Guidance for the Development of Ship Energy Efficiency Management Plan (SEEMP)

May, 2013

Introductory Note

The Marine Environment Protection Committee (MEPC) of International Maritime Organization adopted, on its 62nd session (held on 15th July 2011), the Amendments to Annex VI of the **International Convention for the Prevention of Pollution from Ships** (**MARPOL**), which introduced the new Chapter 4 "Regulations on Energy Efficiency for Ships", requiring that ships of 400 gross tonnage and above engaged in international voyages must carry a Ship Energy Efficiency Management Plan (SEEMP) which meets the requirements under the Convention.

The Convention also requires all ratifying countries to take corresponding measures to ensure that ships engaged in domestic voyages are constructed and operated within a reasonable and feasible scope in accordance with Chapter 4 "Regulations on Energy Efficiency for Ships" of Annex VI. The Ministry of Transport issued in April 2012 the Announcement on the Index System for Inland Navigation Vessels of Standard Sizes (as per MOT Announcement No. 13 of 2012 effective from 1 July 2012), which requires that newly constructed vessels operating on inland rivers must carry a Ship Energy Efficiency Management Plan as of the effective date.

This Guidance also applies to the domestic seagoing ship which will be granted with Class Notation "Green Ship" according to Rules for Green Ships 2012 published by China Classification Society. When developing SEEMP, the Guidance shall be referred to.

This Guidance is formulated by China Classification Society in accordance with the Amendments to MARPOL Annex VI (Resolution MEPC. 203(62)) and the requirements under the 2012 Guidelines for the Development of a Ship Energy Efficiency Management Plan (SEEMP) (Resolution MEPC. 213(63)) and the Guidelines for Voluntary Use of the Ship Energy Efficiency Operational Indicator (EEOI) (MEPC. 1/Circ. 684), for the purpose of guiding shipping companies to develop the contents of the plan from perspective of the four stages of a SEEMP, which are, "planning, implementation, monitoring, and evaluation and improvement", as well as in terms of best practices of energy efficiency. This Guidance also refers to relevant guidelines published or established by industry organizations such as OCIMF and INTERTANKO.

Chapter 1 General

1.1 Purpose

1.1.1 This Guidance is intended to provide the ship owners, managers and operators with general methods and guidelines to develop a Ship Energy Efficiency Management Plan (hereinafter referred to as SEEMP).

1.1.2 This Guidance is also intended to provide guidance for the verification of SEEMP compliance carried out by China Classification Society (hereinafter referred to as CCS).

1.2 Ground

1.2.1 The Amendments to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL), adopted on the 62nd session of IMO Marine Environment Protection Committee (MEPC) through Resolution MEPC.203 (62).

1.2.2 The 2012 Guidelines for the Development of Ship Energy Efficiency Management Plan, which was adopted on 2 March 2012 by International Maritime Organization (IMO), at its 63th session of IMO Marine Environment Protection Committee (MEPC) through Resolution MEPC.213(63).

1.2.3 Guidelines for Voluntary Use of the Ship Energy Efficiency Operational Index (EEOI) (MEPC.1/Circ.684).

1.2.4 Announcement on the Index System for Inland Navigation Vessels of Standard Sizes of the Ministry of Transport (MOT Announcement No. 13 of 2012).

1.3 Scope of Application

1.3.1 This Guidance applies to all ships of 400 gross tonnage and above engaged in international voyages and the applicable ships under the Announcement on the Index System for Inland Navigation Vessels of Standard Sizes of the Ministry of Transport.

1.3.2 All ships of less than 400 gross tonnage, engaged in international and domestic voyages, can refer to this Guidance.

1.4 Definitions and Abbreviations

1.4.1 Definitions

1.4.1.1 Company: Company means the owner of the ship or any other organization or person such as the manager or bareboat charterer, who has assumed the responsibility for operation of the ship from the ship owner.

1.4.1.2 Ship Safety Management System: A structured and documented system enabling company personnel to implement effectively the company safety and environmental protection policy.

1.4.1.3 Energy efficiency: Utilization ratio of energy, i.e. the relationship between the result obtained and the energy used.

1.4.1.4 Energy efficiency factors: The factors that influence the ship energy utilization efficiency and CO_2 emission during the ship transportation/operation.

1.4.1.5 Energy efficiency management system: It is a part of the company management system, which is utilized to establish energy efficiency policy and goals, manage energy efficiency factors, and realize the integration of policy and goals, including the company structure, responsibilities, usual practice, procedures, processes and resources.

1.4.1.6 Energy efficiency policy: The objectives of the ship energy efficiency management officially released by the top management of the company.

1.4.1.7 Energy efficiency goal: The overall requirements for the reduction of ship unit energy consumption and the improvement of energy efficiency that the company plans to meet.

1.4.1.8 Energy efficiency index: The specific requirements stipulated for the achievement of the energy efficiency goal, which are applicable to the whole or part of the company (including ships).

1.4.1.9 Energy efficiency baseline: The level of the energy utilization efficiency and CO_2 emission determined by the company as the comparison basis in accordance with the historic energy efficiency status of the ship or fleet.

1.4.1.10 Energy efficiency benchmark: The level of the energy efficiency and CO_2 emission determined by the company in accordance with the comparison between the same types of ship.

1.4.1.11 Energy efficiency operational indicator: Energy efficiency operational indicator is defined as the ratio of mass of CO_2 (M) emitted per unit of transport work, namely, the ratio of CO_2 emission from the fuel consumption to the quantity of cargo/number of people multiplied by transport distance, which is used to measure the ship operational energy efficiency during a certain period.

1.4.1.12 Energy consumption intensity index: The energy consumption by the unit transport turnover of ships in service.

1.4.1.13 CO_2 emission intensity index: The CO_2 emission in unit transport turnover of ships in service.

1.4.1.14 Energy efficiency data: The energy efficiency data means all the data related to the calculation of the energy consumption, energy efficiency and CO_2 emission.

1.4.2 Abbreviations

1.4.2.1 IMO--- International Maritime Organization;

1.4.2.2 MEPC--- Marine Environment Protection Committee of International Maritime Organization;

1.4.2.3 EEOI--- Ship Energy Efficiency Operational Indicator;

1.4.2.4 SEEMP--- Ship Energy Efficiency Management Plan;

1.4.2.5 EEMS--- Energy Efficiency Management System;

1.4.2.6 SEEMC--- Ship Energy Efficiency Management Certificate;

1.4.2.7 CEEMC--- Company Energy Efficiency Management Certificate;

1.4.2.8 IEEC--- International Energy Efficiency Certificate.

Chapter 2 SEEMP Contents and Requirements

2.1 General Requirements

2.1.1 SEEMP shall clearly reflect the ship's own characteristics. When developing a SEEMP, adequate consideration should be given to a company's business scale, fleet size, ship types, shipping routes, distance sailed, navigating zones, characteristics of trade, ship management staff as well as situations that may occur in practice.

2.1.2 SEEMP shall comply with the improvement cycle steps of planning, implementation, monitoring and checking, and evaluation and improvement.

2.1.3 SEEMP shall include elements such as basic energy efficiency policy, goals and indexes, resources and responsibilities, as well as document management and operational control, etc.

2.1.4 Energy Efficiency Policy and Goals

2.1.4.1 The content of energy efficiency policy should reflect a commitment of the top management to improve energy efficiency and make such continuous improvement by fully utilizing energy in accordance with the requirements under laws and regulations.

2.1.4.2 Energy efficiency policy, which is the basis for establishing energy efficiency goals, should be prescribed in a document with its content clearly specified in order to make it understood by the implementing staff, and regular review and revision should be made to the policy to reflect the constantly changing internal and external conditions and information.

2.1.4.3 Energy efficiency policy established by companies may:

(1) apply to the characteristics of the ship transportation/operation and coordinate with the other existing management system policies of the company;

(2) include the commitment to reduce ship unit consumption, improve energy efficiency as well as continue to make such improvement;

(3) include the commitment to comply with the international conventions, laws, regulations, standards and other requirements applicable to the ship energy efficiency management;

(4) provide framework for the formulation and evaluation of the energy efficiency goals and indexes;

(5) be documented for full understanding and implementation by all employees;

(6) Be accessible to relevant parties.

2.1.5 Energy Efficiency Goals and Indexes

2.1.5.1 Energy efficiency goals shall meet the requirements set out by the existing national and international laws and regulations as well as energy efficiency policy, and shall be measured with measurable performance indicators on the basis of important energy efficiency factors.

2.1.5.2 Energy efficiency indexes, generated from Energy efficiency goals, are the detailed breakdown of the energy efficiency goals and the specific requirements to achieve such goals. Energy efficiency indexes should be of quantifiable feature, indicated by certain parameters. As important energy efficiency factors play a decisive role in quantifying and measuring energy efficiency, energy efficiency indexes should therefore be also based on important energy efficiency factors.

2.1.6 Resources and Responsibilities

2.1.6.1 Essential resources required for the implementation of a SEEMP include human resources, financial resources as well as material resources.

2.1.6.2 Provision of resources, such as shore-based management staff with ship expertise and competent crews; relevant energy efficiency measuring tools, instruments and software systems with which a ship is required to be equipped for the purpose of monitoring and measuring energy efficiency data as well as capital investments to implement a particular new energy-saving technology; adequate identification and use of the best management practices and experience, as well as use of the new energy-saving technologies and new methods and etc. developed at present.

2.1.6.3 Company should develop written documents specifying the duties, roles and authorities for staff at every level. Company should, according to its own characteristics, expressly prescribe the corresponding responsibilities and duties of such departments and persons as operation management, scheduling management, machinery management, marine management, system management, ship master, deck department and engine department when implementing energy efficiency management.

2.1.7 Document Management and Control

2.1.7.1 This plan shall be either part of the existing management systems (i.e. Safety Management System) or a separate document. Regardless of relationship with the existing systems, the company shall work out relevant procedures to ensure the effective execution of this plan at each step of planning, implementation, monitoring and improvement.

2.1.7.2 This plan, as part of the company's controlled documents, should be managed in accordance with the company's document management and control procedure.

2.1.7.3 For ships engaged in international voyages, SEEMP and IEEC should be carried on board ship and available for inspection and verification; for inland navigation vessels, SEEMP should also be carried on board ship.

2.1.7.4 SEEMP running records and energy efficiency monitoring records should be maintained, for the purpose of evaluating the running status of SEEMP and improving energy efficiency measures by the company/ship.

2.2 Planning of SEEMP

Planning is the most crucial stage of the SEEMP. This stage primarily determines the energy efficiency policy, the current status of ship energy usage, the energy efficiency management baseline and benchmark and the expected improvement of ship energy efficiency, identifies energy efficiency factors, and finally sets the energy efficiency goals and indexes.

2.2.1 Energy Efficiency Factors

2.2.1.1 Identification of energy efficiency factors: In identifying energy efficiency factors, it is necessary for both company staff at every level and crew members to be involved in order to completely identify existing and potential energy efficiency factors. Factors such as company size, operation features, ship types, trading zones, navigation zones, shipping routes and voyages are to be taken into account when identifying energy efficiency factors. All aspects of energy consumed during ship's production and operation activities are to be identified at first, and then consideration should be given to each area that may exert control and impact on energy utilization rate, thus to determine the energy efficiency factors.

2.2.1.2 Procedure to determine energy efficiency factor checklist: Company is required to establish relevant procedure specifying the rules for and control of the identification, evaluation and updates of energy efficiency factors.

2.2.1.3 Updates of energy efficiency factors: After the reasonable measures identified as per the energy efficiency factor checklist have been implemented for a certain period of time or when changes of certain factors occur to a ship, such as changes of shipping routes, currencies, updates of relevant laws and regulations, internal management requirements, management review requirements and etc., the company is required to evaluate and review the ship's energy efficiency factors again, and re-determine the energy efficiency factor checklist. Therefore, updates of energy efficiency factors can be either periodical or at any time.

2.2.1.4 Procedure to determine energy efficiency factor checklist: Company is required to establish relevant procedure specifying the rules for and control of the identification, evaluation and updates of energy efficiency factors.

2.2.1.5 Ships' energy efficiency factors include but not limit to:

1) Route design; 2) Speed management; 3) Weather routing; 4) Fuel and lubrication oil consumption of main/auxiliary engine and boiler; 5) Fuel and lubrication oil management; 6) Hull maintenance; 7) Ballast voyage; 8) Drafts and trims; 9) Ship cargo carrying capacity; 10) Maintenance of ships' constant; 11) Propulsion system; 12) Propeller status; 13) Fuel consumption of incinerators and inert gas generators; 14) Rudder and heading control system; 15) Loading/discharge operation; 16) Waste heat recovery; 17) Insulation, ventilation and warming; 18) Fuel Type; 19) Use of shore power; 20) New energy-saving technologies; 21) Navigation with the tide; 22) Formation of inland navigation vessels; 23) Scheduling Management.

2.2.1.6 Increase or improvement of the operational energy efficiency of a ship depend not only on single ship management, but also on many stakeholders including ship repair yards, shipowners, operators, charterers, cargo owners, ports and traffic management services, for example, timely communication with traffic management services and ship representatives can save sailing days which can be further used to sail at reduced speed to achieve energy-saving results. For communication and coordination with stakeholders, it can be managed by a company through incorporation into its existing system documents or establishment of a separate Company Energy Efficiency Management Plan (CEEMP).

2.2.2 Energy Efficiency Measures

2.2.2.1 Determination of Energy Efficiency Measures: Upon determination of the energy efficiency factor checklist, the company is to evaluate the existing energy efficiency measures according to the existing status of ships' energy efficiency mastered, the energy efficiency measures already adopted and the best ship operation practice, and then to optimize and develop more reasonable measures as the energy efficiency measures at implementation stage. Energy efficiency measures should be based on the premise of safety and meet the requirements of relevant laws and regulations.

2.2.2.2 Ship master should, according to the characteristics of the vessel and the voyage, develop the specific implementation rules for this ship's energy efficiency measures within a period of time.

2.2.2.3 Re-determination of Energy Efficiency Measures: After re-determination of the energy efficiency factor checklist, it is also required to re-evaluate the energy efficiency measures, and choose and develop new measures against the energy efficiency factor checklist, in order to be implemented in the energy efficiency management plan of next cycle.

2.2.3 Energy Efficiency Baseline and Benchmark

2.2.3.1 Company may, in appropriate manners, gather statistics of and analyze company/ship energy efficiency data to determine the baseline and benchmark for measuring and evaluating energy efficiency.

2.2.3.2 Energy efficiency baseline is the company's statistics of the ship / fleet historical data of many years, which uses the stage (or year) representing energy efficiency analysis result as a baseline reference point for the implementation of energy efficiency management plan, and is also the reference point for vertical comparison of the ship / fleet energy efficiency level.

2.2.3.3 Energy efficiency benchmark is set out according to the level of energy efficiency between the comparison of same types of ships in the industry or from different companies as the energy efficiency management goals or baseline reference point for the company's fleet / ship, and is also the reference point for horizontal comparison of the ship / fleet energy efficiency level. The determination of energy efficiency benchmark is relatively complicated, which can be used with some flexibility in the SEEMP.

2.2.3.4 Company shall evaluate and adjust the energy efficiency baseline and benchmark regularly so as to make them more reasonable.

2.2.4 Human Resources

2.2.4.1 Staff's energy efficiency awareness and skills play an important role in energy efficiency management. Therefore, adequate attention is required to be paid to the development of human resources at planning stage, and relevant training courses need to be carried out for the shore-based and onboard staff in connection with energy efficiency management in order to improve their awareness of energy efficiency as well as their capability to execute the energy efficiency measures.

2.2.4.2 Identifying Training Demand. It is required to adequately identify the training projects and staff demands of energy efficiency management at planning stage, especially the demands of those who play major roles in the works of energy efficiency management.

2.2.4.3 Improving Staff Awareness. It is intended through training to make all staff aware of: the significance of compliance with the energy efficiency policy and energy efficiency management system; the benefits from reduction of the ship energy unit consumption and improvement in the energy efficiency as well as the energy efficiency improvement performance by personal work improvement; and the potential consequences that may occur due to an operation deviated from procedures.

2.2.5 Energy Efficiency Goals and Indexes

2.2.5.1 The setting of energy efficiency goals and indexes is the last part of the planning stage. The company may determine, according to the energy efficiency baseline and benchmark, the energy efficiency goals and indexes for a particular period of time, such as a five-year goal or the goal of each year. However, if the goal is set for a long period of time, it would be better to break it down into goals at certain time nodes so as to make such goal more reasonable. The energy efficiency goal and index must be measurable and easy to understand. Where specific provisions related to energy efficiency goal have been laid down by international laws and regulations or relevant laws of flag State, energy efficiency goal has to meet relevant requirements.

2.2.5.2 Energy Efficiency Monitoring Tools. Energy efficiency monitoring tools and methods are the means used to monitor the achievement level of the energy efficiency goals, among which Ship Energy Efficiency Operational Indicator (EEOI) is one of the internationally recognized tools to acquire ship and / or fleet operational energy efficiency values. Therefore, EEOI can be deemed as the main monitoring tool. Besides EEOI, for the convenience of company or ship energy efficiency management as well as the energy efficiency performance assessment for ship or fleet and shore-based departments, other monitoring tools can also be used, such as fuel consumption per thousand tonnes nautical mile (tonnes kilometer), main engine fuel consumption, fuel consumption per nautical mile (kilometer), annual overall fuel consumption, and fuel consumption per unit of output value.

2.3 SEEMP Implementation

2.3.1 Supporting Procedures for Implementing SEEMP

2.3.1.1 Company should establish SEEMP implementation system and prepare supporting procedures to ensure an effective implementation of SEEMP. These procedures can be separate documents, or be described in the SEEMP, or otherwise be part of the existing management system.

2.3.1.2 These procedures may include Energy Efficiency Management Manual, Training Procedure, Information Communication Procedure, Document and Data Control Procedure, Record Management Control Procedure, Ship and Equipment Maintenance Management Procedure, Energy Efficiency Factor Evaluation Procedure, and Procedure for Collecting Laws, Regulations and Relevant Requirements, and if they are basically the same as the procedures in the existing systems, these procedures should also include the contents concerning ship energy efficiency management.

2.3.1.3 The company is to develop a specific SEEMP for each vessel, which may include the dates of development, approval, implementation and next evaluation, goals to be achieved, energy efficiency measures, specific contents to be implemented, responsible persons both on board and ashore, implementing records, etc. In addition, to effectively implement the energy efficiency measures and maintain good monitoring during the implementation process, where appropriate, the company is to develop process control charts for the implementation processes of various energy efficiency measures, especially for key processes, and carry out standardized process flow management, such as Fuel Bunkering Management Process, Ship Speed Control Process and Cargo Oil Heating Control Process.

2.3.2 SEEMP Implementation

2.3.2.1 Necessary support of shore resources must be provided in the process of implementing energy efficiency measures.

2.3.2.2 Training of staff awareness and professional skills as well as exchange of experience are to be paid close attention in the process of SEEMP implementation.

2.3.2.3 Information Exchange. The company is required to keep better exchange and communication information between all internal functional departments and staff at every level (including both on board ship and shore staff), receive, respond to and document relevant external information as well as to communicate and coordinate timely with external stakeholders to improve ship turnaround utilization rate.

2.3.2.4 To keep controlling of records of the energy efficiency data, relevant activities as well as documents generated during the implementation of SEEMP.

2.3.2.5 When implementing energy efficiency measures, it is necessary to monitor the whole process in accordance with process control procedure and other relevant procedures in order to ensure the effectiveness of the implementation and avoid potential deviations.

2.4 Energy Efficiency Monitoring and Measuring

According to the identified energy efficiency implementation plan and predetermined monitoring method at planning stage, the company is to measure and monitor key data that have major impact on ship energy consumption, energy utilization efficiency, and CO_2 emission, etc., in order to make energy efficiency statistics and analysis regularly.

2.4.1 Monitoring and Measuring Equipment (Energy Efficiency Measuring Instrument)

2.4.1.1 Ships are to be equipped with appropriate energy efficiency measuring devices and instruments according to the prescribed energy efficiency indexes, such as fuel flow meter, capacity meter, and dipstick, etc.

2.4.1.2 Energy efficiency measuring devices and instruments should be maintained and calibrated regularly to ensure accuracy of the measuring results, and relevant maintenance and calibration records should be kept.

2.4.1.3 If provided, ships should be equipped with computers and installed relevant software to provide management tools for energy efficiency data collection, statistics and analysis.

2.4.2 Energy Efficiency Index

2.4.2.1 There are various indexes to measure ship energy efficiency, such as EEOI, fuel consumption per thousand tons nautical mile (ton kilometer), main engine fuel consumption, fuel consumption per nautical mile (kilometer), annual overall fuel consumption, and fuel consumption per unit of output value as mentioned at the planning stage of this Guidance. A ship may adopt one or several indexes to measure ship energy efficiency.

2.4.2.2 When selecting energy efficiency measuring index for a ship, it is required to select a tool that is representative and widely used as one of the measuring index, such as EEOI, ship energy efficiency operational indicator recommended by IMO, which is in line with the index "CO_2 Emission Intensity" released by Administrations of Chinese Government. For the use of EEOI, on the one hand there are mature calculation method and application software, and on the other hand it is convenient to make horizontal comparison and gap analysis concerning operational energy efficiency so as to seek for improvement directions.

2.4.3 Data Collection

2.4.3.1 Data sources should be determined according to the energy efficiency indexes.

2.4.3.2 Regardless of the energy efficiency indexes adopted for a ship, it is required to plan and expressly specify monitoring and measuring methods and collection requirements of the energy efficiency data in connection with these indexes prior to use.

2.4.3.3 The following shall be specified:

(1) Ship energy efficiency data, including voyage distance, cargo capacity, fuel consumption data and relevant fuel information.

(2) The calculation of EEOI shall include both cargos carrying voyages and empty load voyages, such as ballast voyage and docking voyage. Voyages for the purpose of securing the safety of a ship or saving life at sea should be excluded.

(3) Fuel consumption shall count all fuel consumed at sea, in port or for a voyage or period in question, by main and auxiliary engines including boilers and incinerators. Besides, fuel types and all other fuel information that may affect CO_2 emission are to be collected.

(4) Voyage generally means the period between a departure from a port to the departure from the next port, including the period of sailing and berthing at ports.

(5) Distance sailed means the actual distance sailed in nautical miles (deck log-book data) for the voyage or period in question.

(6) Cargo capacity shall be applicable to different ship types in accordance with Article 3.5 of Annex to MEPC.1/Circ.684.

2.4.3.4 It should be noted that whatever measurement indexes are used, continuous and consistent data collection is the foundation of monitoring. Corresponding monitoring and measuring procedure should be established for a ship. It shall specify:

(1) Appropriate energy efficiency data collection frequency determined according to ship types and shipping service characteristics;

(2) Collection source of energy efficiency data (statutory log-book) and necessary measurements as well as relevant responsible persons;

(3) Uniform units and data format, and their detailed instructions;

(4) Quality control procedure established to ensure data accuracy.

2.4.4 Calculation and Analysis

2.4.4.1 Calculation shall be based on the definition of energy efficiency index in SEEMP and data collected, and it is therefore required to give specific instructions on the calculation method and relevant parameters and definitions.

2.4.4.2 For some energy efficiency indexes, for example EEOI, the calculated value for a particular voyage (e.g. ballast voyage) does not have any actual sense, and it should be indicated by the rolling average of an appropriate calculating cycle. Calculating cycle shall be kept constant and long enough, in so doing, short term unusual fluctuations will be filtered to present a relatively smooth trend of energy efficiency variations, while it is also conducive to reflecting reasonable average values within the chosen period of time.

2.4.4.3 Reference is to be made to Appendix 6 for the calculation methods of EEOI and EEOI rolling average indicator.

2.4.5 Monitoring System

2.4.5.1 It can be considered for a ship to establish a computerized monitoring system or combine it with the existing message communication, maintenance and navigation management systems, covering the range from data collection, analysis and calculation to output of energy efficiency data, which can not only help standardize data collection method and data formats, thereby reduce human understanding differences and calculation errors for obtaining continuous and reliable data, but also relieve the work burdens for crew member and shore-based staff.

2.4.5.2 Regular monitoring shall be carried out on ships✓ energy efficiency data and indexes. If any anomaly is detected, the company should analyze the causes and search for the impact factors during operation. The company is to monitor ship energy efficiency data and energy efficiency variation trend, and make comparison within the fleet, especially comparison of the energy efficiency between sister ships, which is much easier to find the differences existing in the management.

2.4.5.3 To standardize and unify industry energy efficiency data collection and statistical analysis, CCS has developed "Ship Energy Efficiency Management System" in website and independent software for company and ship in accordance with IMO MEPC.1/Circ.684 and Transportation Energy Consumption Statistics Monitoring and Reporting System. This system can output energy efficiency indexes (i.e. EEOI/CO_2 Emission Intensity, fuel consumption per unit transport turnover volume, energy consumption/CO_2 emission per unit transport volume, energy consumption per nautical mile/CO_2 emission, utilization rate of cargo capacity, speed reduction ratio) and other operational energy efficiency data (such as energy consumption, voyage distance, cargo capacity, turnover volume) according to sub-category statistics (company, ship type, ship age, tonnage, route, etc.), and can also make trend, comparison and correlation analysis in graphics of energy efficiency indexes. It is recommended to be used by companies and ships.

0.4.5.4 Calculation methods of the indexes adopted in the CCS energy efficiency database and statistical analysis system are as below:

(1) EEOI or CO_2 Emission Intensity (see Appendix 6)

$$AverageEEOI = \frac{\sum_i \sum_j FC_{if} \times C_{Fj})}{\sum_i m_{cargo,i} \times D_i)}$$

- 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 fuel mass to CO_2 mass conversion factor for fuel j;
- m_{cargo} is cargo carried (tonnes) or work done (number of TEUs or passengers) or gross tonnage for passenger ships;
- D is the distance in nautical miles corresponding to the cargo carried or work done.

