relevant procedures.
- Details of the procedures for the disposal of sediments at sea and to shore.
- Designation of the on-board officer-in-charge of the implementation of BWMP.
- Method of the sediment removal or reduction at sea, and when cleaning of the ballast tanks takes place.

To reduce the sediment levels, the following general advice is provided by the IMO:

- All practical steps should be taken during ballast uptake to avoid sediment accumulation.
- When sediment has accumulated, consideration should be given to flushing tank bottoms and other surfaces when in suitable areas.
- The volume of sediment in each ballast tank should be monitored regularly.
- The frequency and timing of removal will depend on factors such as sediment build up, ship's trading pattern, availability of reception facilities, work load of the ship's personnel and safety considerations.
- Removal of sediment from ballast tanks should preferably be undertaken under controlled conditions in port, at a repair facility or in dry dock.

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- The removed sediment should preferably be disposed of in a sediment reception facility if available, reasonable and practicable. Disposal should take place in areas outside 200 nm from land and in water depths of over 200 m.

Officer-in-charge of ballast water management should perform the following duties and responsibilities

- Ensuring that the ballast water operations follow the procedures in the BWMP
- Ensuring that the Ballast Water Record Book and any other necessary documentation are maintained.
- Being available to assist the inspection officers authorized by a Party for any sampling that may need to be undertaken.

There are three methods of ballast water exchange which have been evaluated and accepted by the IMO.

- Sequential method
- Flow-through method
- Dilution method

In summary aspects regarding energy efficiency necessitates the observation of the following:

- **Carrying less ballast water:** The displacement of a vessel is a function of lightweight, fuel, cargo and ballast weights. Therefore, it is generally desirable to have less ballast from an energy efficiency point of view.
- **Optimizing use of the equipment**: This item relates to the use of ballast water equipment via management of the amount of ballast water to uptake, discharge, correct method of uptake/discharge and so on. The aim would be to reduce or optimise the usage of relevant ship-board equipment.
- **Efficient ballast management operations:** This means performing ballast exchange or ballasting and de-ballasting in a way that is more energy efficient.

Quizzes

True or False

1. The ship loading management has implications for ship energy efficiency
2. The measured load-lines on a ship is defined as the measurement from the uppermost continuous watertight deck to the ships waterline at its mid-point.
3. Reefer containers are usually equipped by default with water-cooled condensers, some are designed to run as air-cooled units.
4. As economies of scale basis, overall energy efficiency may also be improved for smaller vessels with access to more ports and cargo types and able to fill cargo holds to full capacity.

Multiple Choice

1. Which type of ships have a good deal of scope for improving stability and changing trim using ballast tanks
    a. Crude Oil Carrier Tanker
    b. Bulk Carrier
    c. IMO Type I Chemical Tanker
    d. Container Ship

2. Who should be verified ,confirmed and forwarded the gross weight of the containers to the port facility representative and to the captain or representative of the ship?
    a. Exporter
    b. Stevedore
    c. Packing Unit
    d. Ship Owner

3. Which factors are not linked the amount of ballast water discharge/uptake in a port?
    a. Type of vessel,
    b. Amount of cargo loaded/un-loaded
    c. Weather condition
    d. Ship loading planning

4. How many methods are there for ballast water exchange which have been evaluated and accepted by the IMO?
    a. 4
    b. 2
    c. 3
    d. 5

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Fill in the Blanks

1. The displacement of a vessel is a function of lightweight, fuel, cargo and ballast weights. Therefore, it is generally desirable to have …………… ballast from an energy efficiency point of view.

2. Officer-in-charge of ballast water management should ensure that the ………………..Book and any other necessary documentation are maintained.

3. The removed sediment should preferably be disposed of in a sediment reception facility if available, reasonable and practicable. Disposal should take place in areas outside ………….. from land and in water depths of over 200 m.

4. Sediment uptake and removal should be controlled as part of voyage planning to ensure the ……………. level of sediments

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Chapter 11 -Ship Maintenance And Energy Efficiency

1 Rules & regulations

Examples of the rules and regulations influencing the shipping industry are the International Safety Management Code (ISM), the International Convention on Standards of Training Certification and Watch keeping for Seafarers (STCW), the International Ship and Port Facility Security Code (ISPS) and the International Convention for the Prevention of Pollution from Ships (MARPOL), (IMO, 2010).

The ISM Code Chapter 10 Maintenance of the ship and is equipment describes in general how ships should be maintained, inspected, non-conformities be reported and corrective actions be taken.

Paragraph 10.1 of the ISM Code states that the Company should establish procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Company.

In paragraph 10.3 of the ISM Code it states that the Company should identify equipment and technical systems that through sudden operational failure might result in hazardous situations (ISM, 2002).

When implementing a maintenance management system onboard a vessel as part of the shipping company's safety management system it is imperative to define the critical systems and equipment (IMO, 2002). Maintenance instructions according manufacturers and others instructions should be issued to ensure the uninterrupted and safe operation at all times (IACS, 2008).

In the design phase of a vessel some of the critical equipment and systems could be duplicated or even tripled in order to gain redundancy.

Such equipment requires specific maintenance management routines in their idle phase in order to function properly when taken in operation (IACS, 2008).

Shipping companies must strive for continuous improvement by monitoring safety and conducting internal audits to prevent recurrence of faults. Particular attention must be given to the human element in accidents and man/equipment interface.

The classification societies develop according, and in addition, to the above rules detailed regulations for different types of ships and operation environments. The rules and regulations are continuously adjusted to new findings and new technology through additions to the class rules, e.g. continuous Survey for Hull and Machinery and Condition Based Maintenance

The major classification societies are supporting routines for condition based maintenance where equipment and whole systems can receive a specific class certificate of alternative survey arrangement if maintained according this alternative method. The class notation grants simplified classification routines of the specific equipment and systems and thus lead to more flexible operation and reduced classification costs.

The charterers also raise their specific requirements on operators and ships. In the tanker sector vetting inspections aboard are performed before a vessel for is accepted for charter.

The major oil companies have through their organisation The Oil Companies International Marine Forum (OCIMF), in addition to vetting inspections issued a system how to control that the tanker operators are adhering to OCIMF's specific requirements. The system is based upon the tanker operators' control of their own operation, summarised in Tanker Management Self-Assessment (TMSA), where the outcome is compared with an agreed Best Practice standard (OCIMF, 2008).

2 Maritime Maintenance Management

The ISM Code stipulates that each ship operator is responsible for that safe and pollution free operation of the ship is ensured, and that the ship's hull, machinery and equipment is maintained and operated in accordance with applicable rules and regulations (ISM, 2002).

The senior management has to be committed to provide required resources, competent crew and a well designed and implemented maintenance management system in order to achieve these objectives onboard.

The fundamental part of the maintenance management system is a database that contains a register of all equipment onboard that need to be maintained.

In the databases various registers are kept and the following information should be recorded (IACS, 2008).

- Maintenance intervals
- Inspection intervals and methods
- Inspection and measuring equipment to be utilised
- Acceptance criteria
- Personnel responsible for inspection and maintenance activities Reporting requirements
- Establishment of maintenance intervals should be according:
- Manufacturers' recommendations and specifications
- Condition based maintenance management techniques
- Practical experience
- The current operational mode of the equipment

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- Certain operational requirements
- Class or other administration or company requirement
- Testing of redundant equipment

Establishment of inspection intervals should be based according to acceptance criteria and the measuring and testing equipment's calibration and accuracy. Checklists according manufacturers' recommendations should be developed.

The following types of inspections and test may be applicable;

- Visual inspection
- Vibration tests
- Pressure tests
- Temperature measurements
- Electrical tests
- Load tests
- Water tightness inspections

Different methods and strategies are available when developing maintenance management routines for equipment and systems for a particular vessel or fleet of vessels.

An analysis of the equipment and systems criticality should be performed.

3 Type of maintenance

3.1 Corrective Maintenance

The traditional way to perform maintenance activities is to repair an object when it has broken down either by accident or as an expected event.

Corrective maintenance is defined as activities undertaken to detect, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to its required function (Stoneham, 1998).

3.2 Run to failure

Run to failure can be used as a maintenance management methodology i.e. no repairs are undertaken until an object actually breaks. "If it's OK, don't fix it" (Stoneham, 1998).

A synonymous description is Run to break down.

3.3 Run to destruction

Run to destruction is an alternative method meaning that the object is completely replaced when broken down.

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Examples on board where either of these two methods could be applicable are for redundant circulation pump functions, e.g. in a fresh water system.

Often the three concepts Run to failure, Run to break down and Run to destruction are used interchangeably without the distinction if it is a repair or complete replacement to be performed.

3.4 Planned/Preventive Maintenance

Planned/preventive maintenance can be defined as systematic inspection, detection, correction and prevention of failures before they become actual or major failures.

Planned/preventive maintenance is always time based either by calendar or by the objects actual run-time. The maintenance intervals are mainly based on empirical data of the mean time between failures (MTBF), (Mobley, 1990).

Examples on board where Planned/Preventive maintenance activities are utilised are for propulsion and auxiliary engines.

3.5 Condition Based Maintenance (CBM)

CBM is carried out according to the need indicated by Condition Monitoring (CM).

CM is defined as continuous or periodic measurement and interpretation of data to indicate the condition determine the need for maintenance. The monitoring is carried out when the object is in operation.

An example on board where CBM activities are carried out is a rotating shaft in a turbo charger where e.g. CM according vibration monitoring indicates that there is a need for replacement of a bearing.

3.6 Opportunistic Maintenance

Opportunistic maintenance is carried out for an object when the opportunity is given, often in connection with unplanned activities for other objects in a system when the system is out of operation. It could also be performed in connection with planned activities for other objects.

An example on board is when overhauling a purifier, all wear and tear parts are replaced, despite their actual status at the time for the scheduled overhaul of the main parts.

3.7 Reliability Centred Maintenance, RCM

Reliability Centred Maintenance (RCM) is a methodology where the maintenance activities are planned according a qualitative risk based method in order to find the optimal balance between preventive, condition based or periodic, and corrective maintenance.

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When assessing the maintenance strategy for assets that are part of a technical system their functions and associated performance standards are evaluated.

The assets are categorised in primary and secondary functions and their maintenance activities are structured accordingly.

- Malfunctions are categorised in four categories depending on their consequences.
- Hidden failure consequences
- Safety and environmental consequences
- Operational consequences
- Non-operational consequences

The secondary functions and the non-operational consequences are treated with a less stringent maintenance methodology; some equipment can be classified as Run-to-failure instead of being maintained.

4 Maintenance and Energy Efficiency

4.1 Hull And Propeller Cleaning

Hull and propeller condition have significant impact on fuel consumption. Main reason for that is marine growth on ships hull and propeller. e most visible forms of these fouling are barnacles and shells which reduce vessels efficiency substantially. These marine growths create a rough surface on the hull which increases resistance of the vessel. Therefore extra fuel is being consumed to overcome that resistance and maintain vessels speed. Regular maintenance and cleaning of hull and propeller may help to achieve a cost effective solution for better operational efficiency.

Hull and propeller roughness increases the frictional drag of the vessel, therefore increases fuel consumption. IMO states that hull and propeller cleaning may increase fuel efficiency significantly. Hull cleaning and propeller polishing which reduces fouling and roughness may provide up to 10% savings in fuel consumption. Therefore monitoring performance of the hull and propeller is crucial for operational efficiency.

Modern hull coatings have a smoother and harder surface finish, resulting in reduced friction. Since typically some 50-80% of resistance is friction, better coatings can result in lower total resistance.

Algae growing on the hull increases ship resistance. Frequent cleaning of the hull can reduce the drag and minimise total fuel consumption.

Reduced fuel consumption :

Tanker: Container: PCTC: Ferry: OSV:

~ 3% ~ 2% ~ 2% ~ 2% ~ 0.6%

A modern coating also results in less fouling, so with a hard surface the benefit is even greater when compared to some older paints towards the end of the docking period.

Saving in fuel consumption after 48 months compared to a conventional hull coating:

Tanker: Container: PCTC: Ferry: OSV:

~ 9% ~ 9% ~ 5% ~ 3% ~ 0.6%

Regular in-service polishing is required to reduce surface roughness on caused by propellers of every material organic growth and fouling. This can be done without disrupting service operation by using divers. Up to 10% improvement in service propeller efficiency compared to a fouled propeller.

4.2 Condition Based Maintenance (CBM)

In a CBM system all maintenance action is based on the latest, relevant information received through communication with the actual equipment and on evaluation of this information by experts.

The main benefits are: lower fuel consumption, lower emissions, longer interval between overhauls, and higher reliability.

Correctly timed service will ensure optimum engine performance and improve consumption by up to 5%.

5 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. Darabnia B and Demichela M, 2013 “Maintenance an Opportunity for Energy Saving” ChemicalEngineering Transactions, Vol. 32, 2013. Viewed Dec 2016.
2. Terry Wireman 2011, “Tips on saving energy using preventive maintenance techniques”,

   http://www.pem-mag.com/Features/Tips-on-saving-energy-using-preventive-maintenancetechniques.html#sthash.F31kH9iP.dpuf viewed Dec 2016.
3. Gösta, B. Algelin 2010, “Maritime Management Systems - A survey of maritime management systems and utilisation of maintenance strategies”, Department of Shipping and Marine Technology, Chalmers University Of Technology, Gothenburg, Sweden, 2010. Viewed Dec 2016.

4. Alhouli, Y. 2011 “Development of Ship Maintenance Performance Measurement Framework to Assess the Decision Making Process to Optimise in Ship Maintenance Planning” PhD Thesis, School of Mechanical, Aerospace and Civil Engineering, University of Manchester, 2011. Viewed Dec 2016.
5. “IMO train the trainer course material”, developed by WMU, 2013. Viewed Dec 2016.
6. Maritime Management Systems , A survey of maritime management systems and utilisation of maintenance strategies , Master of Science Thesis , GÖSTA B. ALGELIN, Department of Shipping and Marine Technology CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Sweden, 2010, Master’s Thesis NM-10/3
7. Boosting Energy Efficiency, © Wärtsilä 3 February 2009 Energy Efficiency Catalogue / Ship Power R&D.

Quizzes

Q.1 Which of the following is not related to maritime planned maintenance management philosophy ?

a) Providing required resources
b) Designing and implementation of a management system
c) Employing competent crew
d) Fix-it upon damage
e) Database containing register of all equipment onboard

Q.2 " Marine growths create a rough surface on the hull which .... resistance of the vessel and .... the fuel consumption "

a) Increases / Decreases
b) Increases / Increases
c) Decreases / Decreases
d) Decreases / Increases
e) None of the above

Q.3 " Corrective maintenance is defined as activities undertaken to detect, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to its required function "

1. True
2. False

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Chapter 12 - Energy Efficiency Management and Operational Measures

1 MARPOL Annex VI

1.1 Overview

Ship energy efficiency plays a significant role in field of creating the green shipping now-a-days, especially the world is facing the great problems about the climate changes from enhancement of economics and industrials in parallel with the population explosion.

The reduction of CO2 gas emissions also EEDI index is a great issue that needs to solve from ships. In recent years, the marine industry is gradually developed both the quantity and quality by applying the modern science and technology into the field of ship building and operating. Marine Environment Protection Committee (MEPC) is also given the amendment about Regulations with desire of the climate changes reduction.

The "International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)" keeps the important role in controlling the harmful gasses emissions to the environment from navigation activities. It was adopted in July 2011 and added a new Chapter 4 with Regulations on Energy Efficiency for ships to MARPOL Annex VI through the "Energy Efficiency Design Index (EEDI) for new ships", and "the Ship Energy Efficiency Management Plan (SEEMP) for all ships". On the other hand, Annex VI (MARPOL 73/78) also added the new definitions and the requirements for survey and validated of the formats for "the International Energy Efficiency (IEE) Certificate". Furthermore, the role of new ships energy efficiency managements is very significant so contributing to the later ships operation through EEDI index.

Nowadays, the environmental pollution is the big problem that affects harmfully to the life environment and humans in the earth. The effects have been causing like as acid rain and global warming.

In the field of shipping transportation, IMO "International Maritime Organization" has a mandatory of ensuring the green shipping with reducing fuel consumption on ships and greenhouse gas (GHG) emission, under Annex VI of the harmful gas pollution prevention in "International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)".

According to the "International Maritime Organization's (IMO)" (2010), second greenhouse gas (GHG) study, shipping emitted 1046 million tonnes of CO2 in 2007; about 3.3% of global emissions. For many existing ships, reducing fuel consumption to reduce these types of emissions involves applying operational measures rather than adopting an alternative technology because of the long payback periods associated with new investment.

