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CONSIDERATION OF THE ENERGY EFFICIENCY DESIGN INDEX FOR NEW SHIPS

Proposal for new concept approach to EEDI for new ships

Submitted by the Republic of Korea

SUMMARY

Executive summary:	This document provides a new concept approach and formula for EEDI covering the various types of propulsion systems and power generation systems available for ships as well as all energy saving technologies, including these that may be developed in the future. In addition, this document proposes an amendment of the definition for V_{ref} and deletion of f_W
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.3
Action to be taken:	Paragraph 12
Related documents:	MEPC 58/4 and MEPC 58/23

Introduction

1 MEPC 58 approved the use of the draft Interim Guidelines on the method of calculation of the Energy Efficiency Design Index for new ships, for calculation/trial purposes with a view to further refinement and improvement, and endorsed the GHG working group's agreement to use document MEPC 58/4/8 (Denmark) as basis for further studies and trials (MEPC 58/23, paragraph 4.54).

2 MEPC 58 invited delegations and industry observers to disseminate the Interim Guidelines on the EEDI to the maritime community at large, so that adequate experience can be gained on its adequacy as a tool to improve energy efficiency for new ships (MEPC 58/23, paragraph 4.55).

Objective and principle

3 The objective of this document is to provide proposals for the refinement and improvement of the current EEDI formula and the reason for doing it based on the following principles:

.1 EEDI should be capable of covering the various types of propulsion systems and power generation systems available for ships as well as all energy saving technologies that may be developed in the future;

.2 the EEDI proposed in this document only considers CO_2 emission from prime movers, which produce the power for ship's propulsion and the electric power generation for normal maximum sea load (hereinafter refer to "NMSL"). Consequently, the auxiliary boiler, which is used for the purpose other than ship's propulsion and electric power generation, is excluded in the EEDI formula proposed in this document; and

.3 in cases of the "Energy Saving Technologies", there are two cases: (1) a case where the performance of the prime movers for propulsion and electric power generation is affected by the energy saving technologies and (2) a case where energy saving technologies capture the CO_2 emission from the ships.

Discussion

4 CO_2 emissions from ships are produced by the fossil fuel used in the prime mover for propulsion and electric power generation.

5 The prime mover for propulsion converts the thermal energy of fossil fuel into rotational kinetic energy, either directly, as in the case of diesel engines or gas turbines, or by creating steam to drive steam turbines. The output of the prime mover for propulsion is then transmitted (and combined) by the drive system to the propulsor, usually a propeller with either fixed or controllable pitch.

6 The prime mover for electric power generation is similar to the prime mover for propulsion in concept, except that its output is transmitted (and combined) by the drive system to a generator.

7 The prime movers and machinery available for propulsion and electric power generation are summarized in Table 1 according to the ship's propulsion system. Based on the assumption of principles described in paragraph 3 above, the following could be derived from Table 1.

Table 1

Propulsion system applicable to general merchant ship	Prime movers for propulsion	Prime movers for electric power generation
	Machinery available for propulsion	Machinery available for electric power generation
Conventional propulsion system	Main engine	Aux. engine
	M/E	A/E, S/G, WHRS
Diesel-electric propulsion system	Aux. engine	Aux. engine
	A/E, shaft motor	A/E, WHRS
Hybrid propulsion system	Main engine or aux. engine	Aux. engine
	M/E or A/E, shaft motor, PTI	A/E, S/G, WHRS
Steam turbine propulsion system	Steam turbine	Steam turbine, aux. engine
	S/T, main boiler	T/G, A/E

.1 The prime movers to be considered in developing EEDI, providing a fair basis for comparison depending on ship type and ship size, are the main engines, auxiliary engines and the main boilers only. The steam turbine need not be considered since it does not burn the fossil fuel directly, but rather uses the steam provided by the main boiler. If considered necessary, auxiliary boiler used for the purposes other than ship's propulsion and electric power generation and economizer could be included in the EEDI formula. However, auxiliary boilers are not considered in this document;