(2) Unit transport turnover energy consumption

$$\text{Unit transport turnover energy consumption} = \frac{\sum \text{voyage fuel consumption})}{\sum \text{voyage freight volume} \times \text{voyage distance})}$$

- $\sum$ voyage fuel consumption): the total sum of the fuel consumption of each voyage, including sailing and mooring fuel consumption;
- $\sum$ voyage freight volume x voyage distance): the sum of the products of freight volume and distance of each voyage;

(3) CO_2 emission per freight volume

$$CO_2 \text{ emission per freight volume} = \frac{\sum \text{voryage satling category fuel consumption} \times CO_2 \text{ conversion factors})}{\sum \text{voyage freight volume})}$$

- $\sum$ voyage sailing category fuel consumption x CO_2 conversion coefficient):
  The sum of products of fuel consumption (heavy fuel oil, light fuel oil, diesel oil) during sailing of each voyage and the respective CO_2 conversion factors (CF)
- $\sum$ voyage cargo capacity): the sum of freight volume of each voyage

(4) CO_2 emission per nautical mile

$$CO_2 \text{ emission per nautical mile} = \frac{\sum \text{voyage sailing category fuel consumption} \times CO_2 \text{ conversion factors})}{\sum \text{voyage distance})}$$

- $\sum$ voyage sailing category fuel consumption x CO_2 conversion coefficient):
  The sum of products of fuel consumption (heavy fuel oil, light fuel oil, diesel oil) during sailing of each voyage and the respective CO_2 conversion factors (CF)
- $\sum$ voyage distance): the sum of distance of each voyage

(5) Cargo capacity utilization rate

$$\text{Cargo capacity utilization rate} = \frac{\sum \text{voyage freight volume} \times \text{voyage distance})}{\text{design cargo capacity} \times \sum \text{voyage distance})}$$

- $\sum$ voyage freight volume x voyage distance): the sum of the products of freight volume and distance of each voyage
- $\sum$ voyage distance): the sum of distance of each voyage
- design cargo capacity: the maximum cargo capacity designed for a ship

(6) Speed reduction ratio

$$\text{Speed reduction ratio} = \frac{\sum \text{voyage average speed} \times \text{voyage distance})}{\text{design speed} \times \sum \text{voyage distance})}$$

- $\sum$ voyage average speed x voyage distance): the sum of products of the average speed and distance of each voyage

- ∑ voyage distance) : the sum of distance of each voyage

2.4.5.5 T To meet the demands for elaborate management and performance appraisal and motivation, the company may adopt other measurement indicators to monitor individual ship or fleet energy efficiency, and take full account of the applicability and rationality of indexes according to the ship types and shipping routes, etc.

2.4.5.6 Individual ship indexes: EEOI, daily fuel consumption of main engine, daily fuel consumption of auxiliary engine, boiler fuel consumption at port, fuel consumption per nautical mile, fuel consumption per freight volume, and cargo capacity utilization rate, etc.

2.4.5.7 Company indexes: EEOI, fuel consumption per unit transport turnover volume, fuel consumption per unit of output value, annual overall fuel consumption, cargo capacity utilization rate, etc.

2.5 SEEMP Evaluation and Improvement

2.5.1 Evaluation and improvement phase should produce meaningful feedback for the coming first stage, i.e. planning stage of the next improvement cycle.

2.5.2 Basis of evaluation: the basis of evaluation shall be the energy efficiency goals and indexes set in this energy efficiency management implementation cycle and the energy efficiency management measures adopted.

2.5.3 Evaluation content:

(1) compliance of SEEMP;

(2) applicability of the ship energy efficiency management measures;

(3) effectiveness of the ship energy efficiency management activities;

(4) realization of the ship energy efficiency management goals and indexes;

2.5.4 Evaluation method: evaluation includes ship self-evaluation and company assessment. Energy efficiency management plan shall provide specific requirement for evaluation date, normally at the end of one energy efficiency management plan of one cycle and before the implementation of the energy efficiency management plan of the next cycle.

2.5.5 Evaluation report shall not only present evaluation and improvement advices for the operation effectiveness of SEEMP, but also include evaluation and improvement advices on implementing each energy efficiency measure, as input for the planning stage of next cycle of energy efficiency management plan.

2.5.6 Correction and Improvement

2.5.6.1 Upon completion of evaluation of the SEEMP within the cycle, there may be some situations that do not meet the prescribed requirements, and therefore the ship should, according to the improvement advices put forth in the self-evaluation report and company feedbacks, propose specific corrective measures with regard to the issues existing during the SEEMP implementation within the cycle, specify the improvement methods and completion dates, and organize to implement such measures.

2.5.6.2 When preparing for next cycle of ships✓ energy efficiency management plan, it is required to combine the implementation experience in the previous cycle, the issues identified during evaluation and the energy efficiency goals of next cycle.

2.5.6.3 When preparing for next cycle of ships✓ energy efficiency management plan, if company support is needed, the ship should request from the company at planning stage, and the company should provide necessary support.

2.5.6.4 Companies are encouraged to establish motivation and performance appraisal system.

Chapter 3 SEEMP Verification

3.1 SEEMP Verification Requirements

3.1.1 Scope of Application

3.1.1.1 These requirements apply to all ships of 400 gross tonnage and above engaged in international voyages.

3.1.1.2 For ships only engaged in voyages within the waters under the flag State's sovereignty or jurisdiction, the flag State should ensure, by the adoption of appropriate measures, that such ships keep SEEMP on board, so far as it is reasonable and practicable.

3.1.2 Verification Time

3.1.2.1 For any existing ship of 400 gross tonnage and above, the SEEMP verification shall be carried out no later than the first intermediate or renewal survey for International Air Pollution Prevention Certificate (IAPP), whichever is the first, on or after 1 January 2013.

3.1.2.2 For a new ship that shall meet the EEDI requirements as required by MARPOL Annex VI, the verification of SEEMP should be carried out before it is put in service and the International Energy Efficiency Certificate is issued.

3.1.3 Contents To Be Verified

3.1.3.1 SEEMP should be kept on board ship and available for verification.

3.1.3.2 The contents of SEEMP should meet the requirements of Resolution MEPC. 213(63), and include at least:

(1) Energy efficiency goal.

(2) Respective responsibilities and authorities of relevant functions and staff at all levels.

(3) Energy efficiency measures and implementation requirements.

(4) Monitoring system and monitoring requirements.

(5) Implementation timetablev.

(6) Self-evaluation and improvement requirements.

3.1.3.3 SEEMP should be developed specifically for target ships either as a separate document or as part of the company Safety Management System. The management characteristics of companies and ships (such as self-operated ship, chartered ship, etc.) should be taken into account during the development of SEEMP, which should be practical. The energy efficiency measures within SEEMP should be drawn up according to ships' characteristics, sailing areas, trading nature as well as relevant recommendations from industry organizations, and take comprehensive account of the compatibility of all energy-saving measures.

3.1.3.4 Procedural documents in planning, implementation, monitoring, evaluation and improvement of SEEMP are to be developed to ensure effective implementation of the SEEMP, and it should also be considered to minimize any onboard administrative burden. These procedural requirements can be developed within the SEEMP or refer to relevant contents of existing system documents.

3.1.4 Verification Process

3.1.4.1 Verification procedure and process are developed for CCS to fulfill the requirements of MARPOL Annex VI.

3.1.4.2 Companies are to submit verification application for the SEEMP of individual ship to local CCS branches in which these companies are located, with a soft copy and a hard copy of the SEEMP attached;

3.1.4.3 CCS branch shall review compliance of SEEMP, and if the SEEMP complies with the requirements of Resolution MEPC.213(63), SEEMP Statement of Compliance will be issued and the cover of the SEEMP will be stamped with "Verified". SEEMP and SEEMP Statement of Compliance should be kept on board ship.

3.1.4.4 CCS surveyors will verify on board ship if the ship carries SEEMP and SEEMP Statement of Compliance no later than the first intermediate or renewal survey for International Air Pollution Prevention Certificate (IAPP), whichever is the first, on or after 1 January 2013, and an International Energy Efficiency Certificate (IEEC) or International Energy Efficiency Statement of Compliance (if the ship flies flag of the state not ratifying the convention) will be issued after satisfactory survey.

3.1.4.5 For a new ship or existing ship with major conversion that is regarded as new ship by the administration, SEEMP compliance verification process is the same as per section 3.1.4.2, 3.1.4.3 and 3.1.4.4. Before the ship is put into service, the SEEMP Statement of Compliance will be issued after satisfactory SEEMP verification, and the IEEC will be issued after verifying that the SEEMP and the SEEMP Statement of Compliance are kept on board the ship and satisfy EEDI requirements.

3.1.4.6 Ships applying for (voluntary) ship energy efficiency management system certification from CCS do not need to apply for SEEMP verification separately.

3.2 Certification

3.2.1 Existing ships that have submitted applications and passed SEEMP document compliance verification and onboard verification will be issued with IEEC or International Energy Efficiency Statement of Compliance (if the ship flies flag of the state not ratifying the convention).

3.2.2 IEEC or International Energy Efficiency Statement of Compliance (if the ship flies flag of the state not ratifying the convention) will be issued to new ships or existing ships with major conversion that are regarded as new ships, after having submitted application and passed SEEMP document compliance verification and onboard ship verification as well as met the provisions in connection with EEDI under MARPOL Annex VI.

3.2.3 Ships that completed ship energy efficiency management system certification by CCS and obtained Ship Energy Efficiency Management Certificate (SEEMC) shall also be issued with SEEMP Statement of Compliance at the same time.

3.2.4 Only the ship with CCS class will be issued IEEC or International Energy Efficiency Statement of Compliance (if the ship flies flag of the state not ratifying the convention) by CCS.

3.3 Invalidation of IEEC and SEEMP re–verification

3.3.1 An IEEC has long–term effectiveness unless the following cases occur:

(1) Ship decommissioned; or

(2) Ship with major conversion (as defined per MARPOL Annex VI); or

(3) Ship changing flag.

3.3.2 If an IEEC becomes invalid, the company may submit application to CCS for SEEMP re–verification, and the re–verification process shall be carried out in accordance with the requirements set out in Section 3.1.4 under this Chapter.

3.3.3 Due to the reason of section 3.3.1 (2) that causes the invalidation of IEEC, in cases where the major conversion of the ship is so extensive that the ship is regarded by the Administration as a newly constructed ship, EEDI verification and SEEMP re-verification should be carried out, and apart from this, SEEMP re-verification is not required; this ship will be re-issued with an IEEC after SEEMP re-verification and its EEDI has been verified as complying with the provisions under MARPOL Annex VI.

3.3.4 Due to the reason of section 3.3.1 (3) that causes the invalidation of IEEC, SEEMP re-verification should be carried out before that ship may engage in voyages to ports or offshore terminals under the jurisdiction of other contracting countries. An IEEC will be re-issued after passing the verification.

3.3.5 In cases where the ship changes its class from other society classification to CCS, the SEEMP need not to be re-verified if IEEC has been obtained and the management company has not been changed, and CCS surveyor will re-issue IEEC directly; if the management company has been changed, the ship should submit an application for SEEMP verification according to section 3.1.4. CCS surveyor will re-issue IEEC after a satisfactory verification of SEEMP.

APPENDIX

Appendix 1 Best Practices for Energy - Efficient Operation of Ships Engaged In International Voyages

1 General

1.1 Purpose and Scope

1.1.1 The best practices for energy – efficient operation of ships provided in this Appendix are intended to provide the shipping companies with guidelines for the development of ship – specific energy efficiency measures.

1.1.2 The best practices for energy – efficient operation provided in this Appendix apply to cargo carriers engaged in marine transportation, but the energy efficiency measures listed or combination of such measures do not necessarily apply to specific ships, and the shipping companies should therefore develop specific energy efficiency measures according to the characteristics of ships.

1.2 General Requirements

1.2.1 Energy efficiency measures of ships' operation are the core of a SEEMP, and energy efficiency can be improved mainly through reduction of ship resistance, Improving propulsion efficiency, improving power generation (machinery) as well as optimization of management and operation, while the results of energy efficiency measures depend on ship sizes and their relevant operational mode.

1.2.2 The improvement of energy efficiency across the entire transport chain takes responsibility beyond what can be delivered by the owner / operator alone, and to some degree depends on the coordinated actions between many involved stakeholders. The list of all the possible stakeholders in the efficiency of ship operation is long, which includes designers, shipyards and equipment manufacturers, as well as charterers, ports and vessel traffic management services, etc. Relevant parties should consider the inclusion of efficiency measures in their operations collectively.

1.2.3 The improvement of energy efficiency of ship operation does not necessarily depend on single ship management only. Whether a better coordination among relevant stakeholders can be maintained or not shall have major influences on the energy efficiency of ship operations. It is therefore necessary to establish corresponding measures at the company level to maintain necessary coordination among stakeholders.

1.2.4 When establishing energy efficiency measures of ship operation, the company and / or ship shall give adequate consideration to the above – mentioned factors, and according to the management and operation of company's ships as well as ships' own characteristics, sailing regions, trading and other relevant requirements, adopt the best plan of energy efficiency measures in view of the compatibility and cost – efficiency of various energy – saving measures.

1.2.5 The development of energy efficiency measures shall be specific and practical, identifying implementing method, steps, frequency, parameters, implementation requirements as well as responsible persons of the provided measures. Through continuous evaluation and improvement, it will finally form the best operational plan for energy efficiency or implementation guideline with guiding significance that fits the ship.

2 Best Practices for Energy - Efficient Operation of Ships

2.1 Management optimization for the operational energy efficiency of company flee

2.1.1 To optimize and configure liner routes

it is required to analyze factors in technical, economical and seasonal aspects, and evaluate overall energy efficiency and level of economy of the voyages. Normally a ship of higher operational energy efficiency (lower EEOI) has a better level of economy. Companies are recommended to develop fleet operation management and allocation system, and evaluate and adjust regularly the fleet energy efficiency and economy level to achieve an optimized liner route and feet configuration. To optimize liner fleet operation management, the following measures can be considered, but not limit to:

2.1.1.1 Route structure optimization

Such as multi - port calling direct transport program, integrated trunk and feeder transport program, and etc. Evaluation shall be conducted on many factors in these several programs, such as market supplies and demands, cargo fluctuation and development trends, ship utilization rate, voyage distance, and etc., and meanwhile, comparison and analysis of ship and fleet energy consumption and energy efficiency level should be carried out so as to develop an energy efficiency goal evaluation system, which shall be used as the basis for judging each decision program to select an optimal program.

2.1.1.2 Optimization of the port of call

Major factors in connection with ship energy efficiency and ship utilization efficiency should be considered, including geography, cargo sources and ports. For example, the selection of base port and shipping route distance; as distance sailed correlates with ship energy efficiency, if a base port is selected in a port where cargo sources are relatively centralized, it will help reduce cargo turnover volume and thereby reduce energy consumption. The natural conditions of a port, its efficiency of cargo - handling and facility services are also the operational energy efficiency factors shipowners or ship operators need to consider.

2.1.1.3 Ship type allocation and optimization

Liner route ship allocation program is to deploy the ships of different classification within the liner fleet to various voyages the company operates in a most reasonable manner; the company may select the optimum ship type or combination of optimum ship types through evaluating the technical reliability, the economic rationality as well as the design energy efficiency of ships. Generally speaking, the unit transport cost of ships with larger tonnage is lower than that of ships with smaller tonnage, and under the circumstances that other factors are not considered, ships with larger tonnage, only in terms of energy efficiency, tends to have lower energy consumption per unit transport turnover volume than ships with smaller tonnage.

2.1.1.4 Allocation and optimization of ship number

As containerships have higher speed and fuel consumption, speed reduction and adding ships are the existing main energy - saving measures the container liner shipping companies often take. When adopting the measures of ship addition and speed reduction, the company should, according to the voyage distance as determined for ships in this route and the conditions of the calling ports such as pier schedule arrangements and freight volume within the same cycle, analyze the overall fuel saved for the fleet and freight volume through checking the fuel consumption volume saved / cost savings / freight volume reduced on this same route after speed reduction taken by a single ship, and such analysis results shall be used to calculate and check the overall fuel consumption volume, freight volume as well as costs after adding more ships. The ship type, tonnage, draft of ships to be added and number of these ships shall thereby be determined in accordance with the analysis and calculation results, and then shipping companies have to find the match point between optimum energy saving and cost reduction in line with their business scale and specific operations.

2.1.1.5 Reasonable planning of sailing schedule and voyage schedule

The preparation of sailing schedule and voyage schedule should give consideration to many factors including ship speed at particular route and seasons, and an economic speed should be adopted in the view of ship energy efficiency and economy. During liner operation, as the cargo flows among ports are changing all the time, the scheduled ports of call and calling sequences should be adjusted accordingly, seeking to achieve full load and improve the load rate. Adjustment should be timely made to the voyage schedule or frequency of dispatching according to the ship loading capacity, and the designed surplus time of ship arrival at port should be seriously planned and arranged by the company according to the specific situations at a particular port, thus to give flexibility to the scheduled sailing dates and hence adapt to the changes of external conditions. Ships should reduce their speed properly in line with the sailing schedules and use economic speed to avoid fuel consumption brought by accelerated sailing due to a tight design sailing schedule which leads to ship delays and behind schedule. The freight volume reduced due to speed reduction can be offset by the addition of ships, and the corresponding actions taken must be communicated to and coordinated with relevant port side of the piers and cargo owners.

2.1.2 Fleet operation management optimization of tramp shipping company

Tramp shipping (voyage charter, time charter, bare boat charter) has a characteristic that routes, cargo types and lay days vary constantly with shipping demands.

2.1.2.1 Reasonable management of ships

If a company controls a large fleet and operates numerous shipping routes, then it is necessary to carry out multi-cargo, multi-route and multi-ship type optimization, especially for fixed route transport ships ordinarily engaged in transportation among many ports; as the transport volume is very large, the economic results of different sailing allocation programs are different, and therefore the results of ship energy efficiency are also different. Shipping companies can plan ship energy efficiency through various methods of route allocation optimization and fleet planning, such as linear programming technique, and it is of major significance for energy consumption saving of the company fleet if shortest fleet voyage distance can be set as goals through organization optimization.

2.1.2.2 Selection of shipping routes

If a tramper is used for voyage charter, it will often face several cargo carrying opportunities at the same time. As different opportunities have different cargo types, different loading and unloading ports, and different freight charges, the operators must make quick decisions on which batch of cargoes to carry in the next voyage. And furthermore, the operation of voyage charter feathers that the voyages have to be selected and nailed down one after another and the sequences of voyages need to be maintained in a continuous order in terms of time and geographic locations, it is therefore not enough to just consider one voyage, and the selections of next voyage and subsequent voyages are also to be considered. Freight coordination is necessary to, through reasonable freight scheduling arrangement of the company fleet and selection of continuous voyages of ships, avoid or reduce empty load voyage distance and improve ships' utilization rate and full-load rate, thus to improve ship energy efficiency.

2.1.2.3 Shipping route optimization

When the ports of loading and discharge for a particular voyage of ships are fixed, it is still needed to consider if there are sometimes several routes available for selection between the port of loading and the port of discharge. If one of these routes is short in distance, with good wind conditions and large ship loading capacity, then it is the optimum route. But often each route has its own advantages and disadvantages: for example, one route may have short distance, yet the draft is limited, which will prevent ship from full-load, while another may be with a good draft, but long in distance. Shipping companies are to consider the factors such as ship types, cargo capacity, ship energy consumption and greenhouse gas emission while planning voyages.

2.1.2.4 Direct and transit shipment optimization

If a ship has to wait for cargo at the direct ports with high use of port charges, crowded berth and poor efficiency of cargo-handling, etc., the energy consumption and greenhouse gas emission will be increased; in case that there is a port of call nearby, ship energy efficiency can be improved in a better way by transit shipment of cargoes.

2.1.2.5 Voyage estimation optimization

Ship cargo-worthiness, voyage time, cargo capacity, voyage fuel, water and necessities supplement, crew replacement, ship repair, hydro-meteorology, and etc., reasonable consideration of these factors can avoid ships' empty load rate and improve vessel utilization.

2.1.2.6 Charter contract management

1) In the voyage charter contract, shipowner shall add "Interpellation Clause", which stipulates that, if it is clear to the shipowner or ship master that the ship cannot arrive at the port of loading and get ready for cargo loading before the contract termination date, they can notify the charterer the delay of the ship and its estimated arrival date at the port of loading, and the charterer has to reply within a given period of time whether to terminate the charter contract or not. If the charterer keeps silent, it is considered an agreement to continue the contract. This is to avoid such awkward situation that the charterer declares termination of the contract when the ship arrives at the port of loading with ballast passage due to execution of the contract.

2) The ship speed under the charter contract is normally decided by the charterer rather than the ship operator, and the shipowner is obliged to provide ships that meet the speed requirement as defined in the contract. In a voyage charter, the shipowner should also try the best to sign the charter with an economic speed when concluding the contract.

3) For single voyage charter, there is normally a "not before clause", that is, when the ship arrives at the port of loading ahead of schedule, the charterer is not obliged to load in advance. Shipowner and ship operator should, upon the end of last voyage, notify the ship in advance to optimize the sailing speed in line with the sailing schedule.

4) Shipowner and charterer need to coordinate the required time of arrival (RTA) for each voyage, which should be the time for the ship to berth at the pier, and the ship should manage its speed according to the actual berthing plan, thus to avoid extra fuel consumption of the ship due to arrival in advance according to the charter contract and adoption of higher speed.

2.2 Voyage Plan Optimization

2.2.1 Development of voyage plan

Optimum route and improved energy efficiency can be achieved by careful planning and execution of voyages. For different ships, different loading conditions and different marine environment, the voyage plan may have some variations, but should include the following contents and steps:

(a) Evaluation of all information in connection with estimated voyages;

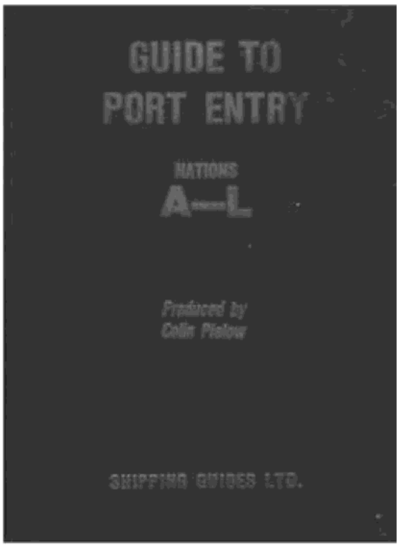
(b) Development of detailed berth-to-berth voyage plan, which should include necessary piloting information;

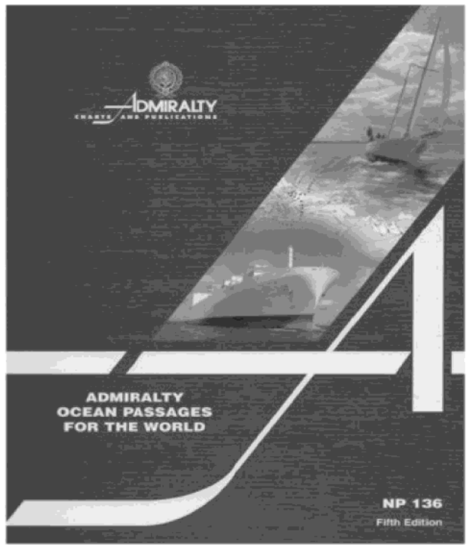
(c) Execution of voyage plan;

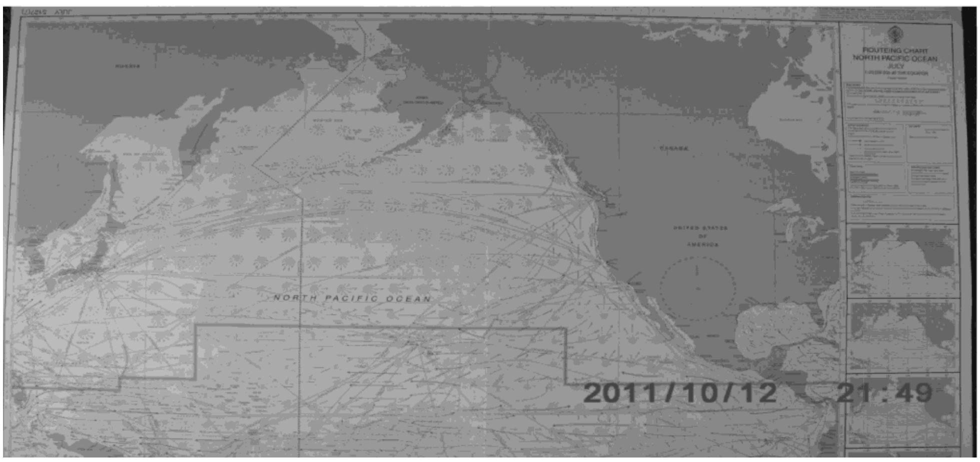
(d) Monitoring of this voyage plan's execution.

2.2.2 Route design;

Improvement of energy efficiency can also be acquired from optimization of route design. The company needs to cautiously consider route selection and speed, and designs the routes according to the latest meteorological data mastered, taking maximum advantage of ocean currents and tides while avoiding the impacts from bad weather and strong countercurrents; restrictions of traffic separation scheme and navigation safety should also be noted, references shall be made to nautical publications such as CHART: 5124 – 5128, NP136: Ocean Passages for the World, Ship's Routing, SAILING DIRECTION, Guide to Port Entry and etc.







To develop voyage plan, companies should:

(a) Often consider a route with the shortest distance, for example, use of the great circle line.

(b) Under the prerequisite of ship safety, select a route with the shortest distance; however, the shortest route may not be the optimum route, especially in an ocean crossing sailing, and the optimum route should be an optimized route after taking comprehensive account of factors such as wind, current, meteorology and oceanic condition.

(c) Weather routing

Weather routing has a high potential for efficiency savings on specific routes. It is commercially available for all types of ship and for many trade areas. Significant savings can be achieved, but conversely weather routing may also increase fuel consumption for a given voyage.

Weather routing will, combining ship's performance, loading features, technical conditions and sailing tasks, choose the optimum weather route for ships according to more accurate short and medium term weather forecast and marine forecast. The core of weather navigation is the study of the design method of ship's optimum route, which is, by fully utilizing the marine hydro – meteorological conditions during sailing and combining ship's performance and shipowner's requirements, to achieve as possible as it can such optimum performances as shortest sailing days, minimum fuel consumption as well as minimum ship and cargo damages under the precondition of ship's sailing safety, so as to reduce operational cost and improve transport efficiency. When ships are engaged in oceanic and long distance voyages, it is better for the company to apply weather navigation services.