MEPC 67 (Marine Environmental Protection Committee) approved the Regulations of IMO in 2014, providing the updated emission estimated for greenhouse gasses from ships. Following of the statistics source of CO2 gas emission in the international shipping, there are about 796 million tonnes of CO2 gas emission in 2012, 2.2% of the total global CO2 emissions for that year. In contrast, this figure has been declining slightly. In 2007 before, the international shipping was given out approximately 885 million tonnes of CO2, the proportion of 2.8% of the total CO2 emissions for that year.

The “International Convention for the Prevention of Pollution from Ships”, MARPOL 73/78 gradually applies effectively from then Annex VI with a new Chapter 4 concerns about the ship energy efficiency management for all types of ship includes Bulk Carrier, Gas Carrier, Tanker, Container ship, General Cargo ship, Refrigerated Cargo Carrier, Ro-Ro cargo ship, etc. by providing with the energy efficiency measures: EEDI for new ships and SEEMP for all ships 400 gross tonnages and above.

It is cleared that the calculation and assessment of the ship energy efficiency management play an important role following the MARPOL Convention Annex VI, especially this working is applied to new ships with over 400 gross tonnages.

1.2 Changes to the MARPOL annex VI regulations

In July 2011, IMO has debated for changing the Regulations on ship energy efficiency management. At conference, the delegates have been agreed and decided to the regulations implementation. In particular, the changes were indicated in Table 4.

Resolution MEPC.176(58)	Resolutions MEPC.203(62)&MEPC251(66),…
Chapter I Reg.1 Application Reg.2 Definitions Reg.3 Exceptions and Exemptions Reg.4 Equivalents	Chapter I Reg.1 Application Reg.2 Definitions Reg.3 Exceptions and Exemptions Reg.4 Equivalents
Chapter II Reg.5 Surveys Reg.6 Issue or endorsement of a Certificate Reg.7 Issue of a Certificate by another Party	Chapter II Reg.5 Surveys Reg.6 Issue or endorsement of a Certificate Reg.7 Issue of a Certificate by another Party Reg.8 Form of Certificate

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Reg.8 Form of Certificate Reg.9 Duration and Validity of Certificate Reg.10 Port State Control on Operational Requirements Reg.11 Detection of Violations and Enforcements	Reg.9 Duration and Validity of Certificate Reg.10 Port State Control on Operational Requirements Reg.11 Detection of Violations and Enforcements

(Note: Reprinted from Module 2 – Ship Energy Efficiency Regulations and Related Guidelines, IMO)

Table 4: "Summarizes the existing regulations in Chapters 1 and 2 of MARPOL Annex VI and the ones that were changed (in red colour) to accommodate the energy efficiency regulations".

Regulation 2: "The amendments mainly include definitions for "new ship" as applicable to various phases of EEDI regulations, "major conversion" and "ship types" for which EEDI regulations apply".

Since EEDI only applies to new ships and those ships that undergo major conversions beyond 1 January 2013, the exact definition of the above terms was required. Additionally, terms such as "Attained EEDI" and "Required EEDI" have been defined [3].

Regulation 5: "The requirement for surveys including an initial for newly built ships, a full or partial survey in case of major conversion of existing ships, survey for SEEMP to verify its existence on board ship, etc. are specified in this regulation. This regulation states that EEDI survey and verification shall be carried out according to relevant IMO guidelines".

Regulations 7 and 8: "The changes to these regulations deal with energy efficiency certification, making it mandatory for ships to have an International Energy Efficiency (IEE) Certificate; also emphasizing the responsibility of flag State Administration".

"An International Energy Efficiency Certificate for the ship shall be issued after a survey in accordance with the provisions of regulation 5.4 to any ship of 400 gross tonnages and above, before that ship may engage in voyages to ports or offshore terminals under the jurisdiction of other Parties.

The certificate shall be issued or endorsed either by the Administration or any organization duly authorized by it. In every case, the Administration assumes full responsibility for the certificate." [MEPC Resolution 203(62)]

Regulation 9: "This regulation defines the validity aspects of the IEE certificate. It will be valid for the life of the ship unless otherwise invalidated by a major conversion or change of flag or ship withdrawal for service".

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“The International Energy Efficiency Certificate shall be valid throughout the life of the ship subject to the provisions of paragraph.

An International Energy Efficiency Certificate issued under this Annex shall cease to be valid in any of the following cases if the ship is withdrawn from service or if a new certificate is issued following major conversion of the ship; or upon transfer of the ship to the flag of another State…”[MEPC Resolution 203(62)].

Regulation 10: “This regulation specifies the requirement for Port State Control (PSC) for energy efficiency. Accordingly, the IEE certificate is the starting point for any PSC inspection”.

“In relation to chapter 4, any port State inspection shall be limited to verifying, when appropriate, that there is a valid International Energy Efficiency Certificate on board, in accordance with article 5 of the MARPOL Convention.” [MEPC Resolution 203(62)]

2 Enhancement of Ship Energy Efficiency Regulations and EEDI Concept

“EEDI – The Energy Efficiency Design Index” is an energy efficiency measure tool that applies in the field of shipping transportation with the aim of measuring and evaluating of CO2 gas emission reduction from operation activities on ships such as equipment, engines, and humans. Also, it is an index to assess the effectively equipment using through its value calculation.

On the other hand, International Maritime Organization has also established a series of regulations about managing of ship energy efficiency through EEDI for new ships design, “EEOI (Energy Efficiency Operational Indicator)” for the existing ships operate, and “SEEMP (Ship Energy Efficiency Management Plan)” for all ship with 400 gross tonnages above.

However, the earth’s climate changes rapidly from the development of industries on shore and at sea. CO2 emission control is to be tightened every five years through the MARPOL Regulations in Annex VI, Chapter 4. In the future, EEDI will be expected with the innovation and development of all the components in the field of ship energy efficiency.

The calculation of Attained EEDI and Required EEDI is necessary for assessing and operating the most effective. One side, it determines not only a mass of CO2 gas emission to the environment but also the energy efficiency management on ships. Regulations for the prevention of air pollution from ships (MARPOL 73/78) with adding the new Chapter 4, Annex VI makes a mandatory the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) for all ships.

An amount of CO2 gas emission per ship’s capacity mile needs as small as possible. It leads to the EEDI declining to the significant value, so creating more energy efficient ships [1-5].

The general formula for EEDI calculation is indicated below:

EEDI=CO2 Emissions/Transport Work (1)

Broadly then, EEDI is mainly an amount of CO2 gas emissions from new ships divided by its cargo capacity carrying.

Formula 1 can be expressed following that:

EDDI=Engine Power.SFC.CF/dwt. Speed (g CO2/ton-mile) (2)

In where:

SFC – Specific fuel consumption (g/kWh), represents an amount of fuel used for engines in an hour. The measured value is recorded in NOx Technical file, it is a part of NOx certification;

CF - Carbon factor, It is an amount of CO2 generated per mass of fuel burned. The type of fuel used is corresponding to the NOx Certification (NOx Technical file) and determines the value of the CF conversion factor. Table 1 shows the diversity of fuels corresponding to the difference CF (t-CO2/t-Fuel);

Type of fuel	Reference	Carbon Content	CF (t-CO2/t-Fuel)
Diesel/Gasoil	ISO 8217 Grades DMX through DMB	0.8744	3.206
Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.8594	3.151
Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.8493	3.114
Liquefied Petroleum Gas (LPG)	Propane	0.8182	3.000
	Butane	0.8264	3.030
Liquefied Natural Gas (LNG)		0.7500	2.750
Methanol		0.3750	1.375
Ethanol		0.5217	1.913

(Note: Reprinted from Module 2 - Ship Energy Efficiency Regulations and Related Guidelines, IMO)

Table 1: The CF (t-CO2/t-Fuel) certain value at each type of fuels.

DWT – Dead Weight Tonnage, It is a capacity of vessel that carries full load, Following EEDI formula, with respect of 100% DWT for all ships but container ship is 70% DWT (Table 1).

(Note: Reprinted from Module 2 - Ship Energy Efficiency Regulations and Related Guidelines, IMO, retrieved)

$$\frac{(\prod_{j=1}^{M} f_j)(\sum_{i=1}^{nME} P_{ME(i)}.C_{FME(i)}.SFC_{ME(i)}) + (P_{AE}.C_{FAE}.SFC^*_{AE}) + ((\prod_{j=1}^{M} f_j.\sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)}.P_{AEeff(i)})C_{FAE}.SFC_{AE}) - (\sum_{i=1}^{neff} f_{eff(i)}.P_{eff(i)}.C_{FME}.SFC_{ME})}{f_i.Capacity.V_{ref}.f_w}$$

The formula (3) is described and divided into parts separately for the (1), in detail:

$$(\prod_{j=1}^{M} f_j)(\sum_{i=1}^{nME} P_{ME(i)}.C_{FME(i)}.SFC_{ME(i)})$$

Main Engines Emissions

$$(\ P_{AE}.C_{FAE}.SFC^*_{AE}\ ):)$$

Auxiliary Engines Emissions

$$(\prod_{j=1}^{M} f_j.\sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)}.P_{AEeff(i)})C_{FAE}.SFC_{AE}) :$$

Shaft Generators/ Motors Emissions

fi Capacity . *Vreffw*: Efficiency Technologies

fi Capacity . *Vreffw*: Transport work

EEDI = (CO2 from Propulsion system + CO2 from Auxiliary – CO2 emission reduction)/ DWT. Speed

In where:

PME: Main Engine Power (kW);

PAE: Auxiliary Engine Power (kW);

SFC: Specific fuel consumption (g/kW);

C: Fuel to CO2 factor (g CO2/ g Fuel) (nearly 3);

Capacity: for Cargo ships DWT, for Passenger ships GT;

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Vref: Reference speed (nm/hour);

fi: Correction factor for capacity;

fw: Correction factor for performance in real weather;

fi: Correction factor for efficiency.

i. EEDI reference line: “The EEDI Reference line (EEDI Baseline) for each type of ship is defined as a curve representing an average index value fitted on a set of individual index values for a defined group of ships”. Its curve is described in Figures 1 and 2.

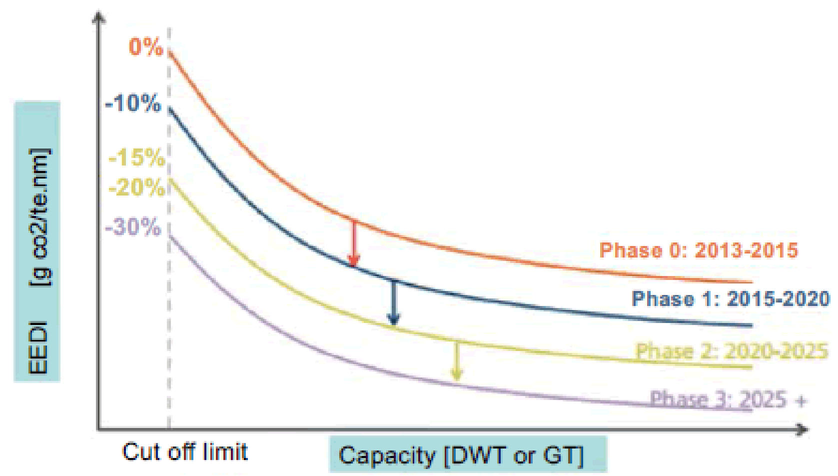

Figure 1: Concept of Required EEDI, reduction factor, cut off limits and EEDI Phases, Note: Reprinted from Module 2 - Ship Energy Efficiency Regulations and Related Guidelines, IMO.

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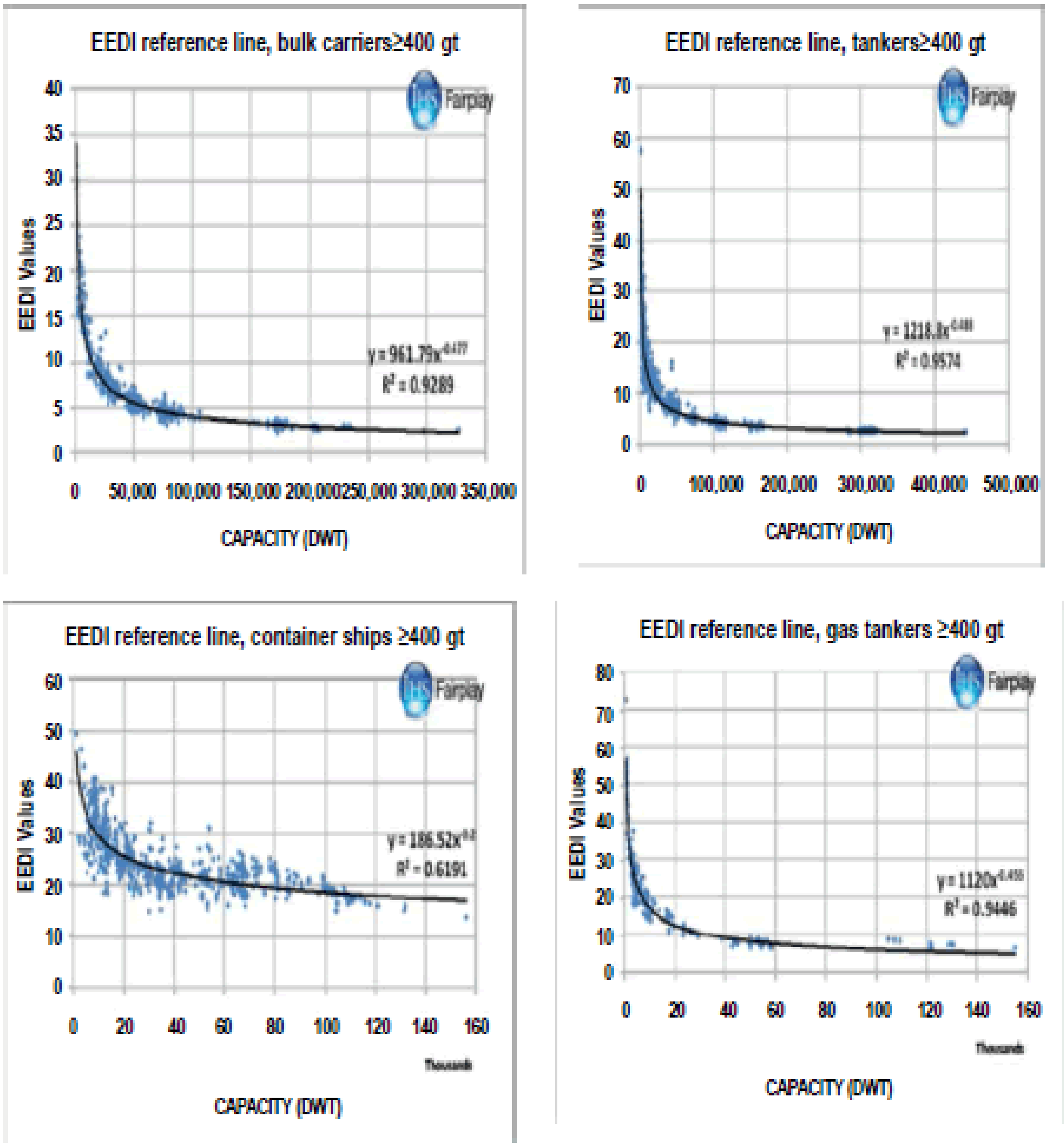

Figure 2: EEDI Reference Lines as developed by the IMO using techniques in Resolution MEPC.231(65)) Note: Reprinted from Module 2 - Ship Energy Efficiency Regulations and Related Guidelines, IMO.

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Each Reference EEDI line was drawn by collecting the different sources of data, data quality checks, a number and type of ships selected, year of ship built, etc. All of them are described in relevant IMO Guidelines (Resolution MEPC.231(65) and MEPC.233(65)). In then, Reference EEDI formula is detail described below:

Reference EEDI = a*b-c (4)

Where: a, b and c are constant determined from the Table 2.

