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PREVENTION OF AIR POLLUTION FROM SHIPS

Consideration of the Energy Efficiency Design Index for New Ships

Refinements to the "draft guidelines on the method of calculation of the energy efficiency design index for new ships" for conventional passenger ships

Submitted by Cruise Lines International Association (CLIA)

SUMMARY

Executive summary:	This document describes the work done to date by CLIA in coordination with the Cruise Ship Safety Forum to address issues with the proposed EEDI formulation contained within annex 2 to MEPC 59/4/12 that are particular to new conventional passenger ships. These refinements include the power table verification process by use of a guideline, the environmental conditions, the propulsion chain's efficiency, an improved Specific Fuel Consumption (*SFC)* definition for auxiliary engines, conversion factor, an improved wording and a diagram of the marine plant
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.2 and 7.3.1.3
Action to be taken:	Paragraph 29
Related documents:	GHG-WG 2/2/21 and MEPC 59/4/2

Introduction

1 GHG-WG 2 approved the use of the draft Interim Guidelines on the method of calculation of the Energy Efficiency Design Index for new ships. However, as was noted by a number of delegations, there remain some issues related to the application of the EEDI to passenger ships and electrically propelled ships.

Objective

2 This document proposes detailed refinements to the guidance contained in annex 2 to GHG-WG 2/WP.1 “Draft guidelines on the method of calculation of the energy efficiency design index for new ships” (which is appended to the document “Draft report of the second Intersessional Meeting of the Working Group on Greenhouses Gas Emissions from ships”) for conventional propulsion passenger ships.

3 Proposed refinement to the current formulation are shown in the boxed-in sections below where the relevant paragraph of the document “annex 2 to GHG-WG WP/1” (“Draft interim guidelines on the method of calculation of the energy efficiency design index for new ships”) is quoted. The addition of text is shown by underlining and the deletion of text is shown by ~~strikethrough.~~

4 CLIA, in coordination with other industry experts, continues to work on proposals to address issues related to electrically powered cruise ships, and hopes to be able to share the work with the Committee at this session.

Environmental conditions

5 The environmental conditions greatly influence the auxiliary power demand “P_{AE}” for passenger ships. This is mainly due to the significant difference between the design power for the HVAC compressors during summer conditions (outside ambient temperature 35°C, 85% R.H., seawater temperature 32°C) and winter conditions (outside ambient temperature -15°C, sea water temp 0°C) needed to maintain similar inside ambient conditions in summer and winter. For similar reasons, the number of passengers on board can also significantly influence the “P_{AE}”. As a consequence, a calculation of the EEDI for a typical large cruise ship has resulted in the following:

Variation found to EEDI calculation at summer vs winter ~ 7.5%.

6 As a consequence, it is considered important to include standard environmental conditions in the EEDI calculation, and in particular, reference potential outside ambient conditions, sea water temperature and passenger loading condition. The inside required ambient conditions will remain typical for any ship. It is proposed to include the normal operating condition to which the HVAC plants are typically designed.

Amendments to 2.5.6.3:

3	For ships where P_{AE} value calculated by .1 or .2 above is significantly different from the total power used at normal seagoing, e.g., in cases of passenger ships, P_{AE} can be estimated by the total consumed electric power (excluding propulsion) at normal seagoing with outside ambient temperature 35°C, 85% R.H. and seawater temperature 32°C and a full passenger load, to be given in the electric power table[3] divided by the conversion factor (0.9) from diesel engine power to electric power.

Conversion factor

7 The current formula for calculation P_{AE} depicts the conversion factor as a constant (0.9). This represents the efficiency of the alternators driven by the auxiliary engines. However, as the constant (0.9) is used rather then the actual alternators' efficiency from their datasheet, it does not reward more efficient alternators where efficiency can exceed 0.9 (a typical value is 0.94). Furthermore, this does not provide any incentive for the design of more efficient alternators.

8 The conversion factor is also found to be inconsistent with the formulation of $P_{PTI(i)}$ (defined as "75% of the rated power consumption of each shaft motor *divided by the weighted average efficiency of the generator(s)*"). The powers P_{AE} and $P_{PTI(i)}$ are both electric powers derived from the switchboard and supplied from the auxiliaries engines. They should be both divided by the weighted average efficiency of the generators for consistency.

9 As a consequence CLIA suggests the conversion factor should be amended to include the weighted average efficiency of the generators.