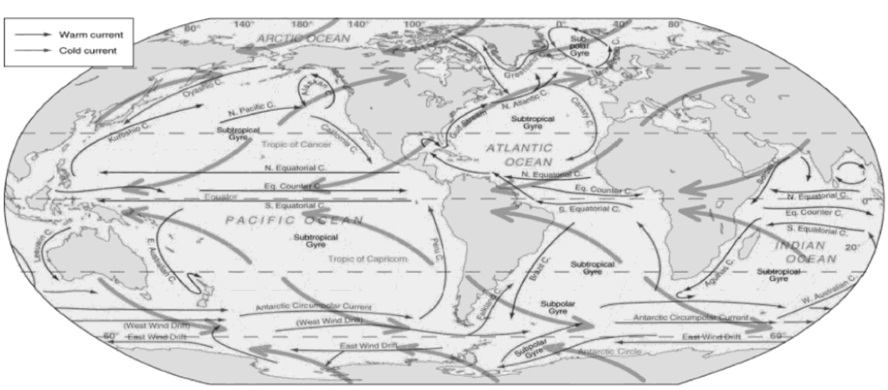
Weather routing is necessary to be considered as a helpful tool for all ships, especially in bad weather seasons such as winter seasons of the Northern Hemisphere and the monsoon seasons in the Indian Ocean. The selection of weather routing also enables the operators to avoid bad weather and acquire optimum ship speed and energy consumption. For ships engaged in ocean crossing voyages, there are more routes available for selection, which is particularly effective. Shipping companies should provide guiding route recommendations for ships engaged in voyages in different seasons and sea areas according to internationally published nautical books and industry nautical experiences.

Weather routing can save as well as increase fuel consumption. To select a route, safety comes first, and the shortening of voyage distance and days follows, which means saving sailing schedule and fuel consumption. Beside consideration of ships' own conditions, under the same meteorological condition, the shorter the voyage distance is the better. However, as the differences of actual oceanic meteorology and sea conditions are huge, sometimes the selection of shortest route will pose unfavorable condition to ships' safety, while at the same time, the voyage days and fuel consumption may increase due to impacts from the bad weather. But sometimes if a longer route is selected, due to the favorable influences from the meteorology and wind currents, beside the reduction of ship damages, the speed is increased and voyage days shortened. Weather routing can forecast the meteorological conditions of the future sailing area in advance, and is the optimized route concluded from a comprehensive consideration of the above situations.

At present there are many weather navigation companies such as WNI in the market. Shipping companies should, beside determining weather routing for ships, also determine the routes according to sailing area tracking factors, such as pirate dynamic areas.

(d) Utilization of ocean current to save energy

There are many ocean currents all over the world, and when designing sailing routes, according to nautical publications (ocean current charts), these currents can be effectively utilized by taking advantage of their characteristics.



2.3 Speed Optimization

The optimization of ship speed is related to many factors and it is necessary to seriously analyze factors and take reasonable measures to optimize the speed. Factors to be considered for speed optimization should include : ship operation mode, charter contract, fuel price, freight rate, shipping date, hydro-meteorological condition, speed requirements and limits from this voyage line and route, ship condition, ship loading status, fuel quality, ship optimization during actual operation, ship machinery and equipment, and etc.

2.3.1 The effects of ship operation mode on speed. Shipping companies are classified into two categories in terms of operation mode, i.e., liner shipping and tramp shipping. Speed optimization should be carried out respectively to different operation modes.

2.3.2 The effects of the content of charter contract on speed: refer to the charter contract. When a charter contract or partnership operation is concluded for a ship, the parties should try their best to fix that the ship is encouraged to operate at economic speed to achieve maximum energy efficiency, while fuel saving and pollution prevention are also related to efficiency and statutory requirements. In addition, dispatch and demurrage in the voyage charter contract may also have effect on speed.

2.3.3 As freight rates and fuel prices may affect shipowners' choice of the speed of vessel, ships may adopt different economic speed in line with the freight rate of cargoes and fuel prices. For example, in case that the fuel price is high, companies should try to use a sailing speed with the lowest fuel consumption.

2.3.4 The effects of sailing schedules: ships should adjust the speed according to the laycan of vessel.

2.3.5 The effects of hydro-meteorological conditions on speed. As ships may meet very large sailing resistance at rough seas, as a result of which the load and slip loss rate of main engines are also very large, speed should be reduced accordingly, otherwise overload of the main engines will occur and the fuel consumption will rise dramatically. As the same occurs when a ship is sailing against the current, the slip loss rate of main engines is especially large, and acceleration will lead to a sharp rise of main engine fuel consumption while the sailing speed will not be increased too much. Therefore, ships should adopt corresponding speed reduction measures according to different hydro-meteorological environment and ship's technical status.

2.3.6 The requirements and limitations of ship's routing and seaways on speed. The requirements of narrow waterway sailing, ship turning point and some fairway sea areas on speed, and the limitations of upper and lower diversion point on speed.

2.3.7 The effects of ship conditions on speed, including ship types, ship operation life, ship main engine status, ship fouling and coating conditions, etc. As the main engines of old ships have larger wear, they will normally sail at reduced revolution and speed, and the optimum economic speed will need to be re-evaluated. As ships of different types differ in wind and wave resistance, some ships may have larger wind area and poor seakeeping, therefore ships should take measures such as change of direction and speed reduction according to the wind wave situations to ensure a safe reduction of energy consumption.

2.3.8 Optimum energy efficiency speed means the speed at which the fuel used per nautical mile is at a minimum level for that voyage. It does not mean minimum speed; in fact, sailing at less than optimum speed will consume more fuel rather than less. Reference should be made to the engine manufacturer's power/consumption curve and the ship's propeller curve. Possible adverse consequences of slow speed operation may include increased vibration and problems with soot deposits in combustion chambers and exhaust systems. These possible consequences and safety risks brought by slow speed sailing should be taken into account.

2.3.9 The effects of fuel quality: Fuel consumption increase and speed reduction due to poor quality fuel. As the charterer is responsible for the fuel cost in time charter contract which usually only states fuel concentration, but without mentioning fuel quality and composition, there may be a large amount of sulphur, impurities or water in the fuel.

2.3.10 A gradual increase in speed when leaving a port or estuary whilst keeping the engine load within certain limits may help reduce fuel consumption.

2.3.11 Optimum energy efficiency speed is the speed at which fuel consumption per nautical mile is at a minimum level. At a certain fuel price and a particular fixed cost, there is always an economic speed at which the sailing cost per nautical mile is the lowest. However, if ship rent and other cost and expenses to maintain ship voyages are considered, optimum energy efficiency speed will not be necessarily the optimum economic speed. But if there is an excess of shipping capacity, under the circumstances that the ship berthing time is fixed and the sailing schedule is loose, optimum energy efficiency speed is therefore normally the optimum economic speed, which will help reduce ships’ fuel consumption and improve energy efficiency. Meanwhile, if a ship has high daily rent, tight schedule and busy transport tasks, in view of the company’s economic interests, it is also allowed to use different economic speed (for example, selection of speed with minimum fuel consumption rate or profit-making speed) according to different situations.

2.3.12 As part of the speed optimization process, due account may need to be taken of the need to coordinate arrival times with the availability of loading/discharge berths. The number of ships engaged in a particular trade route may need to be taken into account when considering speed optimization.

2.3.13 Utilization of optimized speed can save propelling power, but the sailing days of a ship will be increased due to speed reduction, and there are still other costs within the transportation costs of a ship. For ships engaged in particular routes, as a result of speed reduction, the sailing time will be increased and transport efficiency reduced, and the economic results may be therefore reduced. Due account may need to be taken of the need to coordinate arrival times with the availability of loading/discharge berths. by the ship owner according to the content of trading contracts, and as the reduction of ship speed will lead to a reduction of ships’ freight volume within the unit time, shipowners need to consider whether or not to increase the number of ships at the trading routes.

2.3.14 As to the main engine operation when sailing into a port or arriving at the anchorage area, the engine shall be cut out timely, taking full advantage of ships’ head reach (especially the long head reach of large oil tankers) to reduce the use of engine and therefore reduce fuel consumption. It is required to the full extent possible to avoid such operation method of heading to the anchorage with fast engine and then "abruptly braking" during high speed backing astern.

2.4 Optimization of Ship Draft and Trim

Both ship draft and trim will affect ship energy efficiency. As the depth of ship draft will decide the size of sailing resistance of a ship, the submerged depth of propeller will go down at light load, and the propelling efficiency will also be affected. Before a ship launches its sailing, the draft and trim need to be optimized. Trim adjustment through reasonable stowage and ballast is conducive to speed increase or fuel savings.

2.4.1 For confirmed draft, main engine horsepower and ballast condition, there is an optimum ship trim. A recommendation of ship’s optimum trim can be given through a comprehensive analysis of hull, propeller pitch and main engine output power by software tools. So far, such software has been developed and put into application, and it can help achieve an energy-saving result of about 1 to 2 percent. Ships may consider using it.

2.4.2 When the ship confirmed draft, ship’s longitudinal strength should be considered to ensure smooth operation and discharge of ballast water, so as to shorten ship’s port time.

2.4.3 Trimming vary with the consumption of fuel and water stored on voyage, therefore, ship’s trim must be considered in the view of full voyage before cargo stowage, and be monitored and adjusted constantly during sailing.

2.4.4 For ships equipped with variable-pitch propeller, as the pitch is adjustable and slip loss can be changed, in case that the revolution speed of main engine is constant, a ship is able to acquire any speed from zero to the maximum speed. When a ship meets rough weather and strong countercurrents, it is required to obtain the best fit of main engine-propeller-hull through adjusting main engine revolution speed and pitch, avoiding unnecessary consumption of main engine power caused by excessive slip loss.

2.4.5 For ships with half load and above, ballast water shall be used as less as possible to reduce ships’ sailing resistance of friction. For large ships, generally speaking, where appropriate, it would be better to sail with smaller trim and slight uppitch trim. To keep proper draft and trim during sailing, as a precondition the propeller needs to have adequate submerged depth, and it is required to keep enough under water depth for the propeller to maintain optimum propelling efficiency of the main engine and the rudder reaction efficiency.

2.4.6 Ballast voyage, the minimum average draft should be at least 50% and above of the summer full-load draft, and during winter sailing, it should be made between 55% to 60% of the summer full-load draft, when LBP > 150m, $d_{M\min} \geq 0.02LBP + 2$; minimum draft at the bow: when LBP > 150m, $d_{F\min} \geq 0.012LBP + 2$; minimum draft at the stern: $D \geq d$ (propeller diameter), except for entering and leaving port, shoaling water and special circumstances.

2.4.7 In case that there is no optimum trim data of this ship, it is needed to detect the optimum trim of the ship in a ballast voyage at particular speed and displacement through continuous adjustment of the ship’s trim.

2.4.8 A ship’s optimum trim status should meet the principle that the ship maintains minimum resistance and fastest speed while still complying with the requirements of ship stability and longitudinal strength.

2.4.9 As the bulbous bow designs vary with ship types, if possible, the bulbous bow should be sunk into water to the greatest extent possible to reduce the wave drag.

2.4.10 If there is ship’s optimum trim curve diagram drawn after model trial within the ship documents, reference should be made to this diagram to adjust the optimum trim status for this ship.

2.5 Optimization of Ballast Water Operation

2.5.1 To meet the relevant requirements of IMO, WHO and the Administrations of port States, every ship of the company must be equipped with Ship Ballast Water Management Plan. To carry out ballast water operations, it is required to follow the contents of this ship’s Ship Ballast Water Management Plan.

2.5.2 To reduce the sludge within the ballast tank at ports with poor water quality (for example ports with too much silt), during port time, ballast water should be kept at the minimum level under the circumstances that the safety allowance is guaranteed; after leaving port, it is recommended to re-adjust the ballast water at clean waters.

2.5.3 The operation of ballast water shall comply with Conventions and local laws and regulations, and shall be discharged and recorded according to the IMO ballast water management requirements, meanwhile it should be particularly noted that no discharge should be done at special area.

2.5.4 Ballast water should be pressed in and discharged by gravitational method as far as possible in safety, maintaining appropriate draft and trim to shorten ballast water operation time. With reference to the ballast water management plan, if safety and strength permit, emptying and injection method shall be used as far as possible when replacing ballast water.

2.6 Ship Measures When Confronting Rough Weather

2.6.1 Sometimes sea weather such as the local harmful typhoon of South China Sea may happen suddenly, the forecast time of which is short. To avoid the impact of rough weather, ships should, according to their own situations, take many effective measures such as redirection, deceleration, heaving-to, lie-to, anchorage for shelter, deviation and etc. These measures can not only guarantee ships✔ navigation safety, but also avoid fuel consumption of the main engine, and in the meanwhile also avoid damages that may occur to ships due to excessive countervailing forces against the hull. Every ship should develop the wind resistance and speed reduction measures in advance according to its own ship condition and loading status.

2.6.2 Ships may also take such measures, before rough weather comes, as sailing at full speed to shelter or safe waters, some of which may increase ships✔ energy efficiency to ensure the safety of ships and cargo; they are reasonable, but may be a disadvantage for the calculation of energy efficiency indexes such as EEOI. In addition, when adopting relevant operation measures, shipping companies and ships should take appropriate actions, under the premise of ensuring ship safety, to save fuels according to ships✔ sailing schedule and other conditions. Ships and companies should determine the RTA at destination ports in a timely manner, and if the sailing schedule is loose, they should determine and use optimum economic speed according to the hydro-meteorological conditions, or may consider to wait for the wind waves fading away by taking actions such as lie-to or anchorage before sailing again, so as to achieve the goal of cost saving by saving fuels and reducing fuel consumption.

2.7 Use of Rudder and Heading Control Systems (Autopilots)

An integrated Navigation and Command System can achieve significant fuel savings by simply reducing the distance sailed "off track". The principle is simple; better course control through less frequent and smaller corrections will minimize losses due to rudder resistance. By adjusting weather sensitivity, a ship can reduce its frequent rudder sway to reduce energy consumption of the steering engine, and therefore ship energy consumption is reduced. Retrofitting of a more efficient autopilot to existing ships could be considered by affordable companies. Where auto-rudder is used, the parameters of auto-rudder control system must be adjusted timely according to sea conditions, loading status and weather.

2.8 Timely Communication with Relevant Parties

Early communications between shipowners and ship operators and port relevant parties should be mutual, not only a ship needs to know the information from pier and port relevant parties and feed back relevant information to port relevant parties, but port relevant parties also need to timely communicate relevant information with shipowners and ship operators, which is also required by the BLU Code. Ships and ship operators need to know information such as relevant information of ports, vehicle transport service (VTS) and pilotage information, cargo status, passenger goods, loading/discharge machines, fuel and water replenishment at ports and other information. Early communication of these information will help shipping companies to take relevant measures as early as possible to make coordination or arrangement, thus to avoid delay of sailing schedules and deviation of ships, which is of great significance from an energy-saving and emission reduction point of view. For early communication, ships, ship managers and ship operators should establish contact procedures before ships' arrival at ports to effectively and timely exchange information with relevant parties, and the exchange of information should include the following contents:

2.8.1 Ship operators and ships should provide the ports and relevant parties with timely and continuous exchange of relevant information.

2.8.2 Communication of information in connection with the ports and relevant parties from a ship, including relevant information passed from ships to the ports and from port piers to ships or ship operators (ship documents, port pier documents, cargo documents and other relevant documents).

2.8.3 Measures that ships or shipowner and ship operators should take after the accurate berthing time is fixed. Including the measure of using optimum speed taken by a ship to sail to the destination port after the accurate berthing time is confirmed.

2.8.4 Optimum port operation may involve procedure changes including different handling arrangements in ports, and port authorities are encouraged to maximize efficiency and minimize delay.

2.8.5 For ships, good and efficient operation of ports can improve their efficiency to a maximum level and reduce delays to a minimum level, and some effective measures play a significant role in ships' energy saving and consumption reduction. For examples, measures such as good and reasonable berth and berthing programs as well as reasonable use of tugboats can help reduce ships' berthing time to save energy consumption, the use of state of art and economic and environmentally protective machines can improve efficiency of cargo-handling and reduce energy consumption and greenhouse gas emission, active communication between ships and ports as well as the use of shore power by ships to the greatest extent possible could help reduce noises and ships' greenhouse gas emission during port time, improve sea water cleanliness as well as protect resources and environment.

2.9 Optimization of Propeller Energy Efficiency

The efficiency of propeller depends on the design and manufacturing process. During construction of a ship, propeller with high efficiency and nice manufacturing process should be selected and taken a good match with main engine. For propellers that have already been installed to ships and in service, the major means to improve propeller efficiency is management.

2.9.1 Ensure appropriate submerged depth of propeller. It is sometimes noticed that part of the propeller of an empty ship is above water surface when entering or leaving ports, which the loss of propeller efficiency is at a maximum level, the loss rate depends on how much of the propeller is sunken into water. During sailing in a rough sea, the propeller will surface periodically with the waves leading to main engine overspeed, which will reduce propeller efficiency and therefore affect main engine efficiency. Therefore, proper submerged depth of the propellers should be maintained through ballast, reasonable stowage, reasonable allocation of use of fuels and fresh water, as well as adjustment of main engine revolution speed.

2.9.2 Check appearance status of the propeller. Various damages will occur to the propeller during its service, such as cavitation corrosion, propeller blade curling and deformation due to collision with sea floating debris, natural wear, as well as possible sea biofouling due to long term mooring on the propeller blade surface, and etc. All of these damages will lead to an increase of frictional resistance of water during the working period of the propeller, which leads further to a reduction of the propeller efficiency. Opportunities such as dock repair and in-water inspection should be used to inspect the propeller, checking blade surface and repairing damaged blades (curling and corrosion), so as to improve propeller efficiency.

2.9.3 Effects of navigation operating mode on fitting between engine and propeller. During sailing, when ship resistance increases (heavy load, fouling, against the wind and countercurrent, shallow and narrow fairway navigation) or motion state changes (setting sail, turning, reversing), advance ratio of the propeller will decrease (propeller efficiency decrease), and the diesel engine will work in an operating mode with big torque and slow revolution speed, causing high thermal load to the diesel engine and therefore leading to a reduction of reliability. Therefore, in a voyage (whether maneuvering or constant speed), where sailing resistance increases, main engine revolution speed should be adjusted timely to achieve appropriate fitting between engine and propeller, thus to improve efficiency of the propeller and diesel engine. For setting sail, turning and reversing, the main engine revolution speed should be increased gradually to achieve optimum propeller efficiency.

2.10 Hull Inspection

The growth of sea biofouling on the hull will increase ship resistance. Regular hull cleaning can help reduce resistance and thus the overall fuel consumption. Energy efficiency measures against hull include:

2.10.1 Hull coating: to reduce sea biofouling and therefore hull resistance;

2.10.2 When fouling occurs to a ship and seriously affects ship speed, it is required to report in a timely manner to the company, who should arrange a cleaning to the hull at a proper time;

2.10.3 Regular hull maintenance should be maintained; regular docking and assessment of ship performance should be ensured and smooth hull can be optimized by using coating technology. Regular in-water inspection of the condition of the hull and cleaning are recommended to ensure the cleanness of the hull. Timely full removal and replacement of underwater paint systems should be carried out to avoid the increased hull roughness caused by repeated spot blasting and repairs over multiple dockings.

2.11 Selection of proper main engine revolution speed

The navigation of a ship can be generally categorized into 2 phases, which are normal (constant speed) navigation and maneuvering navigation. For most commercial ships, constant speed navigation time accounts for 95% and above of the total navigation time, and therefore the management of main engine revolution speed at constant speed navigation phase plays a key role in energy saving and consumption reduction. The factors affecting constant speed navigation are mainly ship draft, hull cleanness status, sea conditions and seaway conditions (width, depth, etc.). When voyage tasks are fixed, the ship master should define the speed according to dates of arrival at ports and cargo owners' requirements, and adjust the main engine revolution speed in line with the above mentioned affecting factors during sailing:

2.11.1 The effects of ship draft change. When the draft increases, ship resistance increases accordingly, advance ratio of the propeller reduces and revolution speed slows down. For a speed governor of constant speed, this means to increase fuel supply to maintain a constant speed, leading to an increase of main engine fuel consumption or even overload, in cases of which, the main engine revolution speed should be properly reduced; on the contrary, when the ship is with light load or empty load, the main engine revolution speed should also be properly reduced according to the voyage time.

2.11.2 The effects of hull cleanness condition. The hull tends to get adhered by sea creatures when a ship moors at tropical waters, and after long term voyages, roughness of the hull will increase and bring resistance to ship's navigation. The effect of such resistance can be very large, the faster a ship is, the more speed loss it will cause. Usually, for a bulk carrier with a speed of 15 knots, the speed loss caused by resistance can reach 1 to 2 knots. If calculated on a basis of 1 knot loss in speed, a 30-day voyage distance as in the original schedule will actually need another 2.14 days, and consume an extra 53.5 tonnes of fuel if calculated per a daily fuel consumption of 25 tonnes. For such cases, the hull is to be cleaned timely, and if not applicable, the speed should as far as possible be reduced.

2.11.3 The effects of sea conditions and seaways. Rough sea conditions, navigation against wind, narrow seaway and shallow water sailing, all of these will lead to the increase of sailing resistance, therefore, main engine revolution speed should be properly slowed down to reduce losses due to fuel consumption.

2.11.4 Maneuvering navigation operating mode is mainly used for navigation phases such as entering and leaving ports, narrow seaway and inland river navigation, and its feature is that the fitting of engine and propeller is always changing, and main engine revolution speed and speed are also changing always; under such circumstances, drastic increase or decrease of speed should be avoided, except emergencies.

2.12 Maintain Good Operating Condition of Equipment

Usually, the purpose of maintenance is to improve the equipment reliability to ensure navigation safety. Actually, regular and general equipment maintenance, while ensuring the operating reliability of equipment, also plays an important role in energy saving and consumption reduction. For this purpose, maintenance plan of major energy consuming equipment should be developed for a ship, and maintenance shall be carried out regularly according to the plan.

2.12.1 Main engine

For the management of main engine, beside regular monitoring during operation, it is particularly important to carry out maintenance according to equipment manuals and established maintenance system, for example:

1) Poor sealing of high pressure fuel pump and niddle valve couplings in the fuel injection system will affect the performance of high pressure fuel supply and the volume of fuel supplied, as well as the atomization and burning of the fuel injected, therefore oil leakage check should be conducted on a regular basis, and fuel injection time should be regularly checked and adjusted.

2) As dirt and corrosion of the intake and exhaust valves in the scavenge system will lead to increase of the scavenging resistance in the cylinder, deterioration in airtightness of the inlet and outlet valve and increase of the residual gas, it will affect not only the cylinder compression pressure, but also the quality of scavenging, thereby affecting combustion quality. It is necessary to periodically clean and grind the intake and exhaust valves, check the airtightness and corrosion condition; dirt on the air compressor and turbine blades will also affect ventilation quality and thereby need to be cleaned regularly.

3) Wear and corrosion condition need to be checked periodically for cylinder liner and piston, and cylinder liner and piston ring groove should be replaced or sent to factory for repair if their wear condition is out of spec. Piston rings should be measured and airtightness of the cylinder liner be checked at each overhaul.

4) Other systems and components affecting the performance of diesel engine such as cylinder oil feed systems, fuel heating system, cooling system, lubricating system, speed control system, and etc.

The chief engineer should urge the marine engineers and the duty officer to strengthen maintenance and check the operating parameters of the mechanical equipment at any time, adjusting timely in case of any abnormal situation to ensure a good working condition of the equipment, thus to achieve the goals of energy consumption reduction through equipment management. Assuming poor working condition of the main engine could result in a 5% power loss, given the rated power of main engine is 7,208 kW, then the loss will be 360.4 kW, and if the each voyage sailing time is 30 days, then the total power loss will be 360.4kWX 24HX30D = 259,488 kWh; so if calculated on the basis of 170 g per kWh, then there will be a total of 44.1 tonnes loss in fuel consumption.

Beside by maintaining good performance of equipment to achieve the purpose of energy saving and consumption reduction, there are also other technical renovation means such as diesel engine optimization to achieve energy conservation, for example, retrofitting of the turbocharger to increase the intake air volume, cylinder and piston renovation to increase the compression ratio, improved injection nozzles and adoption of electronically controlled cylinder lubrication technology.

5) Taking the improvement of the main engine fuel injector as an example: a company has adopted the new slide valve instead of niddle valve in fuel injector, the slide valve of which has an operational life that is 2 times of that of the former injector, and about 2% fuel can be saved during actual operation. Under the same revolution speed and load, the exhaust gas temperature of the main engine lowers a bit, carbon deposit within the cylinder reduces, carbon deposit at the injection hole of the fuel injection nozzle reduces obviously, carbon deposit at the exhaust gas boiler reduces, and the low-speed running performance of the main engine also improves to a certain degree, which has provided technical support for the main engine to further navigate at reduced speed.

6) Taking the improvement of cylinder lubricator as an example: by using a new type of electronically controlled cylinder lubricator, electronic timing lubricating is realized through an electronic timing Swirl Injection Principle (SIP) cylinder oil lubricator, and the consumption of cylinder oil is saved under the premise of ensuring reliable operation of the equipment. Main engines with different power types have different fuel saving results, and on-board tests of a ship show that the rate of economizing fuel could reach 33%.

For ships navigating with reduced speed, speed reduction may lead to main engine exhaust discharge reduction and temperature decrease, resulting in pressure reduction of the steam generated by the exhaust gas boiler, and if the steam superheat temperature is reduced, it may lead to the problem that the heating of fuel will not satisfy the atomizing requirements, such problem can be solved by increasing heat exchange area of the fuel heater so as to meet the heating requirements.

2.12.2 Auxiliary engines: In addition to controlling the operation between 70% - 90% of the rated load as well as the running time of single and double auxiliary engines, direct factors affecting fuel consumption of the auxiliary engines include:

1) Working conditions of the auxiliary engine fuel supply system: auxiliary engine fuel injector status, high-pressure oil pump state, and delivery valve state.