Ship type defined in Regulation 2	a	b	c
Bulk Carrier	961.79	DWT	0.477
Gas Carrier	1120.00	DWT	0.456
Tanker	1218.80	DWT	0.488
Container ship	174.22	DWT	0.201
General cargo ship	107.48	DWT	0.216
Refrigerated cargo carrier	227.01	DWT	0.244
Combination carrier	1219.00	DWT	0.488
Ro-Ro cargo ship (vehicle carrier)	(DWT/GT)-0.7x780.36 where DWT/GT <0.3	DWT	0.471
	1812.63 where DWT/GT^{3}0.3		
Ro-Ro cargo ship	1405.15	DWT	0.498
Ro-Ro passenger ship	752.16	DWT	0.381
LNG carrier	2253.7	DWT	0.474
Cruise passenger ship having non-conventional propulsion	170.84	DWT	0.214

(Note: Reprinted from Module 2 - Ship Energy Efficiency Regulations and Related Guidelines, IMO)

Table 2: Parameters for determination of EEDI Reference value [Resolutions MEPC.203(62) and MEPC. 251(66)].

ii. EEDI reduction factor (X): It presents the percentage of EEDI reduction relative to EEDI baseline. The value of "reduction factor" is decided by International Maritime Organization (IMO). Its certain value is indicated in Table 3.

Ship Type	Size	Phase 0	Phase 1	Phase 2	Phase 3

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		1Jan 2013-31 Dec 2014	1 Jan 2015 – 31 Dec 2019	1 Jan 2020 – 31 Dec 2024	1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 DWT and above	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000-10,000DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000-15,000DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000-5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000-20,000DWT	n/a	0-10*	0-20*	0-30*

LNG carrier***	10,000 DWT and above	n/a	10**	20	30
Ro-Ro cargo ship (vehicle carrier)***	10,000 DWT and above	n/a	5**	15	30
Ro-Ro cargo ship***	2,000 DWT and above	n/a	5**	20	30
	1,000-2,000 DWT	n/a	0-5*, **	0-20*	0-30*
Ro-Ro passenger ship***	1000 DWT and above	n/a	5**	20	30
	250-1,000 DWT	n/a	0-5*, **	0-20*	0-30*
Cruise passenger ship*** having non-conventional propulsion	85,000 GT and above	n/a	5**	20	30
	25,000-85,000 GT	n/a	0-5*, **	0-20*	0-30*

(Note: n/a, it means no required EEDI applies; * Reduction factor is linearly interpolated between the two values dependent on the ship size. ** Phase 1 is applied to all ships on September, 1st – 2015 *** Reduction factor is applied to the ships after September, 1st – 2019)

Table 3: EEDI reduction factors, cut off limits and implementation phases [Resolutions MEPC.203(62) and MEPC.251(66)].

(Note: Reprinted from Module 2 – Ship Energy Efficiency Regulations and Related Guidelines, IMO)

iii. Required EEDI calculation formula: The Required EEDI is identified base on the reduction factor X for the ship that depends on year of ship built (Table 3) and value of Reference EEDI in formula (4). So, the relationship between these parameters will determine the Required EEDI value through formula (5):

Required EEDI = (1-X/100)* (Reference EEDI) (5)

In where:

X: Reduction rate;

Required EEDI: The EEDI limit value for each ship, in fact the Attained EEDI must be smaller than Required EEDI.

Attained EEDI ≤ Required EEDI

In where:

Attained EEDI, This value is determined by calculation and then ship has just newly built. Moreover, the Regulations also added for the Required EEDI following:

• "If the design of a ship allows it to fall into more than one of the above ship type definitions, the required EEDI for the ship shall be the most stringent (the lowest) required EEDI".

• "For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization".

• "At the beginning of Phase 1 and at the midpoint of Phase 2, the IMO shall review the status of technological developments and, if proven necessary, amend the time periods, the EEDI reference line parameters for relevant ship types and reduction rates set out in this regulation".

3 Survey and Verification

3.1 EEDI Verification

EEDI verification is conducted in accordance with "2014 Guidelines on survey and certification of the energy efficiency design index (EEDI)" (IMO Resolution MEPC.254(67), as amended) and "Industry Guidelines", through two steps: preliminary verification at the design stage and final verification during sea trials.

In addition, if a ship is equipped with innovative energy efficiency technologies (e.g. air lubrication system, waste heat recovery system), relevant verification will be carried out in accordance with "2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI" (IMO MEPC.1/Circ.815).

The basic flow of the EEDI verification process is shown in below figure :

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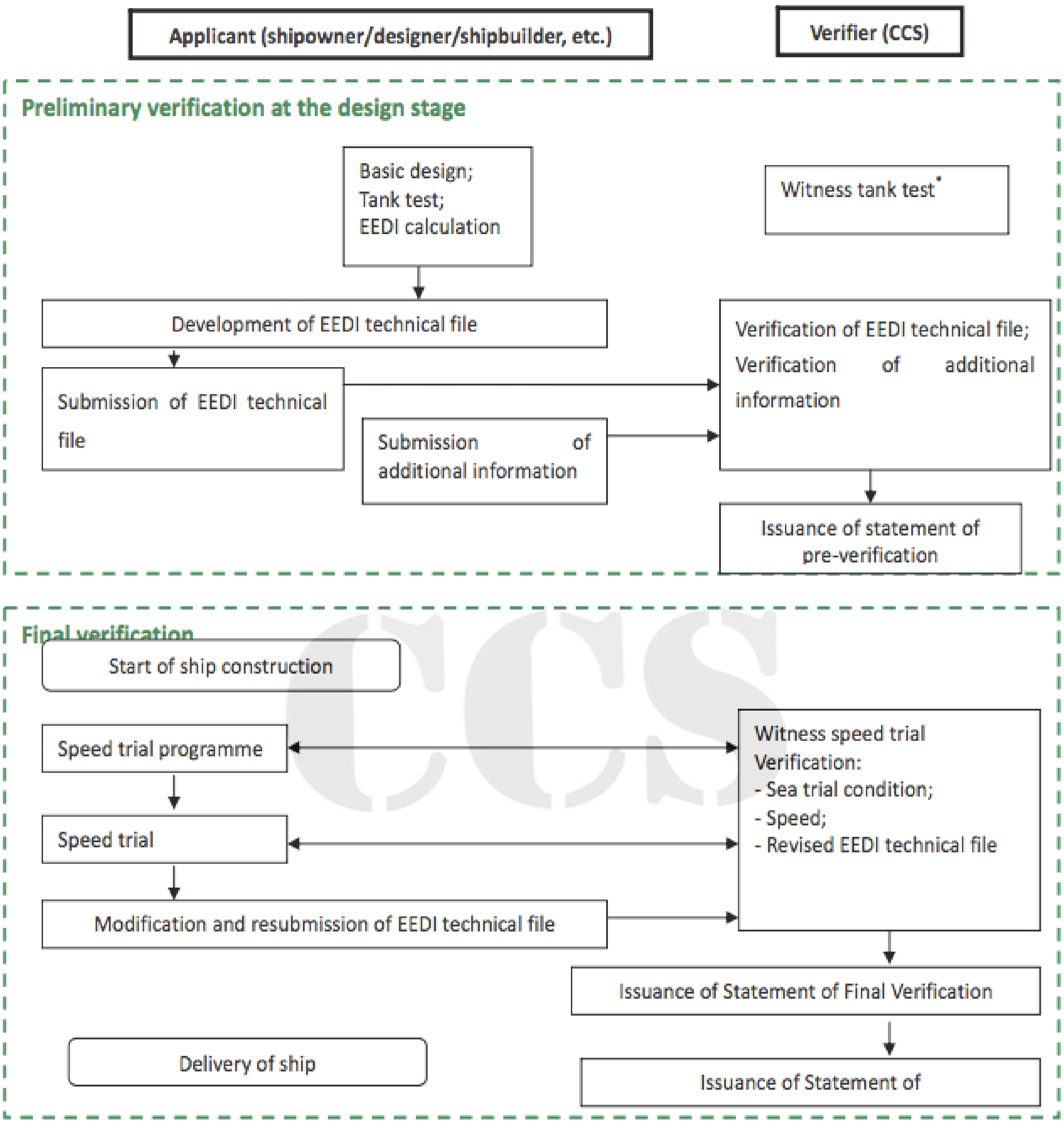

Fig.12.1 Verification Procedure

<u>(1) Procedure of preliminary verification of EEDI</u>

(i) Review of the tank test plan

(ii) Witnessing of the tank tests

Surveyor of Class service site having jurisdiction over the tank test facility attends the tank tests according to the test plan, and confirms the following items, in principle.

(a) Quality control of the tank test facility

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(b) Ship model: Manufacturing accuracy

(c) Propeller Model: Manufacturing accuracy

(d) Calibration records of measuring equipment

(e) Draught at the resistance test and self-propulsion test

(f) Measurement items of resistance test, self-propulsion test and propeller open water test

(iii) Document review

The Class EEDI Department will review the calculation process used for determining the Attained EEDI, which is calculated using a power curve (the relationship between ship speed and main engine output) estimated under the EEDI Condition and principal particulars of the ship, in order to verify the results for the design stage based on the EEDI Technical File and Additional Information.

(iv) Issuance of preliminary verification report

A preliminary verification report will be issued by Class after the completion of the preliminary verification of EEDI at design stage. * A tank test for an individual ship may be omitted in the following cases:

(a) The results of tank tests for ships of the same type are available;

(b) Required EEDI is not applied;

(c) Speed trials are conducted under the EEDI Condition; or

(d) Other cases may be omitted based on suitable technical justifications

Note:

In cases where the tank tests will be carried out at the time of the planning stage of ship construction before making a class entry application, Class can conduct a preliminary verification of EEDI for the proposed ship as an appraisal service instead of as a statutory survey.

<u>(2) Procedure of final verification of EEDI</u>

(i) Review of the Sea Trial procedure

(ii) Witnessing of the sea trial

A Surveyor of the Class service site having jurisdiction over the shipbuilder will attend the sea trial, and confirm the following items for EEDI verification in principle:

(a) propulsion and power supply system, particulars of the engines, and other relevant items described in the EEDI Technical File;

(b) speed trial conditions, including weather conditions, sea conditions, draught, trim and displacement; and

(c) ship speed and output of the main engine.

(iii) Confirmation of Attained EEDI

The relevant data measured during the speed trials is to be confirmed and the correction process for the Attained EEDI is to be verified. Specifically, it is to be confirmed that the reference ship speed (Vref), normally the ship speed at 75% MCR power under EEDI Condition, is determined based on the power curves developed by the results of speed trial and speed correction.

(iv) Approval of EEDI Technical File The final EEDI Technical File is to be confirmed and approved by the Class service site.

Documents to be submitted for EEDI verification

(1) Documents to be submitted

The minimum necessary number of documents and location where they are to be submitted are as follows.

(i) Preliminary verification

(a) Tank tests plan

(b) EEDI Technical File

(c) Additional Information

(ii) Final verification

(a) Procedure of Sea Trial

(b) Results of Speed trial

(c) EEDI Technical File (Final)

(iii) Other documents

(a) NOx Technical File (for confirmation of SFC)

(b) Results of lightweight measurements (for confirmation of deadweight)

(2) Items to be included in the EEDI Technical File

(i) Basic data such as deadweight/gross tonnage, maximum continuous ratings of the main and auxiliary engines, estimated ship speed, specific fuel consumptions of the main and auxiliary engines;

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(ii) Estimated power curves under the fully loaded condition and sea trial condition;

(iii) Principal particulars of the propulsion system and electric power supply system on board;

(iv) Estimation process and methodology for determining power curves;

(v) Description of energy saving equipment;

(vi) Calculated value of Attained EEDI;

(vii) Calculated values of attained EEDI weather and fw values (not equal to 1.0), if those values are calculated; and

(viii) For LNG carriers, relevant data required.

(3) Documents to be submitted as Additional Information

(i) Description of tank test facility;

(ii) Lines of the model ship and actual ship;

(iii) Lightweight of the ship and displacement table;

(iv) Detailed report on the method and results of the tank tests;

(v) Detailed calculation process for determining the ships speed, which includes the way to estimate the power curves;

(vi) Technical justifications for exempting tank test (in cases where the tank test is exempted);

(vii) For LNG carriers, detailed calculation process of auxiliary engine power (PAE) and specific fuel consumption for steam turbine (SFCSteamTurbine) ; and

(viii) Other documents as deemed necessary.

3.2 Details of survey regarding SEEMP

Although the SEEMP itself needs not be approved by the Administration or Classification Society under the revised MARPOL ANNEX VI, it is to be retained onboard. During the Initial Survey, the following items are to be confirmed regarding the SEEMP.

(1) Confirmation items

(i) The ship specific SEEMP is provided onboard.

(ii) The SEEMP is established in a working language or languages understood by ships personnel.

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(iii) The SEEMP is developed taking into account "2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP)" (IMO Resolution MEPC.213(63)), and at least, the following items are included:

(a) Energy efficiency improvement measures (representative example of the measures are presented in chapter 5 of IMO Guidelines, e.g. weather routeing, speed optimization, etc.);

(b) Monitoring methods for energy efficiency;

(c) Measurable goals for energy efficiency; and

(d) Procedures of evaluation.

4 Ship Energy Efficiency Management Plan (SEEMP) Development Guidelines

"SEEMP - The Ship Energy Efficiency Management Plan" is given out by IMO in aims with energy efficiency management for all ships 400 gross tonnages above. Its function is absolutely useful for assessing and improving the existing ships that is operating on international shipping. After finishing the Kyoto conference in 1997, "SEEMP" and "EEOI" are standard component for managing the ships on the international routes that observe the Regulations related to the environmental protection.

Moreover, "The Marine Environment Protection Committee" was held on March, February, 2012, adopted the guidelines in aims with implementation for "the Energy Efficiency Design Index – EEDI" and " the Ship Energy Efficiency Management Plan - SEEMP" component.

The guidelines are adopted the following as:

• "Guidelines for the calculation of the Attained EEDI for new ships"

• "Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)"

• "Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)"

• "Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI)"

4.1 Scope and Application

These SEEMP Guidelines provide the advice of SEEMP development as stated inRes.MEPC.213(63) '2012 Guidelines For The Development Of A Ship Energy Efficiency Management Plan (SEEMP)'.

These SEEMP guidelines are to be applied for ships of 400 GT and above for both new and existing ships,whereas each ship will be required to keep SEEMP on board.

The SEEMP is one of the IMO's new mandatory instruments in line with the efforts to reduce greenhouse gases emitted by shipping activities and will be part of new chapter 4 of MARPOL Annex VI under regulation 22, entering into force on 1 January 2013.

For Existing ship, SEEMP is required to be carried on board not later than the first intermediate or renewal survey of the IAPP Certificate, whichever occurs first, on or after 1 January 2013.

The lack of a SEEMP on board during the first intermediate/renewal survey of the IAPP Certificate does not impact the validity of the IAPP Certificate.

SEEMP will be necessary for issuing of the International Energy Efficiency Certificate (IEEC).

4.1.1 Purposes of SEEMP

The purpose of a SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation. Preferably, the ship-specific SEEMP is linked to a broader corporate energy management policy for the company that owns, operates or controls the ship, recognizing that no two shipping companies or shipowners are the same, and that ships operate under a wide range of different conditions.

4.1.2 Development of SEEMP

4.1.2.1 General

SEEMP presents a key tool of Continous Improvement Process (CIP), which allows a systematic, structured and cost effective optimization of the ship's operation, and ensures improvement of effectiveness.A SEEMP is recommended to be developed by a company to manage the on-going environmental performance of its vessels. Itssuccessful implementation would include four main key areas for development of SEEMP :

- **Planning**
- **Implementation**
- **Monitoring**
- **Self Evaluation and Improvement**

Those components play a critical role in the continous cycle to improve ship energy efficiency management, as shown in fig.1. With each iteration of the cycle, some elements of the SEEMP will necessarily change while others may remain as before.