.2 Since CO_2 emission from ships are produced by the combustion of fossil fuel, the EEDI formula could be simplified by classifying the sources of emission as follows, i.e. by prime mover and machinery available for propulsion or prime movers for electric power generation:

$$\frac{\sum CO2_{propulsion} + \sum CO2_{NMSL} - \sum CO2_{RED}}{Capacity\ V_{ref}}$$

Where,

$\sum CO2_{propulsion}$ = the sum of CO_2 emission from prime mover for propulsion

$\sum CO2_{NMSL}$ = the sum of CO_2 emission from prime mover for NMSL

$\sum CO2_{RED}$ = the sum of reduction of CO_2 emission from ships

$Capacity$ & V_{ref} is same as the annex 11 to MEPC 58/23

.3 Due to the fact that the output of shaft motors and PTI(power-take-in), which are installed to rotate the propulsion shaft in a diesel-electric propulsion system or in hybrid propulsion systems, are used to propel a ship, they are to be included in $\sum CO2_{propulsion}$.

On the other hand, since the shaft generator and waste heat recovery system produce electric power, they are to be included in $\sum CO2_{NMSL}$.

In addition, an equipment which capture the CO_2 emitted from ships is to be included in $\sum CO2_{RED}$; and

.4 Table 2 summarizes where the prime mover and machinery available for ships are to be included, i.e. $\sum CO2_{propulsion}$, $\sum CO2_{NMSL}$ and $\sum CO2_{RED}$ respectively, in calculating EEDI.

Table 2

$\sum CO2_{propulsion}$	$\sum CO2_{NMSL}$	$\sum CO2_{RED}$
Main engine, Aux. engine for propulsion, Main boiler, Shaft motor, PTI	Aux. engine for NMSL, Shaft generator, WHRs	Equipment for CO_2 capture

8 Based on paragraph 7 above, the following proposals are made for the numerator of the EEDI formula developed by MEPC 58 as set out below.

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} C_{FMEi} SFC_{MEi} P_{MEi}\right)^{(1)} + \left(P_{AE} C_{FAE} SFC_{AE}^{*}\right)^{(2)} + \left[\left(\sum_{i=1}^{nPTI} P_{PTIi} - \sum_{i=1}^{nWHR} P_{WHRi}\right) C_{FAE} SFC_{AE}\right]^{(3)} - \left(\sum_{i=1}^{neff} f_{eff} P_{eff} C_{FMEi} SFC_{MEi}\right)}{f_i \; Capacity \; V_{ref} \; f_W}$$

.1 In case of a superscript (1) which considers the prime mover for propulsion, there is a need to revise the formula as below which incorporates the shaft motor and PTI (power-take-in). This is due to the fact that although the shaft motor and PTI (power-take-in) receive the electric power from auxiliary engines, they contribute to the propulsion of a ship. Also, in case of a ship adopting the steam turbine propulsion system, CO_2 emission from the main boiler needs to be included in the following formula, when calculating EEDI.

$$\sum_{i=1}^{nME} C_{FMEi} SFC_{MEi} P_{MEi} = \sum_{i=1}^{nME} C_{FMEi} SFC_{MEi} \left(P_{DEi} + P_{MAINBOILERi} + P_{SMi} + P_{PTIi}\right)$$

Where,

P_{MEi} 75% of the rated power for each prime mover for propulsion.

P_{DEi} 75% of the rated installed power (MCR) for each main diesel engine

$P_{MAINBOILERi}$ 75% of the rated steam evaporation volume for each main boiler

P_{SMi} 75% of the rated power consumption of each shaft motor

P_{PTIi} 75% of the rated power consumption of each PTI except shaft motor.