2) Working conditions of auxiliary engine scavenging and inlet & exhaust systems: state of the exhaust valves, turbine efficiency, and air cooler effect.

3) Geometric dimensions of the auxiliary engine combustion chamber space: inner diameter of the cylinder liner, internal dimension of the cylinder head, piston head size and piston ring side clearance, and the wear condition of piston ring.

4) Timing control system: the state of fuel injection timing system, and the state of the exhaust valve timing system.

2.12.3 Auxiliary boiler / exhaust gas boiler: In addition to controlling the operation time of auxiliary boiler as well as the running time of single and double boilers, direct factors affecting fuel consumption of the auxiliary boiler include:

1) Water quality and scaling conditions of the boiler, and it is recommended to use distilled water generated by the fresh water generator.

2) Regular tests and dosing treatment of boiler water quality.

3) Cleanness of boiler heating surface, and soot.

4) Setting state of air and oil ratio, and the state of fuel full combustion.

5) Water supply temperature (to improve the water supply temperature as much as possible).

6) Cargo insulation, heating, unloading procedure.

7) Timely adjustment of the opening of cargo oil tank heating valves, and working conditions of the steam trap.

2.13 Reasonable Use of Auxiliary Boiler

In addition to energy conservation measures such as strengthening the inspection and maintenance of exhaust gas boilers and fuel auxiliary boilers, regular cleaning of boiler flue in strict accordance with the requirements of instructions, adjustment of the boiler air and oil ratio, as well as prevention of incomplete combustion of the boilers, it is also workable to improve thermal efficiency of the boilers through the following measures.

2.13.1 Reduce steam pressure of the boilers during berthing period;

2.13.2 Fully utilize the steam generated by the exhaust gas boiler during navigation;

2.13.3 Effectively control the distribution of heated steam, and stop invalid heating of unnecessary oil tanks;

2.13.4 During the period of berthing and entering or leaving ports, control the ignition and burning time of the auxiliary boilers in a good manner according to actual situations, and in the case of ensuring steam usage, try to shorten the time of using the auxiliary boilers.

2.13.5 Under the premise of meeting the requirements, proper lowering of the working pressure of auxiliary boilers is an effective energy-saving measure.

2.13.6 According to the actual situation, increase the cleaning frequency of boiler flue.

2.14 Reasonable Control of the Number of Running Auxiliary Engines

In addition to taking measures to strengthen maintenances including fuel valve of auxiliary engines, disassembly of the high-pressure fuel pump, and cleaning of the pressure booster, the air cooler as well as the inlet channels, to keep the best operating mode of auxiliary engines and improve the working efficiency of auxiliary engines so as to achieve the goal of energy consumption reduction, it is also workable to realize energy conservation by reducing the number of running auxiliary engines.

2.14.1 Use the auxiliary engines in a reasonable manner according to the power load of the entire ship, and in such case that the power load does not exceed 75% of the auxiliary engine power, a single engine should be used to the greatest extent possible instead of using two;

2.14.2 Stop equipment that is of non-essential use, and according to the power load, try to operate by using one auxiliary engine;

2.14.3 Try to shorten the period of time when standby state requires the use of double auxiliary engines, such as entering and leaving ports, alongside and leaving berth, narrow seaway navigation, and etc. Assuming a saving of one hour at a time, given the auxiliary engine specific fuel consumption at 170 g / kWh, a total of 0.17 kg fuel can be saved;

2.14.4 During berthing, try to stop unnecessary pumps, such as main engine lubricant pump, main engine jacket water pump, (to heat the cylinder for main engine by using auxiliary engine cooling water), lubrication oil purifier and so on. Given a total power of 100kW and 24 hours stop, if calculated on the basis of an auxiliary engine specific fuel consumption at 170 g / kWh, then a saving of 0.4 tonnes of fuel can be achieved per day;

2.14.5 If a ship is equipped with cargo loading devices, stop it in a timely manner according to the actual situation during loading / discharge period.

2.14.6 If possible, use shore power at ports.

2.15 Control of Freshwater and Fuel Bunkering

2.15.1 Make full use of the fresh water generator equipped on board, utilizing the waste heat generated by the main and auxiliary engines during sailing for sea water desalination, to reduce the fresh water supply quantity at port. When the conditions is suitable, there may be a significant surplus of the water made ? ? by fresh water generator in addition to meeting the demand of daily usage, and it is necessary for a ship to properly control the surplus freshwater generated according to voyage plans, as excessive amount of fresh water will increase the ship load and thereby increase fuel consumption;

2.15.2 The same problem also applies to fuel, and it is necessary to carry out a comprehensive evaluation according to voyage plans as well as refueling ports and prices to define the most reasonable amount of fuel to be bunkered, so as to avoid an excessive load of fuel for a ship. E.g., assuming that a ship consumes 4.3 g of fuel per tonne nautical mile, then there is extra 4.3 g energy consumption for each extra tonne of freshwater / fuel, and the huge non-essential carrying energy consumption for a long voyage is also quite considerable.

2.16 Fuel Purchase, Bunkering and Management

2.16.1 Companies are to evaluate fuel suppliers and determine fuel types and standards to be used based on equipment performance and service areas;

2.16.2 Ships should, in line with voyage plans and the actual stocks of ships✓ lubrication oil and fuel and in combination with route characteristics, reasonably arrange ship refueling places and the amount of lube and fuel to be refilled.

2.16.3 Proper measures shall be taken to effectively manage the usage of the ship energy including:

(1) In order to prevent the deterioration of fuel stored in the ship, vessels should avoid mixing of the fuel bunkered at different refueling times or places as far as possible, to avoid fuel quality changes due to the repelling of mixed fuels which is unable to be used, and therefore, it is necessary to transfer fuel with the same quality into the same tank before bunker refilling;

(2) Scientific storage and use, and the storage time of fuel and lubrication oil on board a ship should better not to exceed one year;

(3) All fuel bunkered shall be sampled for laboratory test and analysis to ensure that the filled fuel meet the IMO standard and ship's fuel standard. Try to use the fuel after the laboratory oil sample test report is obtained and the sample passes the test.

(4) Use of fuel should follow the principle of "first fill, first use"; the longer the fuel has been stored, the more likely the solid substances are to settle out, and the ship is also more likely to encounter with filter clogging and other potential reliability problems. Fuel unsuitable for continuous use should not be used any more.

2.16.4 Control of refueling quantities

It is necessary for ships to measure the fuel purchased to ensure that the amount of fuel supplied conforms to the quantity applied for. The problem of fuel quantity shortage should be taken seriously, and in addition to the selection of reputable suppliers, fuel quantity can be guaranteed by strengthening measurement and monitoring. Although there are a lot of measures to monitor and verify fuel quantities, shortage of fuel quantity at some ports may still occur and the fuel short-supplying methods often used by fuel suppliers may include:

(1) Use of non-standard measurement tools (dipstick, flow meters, etc.);

(2) Incorrect temperature compensation;

(3) Use of different tank table before and after refueling;

(4) Filling air together with fuel during refueling process;

(5) Deliberate misreading of ship fore and after drafts.

2.17 Optimization of Other Machinery and Equipment

2.17.1 If permitted, the chief engineer may, according to experience, decide at his discretion whether or not to shut down the lubricant pump and camshaft lubricant pump (unless standby state is required).

2.17.2 After anchoring or berthing, the ship should timely shut down devices that are no longer in use, such as steering gear, deck machinery, fire-fighting pumps and so on, to reduce load for auxiliary engines.

2.18 Optimization of Cargo Handling

Cargo handling is in most cases under the control of the port authority and optimum solutions matched to ship and port requirements should be explored.

2.18.1 Bulk Carriers

2.18.1.1 Particularly, large bulk carriers are not equipped with crane, but some small bulk carriers such as some Handy sizes are equipped with crane. For ships with crane, generally it is required to start multiple auxiliary engines during cargo loading/discharging with crane, which requires ships and port to keep communication of handling information, and during the loading/discharge process, if cargo loading stops midway, the crane should be promptly stopped, and redundant auxiliary engines should be thereby shut down in a timely manner according to actual situation.

2.18.1.2 If the port is equipped with cargo handling equipment, it is better to use shore handling equipment for loading/discharge as far as possible.

2.18.1.3 Management and operation optimization should be done to ballast pumps, mooring equipment, switch equipment and anchoring equipment, as these devices may need to run 2 sets of auxiliary engines to ensure operation of the equipment. Ships should make good and reasonable management, and immediately shut down the pumps or power if not needed for operation.

2.18.2 Oil Tankers:

2.18.2.1 For cargo oil that requires heating during loading/discharge, its optimum temperature depends to a large degree on the pour point, cloud point, wax content, viscosity, recommended temperature for discharge and transport, ambient weather and sea conditions.

2.18.2.2 Heating instructions after loading should be assessed, and it should be allowed to transport and discharge at optimum temperature.

2.18.2.3 Insulation operation: usually to operate according to the results calculated by cargo oil heating software. For special cargo oil, operation must be done according to voyage instructions.

2.18.2.4 Under the circumstances that the requirements of safety and VOC (volatile organic compounds of tankers) management plan are met, inert gas should be filled as less as possible to save fuel consumption.

2.18.2.5 Ensure that the inert gas system is started at the best timing to prevent long time invalid work of the system, thus to ensure a minimum level of fuel consumption with inert gas filled.

2.18.2.6 It is unnecessary to start the inert gas blower during loading, as the inert gas will be discharged when the cargo oil is loaded into the tank. At this stage, abnormal increase of the inert gas pressure must be noted to keep cabin pressure at the right level.

2.18.2.7 During ballast voyage, vapor within the cargo tank will expand or contract due to the impact of climate, and therefore inert gas filling time and pressure should be arranged in a reasonable manner during the voyage.

2.18.3 Container Ships

Ships should have reasonable arrangements of handling sequence to reduce the number of cargo hold opening/closing and the times for moving the loading pier cranes, and it is required for ships to strengthen maintenance of securing devices, in order to avoid negative impacts to the loading/discharge of containerized cargo due to poor securing devices. The requirements of cargo calling at multiple ports and the loading/discharge sequences should be noted to avoid re-stowage and shift. The requirements of special container for shipping and handling should be considered, such as containers for dangerous goods, refrigerated containers, oversize containers, as well as the operation equipment at ports of loading and discharge, to improve handling efficiency.

2.19 Use of New Energy-saving Technologies on Ships

For ship operation, the use of new energy-saving technologies can improve ship energy efficiency and reduce operation costs, and shipping companies could consider according to their own situations when appropriate. The new technologies include:

2.19.1 Optimization of propulsive mode: For instance, adoption of the electric propulsive mode or diesel-electricity joint propulsive mode, etc.

2.19.2 Optimization of propeller: Such as the adoption of the new type propeller or contra rotating propeller.

2.19.3 Optimization of inflow of propeller: Improvements to the water inflow to the propeller by using arrangements such as fins and/or nozzles could increase propulsive efficiency and hence reduce fuel consumption.

2.19.4 Use of energy-saving appendages of propulsion units: Such as front duct, inlet deflector of duct, propeller boss cap fins, outlet guide vane, and outlet deflector of duct, etc.

2.19.5 Optimization of hull resistance: Hull resistance can be optimized by new technology-coating systems.

2.19.6 Optimization of rudder blade: Improvement of the shape of rudder blades can reduce resistance.

2.19.7 Heading control system: Upgrade or improvement of the heading control systems on board existing ships.

2.19.8 Optimization of diesel engine and boiler: The adoption of low-consumption and high-efficiency main and auxiliary engines and boilers, etc.

2.19.9 Installation of waste heat recovery (WHR) system.

2.20 Energy Conservation in Daily Life

2.20.1 The living areas can provide many energy-saving opportunities. Air-conditioning is one of the major energy consumers. Window concerns almost 50% of heat or heat loss (depending on seasons), in other words, equals 50% extra working load applied to the air conditioning systems or heating systems. Heat exchange in a space with untreated windows is about 20 times of that in spaces of equal size with adiabatic walls and etc. Staff on board ships can take measures such as keeping the curtains closed to restrict heat exchange when sunlight is not needed or no person in such spaces.

2.20.2 Duly regulation of air-conditioning temperature according to seasons and voyage areas. As per the uniform national requirement, the temperature should be no less than 260 C in summer and no more than 200 C in winter.

2.20.3 Prevent excessive waste of hot water, control the use of chamber dryer, and prohibit the use of high power energy consuming equipment such as electrothermal oven in bedrooms.

2.21 Energy-saving Awareness and Energy Conservation Related Training and Motivating Mechanism

2.21.1 Energy-saving awareness:

Cultivation and continuous improvement of energy-saving awareness are an important guarantee for effective implementation of the SEEMP and also the important contents of HR training. Through the cultivation of energy-saving awareness, the goal of improving overall staff's implementing initiative should be achieved. It is a long term process to cultivate energy-saving awareness which cannot be achieved in one or two days, but it can be started from achievable trivial things such as turning off the lights, air conditioners, hot water and kitchen appliances, etc. after use, and institutionalized requirements will be formed to gradually improve overall staff's energy-saving awareness, which will thereby penetrate into daily work as time goes by.

2.21.2 Ship and shore energy efficiency training

As the managers of ships, every crew member is playing a very important role in pursuing better energy efficiency and energy conservation. Everyone should be familiar with the operation of ship equipment, and clearly understand the energy wasting or saving potentials of some particular equipment, so as to manage and operate these equipment in a better way. At the same time, crew members must develop good electric saving habits. There is great potential in energy saving by for example turning off lights, TVs, positive blowers and etc. Each ship should have an energy-saving awareness training plan for new and rejoining crew members. Create a sheet for best energy-saving practices, including major staff on board ship and contents on how to save energy.

2.21.3 Motivating mechanism

The company should build and improve ship's energy efficiency performance assessment and motivating mechanism in relevant internal department and at relevant levels (including ships), the purpose of which is to better implement energy efficiency measures for ships.

Appendix 2 Best Practices for Energy - Efficient Operation of Inland Navigation Vessels

1 General

1.1 Purpose and Scope

1.1.1 This Appendix provides options and references for the development of energy efficiency measures of inland navigation vessels by providing best practices for energy – efficient operation of inland navigation vessels.

1.1.2 The best practices provided in this Appendix do not cover all energy – saving measures of inland navigation vessels, and not necessarily every measure or combination of such measures are applicable to all vessels. For a single ship or a particular fleet, energy efficiency measures that fit ships should be selected according to their own characteristics.

1.1.3 This Appendix applies to inland river fleets, bulk carriers, containerships, tankers / chemical carriers and tourist passenger ships, and references to it can be made for the implementation of other vessels.

2 General Best Practices for Energy – Efficient Operation of Inland Navigation Vessels

2.1 Voyage Optimization Plans

2.1.1 Timely communication

Good early communication with the navigation lock or the next port should be an aim in order to give maximum notice of navigation or berth availability, which helps reduce the waiting time for passing the lock or berthing, thus facilitate the use of optimum speed in advance and cut down the fuel consumption.

2.1.2 Reasonable schedul

2.1.2.1 Strengthening shipping route management, optimizing shipping capacity and cargo resources, arranging ships in reasonable manners, optimizing ship types and fleet formation as well as reducing operations at midway ports.

2.1.2.2 Vessels should give adequate consideration to the factors such as passing through bridges, navigation locks and security checks, tides, weather, water – level, fairways, currents and etc. according to the voyage plans, and select the optimum timing to launch sail in order to reduce the frequency of berthing and mooring.

2.1.3 Speed optimization

As the main engine power is directly proportional to the cube of speed, the ship could choose a reasonable speed according to the priorities of their navigational duties. If time permits, the speed could be reduced appropriately, while the main engine power and fuel consumption rate will reduce in a cubic relationship, which brings an obvious reduction of the fuel consumption. The curve of diesel engine specific fuel consumption ge (g / kw• h) varying with speed v is shown in Figure 2.1.2. Considering the actual running condition of the ship diesel engine, when the power and revolution speed change, its specific fuel consumption ge is not a constant value due to the effects of fuel injection quantity, ventilation quality, revolution speed and etc., and normally the value of ge is at its minimum level when the load is in the range of 75% to 90%, as per the $(ge)_{min}$ shown in Figure 2.1.2, which is the guiding economic speed used in the best practices for ship energy conservation management. Therefore, the principle of speed optimization is, according to the technical data such as speed and fuel consumption of main and auxiliary engines and taking into account of the navigation routes and marketing plan, to select the correct calculation and evaluation methods, analyze and determine the scientific and reasonable economic speed for ships of different types and ages, and thus seek to work out the optimum balance point between diesel engine fuel consumption and sailing speed.

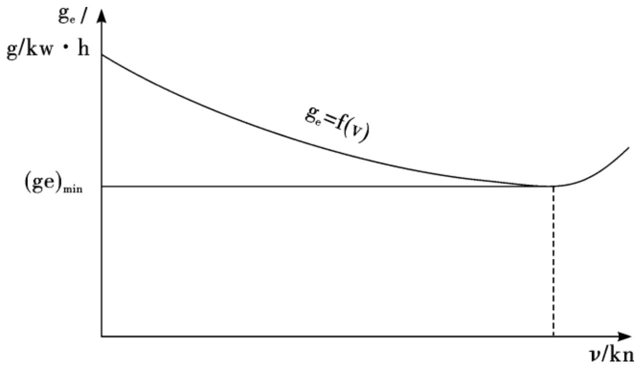


Figure 2.1.2 ge－v Curve

2.1.4 Use of economic routes

2.1.4.1 Under the premise that navigation rules and safety are not compromised, the actual voyage distance should be shortened to a maximum degree.

2.1.4.2 Instruments such as fathometer should be adequately used, and if permitted by the external conditions such as the fairways, weather and laws and regulations, tranquil flow waters should be selected to the utmost for upstream shipping, and mainstream waters should be selected to the utmost for downstream shipping.

2.1.5 Reasonable overtaking

Under normal circumstances, when approaching the vessel to be overtaken, the vessel should accelerate while requesting the other to release the accelerator in order to shorten the overtaking time. Long time overtaking at high speed should be avoided as much as possible.

2.1.6 Optimum trim

When the ship is at a particular fixed displacement? and speed, and drafts at both the bow and the stern are adjusted through reasonable configuration of cargo carried, ballast water and fuel, corresponding changes will occur to the waterline length, relative location of the bulbous bow, in－water geometrical shape, center of floatation, flow fields around the hull as well as the working conditions of the propeller, and there are certain corresponding sailing resistance and main engine power in relation to different conditions of the trim. Model tests carried out for many different ship types and comparative tests of actual ships prove that, under the circumstances that the load and the speed are all the same, hull resistance reduces and therefore propulsion efficiency improves during a voyage that the ship sails at optimum trim. The specific operations include:

1) Draft should be adjusted to keep optimum trim before a ship launches its sailing.

2) Appropriate adjustment should be done to the floating condition according to the conditions of cargo loading/discharge, fairways and consumption of fuel/living water during operation of the ship.

2.1.7 Reasonable ballast

Under the premise that navigation safety is met and sufficient submerged depth of the propeller is ensured, volume of the ballast water should be reduced as much as possible to keep the ship in a good seaworthy condition.

2.1.8 Navigation with the tides

When a ship sails in a leg where tidal phenomenon occurs, the ship should navigate by taking advantage of the tides as far as possible to shorten sailing time and reduce fuel consumption. Although tideway navigation is an effective measure of energy-efficient operation for a ship, the company needs to give a full consideration to such measure from the perspectives of shipping cycles, ship efficiency as well as production planning.

2.1.9 Reduction of ship's non-operational loads

2.1.9.1 Regular tank checks should be carried out, and the oily water should be timely treated through adequate use of the ship's antipollution equipment to get rid of the left water in empty tanks.

2.1.9.2 Volume of living water refilled should be reduced, and the deposit of water generated for daily life and machines should be controlled.

2.1.9.3 Sediments in ballast water tanks, water tanks and fuel tanks should be cleaned in a timely manner.

2.1.9.4 Wastes should be cleaned and discharged off board in a timely manner.

2.1.10 Use of shore power

At some ports, ships can use shore power to reduce fuel consumption.

2.2 Optimization Plan for Propulsion Resistance

2.2.1 Hull maintenance under waterline

Hull maintenance under waterline? can effectively reduce the propulsion resistance of a ship and thereby reduce fuel consumption. Measures such as selection of new hull coating as well as good hull maintenance and cleaning are all effective.

2.2.2 Propeller maintenance or renewal

2.2.2.1 The surface polish of propeller blades should be maintained, and timely treatment should be carried out in case of damages such as curling of the edge, impairment, cracks, corrosion, wearing out of thickness specifications and etc.

2.2.2.2 Propeller is normally determined at the design and construction stage, but in case changes occur to the navigation zones and fairways, appropriate consideration should be given to redesign and re-selection of the propeller. During the redesign and re-section of the propeller, account of ship, engine and propeller as a whole should be taken.

2.2.2.3 Some energy-saving arrangements (such as fins and/or nozzles) can be used to improve propeller efficiency.

2.2.2.4 Appropriate submerged depth of the propeller should be ensured.

2.3 Engine Optimization Plans

2.3.1 Use of new energy

2.3.1.1 Retrofitting is to be carried out to the main engines of existing ships in order to burn clean energy such as natural gas, which can effectively reduce emissions and improve energy efficiency.

2.3.1.2 Devices to use new energy such as solar power plant and onboard wind power plant are to be installed.

2.3.2 Monitoring and optimization of main engine performance

2.3.2.1 Monitoring of main engine performance

1) Optimization of main engine operation and maintenance can be realized through monitoring and analysis of the performance data such as fuel consumption, operating loads as well as cylinder wear, for example, correct adjustment of the volume of fuel supply and fuel supply advance angle, or checks by withdrawing a piston and replacement of piston ring, cylinder sleeve, cylinder gasket and etc. can be done through measurement and analysis of cylinder explosion pressure and compression pressure as well as references of other operation parameters.

2) Monitoring of oxygen content. The combustion performance of the diesel engine can be improved by monitoring and thereby optimizing the oxygen content in the inlet air.

2.3.2.2 Optimization of main engine

1) Retrofitting of diesel engine fuel injection system

As a large number of ships choose to sail at reduced speed, some disadvantages of the traditional fuel injector have gradually become obvious, for example, poor fuel atomization or even dribbling may occur at slow speed operation, resulting in that a particular amount of fuel may enter into the combustion chamber of the cylinder at a lower temperature of insufficient combustion, which may therefore lead to oil dirt, carbon deposit, black smoke and increase of hydrocarbon and particulate matter, or even life reduction of the main engine. Spool valve type fuel injector and common rail EFI technology can be adopted to improve the combustion condition of the diesel engine to save fuel and reduce the emissions of greenhouse gas.

2) Match of turbocharger

Turbocharger should be matched in a reasonable manner according to the operating mode and load of the diesel engine.

3) Use of fuel additives

Addition of fuel additives can improve fuel quality and combustion performance and reduce emissions of harmful substances and carbon deposit in the cylinder. Besides, use of fuel additives does not require installation of new devices or change of the engine structure, and therefore it is considered as a more convenient and effective energy conservation and emission reduction measure.

2.3.3 Use of heavy fuel oil technology

Under the premise that the requirements of marine fuel sulphur content under laws and regulations and relevant technical documents are met, the use of heavy fuel oil on board ships can be considered in the following aspects to achieve the goal of energy conservation:

2.3.3.1 Fuel supply unit and its systems of heating, insulation, separation, filter and de-watering are used to improve the liquidity and quality of low grade fuel to achieve the goal of full combustion.

2.3.3.2 The speed of constant engine should be controlled in a reasonable manner during the use of heavy fuel oil, as a more obvious issue for a ship burning heavy fuel oil is that the speed of constant engine is too slow, which may cause the main engine to work under light loads in a long time and lead to insufficient combustion, serious carbon deposit, fast cylinder sleeve wear as well as heavy pollution of the turbocharger, thus leading to a high unit fuel consumption.

2.3.3.3 Main facilities and equipment such as fuel supply units, boilers and oil purifiers should be managed and used in a good manner, and wash of the boiler and cleaning of residues in the oil tanks and oil containers should be carried out in a regular manner.

2.3.3.4 Regular measurements and tests should be done to lube oil and lube oil use archives should be built for a ship to gradually explore the trends and replace oil in a reasonable way.

2.3.4 Strengthening of main and auxiliary engine maintenance

Main and auxiliary engines are the most direct consumers of marine fuel, and fuel consumption can be reduced effectively by strengthening their maintenance and keeping them in good working conditions. The maintenance of main and auxiliary engines includes but not limited to:

2.3.4.1 Adjustment of the optimum fuel injection advance angle. Every diesel engine has an optimum fuel injection advance angle, and fuel supply advance angles of each cylinder should be inspected and adjusted to ensure the optimum fuel supply location during maintenance;

2.3.4.2 The injection pressure of fuel supply should be checked and adjusted regularly to make sure that it is within specification;

2.3.4.3 Exhaust system should be kept clear, and air valve clearances should be checked and adjusted regularly;

2.3.4.4 Proper clearance between combustion chamber assemblies should be maintained;

2.3.4.5 Smoothness and good maintenance of the lubrication system should be kept;

2.3.4.6 Sufficient fresh air supply should be ensured and air filters of the turbocharger should be cleaned regularly. As most modern diesel engines use exhaust – gas turbo charging, if the air inlet is clogged by for example dirt, coke and deformation, the boost pressure will decrease due to the increase of flow resistance and the results of scavenging will be affected, leading to insufficient combustion, increase of fuel consumption, or even surging in the worst cases;

2.3.4.7 Maintaining the operating system and drive system in good technical conditions will significantly increase the mechanical efficiency, thereby save fuel consumption.

2.3.5 Management of generator sets during anchorage

2.3.5.1 During anchorage, under the circumstances that safety is ensured, the generator should be used as less as possible and the use of electrical equipment should be controlled to stagger the surge of electricity demands, or anchoring generator of small power should be used to improve the efficiency of generator sets.

2.3.5.2 When two or more ships anchor at the same place, one ship is to generate power and other ships are to be supplied.