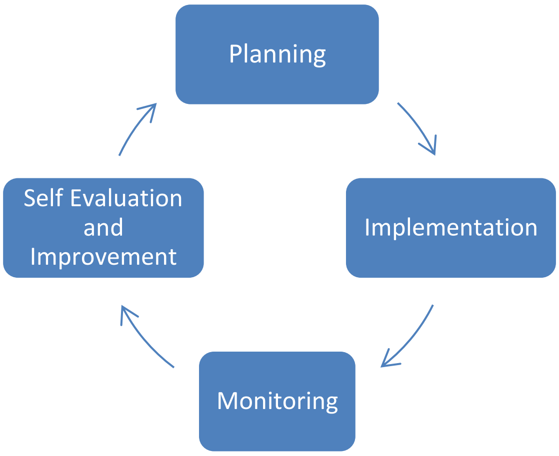

figure.1

4.1.2.2 Application of SEEMP

➢ **Planning**

Planning is the most crucial first step of the SEEMP, in that it primarily determines both the current status of ship energy usage and the expected improvement of ship energy efficiency.The ship owner is required to review current practices and energy usage onboard each ship with a view to determining any shortfalls or areas for improvement of energy efficiency. This stage should be identified as various aspects relating to:

- ***Ship-specific measures:***It is important to determine and understand the ship's current status of energy usage. Special consideration should be given to the ship specific measures as the measures differ to a great extent depending upon ship type, cargoes, routes and other factors. The SEEMP identifies energy-saving measures that have been undertaken and determines effectiveness of these measures.
  There are variousoptions to improve ship efficiency, as for example speed optimization, weather routing, hull maintenance, machinery operation etc.
- ***Company-specific measures:*** The improvement of energy efficiency of ship operation does not necessarily depend on the single ship management only. Rather improvement of better coordination and communication among stakeholders, like operators, ports and traffic management service to achieve 'just in time' operation,is better made by company ratherthan by a ship. As for example, early communication among operators, ports and traffic management service would help in optimizing ship speed and in 'just in time' arrival.
- ***Human resource development:*** By raising awareness and providing training for personnel both onshore and onboard, the effective and steady implementation of the adopted measures may be achieved.
- ***Goal setting:***The goal setting is voluntary.The goal can take any form, such as the annual fuel consumption or a specific target of Energy Efficiency Operational Indicator (EEOI). The goal should be measurable and easy to understand. Neither a company nor a ship is subject to external inspection. The purpose of goal setting is to

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serve as a signal which involved people should be conscious of, to create a good incentive for proper implementation, and then to increase commitment to the improvement of energy efficiency.

- **Implementation**
  - **Establishment of implementation system**
    A ship and a company have to identify the measures to be implemented and establish a system for implementation of the identified and selected measures by developing the procedures for energy management, by defining tasks and by assigning them to qualifiedpersonnel. The development of such a system can be considered as a part of planning, and therefore may be completed at the planning stage.
  - **Implementation and record-keeping**
    Predetermined implementation system is to be developed to ensure that the planned measures are carried out satisfactorily. Record-keeping for the implementation of each measure is beneficial for self-evaluation at a later stage. Reasons of failure to implement the identified measures to be recorded for internal use.

- **Monitoring**
  - **Monitoring tools**
    The EEOI could be considered as the primary monitoring tool and should be calculated in accordance with the Guidelines developed by the Organization (MEPC.1/Circ.684). In addition to the EEOI, if convenient and/or beneficial for a ship or a company, other measurement tools can be utilized.
  - **Establishment of monitoring system**
    To allow for meaningful and consistent monitoring, the monitoring system, including the procedures for collecting data and the assignment of responsible personnel, should be developed. The monitoring should be carried out as far as possible by shore staff, utilizing data obtained from existing required records such as the official and engineering log-books and oil record books, etc.

- **Self-evaluation and improvement**

This phase should produce meaningful feedback for the coming first stage, i.e. planning stage of the next improvement cycle. The purpose of self-evaluation is to evaluate the effectiveness of the planned measures and of their implementation. It would help in ascertaining which measure functions effectively and the reason thereof to develop improved SEEMP cycle.

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5 Energy Efficiency Operational Indicator (EEOI)

5.1 Introduction

The EEOI developed by the Organization is one of the internationally established tools to obtain a quantitative indicator of energy efficiency of a ship and/or fleet in operation, and can be used for this purpose. Therefore, EEOI could be considered as the primary monitoring tool, although other quantitative measures also may be appropriate.

The Energy Efficiency Operational Indicator (EEOI) is a monitoring tool for managing ship and fleet efficiency performance over time. The EEOI enables operators to measure the fuel efficiency of a ship in operation and to gauge the effect of any changes in operation, e.g. improved voyage planning and more frequent propeller cleaning, or the introduction of technical measures such as waste heat recovery systems or a new propeller.

If used, the EEOI should be calculated in accordance with the guidelines developed by the Organization. If deemed appropriate, a Rolling Average Index of the EEOI values may be calculated to monitor energy efficiency of the ship over time.

5.2 Establishing the EEOI

The EEOI provides a specific figure for each voyage. The unit of EEOI depends on the measurement of cargo carried or the transport work done, e.g., tonnes CO_2/(tonnes/nautical miles), tonnes CO_2/(TEU/nautical miles) or tonnes CO_2/(person/nautical miles), etc. The EEOI is calculated by the following formula, in which a smaller EEOI value means a more energy efficient ship [6]:

$$EEOI = \frac{actual\_CO_2\_emission}{performed\_transport\_work} \qquad (1)$$

The EEOI for a voyage is calculated as follows:

$$EEOI = \frac{\sum_j FC_j \cdot C_{FJ}}{m_{cargo} \cdot D} \qquad (2)$$

For a number of voyages or voyage legs, the indicator is expressed as presented below:

$$Average\_EEOI = \frac{\sum_i \sum_j FC_{ij} \cdot C_{Fj}}{\sum_i m_{cargo,i} \cdot D_i} \qquad (3)$$

Where :

- *j* is the fuel type ,
- *i* is the voyage number ,
- - *FC i j* is the mass of consumed fuel *j* at voyage *i*;
- - *CFj* is the fuel mass to CO_2 mass conversion factor for fuel *j*;
- - *M*cargo is cargo carried (tonnes) or work done (number of TEU or passengers) or gross tonnes for passenger ships; and
- - *D* is the distance in nautical miles corresponding to the cargo carried or work done.

The actual CO_2 emission represents total CO_2 emission from combustion of fuel on board a ship during each voyage, which is calculated by multiplying total fuel consumption for each type of fuel (distillate fuel, refined fuel or LNG, etc.) with the carbon to CO_2 conversion factor for the fuel(s) in question (fixed value for each type of fuel). C_F is a non-dimensional conversion factor between fuel consumption measured in g and CO_2 emission also measured in g based on carbon content. The value of C_F is as follows:

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1. Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206000
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151040
3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114400
4. Liquified Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000000 3.030000
5. Liquified Natural Gas (LNG)		0.75	2.750000

The performed transport work is calculated by multiplying mass of cargo (tonnes, number of TEU/cars, or number of passengers) with the distance in nautical miles corresponding to the transport work done.

Rolling average, when used, can be calculated in a suitable time period, for example one year closest to the end of a voyage for that period, or number of voyages, for example six or ten voyages, which are agreed as statistically relevant to the initial averaging period. The Rolling Average EEOI is then calculated for this period or number of voyages by Equation 3

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above.

5.3 Finding the optimum EEOI , example

This study applies the comparative analyses by varying some of the voyage parameters in order to obtain the optimum EEOI. The voyage parameters that influence the value of the Energy Efficiency Operational Index are:

- the distance sailed as recorded in the ship's Bridge Log Book,
- the cargo mass as per Bill of Lading and Deck Log Book and
- the fuel consumption as recorded in Engine Log Book.

The characteristics of the vessel considered for this study: a handy size type, Chemical Tanker, 38000 DWT, equipped with the following main consumers: a MAN B&W 6S50MC-C Main Engine (ME) of 9480KW at 127RPM, three Wartsila Auxpac 975W6L20 Diesel Generator (DG) Sets of 975KW and 900RPM and Saacke KLN/VIC 16/10 / 16t/h Auxiliary Boiler (AB).

The program emphasizes the variation of the EEOI while reducing the speed of the vessel from 14 knots to 10 knots and also by changing the voyage parameters: manoeuvrings, anchoring or ballast voyage days (having different consumption for the main engine, diesel generators or auxiliary boilers).

An xls analysis for EEOI optimization - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Voyage Leg	Consumers	Days	Speed 14 kt	Days	Reduced Speed 13 kt	Days	Reduced Speed 12 kt	Days	Reduced Speed 11 kt	Days	Reduced Speed 10 kt	Increased cargo quantity	Days	Increased distance loaded	Days	Decreased distance ballast	Days	Berth on arrival No anchor	Days	Load/ Discharge at full rate	Days	"Perfect" voyage
2	Anchor	DG Iddle	3.0	7.5	3.0	7.5	3.0	7.5		7.5	3.0	7.5	7.5	3.0	7.5	3.0	7.5	0.0	0.0		7.5	0.0	0.0
3		AB Iddle		6.0		6.0		6.0	3.0	6.0		6.0	6.0		6.0		6.0		0.0	3.0	6.0		0.0
4	Maneuver	ME Maneuver	0.2	3.6	0.2	3.6	0.2	3.6		3.6	0.2	3.6	3.6	0.2	3.6	0.2	3.6	0.2	3.6		3.6	0.2	3.6
5		DG Maneuver		0.8		0.8		0.8	0.2	0.8		0.8	0.8		0.8		0.8		0.8	0.2	0.8		0.8
6	Loading	DG Iddle	3.0	7.5	3.0	7.5	3.0	7.5		7.5	3.0	7.5	7.5	3.0	7.5	3.0	7.5	3.0	7.5	0.6	1.5	0.6	1.5
7		AB Iddle		6.0		6.0		6.0	3.0	6.0		6.0	6.0		6.0		6.0		6.0		1.2		1.2
8	Maneuver	ME Maneuver	0.2	3.6	0.2	3.6	0.2	3.6		3.6	0.2	3.6	3.6	0.2	3.6	0.2	3.6	0.2	3.6	0.2	3.6	0.2	3.6
9		DG Maneuver		0.8		0.8		0.8	0.2	0.8		0.8	0.8		0.8		0.8		0.8		0.8		0.8
10	Loaded Voyage	ME at sea	18.8	637.5	20.2	605.8	21.9	568.8	23.9	536.9	26.3	525.0	637.5	24.7	839.9	18.8	637.5	18.8	637.5	18.8	637.5	34.6	691.7
11		DG at sea	18.8	46.9	20.2	50.5	21.9	76.6	23.9	83.5	26.3	91.9	46.9	24.7	61.8	18.8	46.9	18.8	46.9	18.8	46.9	34.6	121.0
12		AB at sea	18.8	0.0	20.2	0.0	21.9	6.6	23.9	16.7	26.3	26.3	0.0	24.7	0.0	18.8	0.0	18.8	0.0	18.8	0.0	34.6	34.6
13	Anchor	DG Iddle	10.0	25.0	8.6	21.4	6.9	17.2	4.9	12.2	2.5	6.3	25.0	10	25.0	10.0	25.0	0.0	0.0	10.0	25.0	0.0	0.0
14		Boiler Iddle	10.0	20.0	8.6	17.1	6.9	13.8	4.9	9.8	2.5	5.0	20.0	10	20.0	10.0	20.0	0.0	0.0	10.0	20.0	0.0	0.0
15	Maneuver	ME Maneuver	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2
16		DG Maneuver		1.6		1.6		1.6		1.6		1.6	1.6		1.6		1.6		1.6		1.6		1.6
17	Discharge	DG Discharge	3.0	16.8	3.0	16.8	3.0	16.8	3.0	16.8	3.0	16.8	16.8	3.0	16.8	3.0	16.8	3.0	16.8	0.6	4.2	0.6	4.2
18		AB Iddle		6.0		6.0		6.0		6.0		6.0	6.0		6.0		6.0		6.0		1.2		1.2
19	Maneuver	ME Maneuver	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2	0.4	7.2
20		DG Maneuver		1.6		1.6		1.6		1.6		1.6	1.6		1.6		1.6		1.6		1.6		1.6
21	Anchor	DG Iddle	5.0	12.5	5.0	12.5	5.0	12.5	5.0	12.5	5.0	12.5	12.5	5.0	12.5	5.0	12.5	0.0	0.0	5.0	12.5	0.0	0.0
22		AB Iddle		10.0		10.0		10.0		10.0		10.0	10.0		10.0		10.0		0.0		10.0		0.0
23	Ballast Voyage	ME at sea	2.8	79.8	3.0	75.6	3.2	70.7	3.5	66.6	3.2	54.6	79.8	2.8	79.8	0.1	2.6	2.8	79.8	2.8	79.8	0.1	2.6
24		DG at sea	2.8	6.9	3.0	7.4	3.2	11.2	3.5	12.3	3.2	11.2	6.9	2.8	6.9	0.1	0.2	2.8	6.9	2.8	6.9	0.1	0.2
25		AB at sea	2.8	0.0	3.0	0.0	3.2	1.0	3.5	2.5	3.2	3.2	0.0	2.8	0.0	0.1	0.0	2.8	0.0	2.8	0.0	0.1	0.0
26	Fuel consumption		[T]	914.8		876.5		864.4		839.1		822.1	914.8		1132.1		830.9		833.8		886.6		884.6
27	CO2/1000000		[T]	2849		2730		2692		2613		2560	2849		3526		2588		2597		2761		2755
28	Cargo		[T]	30000		30000		30000		30000		30000	38000		30000		30000		30000		30000		38000
29	Distance Loaded		[Nm]	6300		6300		6300		6300		6300	6300		8300		6300		6300		6300		8300
30	Distance Ballast		[Nm]	925		925		925		925		925	925		925		30		925		925		30
31	EEOI			15.07		14.44		14.24		13.83		13.55	11.90		14.16		13.69		13.74		14.61		8.73

EEOI Calculation | Consumptions

Fig.3 The program interface

The variation of the EEOI was studied for the following situations that can occur during the voyage:

A. Increasing the quantity of cargo,
B. Increasing the length of the loaded voyage,
C. Decreasing the length of the ballast voyage,
D. Avoiding idle time,
E. Loading /discharging at full rate, and
F. The “perfect” voyage.

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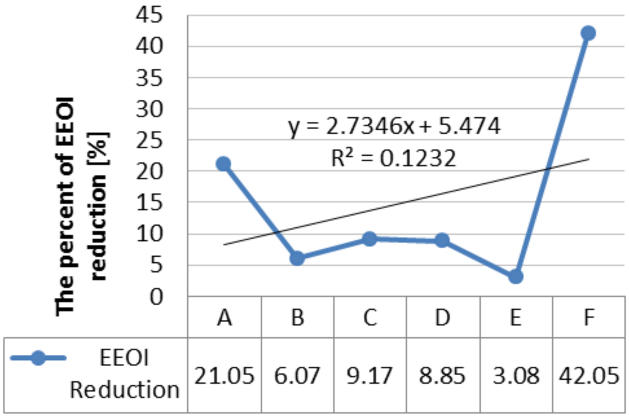


Fig.4 The percent of the EEOI reduction for the A-F situations related to the initial case

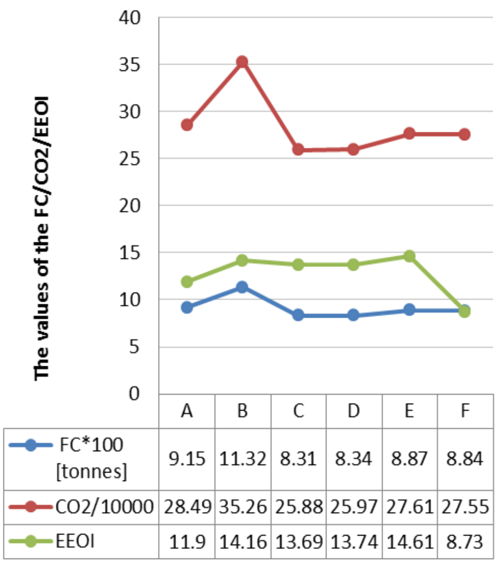
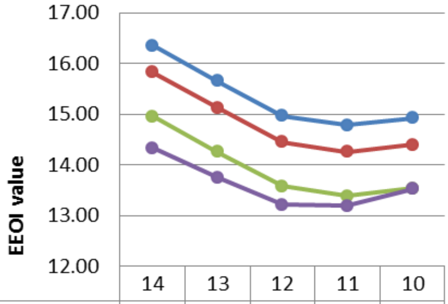


Fig.5 The variation of the voyage parameters for the A-F situations, Fuel consumption/ CO_2/ Energy Efficiency Operational Index

The next graphic shows the changes in EEOI values in terms of speed reduction from 14 to 10 knots, if the ship has loaded the same quantity of cargo (30000 tonnes), the number of the days in port decreased from 12 to 2.8, berthing on fixed date or on arrival.



	14	13	12	11	10
Initial situation	16.35	15.65	14.97	14.78	14.92
decreasing the number of days	15.83	15.13	14.45	14.26	14.4
berthing on fixed date	14.96	14.26	13.58	13.39	13.54
berthing on arrival	14.33	13.75	13.21	13.19	13.53

Fig.6 The variation of the EEOI in terms of speed reduction

As per figure above, the minimum value of the EEOI suppose the ship to maintain a medium speed and also to avoid spending time for anchoring.