.2 In case of a superscript (2) which considers the prime mover for electric power generation and a superscript (3) which considers electric propulsion, there is a need to revise the formula as below. This is because the electric power produced by shaft generators and waste heat recovery systems reduces the output of the prime movers (auxiliary engine) required to supply NMSL.

$$\sum_{i=1}^{nAE} C_{FAEi} SFC_{AEi} P_{AEi} = \sum_{i=1}^{nAE} C_{FAEi} SFC_{AEi} \left(P_{NMSL} - P_{SGi} - P_{WHRi} \right)$$

Where,

P_{AEi} The required auxiliary engine power to supply NMSL including necessary power for machinery, systems, equipment and living on board in the condition where the ship engaged in voyage at the speed (V_{ref}) under the design loading condition of *Capacity*.

P_{NMSL} The NMSL which is calculated on the basis of the "electric load balance" approved by Administration. If an equipment which capture the CO_2 emitted from ships is installed, the required electric power for the equipment is to be included in the NMSL.

P_{SGi} The rated electric power generation of each shaft generator.

P_{WHRi} The rated electric power generation of each waste heat recovery system.

9 In case of "energy saving technologies", they could be dealt with by categorizing them into two cases: (1) a case where the performance of prime movers for propulsion and electric power generation is affected by the energy saving technologies, and (2) a case where energy saving technologies capture the CO_2 emission from the ships.

.1 In cases where "energy saving technologies" affect the performance of prime movers for propulsion and electric power generation, there is no need to consider it in the EEDI formula since such technologies would have direct or indirect effect on the parameters required for the calculation of CO_2 emissions from the relevant prime movers (e.g., V_{ref}, SFC, P, etc.).

.2 In cases where "energy saving technologies" are of a type that capture CO_2 emissions from the ship, the reduction quantity is to be deducted in the numerator. This is due to the fact that such system eliminates CO_2 emissions produced by prime movers, leading to the reduction of overall CO_2 emissions from ships.

10 Furthermore, since the present definition for V_{ref} (reference speed) in the denominator of the EEDI formula developed by MEPC 58 may lead to erroneous interpretation that the sea trial need to be conducted "on deep water in the maximum design load condition (*Capacity*) as defined in paragraph 3 at the output of the engine(s) as defined in paragraph 5", it is to be revised as follows:

*"V_{ref} is the ship speed, measured in nautical miles per hour (knot) during a sea trial, which is corrected to the method acceptable to the Administration with the maximum design load condition (*Capacity*) as defined in paragraph 3 and the output of the engine(s) as defined in paragraph 5 in deep water condition assuming the weather is calm with no wind and no waves. The maximum design load condition shall be defined by the deepest draught with its associated trim, at which the ship is allowed to operate. This condition is obtained from the stability booklet approved by the Administration."*

11 In addition, f_W, which is a non-dimensional coefficient indicating the decrease of speed in the actual sea-going conditions of wave height, wave frequency and wind speed (e.g., Beaufort Scale 6), is to be deleted due to the following reasons:

.1 The EEDI, providing a fair basis for comparison depending on ship type and ship size, is to be calculated on the basis of ship performance in condition assuming the weather is calm with no wind and no waves (refer to paragraph 10 above); and

.2 The decrease of ship's speed and the resulting fluctuation of CO_2 emission are to be considered in EEOI rather than EEDI in concept. This is due to the fact that the purpose of EEDI is not to present the ship performance in actual sea conditions in which the ship navigates throughout her life, but rather than to compare the CO_2 emission performance of each vessel at the design stage.

Action requested of the Intersessional Meeting

12 The Intersessional Meeting is invited to consider the proposal for a new concept approach and formula for EEDI applicable to new ships as set out at annex, and take action as deemed appropriate.

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ANNEX

DRAFT INTERIM GUIDELINES ON THE METHOD OF CALCULATION OF THE ENERGY EFFICIENCY DESIGN INDEX FOR NEW SHIPS

The attained new ship Energy Efficiency Design Index is a measure of ships' CO_2 efficiency and is:

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} C_{FMEi} SFC_{MEi} P_{MEi}\right) + \left(\sum_{i=1}^{nAE} C_{FAEi} SFC_{AEi} P_{AEi}\right) - \left(\sum_{i=1}^{nRED} CO2_{REDi}\right)}{f_i \; Capacity \; V_{ref}}$$

Where:

1 C_F is a non-dimensional conversion factor between fuel consumption measured in g and CO_2 emission also measured in g based on carbon content. The subscripts MEi and AEi refer to the prime mover for propulsion and electric power generation respectively.