2.3.6 Management of other energy consuming equipment

2.3.6.1 Equipment driven by both electricity and steam should be used, and frequency and time to use auxiliary boilers during sailing and berthing should be controlled. For example, equipment such as fuel atomization heater, hot water tank and etc. can still use electricity for auxiliary heating when the steam supply is insufficient during winter voyages, while the use demands of such equipment can also be met by using electricity during berthing.

2.3.6.2 Electrification of ship living facilities should be introduced to improve energy utilization. For example, the use of electric tea bucket, rice cooker, electric rice steamer, and electric stove can help completely shut down the fuel burning auxiliary boilers during the period of voyage suspension and breaks.

2.3.6.3 Peaks of steam demands should be staggered, and at the end of each voyage, heavy fuel oil should be filled into the daily service tank after heating and purification to reduce the use of auxiliary boilers at the beginning of next voyage or the consumption of steams.

2.3.6.4 The boilers, condensers and evaporators of a ship should be cleaned and maintained on regular basis to ensure their working thermal efficiency.

2.3.7 Waste heat recovery and utilization

The waste heat recovery (WHR) system? can convert the redundant heat released during the generation of effective power by the main and auxiliary engines of the ship into effective heat to generate steam or hot water. At present, widely used WHR systems include exhaust gas boilers and hot water tanks, etc.

2.4 Fuel Management Optimization

2.4.1 Fuel bunkering

Reasonable frequency of fuel bunkering should be adopted as often as possible, and preventative measures against running, spilling, dribbling and leaking should be implemented to strengthen the monitoring and control of fuel quality and quantity.

2.4.2 Fuel and oil recycling

Effective recycling, purifying treatment and reasonable reuse should be implemented on fuel and oil materials such diesel oil used to wash components, recovered oil at the bottom of tanks, coating oil within the cargo oil tanks, and etc.

2.4.3 Maintenance of fuel categories

2.4.3.1 Mixture of heavy fuel oil should be prevented to avoid degrading of light fuel oil;

2.4.3.2 Blending fuel of different batches should be avoided or reduced to prevent formation of large amount of oil sludge due to chemical reaction;

2.4.3.3 The storage cycle of blended fuel should be shortened to avoid the occurrence of stratification.

2.4.3.4 The change of fuel quality should be closely tracked in use, and reasonable adjustment of heating temperature and separation volume should be done according to the features of the fuel.

3 General Best Practices for Energy–Efficient Operation of Inland Fleets

3.1 Optimized fleet formation technology

3.1.1 Optimized fleet formation technology is a comprehensive technology application method to improve ship energy utilization through reasonable ship formation under the direction of hydrodynamics theory and on the basis of physical ship experiments. There are generally two methods of optimized fleet formation, which are ship formation optimization and real time capacity increase and tugged barge expansion.

3.1.1.1 Ship formation optimization

The theory and specific method are as follows: when the fleet is sailing upstream, barges of various different types should be grouped and optimized in a reasonable manner according to sailing conditions such as barge types of the fleet, carrying capacity, sailing waters and etc., aiming at achieving reduction of overall resistance of the fleet and improvement in speed and thereby realizing the goal of reduction in fuel consumption and increase in economic benefits for single voyage transportation. Reference can be made to Figure 3.1.1.1 for the theory of fleet formation optimization. As shown in this Figure, the cross sectional view of the fleet with normal formation is the cross sectional area of 4 barges, and there is a cross sectional area of only 3 barges in the optimized formation. Obviously, the water facing area of the optimized formation reduces and the water resistance reduces accordingly.

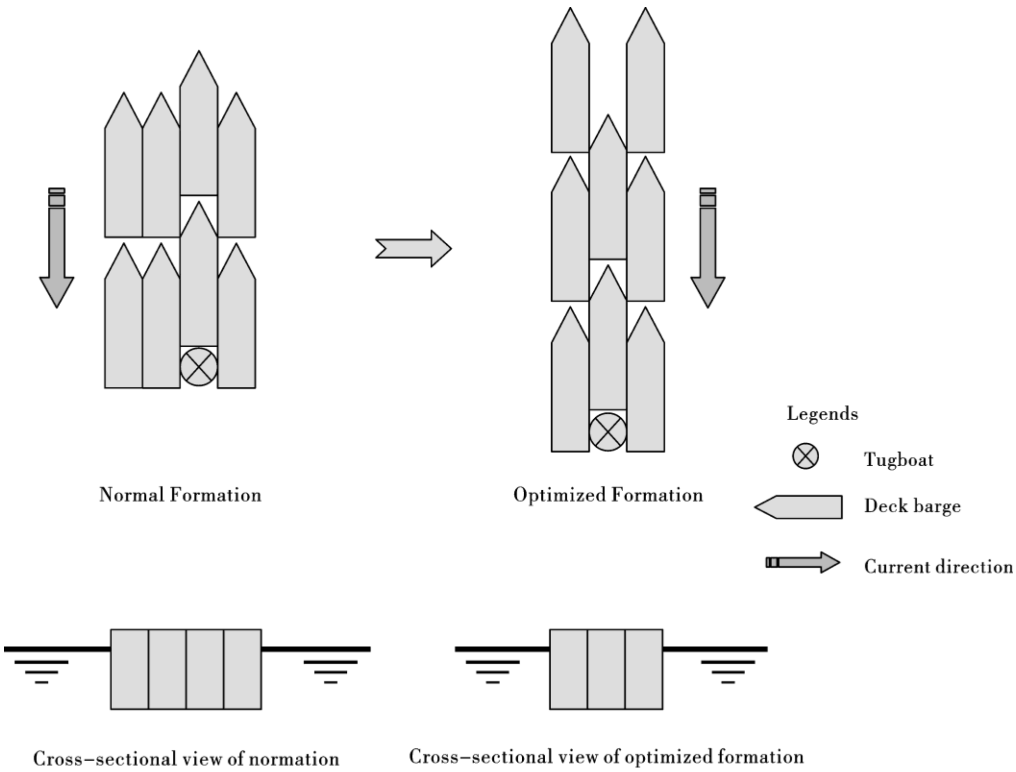
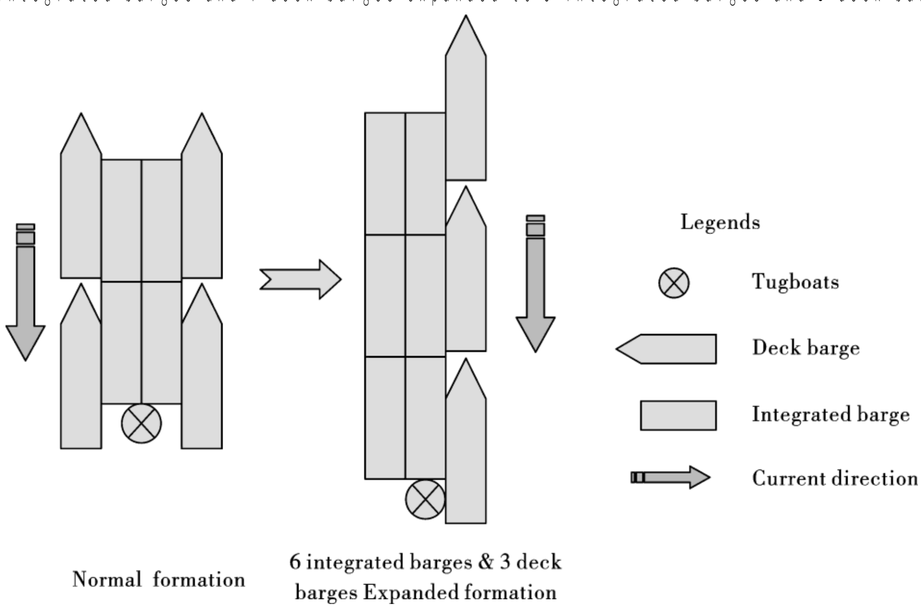


Figure 3.1.1.1 Illustration of the theory of fleet formation optimization

3.1.1.2 Real time capacity increase and tugged barge expansion for the fleet

The theory and specific method are as follows: under the premise of fleet formation optimization and speed increase, mature and stable ship types for capacity increase and tugged barge expansion as proved by trial sailing experiments are adopted to increase the transportation capacity for a single voyage of the fleet and improve ship energy utilization in accordance with industry related safety laws and regulations as well as the technical parameter requirements of ships. Two examples have been given in Figure 3.1.1.1 and 3.1.1.2.

1) 4 integrated barges and 4 deck barges expanded to 6 integrated barges and 3 deck barges



2) 1 integrated barges and 4 deck barges expanded to 2 integrated barges and 4 deck barges

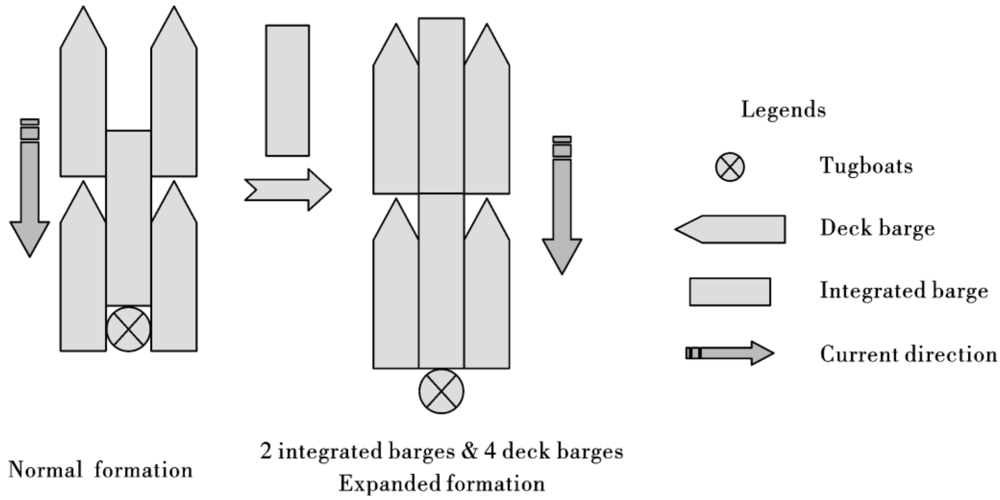


Figure 3.1.1.2 Illustration of the theory of real time capacity increase and tugged barge expansion

4 Best Practices for Energy - Efficient Operation of Inland Bulk Carriers

4.1 Reasonable loading

4.4.1 Loading should be arranged in a reasonable and even manner to avoid reduction in cargo loading capacity of a ship due to sagging.

4.4.2 Reasonable transshipment should be arranged to improve the actual loading rate of ships in consideration of the water levels of different legs and seasons.

4.2 Voyage optimization

4.2.1 When the voyage time of a ship with tugging function overlaps with other carriers, one carrier can tug the other if rules and regulations are complied with and the fairway permits.

5 Best Practices for Energy - Efficient Operation of Inland Containerships

5.1 Reasonable stowage

5.1.1 The container loading rate of a ship should be increased as much as possible under the circumstances that the designed and safe loading of the ship are met.

5.1.2 Reasonable mix of light, heavy and empty containers should be considered to improve the overall utilization of the ship.

5.1.3 Reasonable stowage plan and good adjustment of the floatation state of the ship are essential to avoid re - stowage and shift during transportation.

5.2 Reasonable allocation

5.2.1 Comprehensive consideration should be given to factors such as liner schedule, speed, container types, customer demands, time of departure / arrival as well as calling alongside the route, the places of calling should be reduced to a maximum degree and multi - place operation at the ports should be controlled as far as possible, while the same time good coordination of loading / discharge, stacking and hauling at ports and piers should be carried out to reduce the ship's waiting / berthing time and operation time at piers and ports as well as to reduce fuel consumption.

5.2.2 Under the premise of taking both economy and market into account, ships with large container sizes should be preferred for use when cargo sources are sufficient.

5.3 Energy - saving technology for refrigerated containers

5.3.1 Energy - saving containers equipped with for example refrigeration system of frequency conversion technology and new insulation coating should be preferred.

5.3.2 Cargo within the containers should be stacked appropriately to avoid short circuit of the ventilating air currents and dead - corner areas of air currents.

5.3.3 Loading / unloading time should be shortened as much as possible to avoid frequent opening of the hatches and ensure heat insulation and sealing of the container bodies.

6 Best Practices for Energy - Efficient Operation of Inland Tankers / Chemical Carriers

6.1 Safekeeping of liquid cargo

6.1.1 Once the cargo is on board ship, time staying at the ports (of departure and destination) should be reduced as much as possible to reduce the energy consumption for warming and insulation.

6.1.2 Strengthening of cargo temperature monitoring and reasonable adjustment of heating time and temperature should be carried out to reduce the fuel used for heating to a maximum degree under the premise of maintaining cargo temperature and quality.

6.2 Loading and discharge of liquid cargo

6.2.1 Before loading liquid cargo such as asphalt, if it is required to pre - heat cargo tanks and pipes, loading time should be mastered in an accurate way to prevent longer time of waiting for heating or occurrence of invalid heating.

6.2.2 When discharging, if there is shore - based heating devices connected, shore - based heating system should be preferred to improve the thermal efficiency of liquid cargo heating.

6.2.3 Under the condition that safety is ensured, discharge speed and working head of the cargo pumps should be controlled in a proper way and discharge method of carts docked with ships should be avoided as far as possible, and loading and discharge procedures should be improved and implemented to improve the efficiency of loading and discharge and shorten the time of loading / discharge.

6.2.4 Stripping and scavenging operation should be done in a good way and bottom oil should be cleaned to increase the cargo capacity for the ship's next voyage.

6.3 Cargo pipe heat tracing

6.3.1 Inner－inserted pipes should be preferred for heat tracing pipes to improve heat transfer efficiency.

6.3.2 If external applied pipe type is used, the distance between cargo pipe and heat tracing pipe should be kept as close as possible and the heat conducting mud should be connected in a good manner.

6.3.3 Good insulation wrapping is needed for the cargo pipe and heat tracing pipe. The cargo pipe must be heat traced in full length to prevent blind area of heat tracing.

6.4 Selection of boiler types

6.4.1 Heat conduction oil boiler should be preferred and steam boiler should be avoided to improve heat exchange efficiency.

6.4.2 The thermal power of exhaust gas boiler using heat conduction oil evaporation of exhaust gas boiler using steam should be appropriately smaller to prevent insufficient exhaust energy during sailing with reduced speed or downstream sailing from affecting the thermal efficiency of the boiler and its normal use.

7 Best Practices for Energy－Efficient Operation of Inland Passenger ships

7.1 Use of energy－saving equipment and new material

7.1.1 As the electric power for lighting of a passenger ship is too large, under the premise of compliance with rules and standards, use of new types of efficient energy－saving lighting source such as the use of LED lights for the lighting of passenger area can effectively reduce the energy consumption.

7.1.2 Under the precondition that the requirements of firefighting and structural strength are complied with, energy－saving and environment－friendly light decoration materials can be used to reduce the dead weight of the ship.

7.1.3 Exhaust gas boiler should be installed to the prime motor of large power generators for a ship to take full advantage of the residual heat of the exhaust gas from the generator prime motor.

7.2 Reasonable use of shore facilities

7.2.1 As there are normally fixed piers for passenger ships, facilities such as solar energy water heater and kitchen can be installed to the piers to reduce the living energy consumption of crew members during non－voyage periods.

7.2.2 The washing of passenger beddings on board ship should be contracted to shore based professional service providers to avoid the use of fuel burning boilers during berthing.

7.3 Strengthening of energy conservation management at passenger areas

7.3.1 Regular inspection should be carried out for passenger areas, and timely shut－off should be maintained for air conditioners, water valves, windows and doors as well as lights not in use.

7.3.2 The use of steam in the laundry should stagger the peaks of steam demands and it would be better to use steam at night.

Appendix 3 A Sample Form of A Ship Energy Efficiency Management Plan for the Seagoing Ships

SHIP EFFICIENCY ENERGY MANAGEMENT PLAN

(SEEMP)

Name of ship：XXX

Type of ship：XXX

IMO No.：XXX Gro

ss tonnage：XXX Fl

ag of ship：XXX

Company：XXX

Revision records

(The following form shall be completed upon revising SEEMP each time. Obsolete sections and documents should be destroyed.)

Revision Serial No.	Edition/ Revision No.	Section No.	Summary of the Contents Revised	Preparation/ Revision Date	Prepared/ Revised By	Approved By	Effective Date

1 General

1.1 Purpose

1.1.1 To actively assume the social responsibility of environment protection and build a green shipping enterprise, the company should, according to relevant requirements of international organizations, flag States and industry organizations, develop a Ship Energy Efficiency Management Plan (hereinafter referred to as SEEMP), which is part of the existing company's overall management system, focusing on systems and procedures with the highest energy saving potentials to perfect shipping operation processes, realize maximum energy utilization from the three perspectives of managing measures, technical measures and operational measures as well as increase social benefits and enterprise economic benefits through adoption of continuously improved and effective energy saving and consumption reduction measures and use of systematic methods to fulfill the company's energy efficiency policy, improve ship energy efficiency and reduce CO_2 emissions.

1.1.2 The SEEMP follows the operation mode of PDCA cycles, that is, planning, implementation, inspection (monitoring) and improvement, and the method of continuous improvement is used to keep the SEEMP always in effect.

1.2 Definitions and Abbreviations

1.2.1 Definitions

1.2.1.1 Energy efficiency: Utilization ratio of energy, i.e. the relationship between the result obtained and the energy used.

1.2.1.2 Energy efficiency factors: The factors that influence the ship energy consumption, energy efficiency and CO_2 emission during the ship transportation/operation.

1.2.1.3 Energy efficiency policy: The objectives of the ship energy efficiency management officially released by top management of the company.

1.2.1.4 Energy efficiency goal: Reduction of ship energy consumption, improvement of energy efficiency and reduction of CO_2 emission.

1.2.1.5 Energy efficiency index: The specific requirements stipulated for the achievement of the energy efficiency goal, generated from Energy efficiency goals.

1.2.1.6 Energy efficiency operational indicator (EEOI): The ratio of mass of CO_2 (M) emitted per unit of transport work, namely, the ratio of CO_2 emission from the fuel consumption to freight volume multiplied by transport distance.

1.2.1.7 Average EEOI: The ratio of mass of CO_2 (M) emitted during a certain period of time or per multiple voyages of transport work, namely, the ratio of CO_2 emission from the fuel consumption to the sum of product of freight volume and transport distance, which is used to measure the ship energy efficiency during a certain period.

1.2.1.8 CO_2 emission intensity index: The CO_2 emission by the unit transport turnover of ships in service (The emission reduction index for the 12th five-year plan of the Ministry of Transport, same as EEOI)

1.2.1.9 Energy consumption intensity index: The energy consumption by the unit transport turnover of ships in service. (The emission reduction index for the 12th five-year plan of the Ministry of Transport)

1.2.1.10 Voyage: The period between a departure from a port to the departure from the next port.

1.2.2 Abbreviations

1.2.2.1 IMO--- International Maritime Organization;

1.2.2.2 MEPC--- Marine Environment Protection Committee of International Maritime Organization;

1.2.2.3 EEOI--- Ship Energy Efficiency Operational Indicator;

1.2.2.4 SEEMP--- Ship Energy Efficiency Management Plan;

1.2.2.5 IEEC--- International Energy Efficiency Certificate.

1.3 Ground

1.3.1 Resolution MEPC.213(63) - 2012 Guidelines for the Development of Ship Energy Efficiency Management Plan

1.3.2 IMO. MEPC.1/Circ.684 Guidelines For Voluntary Use of the Ship Energy Efficiency Operational Indicator

1.3.3 ISO 8217 Fuel Standard, international standard of marine fuel oil

1.3.4 China Classification Society's Guidance for the Development and Verification of Ship Energy Efficiency Management Plan

1.4 References

1.4.1 OCIMF's Energy Efficiency and Fuel Management

1.4.2 INTERTANKO's Guide for Ship Energy Efficiency Management Plan

1.5 Use and Management of SEEMP

1.5.1 SEEMP is developed, updated and issued by the XXX Department of Company.

1.5.2 SEEMP is used and maintained by the ship identified and shall be kept by the ship master.

1.5.3 Records generated in connection with the ship's implementation of SEEMP shall be kept on board by the ship for X years.

1.5.4 Records generated in connection with shore monitoring and evaluation of the ship's implementation of SEEMP shall be kept by the XXX Department of Company for X years.

2 Ship Energy Efficiency Management Requirements

2.1 Company energy efficiency policy and goal

(1) Policy: xxx

(2) Goal: xxx

(3) Commitment: The Company is committed to the promotion of methods to reduce ship energy consumption within the fleet, continuous improvement of energy utilization efficiency as well as reduction of CO_2 emissions.

Methods that the company is committed to improve continuously and adopts to achieve above-mentioned goals:

a) Commitment to comply with the international conventions, laws, regulations, standards and other requirements of industry organizations applicable to the ship energy efficiency management;

b) Building a ship operational energy efficiency improvement mechanism that monitors and analyzes ship energy consumption and effectively manage ship energy efficiency with systematic methods, with relentless efforts to improve ship energy efficiency.

2.2 Functions and responsibilities

2.2.1 Company responsible person of energy efficiency management (Person designated by company or acting by the management representative)

Her or his responsibilities and authorities shall be to:

(1) Organize communication and implementation of energy efficiency policy and goal

(2) Ensure development, implementation and maintenance of SEEMP;

(3) Report the SEEMP implementing status to GM and raise improvement advices;

(4) Coordinate company internal energy efficiency management and organize relevant reviews.

2.2.2 Organization structure of energy efficiency management

The company should define the responsibilities and authorities of all departments (and managers) and their mutual relations.

2.2.3 Main responsibilities of the company's every department:

2.2.3.1 Scheming and planning of energy conservation and emission reduction

2.2.3.2 Shipping operations and handling and control of operations

2.2.3.3 Scheming management and control of ship technical design and technical improvement

2.2.3.4 Measurement, monitoring and inspection of the implementation of SEEMP

2.2.3.5 More detailed responsibilities of implementing, monitoring, evaluating and reviewing concerning the best operation plan of ship energy efficiency (and the following responsibilities shall be allocated to departments and staff)

(1) Formulation of company and fleet energy conservation and emission reduction development plan and cascading of the company's annual energy efficiency index.

(2) Selection of ship type and equipment, ensuring that the ship type design will comply with the provisions under the Convention and meet the energy-saving demands of the company to the greatest possible extent.

(3) Supervision of ship construction technics and the selection of spare parts and materials to improve energy-saving and environmental protection.

(4) Cooperation with equipment manufacturers and shipyards to develop and practice new technologies of energy conservation and emission reduction.

(5) Planning and adopting the new technologies of energy conservation and emission reduction on new ships.

(6) Development and maintenance of company energy efficiency management information system.

(7) Arrangement of bunkering time and ports, standardized purchase and reasonable supply of fuels, test of lube and fuel, supervision of energy purchasing standards, as well as direction of ship operation to ensure the quality of lube and fuel.

(8) Statistics and summary of bunkering and consumption of lube and fuels.

(9) Scheduling dispatch and giving voyage orders.

(10) Communication and cooperation with shipowners, ships, ports, piers, ship agents, inspection agencies, pilots and other relevant parties.

(11) Tracking the activities of ships during sailing and mooring and duly providing shore-based support according to ship master's demands.

(12) Identification, assessment and update of the company's ship energy efficiency factors, development of effective control measures and plans, as well as organization of the building of ship energy efficiency management system and maintaining continuous improvement.

(13) Development of ship energy efficiency indexes and supervision of their implementation.

(14) Regular collection, statistics and analysis of ship energy consumption related data, and assessment of energy performance.

(15) Directing ships to adopt reasonable and feasible energy-saving measures.

(16) Energy efficiency awareness and skill training to relevant staff engaged in positions involved in energy efficiency management.

(17) Organizing the development and implementation of renovation plans of new energy saving technologies to existing ships.

(18) Supervision and regular evaluation on the implementation of ship energy efficiency management plan.

2.2.4 Ships

2.2.4.1 The master is to be fully responsible for the implementation of SEEMP.

2.2.4.2 Ships are to record various data and information of SEEMP implementation as per Annex 1&2 Ship Energy Efficiency Management Measures Implementation Plan and Records.

2.2.4.3 Ships are to report at regular intervals the amount of fuel consumed to the company.

2.2.4.4 The master is to organize assessment periodically of the goal achievement status, and report to the company with the Ship Management System Operation and Review Report.

2.2.4.5 The master is to organize assessment periodically of the Ship Energy Efficiency Management Measures Implementation Plan and Records to identify existing issues during implementation and to organize corrections, seek to improve such plan and record.

2.2.4.6 Chief engineer is the main responsible person for the work of pollution prevention and energy management of engineering department, responsible for the maintenance of energy consumption equipment of the entire ship to ensure that the equipment is running under good working conditions, develop energy-saving measures according to the actual situations of the ship, and also responsible for the measurement of energy consumption of the entire ship and ensure data accuracy, directing and supervising the implementation of energy efficiency measures by second engineer and third engineer.

2.2.4.7 Second engineer is responsible for filling lube oil and maintenance of main engine, ensuring the main engine to run under the good working condition, monitoring the cylinder oil consumption rate of the main engine and optimizing it. Third engineer is responsible for the coordination and supervision of bunkering task carried out by crews.

2.2.4.8 Chief mate is responsible for developing and ensuring implementation of the energy efficiency management measures relating to loading (preparing) / unloading, ballasting / deballast as well as the entire transportation process, scientifically carrying out stowage, loading and unloading operations within reasonable scope, and timely advising preparation, reduction and shutting down of boilers to shorten the working time of boilers as far as possible.

2.2.5 As the managers of ships, every crew member is playing a very important role in pursuing better energy efficiency and energy conservation. Everyone should be familiar with the operation of ship equipment, and clearly understand the energy-saving potentials of some particular equipment, so as to manage and operate the equipment in a better way. At the same time, crew members must form the good habit of energy saving, such as timely turning off power consumption equipment (lights, TV, electric stove, ventilation equipment, etc.).