Analysing the variation of Energy Efficiency Operational Index with respect to different voyage parameters it could be noticed that the most preferred parameters that result in major favourable changes in its quantum are: increasing the quantity of cargo transported maintaining same route and decreasing the fuel consumption maintaining a medium speed. The greatest reduction of the EEOI, excepting the “perfect voyage”, 21.05% was obtained for increasing the quantity of the cargo for the same route.

6 References

1 IEA, Reducing Greenhouse Gas Emissions the potential coal, International Energy Agency, 2005

2 IMO, Second IMO GHG Study, MEPC 59/INF.10, 2009

3 Danish Ship-owners Association, Network for Transport and Environment, Sweden, 2009

4 IMO, Guidance for the development of a ship energy efficiency management plan, SEEMP, MEPC 59/24/Add.1, ANNEX 19, 2012

5 IMO, Guidelines for voluntary use of the ship energy efficiency operational indicator, EEOI, MEPC.1/Circ.684 2009

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6 IMO, Interim guidelines for voluntary ship CO2 emission indexing for use in trials, MEPC.1/Circ.471.CO2, 2005

7 The Energy Efficiency Operational Index – An instrument for the Marine Pollution Control

7 Further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

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Quizzes

Q.1 Which of the following is <u>not</u> enough itself to identify the energy efficiency of a vessel ?

a) Attained EEDI
b) EEOI
c) Required EEDI
d) Fuel Consumption
e) IEEC

Q.2 Which of the following is <u>not</u> mandatory while preparing SEEMP ?

a) Determination of current ship energy usage
b) EEOI Goal setting
c) Ship-Specific Measures
d) Company-Specific Measures
e) Raising awareness and providing training for crew

Q.3 " A smaller EEOI value means a more energy efficient ship "

1. TRUE
2. FALSE

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Chapter 13 - Environmental Concerns and IMO Response

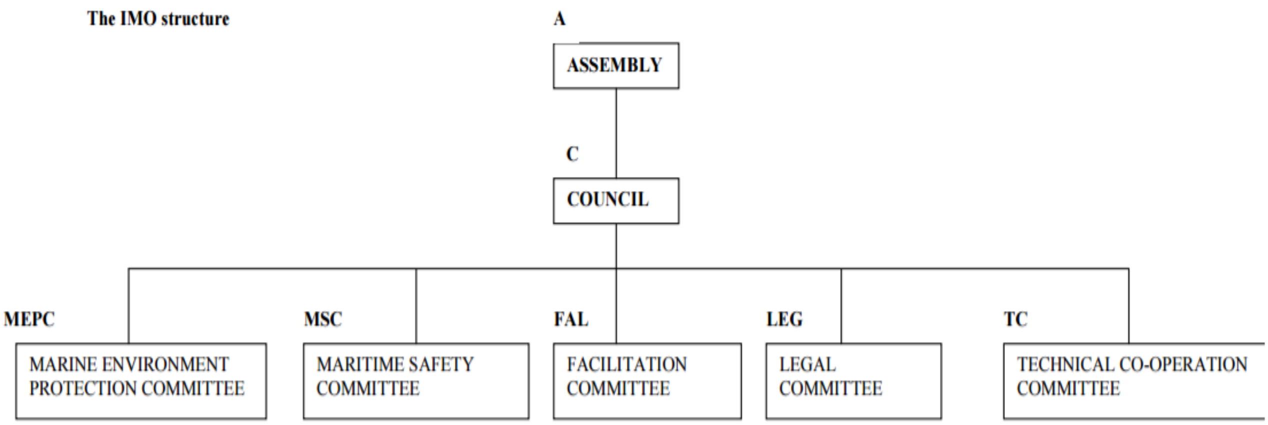
Summary

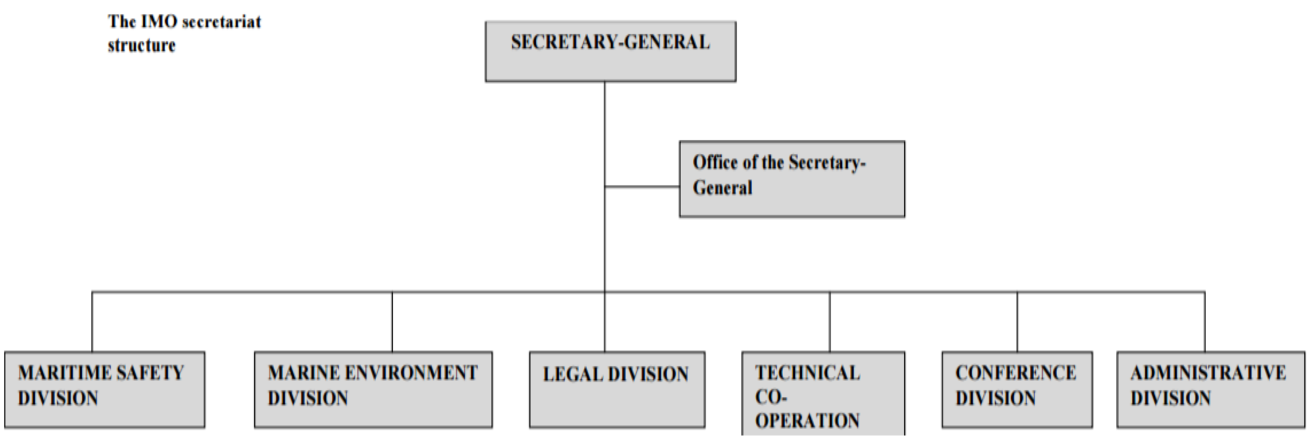
Part 1: IMO Response: Maritime Environmental Regulatory Framework

There are several international rules to govern international shipping, in this section will review the regulatory frameworks developed by IMO, that have to do with the impact shipping has on the environment and the subsequent climate change, in order to address this issue. There are two organizations that together develop regulatory frameworks. Those are the IMO and UNCLOS, that have to do with the regulations of international shipping and international law regarding sea respectively.

The UNCLOS has a plethora of references to the protection of the environment. Some of the most important articles are about the State responsibility for protecting the environment.

The chart below depicts IMO and its secretariat structures.





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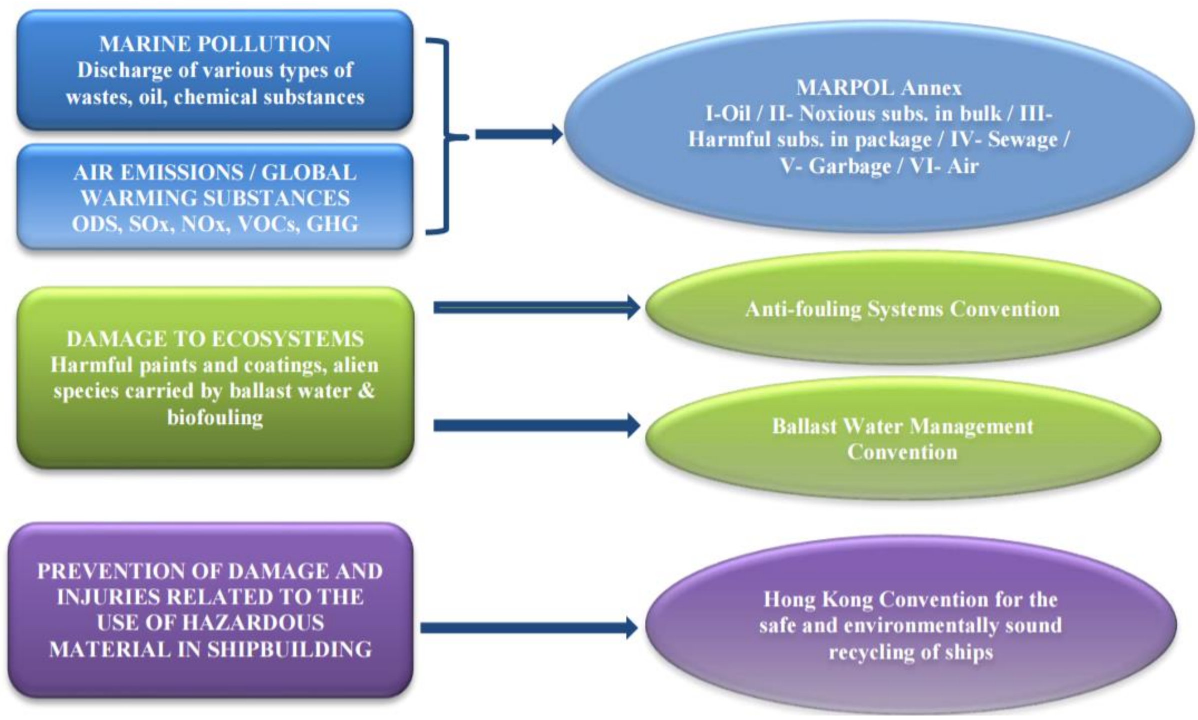
IMO has five aims that are summarized in the Article 1 of its constitutive Convention.

UN and IMO have to closely collaborate in order to enforce the highest practical standards for the protection of the environment. While the IMO develops the governing tools and policies, the implementation and enforcement of those is the responsibility of the member States and their governments.

Specifically, IMO has a number of conventions that have to do with the pollution risks a ship poses. Those conventions are:

- MARPOL Convention
- Anti-Fouling System Convention,
- Ballast Water Management Convention
- Hong Kong Convention
- London Convention

In the figure below is clearly shown the IMO Conventions relating to the prevention of marine pollution relating to ship operations.



MARPOL stands for the International Convention for the Prevention of Pollution from Ships is the main international convention that covers the prevention of pollution of the marine environment by ships. It includes regulations whose purpose is to prevent and minimize pollution from ships, both accidental pollution and that from routine operations, and it includes six technical Annexes.

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The Annex VI includes both air pollutants and GHG emissions. It also includes elements like bunker fuels, incinerators, reception facilities, Emission Control Areas, Ozone Depleting Substances, etc. and currently comprises of four chapters:

- Chapter 1 – General
- Chapter 2 – Survey, certification and means of control
- Chapter 3 – Requirements for control of emissions from ships
- Chapter 4 – Regulation on energy efficiency for ships

Part 2: IMO Response to control of GHG emissions from international shipping

International shipping is an ever expanding trade, which while it has a lot of advantages for the global economy it also has a great disadvantage; the increasing energy consumption that the ships need which has as a result the increase in harmful emissions despite the recent technological developments in more energy efficient ship engines.

IMO has conducted three major studies on GHG emissions from international shipping. The first study in 2000 had the following outputs:

- Shipping is considered an efficient means of transportation compared to others.
- It is difficult to assess with accuracy the overall impact of shipping - because of discrepancy in data concerning bunker figures and the uncertainties in the fuel consumption models.
- The impact of air emission should include NO_x, SO_x and GHG emissions.
- Significant reduction of GHG emission can be achieved through operational and technical measures. However, the increase in demand for shipping services may impede operational and technical savings.
- Environmental indexing, market-based mechanisms and design standards may be appropriate measures to implement in the future.

After the conclusion of the first study there were no regulations based on its results which necessitated a second study in GHG emissions conducted in 2009. The second study is documented under nine chapters as follows:

1. Executive Summary
2. Introduction to shipping and its legislative framework
3. Emissions from shipping 1990–2007
4. Reductions in emissions achieved by implementation of MARPOL Annex VI
5. Technological and operational potential for reduction of emissions
6. Policy options for reductions of GHG and other relevant substances
7. Scenarios for future emissions from international shipping
8. Climate impact

9. Comparison of emissions of CO_2 from ships with emissions from other modes of transport

The following conclusions were drawn:

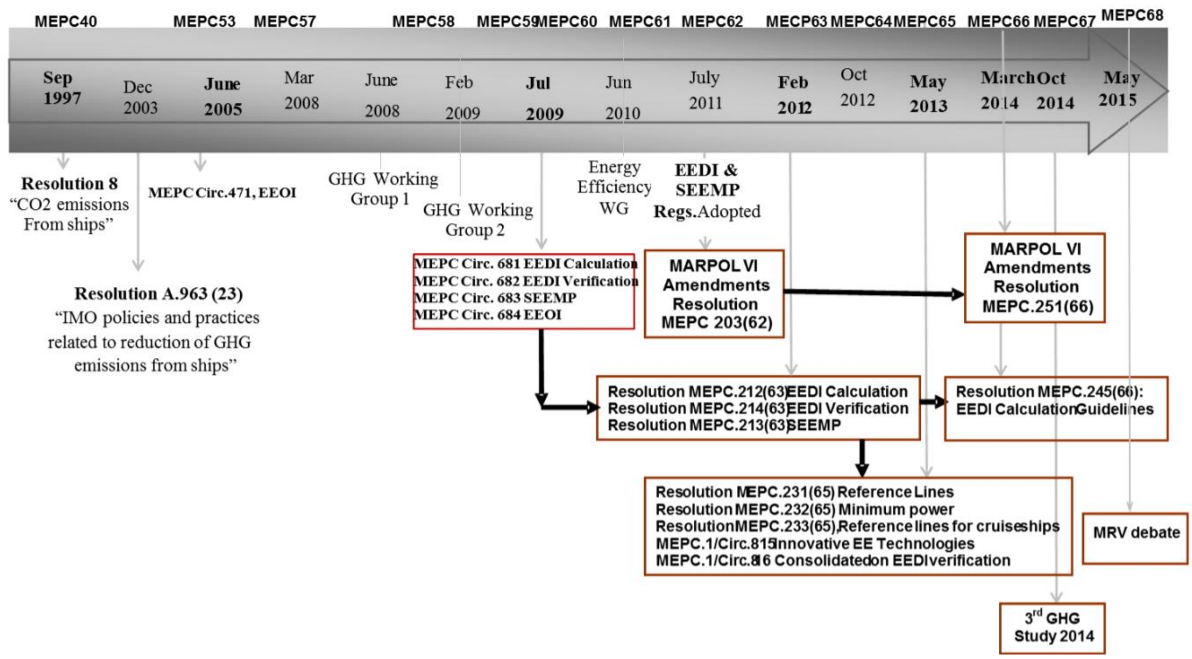
- International shipping was estimated to have emitted 2.7% of the global emissions of CO_2 in 2007.
- In terms of quantity and of global warming potential it was found that exhaust gases were the primary source of air emissions and carbon dioxide was the most important GHG emitted by ships.
- A significant potential for reduction of GHG emissions through technical and operational measures had been identified. That, if implemented, could increase efficiency and reduce the emissions rate by up to 75% below the current levels. Many of these measures seemed to be cost-effective, although non-financial barriers may discourage their implementation.
- A number of policies to reduce GHG emissions from ships were conceivable. The report analysed options and concluded that a mandatory limit on the Energy Efficiency Design Index for new ships was a cost-effective solution that could provide an incentive to improve the design efficiency of new ships. However, its environmental effect was limited because it only applied to new ships and because it only incentivized design improvements and not improvements in operations.
- Shipping had been shown, in general, to be an energy-efficient means of transportation compared to other modes.

There was a third IMO study in GHG emissions on 2014 to provide the IMO Committee with new information about the estimates of emissions from international shipping, in order to update the second study from 2009.

According to the third IMO study the CO_2 emissions caused by international shipping are projected to increase by 50% to 250% in the period to 2050, despite fleet average efficiency improvements of about 40%. This study concluded that under almost all the perceived scenarios, the CO_2 emissions will not decline in 2050 relative to 2012. Thus, further action on efficiency and emissions will be needed to stabilize GHG emissions from international shipping or bring it below 2012 levels in 2050. Another finding of the study was that the total fuel consumption of shipping is dominated by three ship types: oil tankers, containerships and bulk carriers.

As mentioned before IMO is responsible for the MARPOL Conference since its inception and in 1997 they adopted the MARPOL Annex VI for the prevention of air pollution from ships. In the figure below is depicted the IMO activities in chronological order since 1997.