Amendments to 2.5.6.3:

> .3 For ships where the P_{AE} value calculated by .1 or .2 above is significantly different from the total power used at normal sea going, e.g., in cases of passenger ships, P_{AE} ~~can~~ has to be ~~estimated~~ provided by the total consumed electric power (excluding electric power used for propulsion) at normal sea going, ~~to be~~ given in the electric power table[3], divided by the weighted averaged efficiency of the generator(s) ~~the conversion factor (0.9)~~

Sea going conditions

10 CLIA believes there is an error in the current formula regarding the "seagoing conditions". In paragraph 2.5.6 P_{AE} is calculated "in the condition where the ship engaged in a voyage at the speed (*Vref*)" while paragraph 2.5.6.3 P_{AE} is referenced "at normal seagoing conditions". To restore consistency, the following amendment is proposed:

Amendments to 2.5.6.3:

> .3 For ships where P_{AE} value calculated by .1 or .2 above is significantly different from the total power used at normal seagoing, e.g., in cases of passenger ships, P_{AE} ~~can~~ has to be provided ~~estimated~~ by the total consumed electric power (excluding electric power used for propulsion) ~~at normal sea going~~ in a condition when the ship is engaged in voyage at the speed (*Vref*), ~~to be~~ given in the electric power table[3], divided by the conversion factor (0.9) from diesel engine power to electric power.

Guideline for the uniform definition of the Electric Power Table for EEDI

11 The "Electric Power Table" (often referred to as "electric load balance") is a well-recognized document normally provided by the shipyards for a range of seagoing and ambient conditions (for example "100% propulsion power in summer," "manoeuvring in summer/winter," port in summer/winter, etc.).

12 The calculation of P_{AE} should be based on the mature framework of the electric power table document, but at one specific condition: ship engaged in voyage at speed *Vref* in summer and with a full load of passengers. For this reason, "Electric Power Table for EEDI" is considered to be a more appropriate definition.

13 Currently the format of the power table document can vary among different shipyards and designers, even though the information contained within is basically the same. To provide a consistent basis for the P_{AE} calculation through different ships and consistent baselines, it is proposed that a "Guideline for the uniform definition of the Electric Power Table for EEDI" is developed and agreed. This will establish a verifiable and auditable procedure for the future use of the classification societies and flag State authorities that will be requested to approve the "Electric Power Table for EEDI" prepared by the shipyards.

14 CLIA has worked on a draft proposal of "Guideline for the uniform definition of the Electric Power Table for EEDI" for initial consideration that could be used as a base for further development. This document is currently being reviewed by IACS and will be submitted to the Committee for review.

15 The key concepts contained in the draft CLIA proposal are: listing all the electric loads to verify that none are omitted, highlighting the service factors to allow verification by the authorities, a standard grouping of users to allow a consistent verification process and a standard format to gain consistency between different ships. It is believed that the current definition of P_{AE} contains ambiguous definitions regarding "power not for propulsion machinery/system" (the propulsion auxiliaries might be excluded or included and the machinery auxiliaries might be excluded or included, leading to different interpretations of the EEDI calculation and an inconsistent evaluation). A guideline would provide clear and unambiguous definitions avoiding potentially different interpretations.

16 As a consequence, this factor is quoted as the "guideline concept" in the proposed formula for the consideration of the Committee.

Amendments to 2.5.6.3 note 3:

> [3] Note: The electric power table is often verified and approved by the Administration/Recognized Organizations because it can be the documentation relating to the SOLAS chapter II-1, part D, regulation 40.1.1: The electric power table shows the generator load summary in kW and identifies those generators in service in each condition of ship operation, e.g., "normal seagoing", etc. <u>The "Electric Power Table for EEDI" document has to be compiled in accordance with the "Guideline for the uniform definition of the Electric Power Table for EEDI".</u>

17 By combining the refinements proposed in paragraphs 6, 9, 10 and 14, paragraph 2.5.6.3 of annex 2 to GHG-WG 2/WP.1 will give the following (in clean text).

> 3 For ships where the P_{AE} value calculated by .1 or .2 above is significantly different from the total power used at normal seagoing, e.g., in cases of passenger ships, P_{AE} has to be provided by the total consumed electric power (excluding electric power used for propulsion) in a condition when the ship engaged in voyage at the speed (*Vref*) with outside ambient temperature 35°C, 85% R.H. and seawater temperature 32°C and a full passenger load, given in the electric power table[3], divided by the weighted average efficiency of the generator(s).