2.3 Planning

2.3.1 Base on analysis of historic data, consideration of (or reference to) ship fuel consumption as well as judgment of the ship operation condition for next year, the company should assign energy efficiency goals to ships at the beginning of each year, including:

(1) Annual fuel assessment index of individual ship

(2) Ship energy efficiency operational indicator (EEOI)

2.3.2 The company is to develop Ship Energy Efficiency Management Plan for each ship according to 2012 Guidelines for the Development of a Ship Energy Efficiency Management Plan under IMO Resolution MEPC.213(63) in combination with historic experience and lessons of the company and the industry's best practices, identifying recommending methods of improvement energy efficiency for ships to select and use.

2.3.3 During the implementation of ship energy efficiency management measures, the master should adopt appropriate energy efficiency management measures according to the voyage characteristics, develop the Ship Energy Efficiency Management Measures Implementation Plan and Records (as per Annex 1&2), identify the specific implementing methods and effective monitoring measures as well as the responsible persons, determine the execution time and person of the plan and the date for next evaluation of the plan.

2.3.4 The newly developed and updated Ship Energy Efficiency Management Measures Implementation Plan and Records must be reported to the company and be improved according to the direction from the company.

2.3.5 The ship should include the training of ship energy efficiency management measures into its annual training plan, and use the SEEMP as training material. After the development of Ship Energy Efficiency Management Measures Implementation Plan and Records, the master should organize training for the crew members on the implementation of relevant measures.

2.4 Implementation

2.4.1 The ship should implement the measures identified in the Ship Energy Efficiency Management Measures Implementation Plan and Records, and record the implementation status of these measures on relevant records form by the responsible person of each measure. Any reasons that have led to the failure of implementing any measures should be recorded and kept.

2.4.2 The implementation of the plan will be monitored in full range by the implementing person as identified in the Ship Energy Efficiency Management Measures Implementation Plan and Records.

2.4.3 In case of any fuel leak and discharge caused by accidents during ship operation, or fuel loss and accidental discharge caused by malfunction of ship and equipment or improper handling during bunkering, storage, using and oily water discharge, the ship should get prepared for emergency response and take suitable measures according to the related requirements of ship emergency response procedure and Shipboard Oil Pollution Emergency Plan (SOPEP) as defined in the company management system documents.

2.4.4 At the beginning of the implementation of the plan, the implementation cycle of the Ship Energy Efficiency Management Measures Implementation Plan and Records can be set as 3 months; after implementation for a period, the energy efficiency measures that fit to the ship can be basically mastered, and then the implementation cycle of such plan can be prolonged properly, but not exceeding X months at most.

2.4.5 The implementing person as identified in the Ship Energy Efficiency Management Measures Implementation Plan and Records should monitor the implementation of the plan in full range, evaluate the measures and implementation effectiveness at the date of next plan evaluation, identify which types of measures can/cannot function effectively, and how and/or why, comprehend the trend of efficiency improvement of that ship and get prepared to develop improved Ship Energy Efficiency Management Measures Implementation Plan and Records for next cycle.

2.4.6 Identification, reporting, development and implementation of corrective actions for the non-conformities during the implementation of the plan should be carried out in accordance with the company's SMS Procedures for Non-conformity Reporting, Investigation and Analysis and Implementing Corrective and Preventative Actions.

2.4.7 Exchange of information

2.4.7.1 The company is to timely track the promulgation and implementation of new conventions, rules and requirements with regard to environmental protection and energy management from international organizations, flag States and industry organizations, study and analyze relevant impacts to the ship, take positive response measures, and timely distribute such information to ships through various methods.

2.4.7.2 Ships are to, according to the uniform deployment and requirements from the company, carefully implement and strictly execute various measures developed by the company and report to company with regard to the implementation status and issues encountered in time.

2.4.7.3 Information and requirements in connection with energy conservation and environmental protection from local ports as collected during operation of the ship should be fed back to the company in time according to the company's reporting procedure or in other convenient manners.

2.5 Monitoring

2.5.1 Ships are to report after each voyage to the company voyage energy efficiency data, such as fuel consumption, voyage sailing distance and freight volume, and these data should be entered into the "Energy efficiency management information system" after being verified by the company.

2.5.2 Ships are to send the voyage report forms of the lube, fuel and fresh water consumption to the company on a regular basis, and after review, a company monthly ship lube and fuel consumption statistic report will be summarized.

2.5.3 The company will use the data specified in the above-mentioned report to monitor ship fuel consumption and the ship operational energy efficiency:

2.5.3.1 The company is to assess ships' lube and fuel consumption against the company's annual lube and fuel assessment index of individual ships, and draw comparisons among ships of the same type. Annual lube and fuel assessment index of individual ship shall include:

Sailing unit consumption kilogram/nautical mile	Cargo discharge unit consumption kilogram/tonne of cargo	Auxiliary engine unit consumption kilogram/day	Tank wash quota tonne/each task	Light diesel oil ratio (%)	Fuel oil ratio (%)	Main engine cylinder oil kilogram/hour	Main engine system oil kilogram/hour	Auxiliary engine lube oil kilogram/day	Lube oil costs (RMB 10 thousand)

*Fuel consumption occurred due to undertaking of obligations to render salvage service shall be excluded.

2.5.3.2 The company uses EEOI as an auxiliary monitoring method, and in accordance with the IMO guidelines (MEPC.1/Circ.684), EEOI rolling average index shall be used as a tool to monitor the ship operational energy efficiency within a certain period of time.

2.5.4 The ship is to calculate and record the average EEOI of a period according to the energy efficiency monitor records (as per Annex 3 to this Appendix).

2.5.5 Ship Energy Efficiency Operational Indicator (EEOI)

2.5.5.1 EEOI Formulas

(1) According to IMO.MEPC.1/Circ.684 Guidelines For Voluntary Use of the Ship Energy Efficiency Operational Indicator, the basic expression for EEOI for a voyage is defined as:

$$EEOI = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D}$$

(2) Where average of the indicator for a period or for a number of voyages is obtained, the Indicator is calculated as:

$$AverageEEOI = \frac{\sum_i \sum_j FC_{if} \times C_{Fj})}{\sum_i m_{cargo,i} \times D_i)}$$

- j is the fuel type;
- i is the voyage number;
- FC_{ij} is the mass of consumed fuel j at voyage i;
- CF_j 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.

2.5.5.2 The unit of EEOI is g/tonne-mile, and it may be converted from g/tonne-mile to g/tonne-km by multiplication by the factor 0.54.

2.5.5.3 Fuel mass to CO_2 mass conversion factors (CF), CFis 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 CF is as follows:

Type of fuel	Reference	Carbon content	CF ($t-CO_2/t-Fuel$)
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

2.5.6 The company is responsible for the collection of ship energy efficiency management performance data, and conducting the dynamic analysis of fuel consumption data, as well as giving correct direction timely to the ship which energy consumption is abnormal.

2.5.7 The company is responsible for identification of best practices, technology renovation, and statistics of energy efficiency index achievement as well as analysis of the variation trends.

2.6 Evaluation and Improvement

2.6.1 The ship master and the chief engineer should carry out SEEMP evaluation once every half year for the ship to develop continuously improved SEEMP, and report the result of such evaluation to the company.

2.6.2 The company is to hold energy efficiency analysis meeting once every half year to analyze the data of ship energy efficiency management information, evaluate the planned measures and the effectiveness of their implementation and draw comparison of the energy efficiency management performances of all ships within the company; and to draw comparison of energy efficiency management performances with the benchmarking companies within the industry annually to identify gaps and define corresponding measures and feed back such information to ships.

2.6.3 It is recommended to include the data analysis and improvement after being approved by the responsible person as the input for the company's annual management review.

2.6.4 The company is to carry out regular audits against ships according to requirements of the internal audit procedure, and the implementation status of the SEEMP shall be treated as part of the internal audit.

3 Best Practices for Ship Energy Efficiency Management

3.1 The company's operational management of ships

3.1.1 Charter contract management

3.1.1.1 During the execution of voyage charter contract, there may be circumstances of non-full load. The company should take account of ship energy efficiency while conducting economic accounting, and take relevant measures.

3.1.2 Fleet management

3.1.2.1 The company should, according to different cargo types, time, ports of loading/discharge, and freight of different cargo carrying opportunities, develop the company's fleet cargo transport schedule in a reasonable way and coordinate and resolve special circumstances that may arise, try the best to keep the consistency of voyages in terms of time and geographical location, and avoid or reduce long ballast voyages and improve ship utilization and utilization rate of deadweight to improve ship energy efficiency.

3.2 Voyage optimization plan

3.2.1 Voyage planning – optimum route and efficiency improvement can be achieved through careful planning and execution of voyages.

3.2.1.1 The company is to allocate reasonable shipping route capacity with good voyage budgets to reduce empty-load voyages, arrange loading volumes by fully utilizing ship capacity and port calling sequences in a reasonable way, reduce loading/discharge time at ports and non-productive berthing time as well as berthing time to wait for cargo, thus to improve ship operational efficiency and ship energy efficiency.

3.2.1.2 The ship master, after being assigned with voyage tasks, should inform the second mate as soon as possible to develop and review the route design, and the route design shall be updated timely once voyage task changes occur.

3.2.1.3 The voyage plan of the ship shall be designed in a reasonable way which seeks for economic efficiency under the premise of safety.

(1) The ship's voyage plan should take a reasonable route with the shortest distance, and the ship master should decide according to the voyage orders whether to use the great circle line or not, which straits and narrow courses to go through, whether to take high latitude route or low latitude and whether to apply for weather routing or not, and select optimum route and recommended route to avoid unnecessary deviation.

(2) The ship master should, according to forecasts of the weather and sea conditions that the ship is to experience, ship's performance and technical condition as well as the voyage tasks, etc., take full account of weather factors of the route and sea conditions of the voyages such as waves, tides, winds and currents to bypass the areas with hazardous winds and waves and take advantage of the ocean currents to take the preferred shipping routes.

(3) Multiple routes shall be designed as backup against voyage tasks.

3.2.1.4 The company is responsible for collection, sorting, statistics and analysis of the major routes for the ships managed by the company, and according to the safe and economic recommended routes designed against different sailing areas, seeks to operate the ships with the most economic sailing distance under the premise of safety and compliance with sailing provisions of relevant countries alongside the route, and figures out the standard energy consumption of each voyage for the direction of ship energy efficiency improvement.

3.2.2 Weather routing and rough weather

3.2.2.1 Weather routing has a high potential for efficiency savings on specific routes. But it would be better to balance the relationships between economic efficiency and voyage safety according to actual situations, and to improve the economic efficiency as far as possible under the premise of safety.

3.2.2.2 When sailing across oceans, the ship master may consider factors such as sea condition forecasts and voyage tasks and raise application for weather navigation to the company timely. The company should give shore-based support in a timely manner after receipt and review of the application from the ship, and notify the ship of the name and contacts of the corresponding weather navigation company. Before leaving ports, the ship should give relevant materials to the weather navigation company and keep timely and accurate exchange of information during subsequent voyages to ensure the energy saving results of weather navigation.

3.2.2.3 Ships equipped with BRIDGE SYSTEM provided by WNI will have details of wind, current, water temperature and weather information along the sailing areas displayed in the system and be automatically provided with recommended optimum routes for ship master's selection.

3.2.2.4 During sailing, if the weather forecast is different from the actual weather, the ship master should contact the weather navigation company timely.

3.2.3 Speed optimization

3.2.3.1 Speed optimization will reduce the energy consumption significantly. However, optimum speed means the fuel consumption per tonne nautical mile of this voyage is at the lowest level. It does not mean minimum speed; in fact, sailing at less than optimum speed will consume more rather than less fuel. When determining the optimum speed for the ship, reference should be made to the engine manufacturer's power/consumption curve and the ship's propeller curve, and meanwhile consideration should also be given to the fact that there will be possible increase of vibration and carbon black at slow speed.

3.2.3.2 Factors to be considered for speed optimization should include: ship operation mode, charter contract, fuel price, freight rate, shipping date, hydro-meteorological condition, speed requirements and limits from this voyage line and route, ship condition, ship loading status, fuel quality, ship optimization during actual operation, ship machinery and equipment, and etc.

3.2.3.3 When leaving a port or estuary, motorized navigation at narrow seaway and passing by shoaling waters, under the premise that the safety of ship navigation is ensured, a gradual increase in speed whilst keeping the engine load within certain limits may help reduce fuel consumption.

3.2.3.4 When concluding charter contracts with charterers, the shipping department of the company should try the best to negotiate and convince the charterer to support operation of the ship at optimum speed so as to improve energy efficiency to the greatest extent.

3.2.3.5 The ship shall strictly follow the economic speed orders from the company according to the voyage plans.

3.2.3.6 The ship is to adjust speed properly and reduce the time of waiting for berthing with voyage suspended according to the berthing plans at ports of loading and discharge within the voyage plans.

3.2.3.7 The ship is to adjust speed properly according to hydro-meteorological conditions, speed requirements and limits from voyage lines and routes so as to reduce the waiting time with suspended voyage.

3.2.3.8 The ship should keep the sailing speed consistent for the entire voyage as possible as it can.

3.2.3.9 The company is responsible for directing the ship to sail at economic speed to avoid energy consumption increase during unreasonable speed increase, and directing large sized ships to maintain better data collection of main engine revolution measurements and energy consumption per tonne nautical mile, and etc.

3.2.4 Optimization of ship draft and trim as well as operation of ballast water

3.2.4.1 Both ship draft and trim will affect ship energy efficiency. As the volume of ship draft will decide the size of sailing resistance of a ship, the submerged depth of propeller will go down at light load, and the propelling efficiency will be affected. Before a ship launches its sailing, the draft and trim need to be optimized through adjustment of ballast water to ensure that the propeller sinks completely into water so as to maintain propeller's efficiency. Less ballast water does not necessarily mean better energy efficiency.

3.2.4.2 The company may consider introducing trim optimization system software to optimize the trim of the ship in a more accurate manner so as to ensure less ship energy consumption.

3.2.4.3 During the implementation of ballast water operation and ballast water management plan, the ship should make reasonable plans to reduce repetitive operations due to the randomness of pressurizing and discharge, and to improve energy efficiency to the greatest extent under the premise that the stability stress and navigation safety of the ship are ensured.

3.2.4.4 The ship is to carefully implement water ballast tank sediment management plan, and wash and control the accumulation of sediments on a regular basis to reduce unnecessary energy consumption.

3.2.4.5 During ballast water operation, the ship should according to plan adopt gravitational self-pressing method to reduce the energy consumption of using ballast pumps.

3.2.5 Optimum use of rudder and heading control systems (autopilots)

3.2.5.1 Ships are recommended to use automated heading and steering control systems to avoid increase of distance sailed due to deviation from planned route.

3.2.5.2 Autopilots should be used correctly and ships are to regulate and configure the pressure angle of wind currents in a reasonable manner according to weather and sea conditions to avoid unnecessary frequent uses of rudder or deviation from planned route due to frequent deviation from preset direction which may lead to increase of the distance sailed.

3.2.5.3 The ship needs to select the right modes of rudder operation according to the route conditions.

3.3 Timely communication with relevant parties

3.3.1 Communication with charterers

3.3.1.1 When concluding charter contracts with charterers, the company should try the best to negotiate and convince the charterer to support operation of the ship at optimum speed so as to improve energy efficiency to the greatest extent.

3.3.1.2 The company should communicate timely with charterers to fix the lay days at port of loading and arrangements at port of discharge, so that the ship can optimize sailing speed and adjust arrival date in a reasonable manner to improve energy efficiency.

3.3.2 Communication with piers

3.3.2.1 The ship should communicate timely with the piers to fix the berthing plan and optimize sailing speed and adjust arrival date according to such plan in a reasonable manner to improve energy efficiency.

3.3.2.2 The ship should communicate timely with the piers to fix the cargo discharge plan to avoid waste of energy due to a long time operation of the discharge system waiting for the start of discharge operation.

3.3.3 Communication between ships and company shore bases

3.3.3.1 The company should strengthen the communication with ships so that it can direct ships timely to optimize speed according to loading/discharge plans, arrange loading and discharge in a reasonable manner, make ship replenishment plans to reduce the occurrences of unnecessary waiting for timing and berthing.

3.3.3.2 The ship is to carefully implement relevant measures of SEEMP, keep records of the implementation status of each measure, and feed back the deficiencies in energy efficiency management.

3.3.3.3 Ships are to feed back the voyage reports of the lube, fuel and fresh water consumption to the company on a regular basis after each voyage, and monthly ship lube and fuel consumption statistic reports will be summarized by the company according to feedbacks from the ship. The company will use the data provided in the above two reports to cover ship energy efficiency data report sheets. By using annual lube and fuel assessment index of individual ships, the company is to monitor the fuel consumption of ships on a regular basis, calculate fuel consumption figures of individual ships and the entire fleet and draw comparison among ships of the same type to optimize ship energy efficiency management.

3.3.4 Internal communication of ships

3.3.4.1 The ship's deck department and engine department should communicate timely to determine more accurate cargo loading/discharge time to avoid redundant operation of auxiliary boilers and inert gas systems.

3.4 Propeller and hull inspection

3.4.1 Inspection and maintenance of propeller

3.4.1.1 The propeller is to be cleaned and polished by utilizing every docking opportunity.

3.4.1.2 Regular inspection should be done to check if there is any foreign matter (fishing nets, ropes) twisting onto the propeller, which shall be removed as soon as possible, if any.

3.4.2 Hull Inspection

3.4.2.1 The in-water part of the hull should be inspected every two to three years, and the hull should be cleaned by docking or in-water cleaning if serious fouling is detected.

3.4.2.2 After long time berthing or slow-speed voyages, the fouling status of the hull should be evaluated to determine the cleaning treatment method.

3.4.2.3 Environment-friendly low frictional resistance anti-fouling coating can be used to ensure the finish of the hull surface.

3.5 Mechanical equipment optimization plan

3.5.1 Monitoring and optimization of main engine

3.5.1.1 During operation of the main engine, relevant parameters should be checked on a regular basis, and thermal parameters should be measured regularly to monitor the combustion operating mode of the main engine to see whether good condition is maintained.

3.5.1.2 The VIT unit and VEC unit of the main engine should be maintained regularly for a good condition to ensure that the main engine maintains good thermal efficiency during operation with part load so as to reduce fuel consumption.

3.5.1.3 Based on the maintenance plan in combination with relevant rules of the manual, daily management and overhaul of the main engine should be carried out in a good manner to keep a good status of the parts such as the high pressure oil pump, fuel injector, exhaust valve and air cooler, etc., so as to keep better combustion operating mode of the main engine.

3.5.1.4 Based on the maintenance plan in combination with relevant rules of the manual, daily management and overhaul of the main engine turbocharger should be carried out in a good manner to keep a good working condition of the turbocharger:

(1) The turbocharger is to be washed periodically to maintain good turbocharger efficiency;

(2) Good condition of the turbocharger trap valve (and the air pressure difference at the trap valve);

(3) Normal exhaust temperature difference at the turbine end of the turbocharger.

3.5.1.5 Maintenance of the exhaust gas boiler should be carried out in a good manner, the exhaust gas boiler should be washed using water, and the discharge flue of the main engine should be kept unclogged to ensure good operation of the turbocharger.

3.5.1.6 During operation of the main engine, the draining operation of the air cooler and scavenging box should be controlled in a reasonable manner to reduce loss of the scavenging pressure.

3.5.2 Monitoring and optimization of auxiliary engines

3.5.2.1 During operation of the auxiliary engines, relevant parameters should be checked on a regular basis, and thermal parameters should be measured regularly to monitor the combustion operating mode of the auxiliary engines to see whether good condition is maintained.

3.5.2.2 Based on the maintenance plan in combination with relevant rules of the manual, daily management and overhaul of the main engine should be carried out in a good manner to keep a good status of the parts such as the high pressure fuel pump, fuel injector, exhaust valve and air cooler, etc., so as to keep better combustion operating mode of the main engine.

3.5.2.3 Based on the maintenance plan in combination with relevant rules of the manual, daily management and overhaul of the auxiliary engine turbochargers should be carried out in a good manner to keep a good working condition of the turbochargers.

3.5.2.4 Under the circumstances that electrical safety is ensured, if the auxiliary engine load allows, it is better to use one auxiliary engine to the greatest possible extent to improve operational efficiency of the generators and reduce fuel consumption.

3.5.3 Waste heat recovery and utilization

3.5.3.1 Regulation of the heating temperature of various oil tanks and containers and use of steam shall be adopted in a reasonable manner to avoid use of auxiliary boilers due to insufficient steam generated by exhaust gas boilers (in winter).

3.5.4 Boiler performance management

3.5.4.1 Daily maintenance of the boilers should be carried out in a good manner, such as regular dust blowing, flue washing and boiler cleaning, to maintain good condition of the auxiliary boilers and ensure their thermal efficiency.

3.5.4.2 Daily maintenance of the auxiliary boiler fuel system and burner should be carried out in a good manner, and reasonable regulation of burning control parameters and atomized steam pressure should be carried out to ensure good combustion working condition.

3.5.4.3 When refilling inert gas to the cargo tanks of ships such as oil tanker and gas carrier, it is required to, according to actual situations, adjust the minimum load of auxiliary boilers required for the status of inert gas mode, so as to reduce auxiliary boiler fuel consumption during the operation of inert gas refilling.

3.5.4.4 Daily maintenance of the exhaust gas boilers should be carried out in a good manner, such as regular dust blowing and flue washing, to maintain good condition of the exhaust gas boilers and ensure their thermal efficiency.

3.5.4.5 Water temperature of the hot water well should be kept above 50oC to reduce variation of the steam pressure of the auxiliary boilers and exhaust gas boilers, so that the fuel consumption of the auxiliary boilers can be reduced.

3.5.4.6 Water within the boilers should be treated in a good manner to keep good boiler water quality, and thereby guarantee good steam quality so as to improve steam efficiency.

3.5.4.7 Steam leak consumption should be reduced for the entire ship, and steam pipes and valve heat-insulating materials should be maintained in good condition to reduce heat loss and improve overall efficiency of the boilers, thus to reduce operation costs.

3.5.4.8 Optimization of relevant operations of the cargo oil pump/ballast pump steam turbine should be carried out for tankers to improve the steam turbine efficiency and reduce the auxiliary boiler load:

(1) Keep the auxiliary boiler air pressure at higher value within normal range (or above 1.5 MPa);

(2) Clean the vacuum condenser of cargo pump turbine thoroughly on a regular basis to ensure good cooling result and higher vacuum level;

(3) Clean the vacuum ejector thoroughly on a regular basis, and remove the ejector nozzle to ensure efficiency of the vacuum ejector;

(4) Regulate the gas sealing steam pressure of the cargo pump turbine and ballast pump turbine to ensure normal gas sealing function.

3.5.5 Ship fuel management

3.5.5.1 Ships must carry a fuel volume at the most economic level according to relevant requirements from the company. Efforts should be made to check on the processes of refueling, use and return of fuel, and carry out fuel management in a good manner to improve the overall energy utilization.

3.5.5.2 The company should strengthen the control of fuel products to ensure fuel quality, and all of the fuel purchased should comply with the widely recognized ISO 8217.

3.5.5.3 Fueling sampling and delivery of samples should be done by the ship master and chief engineer, and the sampling must be correct at each refueling; the company is to designate qualified laboratory to test the samples to be refueled, and the ship should only use the fuel upon receipt of good test results.

3.5.5.4 Mixed refueling of fuel from different batches is prohibited.

3.5.5.5 The use of fuel must follow the principle of FIFO to avoid increase of solid sediment due to long time storage, which may lead to clogging of filters and other hazards to prevent continual use of the fuel.

3.5.5.6 Fuel additives are to be reasonably used according to the user✓s manual to ensure good burning condition, stability and degree of homogeneity of the fuel as well as to prevent the fuel from stratification and settling, thus to improve fuel utilization.

3.5.6 Use and management of incinerator

3.5.6.1 Daily maintenance work should be carried out to the incinerator in a good manner to ensure its good condition.

3.5.6.2 During incineration of waste oil (and residues), thorough treatment must be done to the water within the waste oil (and residues) through heating, depositing and draining, thus to reduce the light diesel oil used to the greatest possible extent during incineration of waste oil (and residues).

3.5.6.3 If waste incineration is required, it should be arranged during the incineration of waste oil (and residues) to reduce the consumption of light diesel oil.

3.5.6.4 Acceptance of shore discharge of oily water from engine room and ship wastes should be arranged as far as possible to reduce the using time of the incinerator and consumption of light diesel oil.

3.5.7 Optimization of other machinery and equipment

3.5.7.1 If permitted, the chief engineer may, according to his experience, decide at his discretion whether or not to shut down the lubricant pump and camshaft lubricant pump (unless standby state is required).

3.5.7.2 After anchoring or berthing, the ship should timely shut down devices that are no longer in use, such as steering engine, deck machinery, fire-fighting pumps and so on, to reduce load for auxiliary engines.

3.5.8 Use of shore power

During repair of the ship, if permitted, shore power should be used as possible as it can.

3.6 Optimization of liquid cargo handling

3.6.1 Reasonable development and effective execution of cargo loading/discharge plans

3.6.1.1 To finish the operation of cargo loading/discharge in a safe and highly efficient manner, the chief mate is to organize the development of complete loading/discharge plans according to voyage loading condition (stowage plan), ship equipment, staff condition and the requirements of ports of loading/discharge. Drivers and relevant marine engineers should participate in the development of such plans as possible as they can, and the plans must be reviewed and signed off by the ship master before execution. The chief mate is to prepare the actual cargo stowage plan according to the liquid level and oil temperature within the liquid cargo tanks.

3.6.2 Heating and insulation of the liquid cargo tanks

3.6.2.1 This section applies to ships with liquid cargo heating systems.

3.6.2.2 The company is responsible for the creation of the heating and cargo tank temperature rising archives, the study of the heating requirements for various cargo oils of ships, understanding of the temperature requirements for liquid cargo from port of discharge, directing ships to control liquid cargo temperature in a reasonable manner and reasonable use of cargo heating facilities.