IMO Energy Efficiency Regulatory Developments



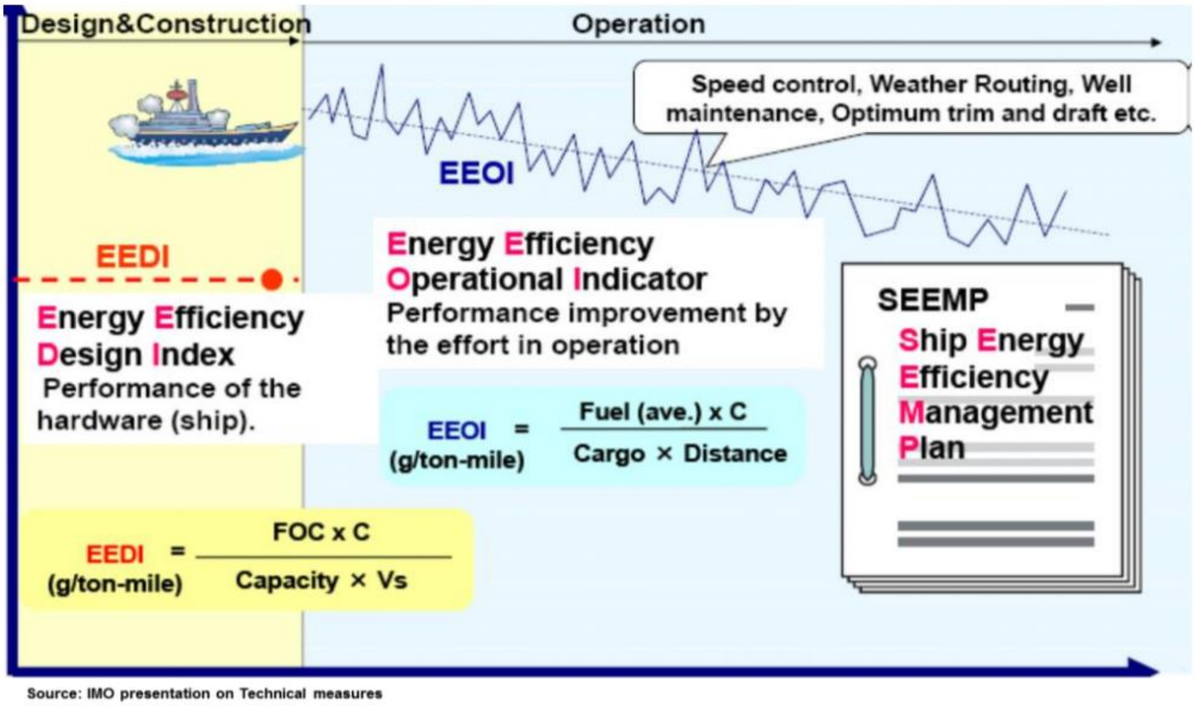
It is important to note the following things:

- To further address the issue of GHG emissions from ships, the IMO Assembly adopted, in December 2003, Resolution A.963 (23) on "IMO Policies and Practices related to the Reduction of GHG Emissions from Ships."A follow-up to this happened in October 2006.
- At MEPC 59 in July 2009 there was the creation of a package of technical and operational measures to reduce GHG emissions from international shipping and also a plan for further consideration and development of suitable and efficient Market Based Measures (MBMs) to complement the technical and operational reduction measures and to provide economic incentives for the shipping industry.
- At MEPC 62 in July 2011 the amendments were concluded for the MARPOL Annex VI in the form of "energy efficiency regulations for ships" was added as a new Chapter 4 to MARPOL Annex VI as a result of which EEDI and SEEMP became mandatory for applicable ships.
- An important series of guidelines to support the uniform implementation of mandatory measures for ship energy efficiency (EEDI and SEEMP) was adopted by the MEPC 63 in 2012.

The regulation mentioned and shown on the figure above are the past regulations that have been made and adopted by the maritime community.

The amendments to MARPOL Annex VI Regulations added a new chapter 4 on Regulations on Energy Efficiency for Ships that made mandatory the Energy Efficiency Design Index (EEDI), for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) for all ships. Other relevant amendments included new definitions and the requirements for survey and certification, including the format for the International Energy Efficiency Certificate and voluntary Guidelines for the calculation of Energy Efficiency Operational Indicator (EEOI).

In the figure below all the amendments to Annex VI are shown.



Since April 2014 as a result of MEPC 67 and 68 meetings, IMO reached preliminary conclusions on a general description of a global data collection system. Based on results of the relevant MEPC working group deliberations, the data collection and reporting requirements would apply to ships involved in international shipping over a certain size threshold and regardless of their flag State.

The draft developed data collection system identifies three core elements including:

- data collection by ships,
- flag State functions in relation to data collected including verification
- establishment of a centralized database by the IMO.

It is worth noting that EU has already legislated an MRV (Measurement, Reporting and Verification) system for shipping that has similarities to IMO current work.

In order for the IMO to support to extent the implementation aspects of its regulations in developing countries, there are the following initiatives:

- IMO Technical Co-operation (TC) programme
- IMO-UNDP-GEF Initiative
- Technology transfer debate

Quizzes

True or False

- MARPOL has four technical annexes.
- At MEPC62 guidelines to support the uniform implementation of mandatory measures for ship energy efficiency (EEDI and SEEMP) were adopted.
- Shipping had been shown, in general, to be an energy-efficient means of transportation compared to other modes.
- The EU hasn't made any legislations with regard to the global data collection system.

Multiple Choice

1. International shipping was estimated to have emitted... of the global CO_2 emissions in 2007?
   a. 3%
   b. 1.5%
   c. 2.7%
   d. 5%
2. What should the impact of air emission include according to the first IMO Study?
   a. NO_x
   b. GHG emissions
   c. SO_x
   d. All of the above
3. When was the second IMO study conducted?
   a. 1998
   b. 2000
   c. 2009
   d. 2010
4. Which two marine conventions are about preventing damage to ecosystems??
   a. MARPOL and Ballast Water Management Convention
   b. Hong Kong Convention for the safe and environmentally sound recycling of ships and the Anti-fouling Systems Convention
   c. Ballast Water Management Convention and the Anti-fouling Systems Convention
   d. MARPOL and Hong Kong Convention for the safe and environmentally sound recycling of ships

Fill in the Blanks

1. MARPOL stands ………………………….. is the main international convention that covers the prevention of pollution of the marine environment by ships.
2. The ………………………. for new ships was a cost-effective solution that could provide an incentive to improve the design efficiency of new ships.
3. Another finding of the study was that the total fuel consumption of shipping is dominated by three ship types: ………………...
4. IMO has a number of conventions that have to do with the pollution risks a ship poses. Those conventions are: the MARPOL Convention, the Anti-Fouling System Convention, the Ballast Water Management Convention, the Hong Kong Convention and the ……………………….

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Chapter 14 - International Energy Management Standards

Summary

Part 1: ISO 50001 Energy Management System

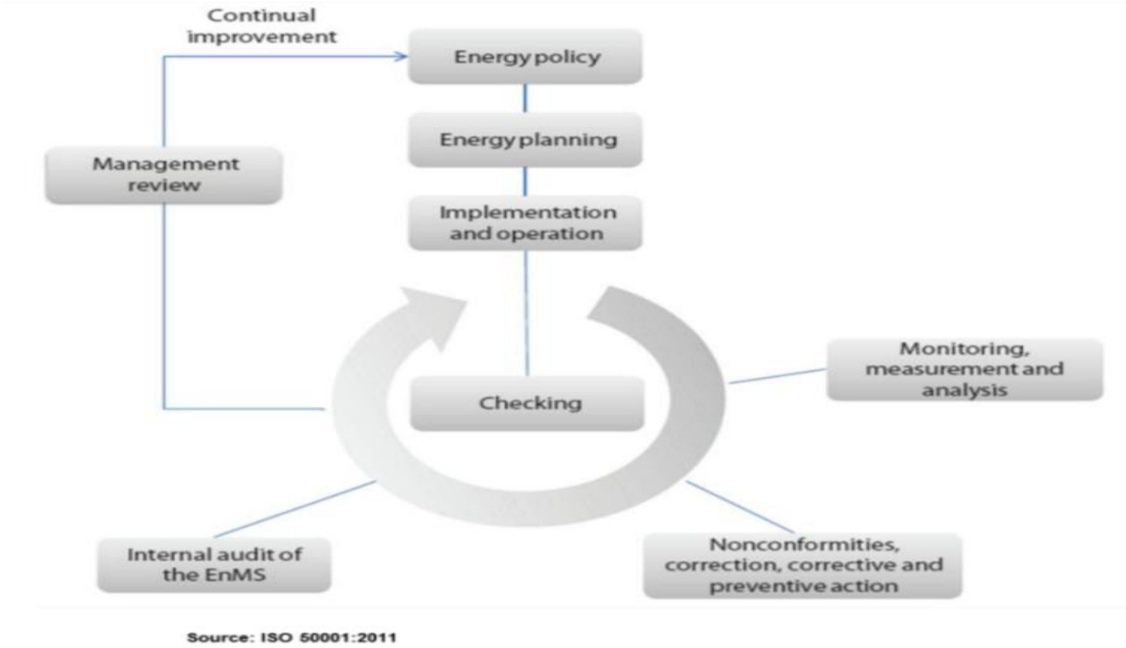
The International Organisation for Standardisation (ISO) created ISO 50001 as a voluntary international standard for a ship's energy management in order for the to improve the energy performance. The standard addresses the following:

- Energy use and consumption evaluation via conducting energy reviews and development of energy policies.
- Measurement, documentation and reporting of energy use and consumption.
- Design and procurement practices for energy-using equipment, systems, and processes.
- Development of an energy management plan and other factors affecting energy performance that can be monitored and influenced by the organization.

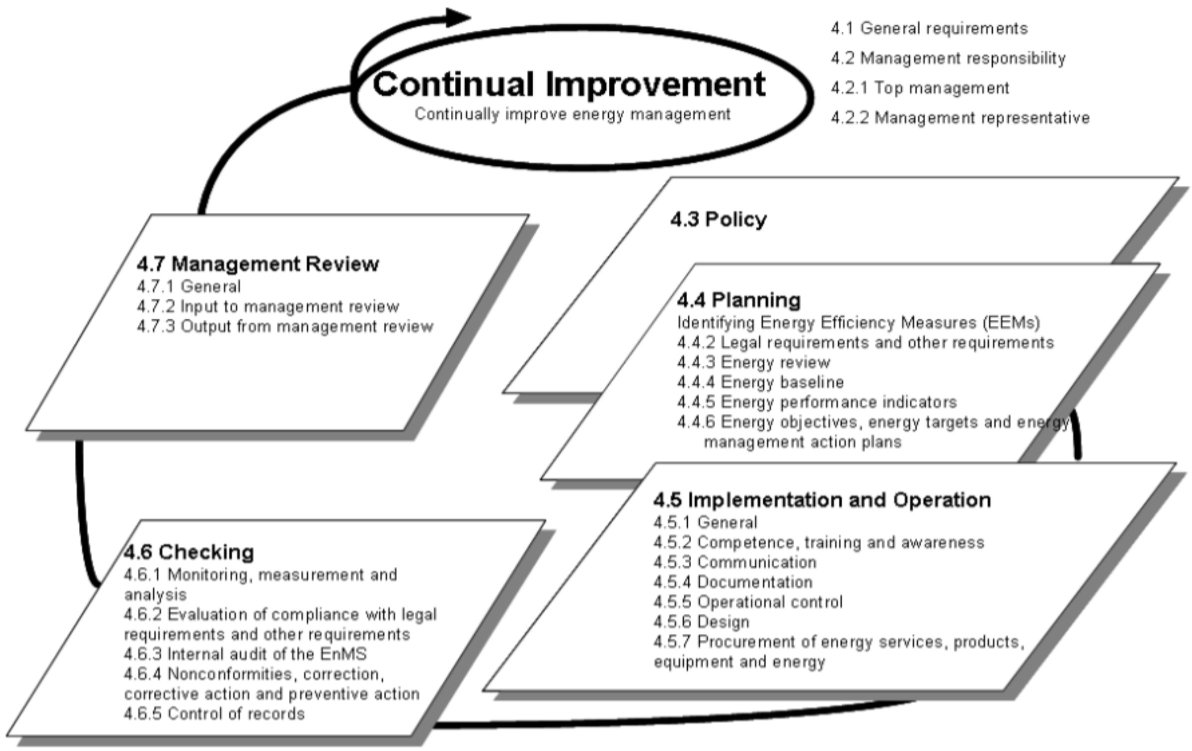
ISO 50001 provides a framework for an “Energy Management System (EnMS)” through which each company can set and pursue its own goals for improving energy performance and it is applicable to all kinds of companies/organisations in multiple industry sectors. EnMS is a series of processes that helps a company use data and information to maintain and improve their energy performance, while improving operational and energy efficiencies and reducing environmental impacts.

The ISO 50001 framework provides a systematic approach to energy management within a company. A company that conforms to the standard can provide proof that they have implemented the international energy management systems and are committed to continual improvement in energy performance.

The figure below shows the processes of ISO 50001 and the continual improvement of the system.



ISO 50001 is based on the Plan-Do-Check-Act approach already employed in ISO 9001, ISO 14001 and IMO SEEMP. The Plan-Do-Check-Act features of the IMO 50001 are shown in the figure below where various sections of ISO 50001 are shown together with the standard relevant headlines.



Even though ISO 50001 does not require any specific performance criteria or target levels to be set it does require the organization to continually improve energy performance. IMO has created the Energy Efficiency Operational Indicator (EEOI), that could be used as a performance indicator for a company when applying the EnMS to shipping.

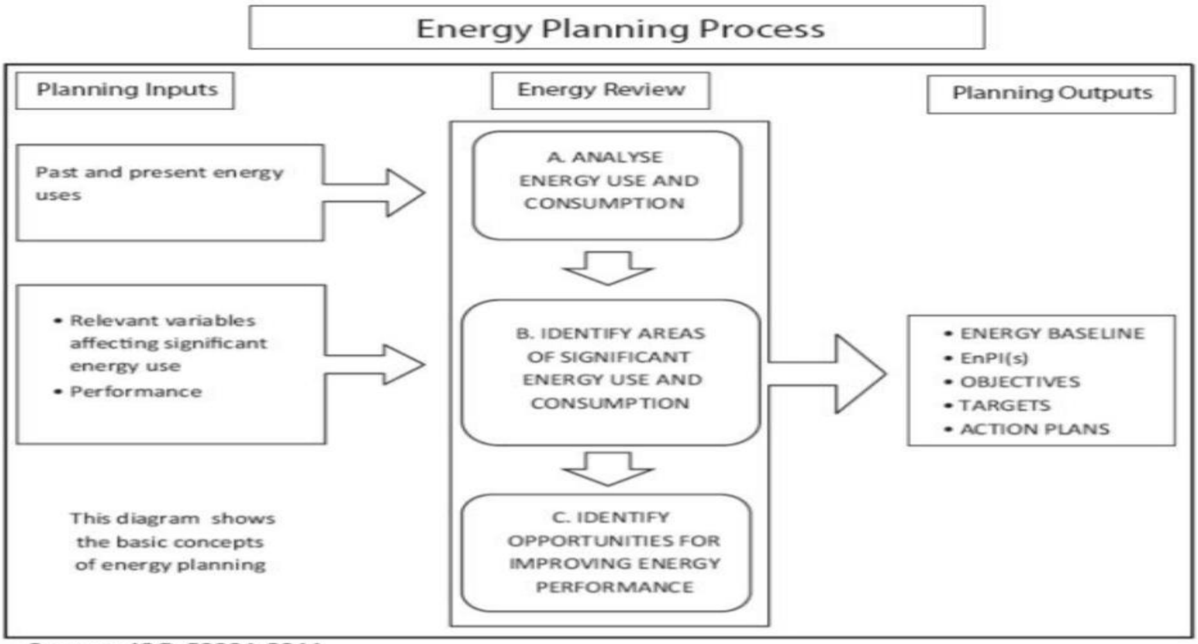
A shipping company EnMS will include features that need to be undertaken both at head office and on-board ships that will be included in a ship's SEEMP. The shipping company's EnMS should also include provisions for activities at shore-based offices.

There are many companies who offer the ISO 50001 certification that are accredited certification bodies via their national standardisation agencies that are competent to certify organizations for conformance to ISO 50001. ISO 50001 certification is voluntary and companies can start improving energy management without needing to become certified. However, certification to ISO 50001 provides a structured approach that incorporates energy management into company culture, resulting in sustained energy savings and continual improvements in energy performance over time.

The ISO 5001 foresees the definition of roles and responsibilities for various activities with the responsibility of top management being the most important.

It is a requirement of ISO 50001 that a company has an energy policy that states the company's commitment to achieving energy performance improvement and it should be defined and endorsed by the top management. The energy policy is one of the first documents that need to be prepared as it will show the intentions of the top management. All other planning activities then will be based on energy policy.