[3] Note: The electric power table is often verified and approved by the Administration/Recognized Organizations because it can be the documentation relating to the SOLAS chapter II-1, part D, regulation 40.1.1: The electric power table shows the generator load summary in kW and lists generators in service by each condition of ship operation, e.g., "normal seagoing", etc. The "Electric Power Table for EEDI" document has to be compiled in accordance with the "Guideline for the uniform definition of the Electric Power Table for EEDI".

SFC for auxiliaries engines correction to calculation

18 It is believed that for ships where P_{AE} is a significant part of the total consumed power, the current formula does not correctly address either the present actual or future complexity of the auxiliary generators where the auxiliary power P_{AE} can be provided by a number of prime movers coupled to alternators.

19 At present, for generators with medium speed diesel engines as prime movers, the individual engine's most efficient loading is normally found to be about 85% of the rated maximum power. Also the marine power plants are designed such that the engines operate at high loads and only occasionally at loads below 50%-60%. Moreover, the designated condition for the calculation of P_{AE} could lead to the situation where the auxiliary's engines are loaded near their maximum rated power (normally between the ranges of 85% to 95%). This means that the current formula (that indicates 50%, see paragraph 2.7 below) is not appropriate because it can represent a worse SFC_{AE} than what is actually experienced.

20 As further justification for the appropriateness of using an 85% loading against the 50% condition, it should be recognized that the 85% service condition is today fulfilled by the design of the generators' management control system. This system is not only designed to start/stop and load the generators to supply the auxiliaries load P_{AE} but also to match the highest possible efficiency, thus allowing individual units to run at their individual most efficient point (about 85%) to the greatest extent. Such systems also address the required redundancy of the auxiliaries system. Spare engines are started only when necessary and the duty engines are run at their optimal point whenever possible.

21 If the 50% criterion is not changed to 85%, this will result in an erroneous EEDI, and there will be an incentive to design marine plants with engines optimized to run at 50%. To demonstrate the impact of the change, a calculation was performed that shows the following:

Variation found by calculating EEDI with and without the "optimal point concept" ~ 5.5%

22 Therefore, an amendment to the formula is considered beneficial to address this issue and text is proposed below.

Amendments to 2.7:

.7 *SFC* is the certified specific fuel consumption, measured in g/kWh, of the engines. The subscripts $_{ME(i)}$ and $_{AE(i)}$ refers to the main and auxiliary engine(s), respectively. For engines certified to the E2 or E3 duty cycles of the NO_x Technical Code 2008 the engine Specific Fuel Consumption ($SFC_{ME(i)}$) is that recorded on the EIAPP Certificate(s) at the engine(s) 75% of P_{ME} MCR power or torque rating. For engines certified to the D2 or C1 duty cycles of the NO_x Technical Code 2008 the engine Specific Fuel Consumption ($SFC_{AE(i)}$) is that recorded on the EIAPP Certificate(s) at the engine(s) 50% of P_{AE} MCR power or torque rating.

For ships where P_{AE} value calculated by .1 or .2 above is significantly different from the total power used at normal seagoing, e.g., in cases of conventional passenger ships the Specific Fuel Consumption ($SFC_{AE(i)}$) of the auxiliaries generators is that recorded on the EIAPP Certificate(s) at the engine(s) 85% of P_{AE} MCR power or torque rating.

SFC_{AE} is the weighted average among $SFC_{AE(i)}$ of the respective engines *i*.

For those engines which do not have an EIAPP Certificate because their power is below 130 kW, the *SFC* specified by the manufacturer and endorsed by competent authority should be used.

PTI chain's efficiency

23 The current EEDI formula is considered to contain a simplification of the definition of the power $P_{PTI(i)}$ because it does not include the efficiency of the shaft motor and does not consider the efficiency of other associated equipment, such as the shaft motor's transformers and shaft motor converter which are normally necessary to transfer the electric power from the switchboard to the shaft motor. The combined efficiency of the shaft motor, shaft motor's transformers, converters, accessories, etc., could be defined as "shaft motor chain efficiency". This efficiency can range from 6% to 10% of the power $P_{PTI(i)}$.