3.6.2.3 Ships should, according to liquid cargo heating requirements, heating facility performance of the ship and berthing and cargo discharge plans at ports of discharge, develop a reasonable heating and insulation plan; to reduce fuel consumption and heating costs, the following factors should be taken account of during the development of such plans: the configuration of the cargo tanks, the number and area of the heating coils, auxiliary engine and boiler specification, details of the cargo oil (including specific heat and pour point), cloud point, viscosity, wax content, weather conditions en route (including ambient temperature), the temperature of the sea water, wind, sea conditions and swell, expected heat loss, temperature drops, reheating of recommended condensed water, as well as the estimated daily heating time and fuel consumption.

3.6.2.4 During carrying out liquid cargo insulation and heating work on board ship, daily measurement of the oil temperature is required to continuously monitor inert gas pressure within the cargo hold, and heating records of the cargo spaces should be maintained on a daily basis; heating effect should be periodically checked and cabin temperature should be recorded in order to timely adjust the steam pressure and heating group number to avoid large temperature difference and unnecessary heat loss; during winter heating, the water leftover in the heating coil should be cleaned first to improve energy efficiency.

3.6.2.5 The ship should use the ballast voyage opportunity to strengthen the maintenance of heating pipeline valves, carry out pressure test once every 6 months by using compressed air at 4kg/cm2, regularly clean the filter and maintain the inlets and outlets of residual valves, and conduct equipment checks to ensure normal status before use to avoid higher energy consumption due to equipment reasons.

3.6.3 Ensure efficiency of turbine cargo pumps and ballast pumps (for liquid tankers)

3.6.3.1 Proper steam pressure and reasonable setting of cargo pump revolution speed are to be ensured to enhance the turbine efficiency of cargo pumps or ballast pumps.

3.6.3.2 Parameters such as the vacuum level of cargo pump vacuum condenser and cargo pump steam sealing pressure should be correctly adjusted to ensure appropriate turbine steam return pressure, and reduce steam consumption and fuel consumption of the boilers.

3.6.4 Controlling inert gas pressure of cargo tanks

3.6.4.1 During loading and discharge of oils, under the circumstances that the requirements of safety and VOC Management Plan are met, cargo tank inert gas pressure value should be set in a reasonable manner to ensure that the normal range of the cargo tank inert gas pressure is between +500--- +800mm water column height, or the inert gas pressure value of cargo tanks is to be set according to the requirements from the pier.

3.6.4.2 After liquid cargo loading is completed, reasonable control of the inert gas pressure could minimize the number of additional inert gas refilling during sailing, thereby reducing the fuel consumption of the boilers.

3.6.4.3 After unloading and cabin inspection are all finished, the chief mate should consider weather conditions of subsequent voyage routes, and timely communicate with the engine department to determine a reasonable cabin air pressure to avoid release of cabin air pressure (due to elevated temperature) or multiple refilling of inert gas (due to decreased temperature) during subsequent sailing distance, so as to reduce fuel consumption.

3.6.4.4 In the course of a voyage, if the inert gas pressure of the cargo tanks is insufficient and therefore need inert gas refilling, full consideration should be given to weather variation factors during the remaining distance before arrival at ports of loading/discharge, and a reasonable pressure of inert gas refilling in the cargo tanks should be determined to avoid repeated refilling during subsequent sailing.

3.6.4.5 In the course of a voyage, if inerting of the cargo tank is needed (after ship repair or repair work in the tank), the chief mate needs to develop a detailed, reasonable inert gas filling plan to reduce the inerting time of the cargo tank and reduce the fuel consumption of the auxiliary boiler.

3.6.4.6 Maintenance of the inert gas system piping, valves and cargo tank hatch covers should be strengthened to ensure air sealing, reduce gas leaks from the cargo oil tanks, and reduce the number of inert gas refilling due to insufficient cargo tank gas pressure.

3.6.5 Inert gas system management and control of its use

3.6.5.1 Before arrival at the ports of discharge, trial operation and related alarm test must be carried out to the inert gas system to facilitate detection of problems and their timely resolution, and try to avoid inert gas system failure during discharge, which could cause increase of the discharge time and the berthing time.

3.6.5.2 Commissioning of the inert gas system is required before arrival at the port of discharge, and during the test of the system, pressure test should be synchronized with the commissioning of the liquid cargo system to avoid fuel waste due to multiple use of auxiliary boilers.

3.6.5.3 Maintenance should be strengthened to the oxygen analyzer of inert gas system and its sampling pipeline to ensure normal working conditions of the oxygen analyzer and avoid inaccurate measurements of the oxygen content, which may lead to increased combustion load of the auxiliary boiler and result in fuel waste.

3.6.5.4 The ship✓s deck department and engine department should communicate adequately to determine the start time of the inert gas system and avoid long time redundant operation of the inert gas system, which may lead to long time redundant operation of the auxiliary boilers and result in fuel waste.

3.6.6 Control of the cargo tank washing

3.6.6.1 Before ship repair or cargo space repair work, or replacement of the liquid cargo, the ship tanks need to be washed, and a detailed and reasonable cargo tank washing plan should be prepared in advance, and in combination with reasonable adjustments of the actual operation, be designed to reduce the time required for tank washing and the fuel consumption of auxiliary boilers.

3.6.6.2 Before each operation of degassing and ventilation, it is necessary for the ship to develop a detailed and reasonable cargo tank degassing and ventilation plan, and in combination with reasonable adjustments of the actual operation to reduce the time required for degassing and ventilation and fuel consumption.

3.7 Energy conservation awareness and new technologies

3.7.1 Energy conservation procedure for specific public areas (living area)

3.7.1.1 Heat exchange of living area (such as closing windows and curtains, etc.) is to be reduced to decrease the work load of the air conditioning system.

3.7.1.2 Ship auxiliary systems, including lighting, ventilation system, kitchen facilities and steam provision, should be turned off if not needed, such as unused lighting in the living area, and reasonable use of fans at pump rooms and the boatswain's warehouse.

3.7.1.3 Rational use of living facilities, such as reasonable use of washing machines and dryers.

3.7.1.4 Some of the household appliances on board ships, such as computers, televisions, DVD, stereo, microwave ovens, etc., should be turned off when not in use.

3.7.2 Utilization of new technology and new energy

3.7.2.1 For ships, the adoption of new energy-saving technology and utilization of new energy can improve the ship's energy efficiency and reduce operating costs.

Annex 1: Ship Energy Efficiency Measures Implementation Plan

Name of ship		Gross tonnage	
Type of ship		DWT/TEU/PCC	
IMO No.		Class No.	
Builder		Date of operation	
IEEC No. (if applicable)			
Date of preparation		Prepared by	
Implementation duration	From… … to… …	Implemented by	
Date of next scheduled evaluation			

Serial No.	Energy efficiency measures	Implementing contents and requirements	Responsible person
	Weather routing	Selection of XXX Company as the weather navigation company for this ship, detailed recording of daily weather conditions and average speed and comparison with weather forecasts to assess the services of the weather navigation company.	
	Selection of shipping routes	For XXX – XXX routes of this ship… is chosen for winter… for summer and… … for typhoon seasons.	
	Speed optimization	This ship sails at a speed of XXX knots, leaving and arriving at port at… …, narrow fairways at… … and intensive navigation zones at… …	
	Port coordination	Description of specific energy efficiency measures for different scenarios, which are of guidance to the actual practices of this ship.	
	Ship–shore communication	… …	
	Control of trim	… …	
	Optimum operation of ballast water	… …	
	… …	… …	
	… …	… …	
	… …	… …	
	… …	… …	

Annex 2: Ship Energy Efficiency Measures Implementation Records

Serial No.	Energy efficiency measures	Actual implementation status	Time	Results
	Weather routing	Focus should be given to the recording of deviations from original plans and corresponding data		
	Selection of shipping routes	… …		
	Speed optimization	… …		
	Port coordination	… …		
	Ship – shore communication	… …		
	Control of trim	… …		
	Optimum operation of ballast water	… …		
	… …	… …		
	… …	… …		
	… …	… …		
	… …	… …		

Annex 3: Energy Efficiency Monitoring Records

Indexes monitored	Index description	Implementation period	Planned goals	Actual achievements
EEOI				
CO_2 emission per nautical mile				
CO_2 emission per tonne cargo (leg)				
… …				
… …				

Annex 4： SEEMP Self－evaluation Records

Description or No. of Energy efficiency measures	Result evaluation	Improvement advices
1. 1		
1. 2		
……		

Accidents and potentials	Root cause analysis	Applicable control and improvement actions

SEEMP operation control	Evaluation	Improvement advices

Appendix 4 A Sample Form of Ship Energy Efficiency Management Plan for Inland Navigation Vessels

SHIP ENERGY EFFICIENCY MANAGEMENT PLAN

(SEEMP)

Name of ship：XXX

Type of ship：XXX

Gross tonnage：XXX

Inspection certificate No.：XXX

Company：XXX

Title Page

Name of ship:	"XXXX" Luxury Cruise Ship
Navigation zone & leg:	Navigation zone: Class A & Navigation leg: Class J1
Type of ship:	Tourist passenger ship
Port of registry:	XX Port
Shipowner:	XXXX Line Ltd.
Ship operator:	XXXX Line Ltd.
Ship registration No.:	XXXXXXXX
Ship ID No.:	XXXXXXXX
	Ship✓s major particulars
LOA (m):	91.5
BM (m):	16.5
DM (m):	4.8
Max. draft (m):	4
M/E Power (kW x Qty):	1280×2
A/G Power (kW x Qty):	300×2, 100×1
GT:	5397

Notes

1、This plan is developed in accordance with the technical requirements under the Rules of Inland Green Vessels and the Guidance for the Development of a Ship Energy Efficiency Management Plan published by China Classification Society.

2、This plan is intended to identify and evaluate the energy efficiency factors of XXX, provide energy－saving means in terms of management, technology and operation to the Company✓s XXXX Department, XXXX✓s ship master, crew and other staff, for the purpose of actual improvement of the ship✓s operational energy efficiency as well as continuous improvement of the energy efficiency management plan through regular evaluation.

3、 XXXX is fully responsible for the organization of implementing this plan and relevant trainings.

4、Any modification to this plan should be submitted to the XXX Department for review and approval, where appropriate.

5、Energy efficiency measures adopted by this ship should be based on the premise of safety and meet the requirements of relevant laws and regulations.

6、This plan should be carried on board ship.

1 General

1.1 Energy efficiency policy

The energy efficiency policy of XXXX Line Ltd. (hereinafter referred to as the Company) is..., and its energy efficiency goal is...

The Energy Efficiency Management Plan (hereinafter referred to as the Plan) of "XXXX" Luxury Cruise Ship (hereinafter referred to as the Ship) is intended to improve the operational energy efficiency building procedures of the Ship and continuously improve the energy utilization of the Ship and reduce emissions by the use of best practices and energy-saving experience as well as recording and analysis of energy consumption data.

1.2 Implementation period and date for next evaluation

The implementation period of the Plan is from DD-MM-YY to DD-MM-YY, and the date for next evaluation is DD-MM-YY.

1.3 Scope of responsibility and training requirements

Publication and training are carried out for people involved in the Plan by the Company's energy efficiency management department (specific department or responsible person should be indicated here) with the Ship master and Chief engineer of the Ship to ensure their understanding and implementation of the Plan, including implementation of the energy efficiency measures as well as data recording and analysis.

The ship master of the Ship is fully responsible for the implementation, and reference can be made to Part 3 of the Plan for specific responsible persons for execution of each energy efficiency measure.

2 Planning

2.1 Evaluation of energy efficiency factors

(1) Propulsion system

The Ship was built in the early 1990s, with a design focusing on meeting the harsh requirement of navigating over shoals at the upstream Yangtze River legs with rapid currents. Its design speed is high and has a harsh requirement for dynamic property of the main engine, while the match of engine and propeller is too heavy. Although energy saving results are obvious during slow speed sailing, there are still disadvantages in the following two aspects: 1) The main engine runs at low load for a long time, the normal operating mode is out of the original design, and propulsion efficiency of the propeller reduces; 2) As the match of engine and propeller of the original design is too heavy, the performance of the main engine becomes worse during operations at slow speed area. After the completion of the Three Georges Dam, the conditions of fairways have been improved essentially, and there are huge changes of the current speed before and after the Dam's construction. Therefore the original design of the Ship is no longer suitable for the fairway changes and operational requirements.

(2) Speed

The original design speed of the Ship is fundamentally between 28 km/h and 30km/h. After the completion of the Three Georges Dam, ships✔ requirements for speed are reduced accordingly. The actual speeds used currently are all between 22km/h and 24 km/h, and obvious reduction of main engine fuel consumption can be achieved through speed reduction. Meanwhile, according to characteristics of the currents at different legs within the Dam area, use of different speed by leg is conducive to the reduction of the ship✔s propulsion energy consumption.

(3) Use of shore power

To meet the requirements of traveling comfort, the Ship has large auxiliary engine power. It is estimated that the cost of power generation for the Ship is around RMB 2.6 per 1 KWh, which is far higher than the price of shore power. At present, there are already shore power facilities at Yichang XXX Pier and Chongqing XXX Pier, and the Ship can use shore power during berthing.

(4) XXXX

2.2 Developing energy efficiency measures

(1) Propeller optimization

The main content of this measure is to, through determination of effective power and propulsion factors, determine design points of the propeller, select reasonable match point between engine and propeller, and re-design and re-match the propeller. The Company has entrusted XXX Company to redesign, XXX Company to manufacture and XXX Company to install the propeller of the Ship. XXX from the Company is responsible for the optimization of the propeller, and will participate in the whole range of work from design, manufacturing, installation to experiment.

(2) Speed optimization

According to the features of the retrofitted propeller and sailing experience of the Ship, the following economic speeds are used:

S/N	Leg	Economic speed (km/h)	
		Upstream	Downstream
1	××— ××	×	×
2	××— ××	×	×
…	××— ××	×	×

(3) Use of shore power

When the Ship berths at Chongqing XXX Pier and Yichang XXX Pier, onboard generator should be shut down and instead, shore power should be used.

(4) XXXX

……

2.3 Training

(1) This Plan should be included in the Ship✔s annual training as training material;

(2) The ship master of the Ship is responsible for publicizing to relevant staff the contents such as speed control and method of using shore power;

(3) ……

2.4 Energy-saving goals

(1) Form and meaning of energy-saving goals

According to the energy efficiency goals of the Company and the features of the Ship, **Average Fuel Consumption per Kilometer** is adopted as the indicator to assess whether the Ship meets the energy efficiency goals, and it means the ratio of overall fuel consumption and overall distance sailed measured in g/km within the implementation period of the Ship.

(2) Setting of energy-saving goals

The energy-saving goal set out in the Plan is that, after XX months of implementation of the Plan, the assessment index should be reduced by XX% relative to that before implementation of the Plan.

3 Implementation

The specific implementation of energy efficiency measures is listed in the following table.

S/N	Energy efficiency measures	Implementing contents	Implementation period	Responsible person
1	Propeller optimization	Participating in propeller redesign, manufacture, experiment and etc.	……	XXXX
2	Speed optimization	To sail at the economic speed as prescribed in the Plan.	……	XXXX
3	Use of shore power	When the Ship berths at Chongqing XXX Pier and Yichang XXX Pier, shore power should be connected.	……	XXXX
……	……	……	……	XXXX

4 Monitoring

(1) XXX of the Ship is responsible for recording refueling activities and statistics of fuel consumption, and reporting the status of voyage fuel consumption to the Company upon completion of each voyage.

(2) Upon completion of each voyage of the Ship, XXX is responsible for calculating and recording the average fuel consumption per kilometer of each voyage. (Please refer to the Annex).

(3) XXXX Department of the Company is to conduct summary and statistics of the reported data after review, enter them into the energy efficiency monitoring system, and calculate the average fuel consumption per kilometer of the Ship within XX months to monitor the improvement status of the Ship✓s energy efficiency.

(4) The calculation method for the average fuel consumption per kilometer of a single voyage:

$$FC = \frac{Q}{D} \times 10^3$$

Where:

FC is the average fuel consumption per kilometer measured in g/km;

Q is the fuel consumption of a single voyage measured in kg;

D is the distance sailed of a single voyage measured in km.

(5) The calculation method for the average fuel consumption per kilometer of multiple voyages or within a period of time:

$$FC_{Aver} = \frac{\sum^{i} Q_i}{\sum^{i} D_i}$$

Where:

FC_{Aver} is the average fuel consumption per kilometer of multiple voyages or within a period of time measured in g/km;

Q_i is the single voyage fuel consumption of the Ship's No. i voyage measured in kg;

D_i is the distance sailed of the Ship's No. i voyage measured in km.

(6) Monitoring of major single energy efficiency measures. To reflect the energy-saving results of major single energy efficiency measures (such as propeller optimization), it is recommended to determine through experiments or comparative analysis of data. Reference can be made to Table (3) in the Annex for results monitoring table for major single energy efficiency measures.

(7) ……

5 Self-evaluation and improvement

(1) The ship master and chief engineer of the Ship should evaluate the implementation status of the Plan once every XX months and submit the evaluation report to the Company. The evaluation contents include:

——— Implementing status of the energy efficiency measures and their adaptability

——— Analysis of energy efficiency data

——— Achieving status of the energy-saving goals

——— Advices for improving energy efficiency measures

……

(2) The Company is to hold energy efficiency analysis meeting once every XX months to analyze the data of ship energy efficiency, evaluate the planned measures and the effectiveness of their implementation, and identify gaps and define corresponding improvement measures and feed back such information to the Ship.

(3) ……

Annex

(1) Recording table for the average fuel consumption per kilometer of a single voyage of XXXX Tourist Passenger Ship

S/N	Voyage	Period	Fuel consumption (kg)	Distance sailed (km)	Average fuel consumption per kilometer (g/km)
1	XX to XX				
2					
……					

(2) Recording table for the average fuel consumption per kilometer within XX months/of XX voyage of XXXX Tourist Passenger Ship

S/N	Period	Goals set out in the Plan (g/km)	Actual average fuel consumption per kilometer (g/km)
1			
2			
3			

(3) Results monitoring table for major single energy efficiency measures (propeller optimization) (other measures should be filled accordingly)

Description of the energy efficiency measure		Propeller optimization		
S/N	Average ship speed km/h	Before/after implementation of this energy efficiency measure	Average fuel consumption per kilometer (kg/km)	Reduction rate (%)
1		Before		
		After		
2		Before		
		After		
…	…	Before		
		After		

(4) SEEMP evaluation report

Appendix 5 2012 Guidelines for the Development of a Ship Energy Efficiency Management Plan – MEPC. 213(63)

Resolution MEPC. 213(63)

(Adopted on 25 March 2012)

2012 GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

THE MARINE ENVIRONMENT PROTECTION COMMITTEE,

RECALLING article 38(a) of the Convention on the International Maritime Organization concerning the functions of the Marine Environment Protection Committee (the Committee) conferred upon it by international conventions for the prevention and control of marine pollution,

RECALLING ALSO that, at its sixty-second session, the Committee adopted, by resolution MEPC. 203(62), amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (inclusion of regulations on energy efficiency for ships in MARPOL Annex VI),

NOTING the amendments to MARPOL Annex VI adopted at its sixty-second session by inclusion of a new chapter 4 for regulations on energy efficiency for ships, are expected to enter into force on 1 January 2013 upon their acceptance on 1 July 2012,

NOTING ALSO that regulation 22 of MARPOL Annex VI, as amended, requires each ship to keep on board a ship specific Ship Energy Efficiency Management Plan taking into account guidelines developed by the Organization,

RECOGNIZING that the amendments to MARPOL Annex VI requires the adoption of relevant guidelines for smooth and uniform implementation of the regulations and to provide sufficient lead time for industry to prepare,

HAVING CONSIDERED, at its sixty-third session, the draft 2012 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP),

1. ADOPTS the 2012 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP), as set out at annex to the present resolution;

2. INVITES Administrations to take the annexed Guidelines into account when developing and enacting national laws which give force to and implement provisions set forth in regulation 22 of MARPOL Annex VI, as amended;

3. REQUESTS the Parties to MARPOL Annex VI and other Member Governments to bring the annexed Guidelines related to the Ship Energy Efficiency Management Plan (SEEMP) to the attention of masters, seafarers, shipowners, ship operators and any other interested groups;

4. AGREES to keep these Guidelines under review in light of the experience gained; and

5. REVOKES the Guidance circulated by MEPC. 1/Circ. 683, as from this date, i. e. 2 March 2012.

ANNEX

2012 GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

CONTENTS

1 INTRODUCTION

2 DEFINITIONS

3 GENERAL

4 SCOPE AND APPLICATION

5 GUIDANCE ON BEST PRACTICES FOR FUEL – EFFICIENT OPERATION OF SHIPS

APPENDIX – A SAMPLE FORM OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

1 Introduction

1.1 These Guidelines have been developed to assist with the preparation of Ship Energy Efficiency Management Plan (hereafter referred to as the "SEEMP") that are required by regulation 22 of Annex VI of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78).

1.2 A Ship Energy Efficiency Management Plan provides a possible approach for monitoring ship and fleet efficiency performance over time and some options to be considered when seeking to optimize the performance of the ship.

1.3 These Guidelines should be used primarily by ships' masters, operators and owners in order to develop the SEEMP.

1.4 A sample form of a SEEMP is presented in the appendix for illustrative purposes.

2 Definitions

2.1 For the purpose of these Guidelines, the definitions in the Annex VI of the Convention apply.

2.2 "Company" means the owner of the ship or any other organization of person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the shipowner.

2.3 "Safety Management system" means a structured and documented system enabling company personnel to implement effectively the company safety and environmental protection policy, as defined in paragraph 1.1 of International Safety Management Code.

3 General

3.1 In global terms it should be recognized that operational efficiencies delivered by a large number of ship operators will make an invaluable contribution to reducing global carbon emissions.

3.2 The purpose of a Ship Energy Efficiency Management Plan (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.

3.3 Many companies will already have an environmental management system (EMS) in place under ISO14001 which contains procedures for selecting the best measures for particular vessels and then setting objectives for the measurement of relevant parameters, along with relevant control and feedback features. Monitoring of operational environmental efficiency should therefore be treated as an integral element of broader company management systems.

3.4 In addition, many companies already develop, implement and maintain a Safety Management System. In such case, the SEEMP may form part of the ship's Safety Management System.

3.5 This document provides guidance for the development of a SEEMP that should be adjusted to the characteristics and needs of individual companies and ships. The SEEMP is intended to be a management tool to assist a company in managing the ongoing environmental performance of its vessels and as such, it is recommended that a company develops procedures for implementing the plan in a manner which limits any onboard administrative burden to the minimum necessary.

3. 6 The SEEMP should be developed as a ship - specific plan by the shipowner, operator or any other party concerned, e. g., charterer. The SEEMP seeks to improve a ship's energy efficiency through four steps: planning, implementation, monitoring, and self - evaluation and improvement. These components play a critical role in the continuous cycle to improve ship energy management. With each iteration of the cycle, some elements of the SEEMP will necessarily change while others may remain as before.

3. 7 At all times safety considerations should be paramount. The trade a ship is engaged in may determine the feasibility of the efficiency measures under consideration.

4 Scope and Application

4. 1 Planning

4. 1. 1 Planning is the most crucial stage of the SEEMP, in that it primarily determines both the current status of ship energy usage and the expected improvement of ship energy efficiency. Therefore, it is encouraged to devote sufficient time to planning so that the most appropriate, effective and implementable plan can be developed.

Ship - specific measures

4. 1. 2 Recognizing that there are a variety of options to improve efficiency – speed optimization, weather routing and hull maintenance, for example – and that the best package of measures for a ship to improve efficiency differs to a great extent depending upon ship type, cargoes, routes and other factors, the specific measures for the ship to improve energy efficiency should be identified in the first place. These measures should be listed as a package of measures to be implemented, thus providing the overview of the actions to be taken for that ship.

4. 1. 3 During this process, therefore, it is important to determine and understand the ship's current status of energy usage. The SEEMP then identifies energy - saving measures that have been undertaken, and determines how effective these measures are in terms of improving energy efficiency. The SEEMP also identifies what measures can be adopted to further improve the energy efficiency of the ship. It should be noted, however, that not all measures can be applied to all ships, or even to the same ship under different operating conditions and that some of them are mutually exclusive. Ideally, initial measures could yield energy (and cost) saving results that then can be reinvested into more difficult or expensive efficiency upgrades identified by the SEEMP.

4. 1. 4 Guidance on Best Practices for Fuel - Efficient Operation of Ships set out in paragraph 4 below can be used to facilitate this part of the planning phase. Also, in the planning process, particular consideration should be given to minimize any onboard administrative burden.

Company - specific measures

4. 1. 5 The improvement of energy efficiency of ship operation does not necessarily depend on single ship management only. Rather, it may depend on many stakeholders including ship repair yards, shipowners, operators, charterers, cargo owners, ports and traffic management services. For example, "Just in time" – as explained in 4. 5 – requires good early communication among operators, ports and traffic management service. The better coordination among such stakeholders is, the more improvement can be expected. In most cases, such coordination or total management is better made by a company rather than by a ship. In this sense, it is recommended that a company also establish an energy management plan to manage its fleet (should it not have one in place already) and make necessary coordination among stakeholders.

Human resource development

4.1.6 For effective and steady implementation of the adopted measures, raising awareness of and providing necessary training for personnel both on shore and on board are an important element. Such human resource development is encouraged and should be considered as an important component of planning as well as a critical element of implementation.

Goal setting

4.1.7 The last part of planning is goal setting. It should be emphasized that the goal setting is voluntary, that there is no need to announce the goal or the result to the public, and that neither a company nor a ship are subject to external inspection. The purpose of goal setting is to 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. The goal can take any form, such as the annual fuel consumption or a specific target of Energy Efficiency Operational Indicator (EEOI). Whatever the goal is, the goal should be measurable and easy to understand.

4.2 Implementation

Establishment of implementation system

4.2.1 After a ship and a company identify the measures to be implemented, it is essential to 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 qualified personnel. Thus, the SEEMP should describe how each measure should be implemented and who the responsible person(s) is. 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

4.2.2 The planned measures should be carried out in accordance with the predetermined implementation system. Record-keeping for the implementation of each measure is beneficial for self-evaluation at a later stage and should be encouraged. If any identified measure cannot be implemented for any reason(s), the reason(s) should be recorded for internal use.

4.3 Monitoring

Monitoring tools

4.3.1 The energy efficiency of a ship should be monitored quantitatively. This should be done by an established method, preferably by an international standard. 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.