In the figure below there is a diagram that shows the energy planning processes with the energy review of the company being at the centre of it.



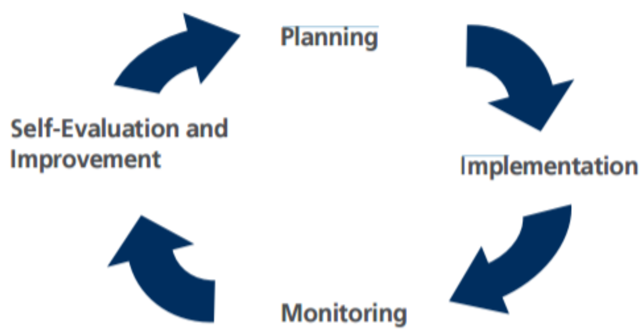
Source: ISO 50001:2011

ISO 50001 states that the company needs to ensure that the operations relevant to energy performance are monitored, measured and analysed at planned intervals. ISO 50001 also suggests the use of internal audits as a monitoring method, which requires an audit plan to be developed.

Another requirement of ISO 50001 is the management review. For the review purposes, some inputs to management review meetings are required and some output is expected to be generated.

1 Part 2: ISO19030 and Application of SEEMP for EEOI Requirements

In comparison with other modes of transportation shipping is relatively efficient as far as the CO_2 emissions produced per mile that each tonne of cargo is transported. Nonetheless, the IMO is researching at measures to improve ship efficiency through better management and implementation of best practice. The SEEMP is a 'live' document that will be ship specific, containing energy improvement measures identified by the ship owner, that will be kept onboard each ship. There are four key processes that the SEEMP addresses and describes and together they form a continuous improvement process as shown in the figure below .



The Ship Energy Efficiency Management Plan (SEEMP) is an operational measure to improve the energy efficiency of a ship in a cost-effective manner. The SEEMP also provides an approach to manage ship and fleet efficiency performance over time using, for example, the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool.

The ISO 19030 was developed for the assessment of the hull and propeller's performance for ships in service. Nowadays hull and propeller performance is a ship efficiency killer. The reasons for this inefficiency are a combination of biofouling and mechanical damages. The reason for this is the inability to properly measure the damage.

ISO 19030 outlines general principles of, and defines both a default as well as alternative methods for, measurement of changes in hull and propeller performance. It shows the way

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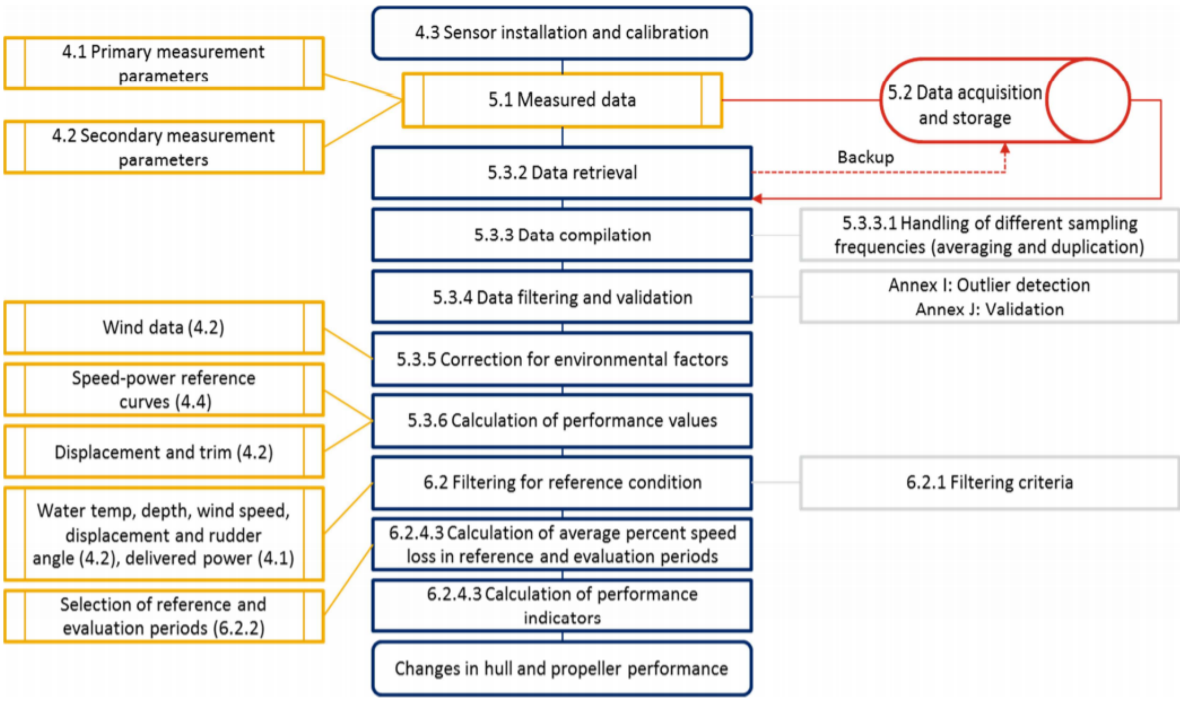
to calculate a set of four performance indicators for hull and propeller related maintenance, repair and retrofit activities. Those are “In-service performance”, “Dry docking performance”, “Maintenance trigger” and “Maintenance effect”.

In the figure below we can see the scope of ISO 19030.



Descriptions and explanations are outlined in ISO 19030-1. Methodological alternatives that are state of-the-art and mature are addressed in ISO 19030-2. Alternatives that are state of the art but not fully mature have either been included in ISO 19030-3 or will be addressed in future revisions of the standard.

Quizzes

True or False

- ISO 50001 does not require a management review.
- In comparison with other modes of transportation shipping is far less efficient as far as the CO_2 emissions produced per mile that each tonne of cargo is transported.
- Nowadays hull and propeller performance is a ship efficiency killer.
- Methodological alternatives that are state of-the-art and mature are addressed in ISO 19030-3.

Multiple Choice

1. Which is not one of the 4 key processes the SEEMP addresses?
    a. Planning
    b. Implementation
    c. Measuring
    d. Self-Evaluation and Improvement
2. EnMS is a series of processes that helps a company...?
    a. use data and information to maintain their energy performance
    b. use data and information to improve their energy performance
    c. improve operational and energy efficiencies and reduce environmental impacts
    d. All of the above
3. Which ISO is responsible for the assessment of the hull and propeller's performance?
    a. ISO 50001
    b. ISO 60001
    c. ISO 19030
    d. ISO 19060
4. Which is not one of the 4 performance indicators the ISO 19030 calculates?
    a. Dry docking performance
    b. Maintenance effect
    c. Maintenance Measuring
    d. In-service performance

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Fill in the Blanks

1. The reasons for the hull and propeller performance inefficiency are a combination of ……………….. and mechanical damages.
2. ISO 50001 is based on the …………………… approach already employed in ISO 9001, ISO 14001 and IMO SEEMP.
3. ISO 50001 states that the company needs to ensure that the operations relevant to energy performance are monitored, ……………….. and analysed at planned intervals.
4. The SEEMP is a …………………. that will be ship specific, containing energy improvement measures identified by the ship owner, that will be kept onboard each ship.

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Sample Assignment

Calculation of EEOI for a certain voyage

Introduction

In order to report to the assessment bodies and for the sake of improving the vessel's efficiency and goal setting, the vessel's EEOI (Energy Efficiency Operational Indicator) needs to be calculated for each voyage and recorded. Therefore we focused into a particular whole voyage of a bulk carrier. Below you will find the vessel's brief description and will be asked to calculate the EEOI value ($x10^6$) for the given voyage.

Aim

To identify the consumptions and to calculate the EEOI.

Learning Outcomes

At the end of assignment you will :

Be familiar with the calculation formula,

Apply the given figures to the formula,

Understand the importance of completing the voyage with more laden days and more cargo.

Assignment Brief

You should use the formula in correct way, by calculating the needed figures from the given clues. The key criteria is to find out the EEOI by using the consumptions for different fuel types.

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Vessel "**M/V MARIEMS"** has been employed for the transportation of **32,800 M/T** of manganese ore cargo from Owendo/Gabon to Point Noirre/Congo. The vessel was drifting off Lagos/Nigeria at the time of fixing and therefore had to perform a ballast voyage to the loading port.

Distances between the ports are as follows :

Owendo – Point Noirre	:	445.6 Nm
Lagos – Owendo	:	450.3 Nm

Brief description of the vessel is as below :

Vessel's name	:	M/V MARIEMS
Flag	:	Liberia
Type	:	Bulk Carrier
Built in	:	2017
DWT Summer	:	34,800 M/T
Loa	:	183.32 m
B	:	28.00 m
D	:	12.50 m
Main engine	:	MAN B&W 6S50 MC , 6,880 kW @ 102 rpm
Diesel Generators	:	3 x Wartsila 4L20, 450 kVA @ 900 rpm
Speed and Consumptions	:	At sea 26.5 M/T of HFO laden daily at 12.0 kn
		At sea 26.0 M/T of HFO ballast daily at 12.0 kn
		In port (cranes working) 3.0 M/T MDO daily

The loading and discharging operations at ports took total 9 days by using the ship's cranes.

Entire voyage was performed at 12.0 knots of speed.

You are asked to calculate the EEOI for above voyage.

Notes :

CF_1, non-dimensional conversion factor for HFO : 3.1144

CF_2, non-dimensional conversion factor for MDO : 3.2060

Answer :

The formula to be used is;

EEOI = (ΣFCj xCFJ) / (mcargox D)

Where

J	is the fuel type,
I	is the voyage number,
FC_{ij}	is the mass of consumed fuel j at voyage I,
C_{FJ}	is the non-dimensional conversional factor for fuel j,
m_{cargo}	is cargo carried (tonnes) or work done (no of TEU or passengers),
D	is the distance in nautical miles corresponding to the cargo carried

HFO consumption during **ballast** voyage from Lagos to Owendo :

26.0 M/T daily *x [(450.3 Nm / 12 knots) / 24 hrs)] = 40.65 M/T HFO (1)*

HFO consumption during **laden** voyage from Owendo to Point Noirre :

26.5 M/T daily *x [(445.6 Nm / 12 knots) / 24 hrs)] = 41.00 M/T HFO (2)*

Total HFO consumption **(1 + 2)** :

40.65 M/T + 41.00 M/T = 81.65 M/T ***(FCij1)***

MDO consumption during loading and discharging :

9 days total x 3.0 M/T daily = 27.0 M/T ***(FCij2)***

The formula is :

EEOI = [(FCij1 x CF1) + (FCij2 x CF2)] / [(mcargo1 x D1) + (mcargo2 x D2)]

= *[(81.65 x 3.1144) + (27 x 3.2060)] / (32,800 x 445.6) + (0 x 450.3)]*
= *340.85 / 14,615,680*
= *0.00002332*

EEOI = 23.32 x $\mathbf{10^{-6}}$

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MariEMS Project Paper

Maritime Energy Management System (MariEMS) Online Delivery Platform

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Abstract: Maritime accounts for approximately 90% of trade in the world today. The maritime transport emits around 1000 Mt of CO_2 per year about 2,5% of global GHG emissions (3rd IMO GHG study).The forecast of new scenarios about the shipping emissions predict an increase between 50% and 250% by 2050, depending on future economic and energy development. The Industry has taken steps to reduce its Air Pollution and Carbon footprint. IMO introduced several new regulations such as the Ship Energy Efficiency Management Plan (SEEMP), Energy Efficiency Design Index (EEDI), & Energy Efficiency Operational Index (EEOI), while the MARPOL Convention new regulations have imposed strict emissions caps in emission control areas. Ship owners have reacted to fulfill these requirements meeting the future environmental requirements set for 2025.

Maritime Energy Management Specification(MariEMS) is an industry-academia collaboration project funded by the EU under the Erasmus+ programme. The project started

in October 2015 and the duration is 30 months. The purpose of this Partnership is the development of an energy management job requirements as well as a training specification, and the development and implementation of an online learning and assessment system for the proposed training programme so that current cadets, as well as existing seafarers, can up-skill themselves to the new regulatory requirements and good practice.

The paper presentation includes the handouts of the proposed job specification and training programme for the ship energy management as well as a demonstration of the MariEMS online e-learning platform.

Keywords: maritime energy management, energy efficiency, online, e-learning,

Introduction

It is generally accepted that around 90% of world trade happens by sea. Indeed the IMO's own International Shipping Facts and Figures report in 2012 stated that the number of propelled sea going vessels across the globe of at least 100 Gross Tonnage was 104,304 ships, with cargo carrying vessels being 55,138 ships (Ziarati, 2016).

With awareness and understanding increasing around the world about the effects of pollution on the Global Environment the International Maritime Organisation (IMO) has tried to tackle the level and type of emissions produced by the Maritime Industry through new regulations. The majority of the IMO requirements on ship emissions are contained within MARPOL, with Air Pollution being the focus of Annex VI. The MARPOL regulations impose strict emissions caps in two emissions control areas (ECA) which are (partly or completely) inside the EU - The North Sea and the Baltic Sea. These emissions caps are intended to control the main air pollutants contained in ships exhaust gas, including, CO_2, sulphur oxides (SO_x) and nitrous oxides (NO_x), and prohibits deliberate emissions of ozone depleting substances (ODS).

As the regulations and technologies governing Energy Efficiency on board ships become ever more complex it has been recognised by the IMO and the shipping industry that seafarers themselves need to be trained to a much higher level in these fields. To this end the IMO (IMO Train The Trainer Course, 2016) has created in a sense a new position on board ship of viz., Energy Trainee/Officer/ Manager; a position that whether collective or given to an individual will play a crucial role in making ships and ports energy conscious and more efficient.

While the efforts by IMO and the many maritime communities particularly in Europe have been commendable the recent US reports to forego the outcomes of recent climate treaties is a cause for concern particularly considering that US and China are the biggest maritime polluters in the world (Oceana report cited in Sahayam, 2014).

IMO Regulations

The IMO has also introduced regulations (DNV, 2014) such as the **Energy Efficiency Design Index (**EEDI), **Ship Energy Efficiency Management Plan** (SSEMP) and **Energy Efficiency Operational Index (**EEOI**)** which all entered in force on January 1st 2013. SEEMPis an operational measure that establishes a cost-effective mechanism in improving the ship's energy efficiency. This measure also assists the shipping companies in providing an approach for managing ship and fleet efficiency performance over time with the help of the EEOI as a monitoring tool. The assistance on the development of the SEEMP operational measure for new and existing ships includes best practices for efficient ship's operation, as well as procedures for deliberate use of the EEOI in new and already existing ships (MEPC.1/Circ.684). SEEMP therefore is a plan to improve the energy efficiency implementation in a ship's operation, reported to provide cost savings of about 5 to 15% and help to bring down GHG emissions; A plan to reduce fuel cost (prediction of 35-65% reduction of operational costs have been reported (Ziarati and Akdemir, 2015; Sahayam, 2014)) with a range of environmental impact based port fees and so forth.

Kollamthodi et al (2008) claims from an interview with the Norwegian ship association that, the charterers (contractors) are ready to pay higher amounts for energy efficient ships when comparing with other normal vessels (Sustainable shipping, 2012). On the other hand, Faber et al. (2011) concludes that, the ship owners investing in ships that are fuel efficient will not be able to recoup their investments unless otherwise their own ships are being operated or by having a long term agreement with charterers. But an argument, on the other side is, investments in the energy efficiency vessels increase the rate of success for winning contracts and hence provides a better utilisation of ships.

Energy Management

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The role of the person designated for energy management should therefore incorporate the improvements in both transformation and use of energy with a view to also reduce harmful pollutants. There are a number of related areas, such as new regulation on sulphur content which in itself is a full-time job as described below, for the Energy Manager on board a vessel, when sailing through Emission Control Areas (ECA) designated waters.

Authorities given responsibility to oversee the implementation of ECA such as USCG and EMSA are issuing safety alert on fuel switching as of recently. Many losses of propulsion have occurred in different ports and have been associated with changeover processes and procedures. At a recent meeting at EMSA it was clear that polluter can be spotted and brought to justice based on evidence gathered by the agency. A review of recent legislations Sahayam, 2014) clearly shows that in terms of legislation there are in reality only two efforts regarding the 2010 ECA Sulphur limit and the 2011 NO_x tier II so far of any significant value which is far short of what is required to make an effective inroad to reduce harmful pollutants as demonstrated in the following figure nº 1.