(Refer to the 2006 IPCC Guidelines and paragraph 15 of MEPC 58/4/3)

2 V_{ref} is the ship speed, measured in nautical miles per hour (knot) during a sea trial, which is corrected to (1) [a method acceptable to the Administration] or (2) [the method recognized by the Organization] with the maximum design load condition ($Capacity$) as defined in paragraph 3 and the output of the engine(s) as defined in paragraph 5 in deep water condition assuming the weather is calm with no wind and no waves. The maximum design load condition shall be defined by the deepest draught with its associated trim, at which the ship is allowed to operate. This condition is obtained from the stability booklet approved by the Administration.

3 *Capacity* is defined as follows:

.1 For dry cargo carriers, tankers, gas tankers, container ships, ro-ro cargo and passenger ships and general cargo ships, deadweight should be used as Capacity.

.2 For passenger ships, gross tonnage in accordance with the International Convention on Tonnage measurement of ships 1969, Annex I, regulation 3 should be used as Capacity.

4 Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1.025 at the deepest operational draught and the lightweight of the ship.

5 P is the power of each prime mover for propulsion and electric power generation, measured in kW. The subscripts ME and AE refer to the prime mover for propulsion and electric power generation, respectively.

.1 P_{MEi} is 75% of the rated installed power (MCR) for prime mover for propulsion (i). P_{MEi} is to be calculated as below. For the steam turbine propelled ships, main boiler is to be considered as prime mover for propulsion.

$$P_{MEi} = P_{DEi} + P_{MAINBOILERi} + P_{SMi} + P_{PTIi}$$

Where,
P_{MEi} is 75% of the rated power for each prime mover for propulsion.

P_{DEi} is 75% of the rated installed power (MCR) for each main diesel engine.

$P_{MAINBOILERi}$ is 75% of the rated steam evaporation volume for each main boiler.

P_{SMi} is 75% of the rated power consumption of each shaft motor.

P_{PTIi} is 75% of the rated power consumption of each PTI except shaft motor.

.2 P_{AEi} is the required auxiliary engine power to supply NMSL and includes power required for machinery, systems, equipment and living on board where the ship is engaged in a voyage at the speed (V_{ref}) and under the design loading condition of $Capacity$. P_{AEi} is to be calculated as below.

$$P_{AEi} = P_{NMSL} - P_{SGi} - P_{WHRi}$$

Where,
P_{NMSL} is the normal maximum sea load, which is to be calculated on the basis of the approved "electric load balance" approved by Administration. In case where an equipment which captures the CO_2 emitted from ships is installed, the required power for the equipment is to be included in the NMSL.

P_{SGi} is the rated electric power generation of each shaft generator.

P_{WHRi} is the rated electric power generation of each waste heat recovery system.

6 $CO2_{REDi}$ is the amount of CO_2 captured by an equipment which captures CO_2 emitted from ships.

7 V_{ref}, $Capacity$ and P should be consistent with each other.

8 SFC is the uncorrected specific fuel consumption, measured in g/kWh, of the prime mover for propulsion and electric power generation at the power output of P determined by paragraph 5. The subscripts MEi and AEi refer to the prime mover for propulsion and electric power generation, including main boiler, respectively. The auxiliary engine Specific Fuel Consumption (SFC_{AE}) is the one recorded on the EIAPP Certificate[1] at the engines 50% of P_{AE} MCR power or torque rating.

9 f_j is corrections to account for ship specific-design elements:

The f_j coefficient for ice-classed ships is determined by the standard f_j "table/curve" which is to be contained in the Guidelines.

10 f_i is the capacity factor for any technical/regulatory limitation on capacity, and can be assumed to be one (1.0), if such coefficient is not needed.

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[1] EIAPP Certificate is the Engine International Air Pollution Prevention Certificate which relates to NO_x emissions.