4.3.2 If used, the EEOI should be calculated in accordance with the Guidelines developed by the Organization (MEPC.1/Circ.684). If deemed appropriate, a Rolling Average Index of the EEOI values may be calculated to monitor energy efficiency of the ship over time.

4.3.3 In addition to the EEOI, if convenient and/or beneficial for a ship or a company, other measurement tools can be utilized. In the case where other monitoring tools are used, the concept of the tool and the method of monitoring may be determined at the planning stage.

Establishment of monitoring system

4.3.4 It should be noted that whatever measurement tools are used, continuous and consistent data collection is the foundation of monitoring. 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 development of such a system can be considered as a part of planning, and therefore should be completed at the planning stage.

4.3.5 It should be noted that, in order to avoid unnecessary administrative burdens on ships' staff, 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. Additional data could be obtained as appropriate.

Search and Rescue

4.3.6 When a ship diverts from its scheduled passage to engage in search and rescue operations, it is recommended that data obtained during such operations is not used in ship energy efficiency monitoring, and that such data may be recorded separately.

4.4 Self-evaluation and improvement

4.4.1 Self-evaluation and improvement is the final phase of the management cycle. This phase should produce meaningful feedback for the coming first stage, i.e. planning stage of the next improvement cycle.

4.4.2 The purpose of self-evaluation is to evaluate the effectiveness of the planned measures and of their implementation, to deepen the understanding on the overall characteristics of the ship's operation such as what types of measures can/cannot function effectively, and how and/or why, to comprehend the trend of the efficiency improvement of that ship and to develop the improved SEEMP for the next cycle.

4.4.3 For this process, procedures for self-evaluation of ship energy management should be developed. Furthermore, self-evaluation should be implemented periodically by using data collected through monitoring. In addition, it is recommended to invest time in identifying the cause-and-effect of the performance during the evaluated period for improving the next stage of the management plan.

5 GUIDANCE ON BEST PRACTICES FOR FUEL-EFFICIENT OPERATION OF SHIPS

0.1 The search for efficiency across the entire transport chain takes responsibility beyond what can be delivered by the owner/operator alone. A list of all the possible stakeholders in the efficiency of a single voyage is long; obvious parties are designers, shipyards and engine manufacturers for the characteristics of the ship, and charterers, ports and vessel traffic management services, etc., for the specific voyage. All involved parties should consider the inclusion of efficiency measures in their operations both individually and collectively.

Fuel-Efficient Operations Impro

ved voyage planning

5.2 The optimum route and improved efficiency can be achieved through the careful planning and execution of voyages. Thorough voyage planning needs time, but a number of different software tools are available for planning purposes.

5.3 IMO resolution A.893(21) (25 November 1999) on Guidelines for voyage planning provides essential guidance for the ship's crew and voyage planners.

Weather routing

5.4 Weather routing has a high potential for efficiency savings on specific routes. It is commercially available for all types of ship and for many trade areas. Significant savings can be achieved, but conversely weather routing may also increase fuel consumption for a given voyage.

Just in time

5.5 Good early communication with the next port should be an aim in order to give maximum notice of berth availability and facilitate the use of optimum speed where port operational procedures support this approach.

5.6 Optimized port operation could involve a change in procedures involving different handling arrangements in ports. Port authorities should be encouraged to maximize efficiency and minimize delay.

Speed optimization

5.7 Speed optimization can produce significant savings. However, optimum speed means the speed at which the fuel used per tonne mile is at a minimum level for that voyage. It does not mean minimum speed; in fact sailing at less than optimum speed will consume more fuel rather than less. Reference should be made to the engine manufacturer's power / consumption curve and the ship's propeller curve. Possible adverse consequences of slow speed operation may include increased vibration and sooting and these should be taken into account.

5.8 As part of the speed optimization process, due account may need to be taken of the need to coordinate arrival times with the availability of loading / discharge berths, etc. The number of ships engaged in a particular trade route may need to be taken into account when considering speed optimization.

5.9 A gradual increase in speed when leaving a port or estuary whilst keeping the engine load within certain limits may help to reduce fuel consumption.

5.10 It is recognized that under many charter parties the speed of the vessel is determined by the charterer and not the operator. Efforts should be made when agreeing charter party terms to encourage the ship to operate at optimum speed in order to maximize energy efficiency.

Optimized shaft power

5.11 Operation at constant shaft RPM can be more efficient than continuously adjusting speed through engine power (see 7). The use of automated engine management systems to control speed rather than relying on human intervention may be beneficial.

Optimized ship handling Optimum trim

5.12 Most ships are designed to carry a designated amount of cargo at a certain speed for a certain fuel consumption. This implies the specification of set trim conditions. Loaded or unloaded, trim has a significant influence on the resistance of the ship through the water and optimizing trim can deliver significant fuel savings. For any given draft there is a trim condition that gives minimum resistance. In some ships, it is possible to assess optimum trim conditions for fuel efficiency continuously throughout the voyage. Design or safety factors may preclude full use of trim optimization.

Optimum ballast

5.13 Ballast should be adjusted taking into consideration the requirements to meet optimum trim and steering conditions and optimum ballast conditions achieved through good cargo planning.

5.14 When determining the optimum ballast conditions, the limits, conditions and ballast management arrangements set out in the ship's Ballast Water Management Plan are to be observed for that ship.

5.15 Ballast conditions have a significant impact on steering conditions and autopilot settings and it needs to be noted that less ballast water does not necessarily mean the highest efficiency.

Optimum propeller and propeller inflow considerations

5.16 Selection of the propeller is normally determined at the design and construction stage of a ship's life but new developments in propeller design have made it possible for retrofitting of later designs to deliver greater fuel economy. Whilst it is certainly for consideration, the propeller is but one part of the propulsion train and a change of propeller in isolation may have no effect on efficiency and may even increase fuel consumption.

5.17 Improvements to the water inflow to the propeller using arrangements such as fins and / or nozzles could increase propulsive efficiency power and hence reduce fuel consumption.

Optimum use of rudder and heading control systems (autopilots)

5.18 There have been large improvements in automated heading and steering control systems technology. Whilst originally developed to make the bridge team more effective, modern autopilots can achieve much more. An integrated Navigation and Command System can achieve significant fuel savings by simply reducing the distance sailed "off track". The principle is simple: better course control through less frequent and smaller corrections will minimize losses due to rudder resistance. Retrofitting of a more efficient autopilot to existing ships could be considered.

5.19 During approaches to ports and pilot stations the autopilot cannot always be used efficiently as the rudder has to respond quickly to given commands. Furthermore at certain stage of the voyage it may have to be deactivated or very carefully adjusted, i.e. heavy weather and approaches to ports.

5.20 Consideration may be given to the retrofitting of improved rudder blade design (e.g., 'twist-flow' rudder).

Hull maintenance

5.21 Docking intervals should be integrated with ship operator✓s ongoing assessment of ship performance. Hull resistance can be optimized by new technology-coating systems, possibly in combination with cleaning intervals. Regular in-water inspection of the condition of the hull is recommended.

5.22 Propeller cleaning and polishing or even appropriate coating may significantly increase fuel efficiency. The need for ships to maintain efficiency through in-water hull cleaning should be recognized and facilitated by port States.

5.23 Consideration may be given to the possibility of timely full removal and replacement of underwater paint systems to avoid the increased hull roughness caused by repeated spot blasting and repairs over multiple dockings.

5.24 Generally, the smoother the hull, the better the fuel efficiency.

Propulsion system

5.25 Marine diesel engines have a very high thermal efficiency (~50%). This excellent performance is only exceeded by fuel cell technology with an average thermal efficiency of 60%. This is due to the systematic minimization of heat and mechanical loss. In particular, the new breed of electronic controlled engines can provide efficiency gains. However, specific training for relevant staff may need to be considered to maximize the benefits.

Propulsion system maintenance

5.26 Maintenance in accordance with manufacturers✓ instructions in the company✓s planned maintenance schedule will also maintain efficiency. The use of engine condition monitoring can be a useful tool to maintain high efficiency.

5.27 Additional means to improve engine efficiency might include:

Use of fuel additives;

Adjustment of cylinder lubrication oil consumption; Valv

e improvements;

Torque analysis; and

Automated engine monitoring systems.

Waste heat recovery

5.28 Waste heat recovery is now a commercially available technology for some ships. Waste heat recovery systems use thermal heat losses from the exhaust gas for either electricity generation or additional propulsion with a shaft motor.

5.29 It may not be possible to retrofit such systems into existing ships. However, they may be a beneficial option for new ships. Shipbuilders should be encouraged to incorporate new technology into their designs.

Improved fleet management

5.30 Better utilization of fleet capacity can often be achieved by improvements in fleet planning. For example, it may be possible to avoid or reduce long ballast voyages through improved fleet planning. There is opportunity here for charterers to promote efficiency. This can be closely related to the concept of "just in time" arrivals.

5.31 Efficiency, reliability and maintenance-oriented data sharing within a company can be used to promote best practice among ships within a company and should be actively encouraged.

Improved cargo handling

5.32 Cargo handling is in most cases under the control of the port and optimum solutions matched to ship and port requirements should be explored.

Energy management

5.33 A review of electrical services on board can reveal the potential for unexpected efficiency gains. However care should be taken to avoid the creation of new safety hazards when turning off electrical services (e.g., lighting). Thermal insulation is an obvious means of saving energy. Also see comment below on shore power.

5.34 Optimization of reefer container stowage locations may be beneficial in reducing the effect of heat transfer from compressor units. This might be combined as appropriate with cargo tank heating, ventilation, etc. The use of water-cooled reefer plant with lower energy consumption might also be considered.

Fuel Type

5.35 Use of emerging alternative fuels may be considered as a CO_2 reduction method but availability will often determine the applicability.

Other measures

5.36 Development of computer software for the calculation of fuel consumption, for the establishment of an emissions "footprint", to optimize operations, and the establishment of goals for improvement and tracking of progress may be considered.

5.37 Renewable energy sources, such as wind, solar (or photovoltaic) cell technology, have improved enormously in the recent years and should be considered for onboard application.

5.38 In some ports shore power may be available for some ships but this is generally aimed at improving air quality in the port area. If the shore-based power source is carbon efficient, there may be a net efficiency benefit. Ships may consider using onshore power if available.

5.39 Even wind assisted propulsion may be worthy of consideration.

5.40 Efforts could be made to source fuel of improved quality in order to minimize the amount of fuel required to provide a given power output.

Compatibility of measures

5.41 This document indicates a wide variety of possibilities for energy efficiency improvements for the existing fleet. While there are many options available, they are not cumulative, are often area and trade dependent and likely to require the agreement and support of a number of different stakeholders if they are to be utilized most effectively.

Age and operational service life of a ship

5.42 All measures identified in this document are potentially cost effective as a result of high oil prices. Measures previously considered unaffordable or commercially unattractive may now be feasible and worthy of fresh consideration. Clearly, this equation is heavily influenced by the remaining service life of a ship and the cost of fuel.

Trade and sailing area

5.43 The feasibility of many of the measures described in this guidance will be dependent on the trade and sailing area of the vessel. Sometimes ships will change their trade areas as a result of a change in chartering requirements but this cannot be taken as a general assumption. For example wind－enhanced power sources might not be feasible for short sea shipping as these ships generally sail in areas with high traffic densities or in restricted waterways. Another aspect is that the world's oceans and seas each have characteristic conditions and so ships designed for specific routes and trades may not obtain the same benefit by adopting the same measures or combination of measures as other ships. It is also likely that some measures will have a greater or lesser effect in different sailing areas.

5.44 The trade a ship is engaged in will also determine the feasibility of some of the measures. Ships that perform services at sea (pipe laying, seismic survey, OSVs, dredgers, etc.) are likely to choose different methods of carbon reductions when compared to conventional cargo carriers. The length of voyage will also be an important parameter as will safety considerations imposed upon some vessels. As a result, it is likely that the pathway to the most efficient combination of measures will be unique to each vessel within each shipping company.

APPENDIX

A SAMPLE FORM OF A SHIP EFFICIENCY ENERGY MANAGEMENT PLAN

Name of Vessel:		GT:	
Vessel Type:		Capacity:	

Date of Development:		Developed by:	
Implementation Period:	From: Until:	Implemented by:	
Planned Date of Next Evaluation:			

1 MEASURES

Energy Efficiency Measures	Implementation (including the starting date)	Responsible Personnel
Weather Routing	<Example> Contracted with [Service providers] to use their weather routing system and start using on-trial basis as of 1 July 2012.	<Example> The master is responsible for selecting the optimum route based on the information provided by [Service providers].
Speed Optimization	While the design speed (85% MCR) is 19.0 kt, the maximum speed is set at 17.0 kt as of 1 July 2012.	The master is responsible for keeping the ship's speed. The log-book entry should be checked every day.

2 MONITORING

— Description of monitoring tools

3 GOAL

— Measurable goals

4 EVALUATION

— Procedures of evaluation

Appendix 6 Guidelines For Voluntary Use of the Ship Energy Efficiency Operational Indicator – IMO. MEPC. 1/Circ. 684

MEPC. 1/Circ. 684
(17 August 2009)

GUIDELINES FOR VOLUNTARY USE OF THE SHIP ENERGY EFFICIENCY OPERATIONAL INDICATOR (EEOI)

1. The Marine Environment Protection Committee, at its fifty-ninth session (13 to 17 July 2009), agreed to circulate the Guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI) as set out in the annex.

2. Member Governments are invited to bring the Guidelines to the attention of all parties concerned and recommend them to use the Guidelines on a voluntary basis.

3. Member Governments and observer organizations are also invited to provide information on the outcome and experiences in applying the Guidelines to future sessions of the Committe

ANNEX

GUIDELINES FOR VOLUNTARY USE OF THE SHIP ENERGY EFFICIENCY OPERATIONAL INDICATOR (EEOI)

1. The Conference of Parties to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, held from 15 to 26 September 1997 in conjunction with the Marine Environment Protection Committee's fortieth session, adopted Conference resolution 8, on CO_2 emissions from ships.

2. IMO Assembly resolution A. 963 (23) on IMO policies and practices related to the reduction of greenhouse gas emissions from ships urged the Marine Environment Protection Committee (MEPC) to identify and develop the mechanism or mechanisms needed to achieve the limitation or reduction of Greenhouse Gas (GHG) emissions from international shipping and, in doing so, to give priority to the establishment of a GHG baseline; and the development of a methodology to describe the GHG efficiency of a ship in terms of GHG emission indicator for that ship.

3. As urged by the Assembly, MEPC 53 approved Interim Guidelines for Voluntary Ship CO_2 Emission Index for Use in Trials.

4. These Guidelines can be used to establish a consistent approach for voluntary use of an EEOI, which will assist shipowners, ship operators and parties concerned in the evaluation of the performance of their fleet with regard to CO_2 emissions. As the amount of CO_2 emitted from a ship is directly related to the consumption of bunker fuel oil, the EEOI can also provide useful information on a ship's performance with regard to fuel efficiency.

0. These Guidelines may be updated periodically, to take account of:

— Operational experiences from use of the indicator for different ship types, as reported to MEPC by industry organizations and Administrations; and

— Any other relevant developments.

6. Industry organizations and interested Administrations are invited to promote the use of the attached Guidelines or equivalent approaches and their incorporation in company and ship environmental management plans. In addition, they are invited to report their experience in applying the EEOI concept back to MEPC.

7. In addition to these Guidelines, due account should be taken of the pertinent clauses within the ISM Code in voluntary basis along with reference to relevant industry guidance on the management and reduction of CO_2 emissions.

Appendix GUIDELINES FOR VOLUNTARY USE OF THE SHIP ENERGY EFFICIENCY OPERATIONAL INDICATOR（EEOI）

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1 Introduction

In 1997 IMO adopted a resolution on CO_2 emissions from ships1.

IMO Assembly further adopted resolution A. 963 (23) on IMO policies and practices related to the reduction of greenhouse gas emissions from ships, which requests the MEPC to develop a greenhouse gas emission index for ships, and guidelines for use of that index.

This document constitutes the Guidelines for the use of an Energy Efficiency Operational Indicator (EEOI) for ships. It sets out:

— what the objectives of the IMO CO_2 emissions indicator are;

— how a ship✓s CO_2 performance should be measured; and

— how the index could be used to promote low-emission shipping, in order to help limit the impact of shipping on global climate change.

2 Objectives

The objective of these Guidelines is to provide the users with assistance in the process of establishing a mechanism to achieve the limitation or reduction of greenhouse gas emissions from ships in operation.

These Guidelines present the concept of an indicator for the energy efficiency of a ship in operation, as an expression of efficiency expressed in the form of CO_2 emitted per unit of transport work. The Guidelines are intended to provide an example of a calculation method which could be used as an objective, performance-based approach to monitoring the efficiency of a ship✓s operation.

These Guidelines are recommendatory in nature and present a possible use of an operational indicator. However, shipowners, ship operators and parties concerned are invited to implement either these Guidelines or an equivalent method in their environmental management systems and consider adoption of the principles herein when developing plans for performance monitoring.

3 Definitions

ϐ Indicator Definition

In its most simple form the Energy Efficiency Operational Indicator is defined as the ratio of mass of CO_2 (M) emitted per unit of transport work:

$$\text{Indicator} = MCO_2 / (\text{transport work})$$

For more details of indicator calculation, see 3.2 to 3.4 and Appendix 1.

3.2 Fuel consumption

Fuel consumption, FC, is defined as all fuel consumed at sea and in port or for a voyage or period in question, e.g., a day, by main and auxiliary engines including boilers and incinerators.

3.3 Distance sailed

Distance sailed means the actual distance sailed in nautical miles (deck log-book data) for the voyage or period in question.

0 Ship and cargo types

The Guidelines are applicable for all ships performing transport work.

.1 Ships:

- Bulk Carriers

- tankers
- gas tankers
- containerships
- ro－ro cargo ships
- general cargo ships
- passenger ships including ro－ro passenger ships

.2 Cargo:

Cargo includes but not limited to:

all gas, liquid and solid bulk cargo, general cargo, containerized cargo (including the return of empty units), break bulk, heavy lifts, frozen and chilled goods, timber and forest products, cargo carried on freight vehicles, cars and freight vehicles on ro－ro ferries and passengers (for passenger and ro－ro passenger ships)

3.5 Cargo Mass Carried or Work Done

In general, cargo mass carries or work done is expressed as follows:

.1 for dry cargo carriers, liquid tankers, gas tankers, ro－ro cargo ships and general cargo ships, metric tonnes (t) of the cargo carried should be used;

.2 for containerships carrying solely containers, number of containers (TEU) or metric tons (t) of the total mass of cargo and containers should be used;

.3 for ships carrying a combination of containers and other cargoes, a TEU mass of 10 t could be applied for loaded TEUs and 2 t for empty TEUs; and

.4 for passenger ships, including ro－ro passenger ships, number of passengers or gross tonnes of the ship should be used; In some particular cases, work done can be expressed as follows:

.5 for car ferries and car carriers, number of car units or occupied lane metres;

.6 for containerships, number of TEUs (empty or full); and

.7 for railway and ro－ro vessels, number of railway cars and freight vehicles, or occupied lane metres.

For vessels such as, for example, certain ro－ro vessels, which carry a mixture of passengers in cars, foot passengers and freight, operators may wish to consider some form of weighted average based on the relative significance of these trades for their particular service or the use of other parameters or indicators as appropriate.

3.6 Voyage

Voyage generally means the period between a departure from a port to the departure from the next port. Alternative definitions of a voyage could also be acceptable.

4 ESTABLISHING AN ENERGYEFFICIENCY OPERATIONAL INDICATOR (EEOI)

The EEOI should be a representative value of the energy efficiency of the ship operation over a consistent period which represents the overall trading pattern of the vessel. Guidance on a basic calculation procedure for a generic EEOI is provided in the Appendix. In order to establish the EEOI, the following main steps will generally be needed:

.1 define the period for which the EEOI is calculated;

.2 define data sources for data collection;

.3 collect data;

.4 convert data to appropriate format; and

.5 calculate EEOI.

*Ballast voyages, as well as voyages which are not used for transport of cargo, such as voyage for docking service, should also be included. Voyages for the purpose of securing the safety of a ship or saving life at sea should be excluded.

5 GENERAL DATA RECORDING AND DOCUMENTATION PROCEDURES

Ideally, the data recording method used should be uniform so that information can be easily collated and analyzed to facilitate the extraction of the required information. The collection of data from ships should include the distance travelled, the quantity and type of fuel used, and all fuel information that may affect the amount of carbon dioxide emitted. For example, fuel information is provided on the bunker delivery notes that are required under regulation 18 of MARPOL Annex VI.

If the example formula given in the Appendix is used, then the unit used for distance travelled and quantity of fuel should be expressed in nautical miles and metric tonnes. The work done can be expressed using units appropriate for the ship type in paragraph 3.5.

It is important that sufficient information is collected on the ship with regard to fuel type and quantity, distance travelled and cargo type so that a realistic assessment can be generated.

The distance travelled should be calculated by actual distance travelled, as contained in the ship's log-book.

Amount and type of fuel used (bunker delivery notes) and distance travelled (according to the ship's log-book) could be documented by the ship based either on the example described in the Appendix or on an equivalent company procedure.

6 MONITORING AND VERIFICATION

6.1 General

Documented procedures to monitor and measure, on a regular basis, should be developed and maintained. Elements to be considered when establishing procedures for monitoring could include:

- identification of operations/activities with impact on the performance;
- identification of data sources and measurements that are necessary, and specification of the format;
- identification of frequency and personnel performing measurements; and
- maintenance of quality control procedures for verification procedures.

The results of this type of self-assessment could be reviewed and used as indicators of the System's success and reliability, as well as identifying those areas in need of corrective action or improvement.

It is important that the source of figures established are properly recorded, the basis on which figures have been calculated and any decisions on difficult or grey areas of data. This will provide assistance on areas for improvement and be helpful for any later analysis.

In order to avoid unnecessary administrative burdens on ships' staff, it is recommended that monitoring of an EEOI should be carried out by shore staff, utilizing data obtained from existing required records such as the official and engineering log-books and oil record books, etc. The necessary data could be obtained during internal audits under the ISM Code, routine visits by superintendents, etc.

6.2 Rolling average indicator

As a ship energy efficiency management tool, the rolling average indicator, when used, should be calculated by use of a methodology whereby the minimum period of time or a number of voyages that is statistically relevant is used as appropriate. "Statistically relevant" means that the period set as standard for each individual ship should remain constant and be wide enough so the accumulated data mass reflects a reasonable mean value for operation of the ship in question over the selected period.

7 USE OF GUIDELINES

Methodology and use of EEOI, as described in these Guidelines, provide an example of a transparent and recognized approach for assessment of the GHG efficiency of a ship with respect to CO_2 emissions. The Guidelines are considered to be suitable for implementation within a company environmental management system.

Implementation of the EEOI in an established environmental management system should be performed in line with the implementation of any other chosen indicator and follow the main elements of the recognized standards (planning, implementation and operation, checking and corrective action, management review).

When using the EEOI as a performance indicator, the indicator could provide a basis for consideration of both current performance and trends over time.

One approach could be to set internal performance criteria and targets based on the EEOI data.

APPENDIX

CALCULATION OF ENERGY EFFICIENCY OPERATIONAL INDICATOR (EEOI) BASED ON OPERATIONAL DATA

1 General

The objective of the Appendix is to provide guidance on calculation of the Energy Efficiency Operational Indicator (EEOI) based on data from the operation of the ship.

2 Data sources

Primary data sources selected could be the ship's log-book (bridge log-book, engine log-book, deck log-book and other official records).

3 Fuel mass to CO_2 mass conversion factors (CF)

CF 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 CF 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

4 Calculation of EEOI

The basic expression for EEOI for a voyage is defined as:

$$EEOI = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \qquad \text{Equation 1}$$

Where average of the indicator for a period or for a number of voyages is obtained, the Indicator is calculated as

$$\text{Average EEOI} = \frac{\sum_i \sum_j FC_{if} \times C_{Fj})}{\sum_i m_{cargo,i} \times D_i)} \qquad \text{Equation 2}$$

Where:

- j is the fuel type;
- i is the voyage number;
- FC_{ij} is the mass of consumed fuel j at voyage i;
- CF_j 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 unit of EEOI depends on the measurement of cargo carried or work done, e.g., tonnesCO_2/(tonnes ? nautical miles), tonnes CO_2/(TEU ? nautical miles), tonnes CO_2/(person ? nautical miles), etc.

It should be noted that Equation 2 does not give a simple average of EEOI among number of voyage i.

5 Rolling average

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 2 above.

6 Data

For a voyage or period, e.g., a day, data on fuel consumption/cargo carried and distance sailed in a continuous sailing pattern could be collected as shown in the reporting sheet below.

CO_2 Indicator reporting sheet

Name and type of ship						
Voyage or day (i)	Fuel consumption (FC) at sea and in port in tonnes				Voyage or time	
	Fuel type ( )	Fuel type ( )	Fuel type ( )		Cargo (m) (tonnes or units)	Distance (D) (NM)
1						
2						
3						

NOTE: For voyages with mcargo = 0, it is still necessary to include the fuel used during this voyage in the summation above the line.

7 Conversion from g/tonne-mile to g/tonne-km

The CO_2 indicator may be converted from g/tonne-mile to g/tonne-km by multiplication by 0.54.

8 Example:

A simple example including one ballast voyage, for illustration purpose only, is provided below. The example illustrates the application of the formula based on the data reporting sheet.

NAME AND TYPE OF SHIP						
Voyage or day (i)	Fuel consumption (FC) at sea and in port in tonnes				Voyage or time	
	Fuel type (HFO)	Fuel type (LFO)	Fuel type ( )		Cargo (m) (tonnes or units)	Distance (D) (NM)
1	20	5			25000	300
2	20	5			0	300
3	50	10			25000	750
	10	3			15000	150

$$EEOI = \frac{100 \times 3.114 + 23 + 3.151}{(25,000 \times 300) + (0 \times 300) + (25,000 \times 750) + (15,000 \times 150)} = 13.47 \times 10^{-6}$$

Unit: tonnes CO_2/(tons • nautical miles)