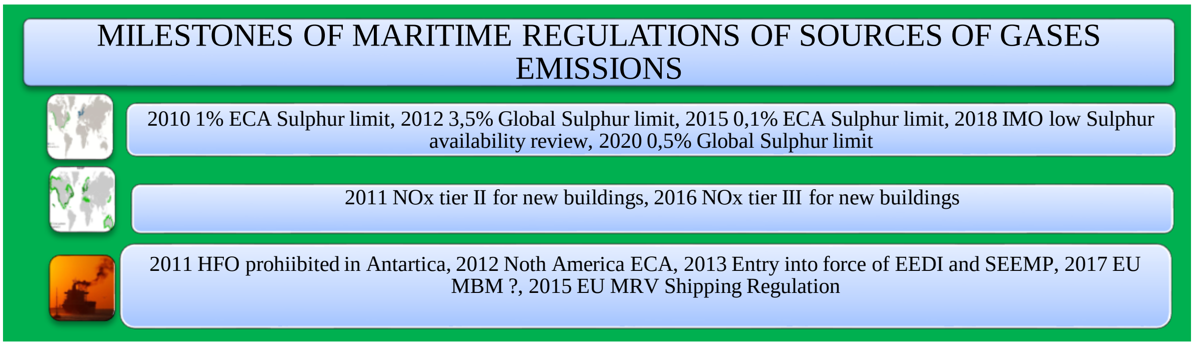

Figure nº 1; **Milestones of Maritime Regulations of Sources of Gases Emissions**

Ziarati and Akdemir (2015) have argued that to make a real impact on reducing engine emissions there needs to be a combined effort applying a range of options such i) Maximising thermal efficiency, ii) considering adaptation of hybrid propulsion, iii) using alternative fuels and or fuel cells/batteries, iv) integration of novel catalysts, exhaust recirculation systems and exhaust treatment, v) including multi-Stage inter-cooling, vi) using variable Geometry turbochargers, vii) considering use of lighter materials, viii) using more efficient bearings, ix) Injecting water after end of combustion to reduce NO_x formation and for cooling the engine hence reducing heat losses through primarily conduction, x) using novel injectors with high injection pressures as part of the common rail systems.

Maritime Record Verification, MRV

The management and oversight of any fuel oil mixing that may be part of a changeover process including, proper control and reduction of the operating temperature of fuel supplied, varying ratios of the mixed fuels and control of mixed fuel viscosity to the engines must take place before the vessel enters the ECAs or after the vessel leaves the ECAs.

The EU has the aim to reduce the emissions of CO_2 from shipping and has created a system called Monitoring Record Verification, MRV, to control the CO_2 emissions from vessels larger than 5000 GT and which call at any EU port.

The shipping companies must prepare a monitoring plan for each of their vessels that has to comply with the MRV Regulation. The MRV Regulation was adopted in April 2015 and entered in force on July 2015; by August 2017 the shipping companies must have submitted the monitoring plans to the administration or accredited verifier. In January 2018 each vessel will start to voyage reporting till December of that year, that will be completed a period. In the next year the EC will publish the data of MRV.

The parameters that must be monitored per voyage are: Port departure and arrival, including date and hour of departure and arrival, type of fuel consumed and the quantity and emission factors of each one, CO_2 emitted, distance travelled, transport carried and transport work.

Energy Efficient Ship Operation Training The Trainer course (EESO-TTT) and the MariEMS Project

IMO in recent years has produced an Energy Efficient Ship Operation Training The Trainer course (EESO-TTT). The MariEMS Project was initiated for the intended trainees of this course and also for use by all ship crew particularly those with direct responsibility for energy management and efficient ship operation. MariEMS is primarily an online course and has several intellectual outputs. The first key output is the design of a specification for the role that the trainees of the IMO EESO-TTT course are anticipated to play and the second key output is the specification for the trainees training programme in a similar way that

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EESO-TTT was for the trainers. To this end, care has been exercised in ensuring the full use of the IMO EESO-TTT content so that the trainers and trainees would use a common teaching/learning material.

Currently there are no job specifications, and no training specifications for the intended trainees/energy efficiency team members and so existing crew members are learning 'on the job' how to implement these new regulations as best they can, which is not an effective method of applying these regulations and will of course mean that the best results are not currently being achieved.

The purpose of this Strategic Partnership is the development of an energy management job and training specifications, and the development and implementation of an online leaning and assessment system for the new training programme so that current Cadets, as well as existing seafarers, can up-skill themselves to the new IMO regulatory requirements. The needs that this proposal will fulfil are as follows:

1. The need for qualified personnel to be implementing the new regulations and technologies.
2. The need for Energy Efficiency to be embraced by Shipping Companies in order to achieve the best results through cost savings gained through more efficient use of fuels etc.
3. Enhanced employability and mobility in a global labour market for EU seafarers and cadets who take the qualification either as part of their initial studies or as part of a continuing VET.
4. METs continuing to offer courses that are relevant and comply with latest regulations and requirements of the industry.
5. Integrating and developing e-learning and digital skills into the EU MET's so that they can design and deliver e-learning materials and an online learning platform. In the 2010 STCW amendments the IMO officially recognised the validity of e-learning for the maritime sector.

The partners are anticipating to bring together a unique blend of industrial, academic and industrial partners who can bring to the table valuable and necessary experience in ship types, ship propulsion, ship navigation, energy transformation, electrical and mechanical parts and circuitry, safety issues, national certification, accreditation and validation of learning materials, pedagogical aspects of learning and last but by no means least online application. The partners have developed a sustainability plan and the activities contained in this plan are expected to invite as many ship companies, ports and other key stakeholders including maritime institutions into the project team. Within their sustainability plan several areas have been identified which could help to reduce ship fuel consumptions as well as reducing harmful emissions both due to reduction in fuel consumption and due to other measures being introduced to filter or re-circulate/burn some of the more vicious pollutants using now novel systems as are the following: slow steaming, weather routing, green energy wind and sun (Flettner rotor & sun panels), use of sea currents, e-navigation, ballast water management, hull and trim optimisation, ship-port and port-ship system integration, port-road-train-airport system integration, on-board ship management and Artificial Intelligence and Virtual Reality applications such as virtual arrival and departure, advanced satellite and drone communications, Just-In-Time data using neural network predictive techniques.

Innovative aspects of the Project

The innovative characteristic of the project is to develop the first European specifications for the Ship Energy Trainee/Officer/Manager position, as well as developing the standards and specifications for the training courses for that position, and the specifications and first online delivery platform for these training courses and materials. The skills shortage that is currently emerging between traditional education and the latest technologies, requirements and practices for maritime energy efficiency needs to be addressed urgently in order for cadets and seafarers to have the skills necessary to implement the latest regulation and technologies to their best effect and thus secure the energy efficiency and pollutant reduction needed to help the EU meet its 20% reduction target by 2020.

Another innovative characteristic of this project is the involvement of the shipping industry in the formation of training course right from the specification stage. The Maritime Energy Manager Role is entirely new. The team of project partners has the opportunity to embed the industry's requirements into the training courses right from their development stage. Also with industry involvement in the design and development stage of the training courses comes the ability to accurately tailor the training programme to the current skill and knowledge level of seafarers working in the industry.

The ship energy manager is primarily responsible for managing all aspects of energy management and efficiency on board vessels. The manager should have knowledge, understanding and application of IMO Energy Requirements/Regulations and is expected that the manager should be familiar with application of EEOI and EEDI with a specific knowledge of energy transformation on board of vessels, with skills in energy saving practices including engine propulsion, heating cooling and so forth. The manager should be familiar with the ISM practices, and company specific measures including aspects relating to any quality standards which may relate to ISO 9000/EN 29000 or ship specific standards such as ISO 50001 and ISO 14000. The manager must be aware of IMO's MARPOL, SOLAS, and other related standards including aspects concerning maritime environment protection.

The training programme has four parts; the first part has seven sections: Knowledge, Understanding and Application of IMO Energy Management Requirements/Regulations, EEDI Reference lines – significance, Company Specific Measures, Energy Saving System – Internal and Existing Environmental Protection Requirements. The second part is about Skills, Experience and Qualifications. The third part is about Personal Characteristics and the fourth part is about the term of the contract along with the points discussed and agreed at the point of interview. At the end of course the learners are able to: identify, implement, assess, evaluate the energy efficiency measures of all kind of propulsion and systems on board, and provide guidance to the crew and compliance with the international legislations and requirements

Expected Impact

At the national level the impact of the MariEMS project is to increase the capacity of the partner METs through developing the e-learning infrastructure and capabilities of these institutions and their staff to use and run the MariEMS e-learning platform and training courses to help METs deliver the brand new Energy Manager field of training, to both their cadets and to already qualified seafarers resulting is a more skilled, competent and mobile Maritime labour force educated to the latest regulatory requirements.

Another national impact is that cadets and seafarers who complete the MariEMS course and become qualified Energy Managers will be heavily in demand by the industry as they seek to appoint and Energy Manager on each ship.

The exchange of good practices and knowledge between the partner METs, and also between the partnership and international shipping companies and ports, as well as with the IMO (170 member states and growing) and international awarding, accrediting and licensing bodies will be a truly international impact of the project as it will allow for industry, academia and policymakers to exchange knowledge and best practices right at the birth of a new educational field so that the MariEMS outputs developed as a result of the project will reflect all parties involved.

International impact is expected to be a decline in emissions from ships and countries that train and employ truly qualified and effective Energy Managers. It is believed that the Maritime Industry currently account for some 50% of CO_2emissions at ports with substantial level of other dangerous pollutant particularly outside the ECA zones, and so the energy saving measures that are intended by the IMO to be employed by the Energy Managers, such as reductions in fuel consumption, will result in emissions drops of by at least 20 to 30% (Sahayam, 2013). The environment is a global issue and so such a reduction in emissions by the shipping Industry will also have a global impact.

Another international impact of the project will be the designing of the first full training specification, course, e-learning delivery platform and sample training materials for the new Energy Manager position, and then submitting this to the IMO as a possible basis for a new model course. The impact of having a single standardised model course for the Energy Manager position would be tremendous because many METs in the IMOs 170 member states prefer to use IMO model curses rather than design their own courses from scratch. Currently almost all METs make use of IMO Model Courses and so the level of uptake and impact that the Energy Manger Model Course would have can be judged to be substantial.. By providing a possibility of a Model Course being developed MariEMS would be speeding up the global timetable of the implementation of the Energy Management training courses complementing the IMO’s EESO-TTT course.

Conclusions

The job specification and training programme content and learning material so far developed are in hand and have been validated by two multiplier events in Finland and in the UK. The feedbacks from these events have been very helpful. A meeting was also organised at EMSA to seek comments on the project from the Agency. There several other opportunities to present the outputs from the MariEMS project to participants of national and international professional networks and seek further feedback.

The most important impact of the project is expected to be the reduction of energy used on board vessels and as the MariEMS course also incorporates ISO 50001 will ensure saving are made. ISO processes will enable a continuous system of development to be in place which is expected to help ship operators and owners, to be more respectful with the environment reducing the uptake of fuel. The reduction of energy is expected also to reduce harmful emissions from ship propulsion systems. In a recent IMO WMU paper by the vice president of BIMCO (Kaptanoglu and Ziarati, 2015) it was stated that the key challenge facing the shipping industry is the competitiveness and environmental issues. It emphasis that the IMO's own reports (Marine Environmental Protection Committee (MEPC), 64 session, Agenda item 4, 29th June 2012) and similar reports by learnt societies and classification societies and maritime organisations give a clear view of the roadmap for reducing the energy consumption and marine engine emissions. It was noted that the whole of Central and North America coastal areas are now almost an ECA (Emission Control Area) and it is expected that coasts of Mexico, Alaska and the Great lakes, Singapore, Hong Kong, Korea, Australia, Black Sea, Mediterranean Sea and Tokyo bay are currently considering becoming ECAs. What is significant is that these constitute 90% of shipping routes so the implications are serious. To this end, MariEMS project is anticipated to play a positive role in addressing the challenges before us at the source and by getting things right the first time.

The project will support the IMO efforts in ship energy efficient operations. IMO has devoted significant time and effort in order to regulate shipping energy efficiency and thereby control the marine emissions in addition to EEDI, EEOI and the SEEMP particularly considering IMO's work in devising a new Chapter 4 of MARPOL Annex VI.

Referring to what has been stated above the impact of this project is expected to be substantial both in terms of energy reduction on board vessels and in port as well as the resulting emission of harmful GHGs helping EU to realise its set goals for 2020 and beyond. The user-friendly e-leaning and e-assessment course will be available free of charge at any place and at any time provided there is access to the internet.

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Quizzes Answers

Chapter 1 - Climate System and Combating Global Warming and Air Pollution

True or False

1. False
2. False
3. True
4. False

Multiple Choice

1. Natural causes and human activity
2. The Ozone layer
3. The 1980s
4. USA

Fill in the Blanks

1. troposphere
2. acidification.
3. World Meteorological Organization (WMO;
   Intergovernmental Panel on Climate Change (IPCC).
4. 18.

Chapter 2 - Ship-Board Operations and Energy Efficiency and references to Crew Responsibilities

True or False

1. False
2. True
3. True
4. False

Multiple Choice

1. All of the above
2. A container ship
3. The Chief Officer
4. None of the above

Fill in the Blanks

1. geography of operation;
   operation.
2. temperature;

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Cleanliness
3. makers
4. port authority.

Chapter 3 - Trim optimisation, Hull and propeller condition

Chapter 4 – e-Navigation and Weather Routing

1. True
2. False
3. True
4. GMDSS
5. False

Chapter 5 - Engines and Machinery Load and Utilisation Management

1. Choice 2
2. FALSE
3. TRUE
4. Choice 5
5. Choice 5
6. Choice 5
7. FALSE
8. TRUE
9. FALSE
10. TRUE
11. FALSE
12. TRUE
13. TRUE
14. FALSE
15. TRUE
16. TRUE
17. Choice 3
18. Choice 5
19. Choice 5
20. Choice 3
21. Choice 5
22. TRUE
23. FALSE
24. TRUE
25. FALSE
26. FALSE
27. FALSE
28. FALSE
29. FALSE
30. FALSE
31. FALSE
32. FALSE

33. FALSE
34. FALSE
35. TRUE

Chapter 6 - Fuel Management

1. FALSE
2. FALSE
3. TRUE
4. Choice 2
5. Choice 2
6. Choice 5
7. Choice 3
8. TRUE
9. TRUE
10. TRUE
11. FALSE
12. TRUE
13. FALSE
14. TRUE

Chapter 7 - Technical Upgrade and Retrofit

1. Choice 2
2. Choice 5
3. TRUE
4. TRUE
5. TRUE
6. TRUE
7. TRUE
8. TRUE
9. FALSE
10. TRUE
11. TRUE
12. TRUE

Chapter 8 - Boilers and Steam System

1. Choice 2
2. FALSE
3. TRUE
4. TRUE
5. FALSE
6. TRUE
7. TRUE
8. TRUE
9. FALSE
10. TRUE

Chapter 9 - Port Operations, Air Emissions and Efficiency Measures

1. Using On-Shore Power Supply
2. Reduce Unnecessary waiting and the idle periods of ship operations
3. Ships

Chapter 10 - Cargo and Ballast Management

True or False

1. True
2. True
3. False
4. True

Multiple Choice

1. Container Ship
2. Exporter
3. Weather condition
4. 3

Fill in the Blanks

1. less
2. Ballast Water Record
3. 200 nm
4. minimal

Chapter 11 - Ship Maintenance And Energy Efficiency

1. Fix-it upon damage
2. Increases
   Increases
3. TURE

Chapter 12 - Energy Efficiency Management and Operational Measures

1. Fuel Consumption
2. EEOI Goal setting
3. True

Chapter 13 - Environmental Concerns and IMO Response

True or False

1. False
2. False
3. True
4. False

Multiple Choice

1. 2.7%
2. All of the above

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3. 2009
4. Ballast Water Management Convention and the Anti-fouling Systems Convention

Fill in the Blanks

1. International Convention for the Prevention of Pollution from Ships.
2. Energy Efficiency Design Index
3. oil tankers, containerships and bulk carriers
4. London Convention

Chapter 14 - International Energy Management Standards

True or False

1. False
2. False
3. True
4. False

Multiple Choice

1. Measuring
2. All of the above
3. ISO 19030
4. Maintenance Measuring

Fill in the Blanks

1. Biofouling
2. Plan-Do-Check-Act
3. measured
4. live' document

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