24 Today's technology of a shaft motor chain can offer improved efficiency at some costs. Possible future development of the transformer-less converter or a more efficient shaft motor and converter set should be rewarded to justify costs for research and installation of more efficient equipment. It should be recognized that if the formula does not consider the shaft motor chain efficiency, the improvement cycle may be stopped as there will be no incentive to design more efficient shaft motor systems and further opportunity to reduce future CO_2 emissions will be lost. It is also felt relevant that if the formula does not include consideration of the shaft motor chain efficiency, the CO_2 figure in the EEDI will be lower than actually experienced.

25 Therefore, an amendment to the formula is considered beneficial to address this issue and text is proposed below.

Amendments to 2.5.3:

.5.3 $P_{PTI(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted averaged efficiency of the generator(s). For conventional passenger ships the shaft motor chain's efficiency needs to be considered (to account for the losses of the equipment from the switchboard to the shaft motor); the shaft motor's chain efficiency is to be obtained from the equipment documents/certificates.

Simpler and more effective wording of formula terms

26 It is considered that the complexity of the current EEDI formula does not lend itself to easy interpretation, and consequently may create misunderstanding in the future as to the actual intent of the EEDI. A simple explanation of the calculation, together with separate detailed formula for the components of the equation, is proposed below. This is felt necessary to ensure a fuller appreciation of the basis and reasoning behind the agreed calculation in future applications, and clarifies that the index is derived from the sum of CO_2 attributable to the equivalent total energy used less the efficient use of that energy divided by the transportation work.

27 The consequential amendment to the EEDI formula suggested to introduce this concept is provided below.

Amendments to 2.2:

2 Energy Efficiency Design Index (EEDI)

The attained new ship Energy Efficiency Design Index (EEDI) is a measure of ships CO_2 efficiency and calculated by the following formula:

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

$$\frac{CO_2\_from\_propulsion + CO_2\_from\_Auxiliaries - Efficent\ use\ of\ energy}{transportation\_work}$$

Amendments to 2.5.7

5.7

$$transportation\_work = f_i \cdot Capacity \cdot V_{ref} \cdot f_W$$

$$CO_2\_from\_propulsion = \left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} + \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot C_{FAE} \cdot SFC_{AE}\right)$$

$$CO_2\_from\_Auxiliaries = \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right)$$

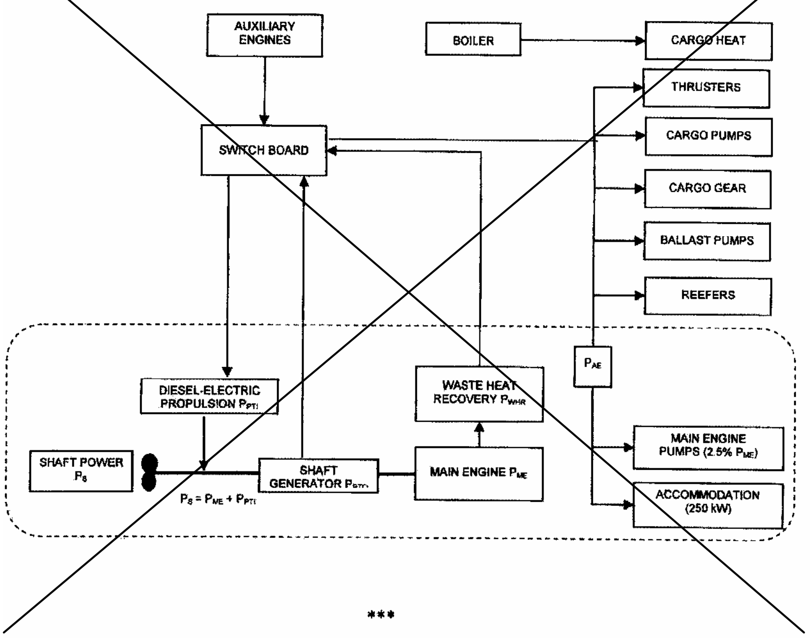
$$Efficent\ use\ of\ energy = \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} + \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)} \cdot C_{FAE} \cdot SFC_{AE}$$

Improved diagram

28 CLIA suggests that the current explanatory diagram would benefit from additional refinement to provide consistency with the detail of the EEDI formula. A proposed revision to achieve consistency with the EEDI calculation is provided below.

Amendments to page 7

(For the purpose of final review of the group, following alternative figure has been prepared:



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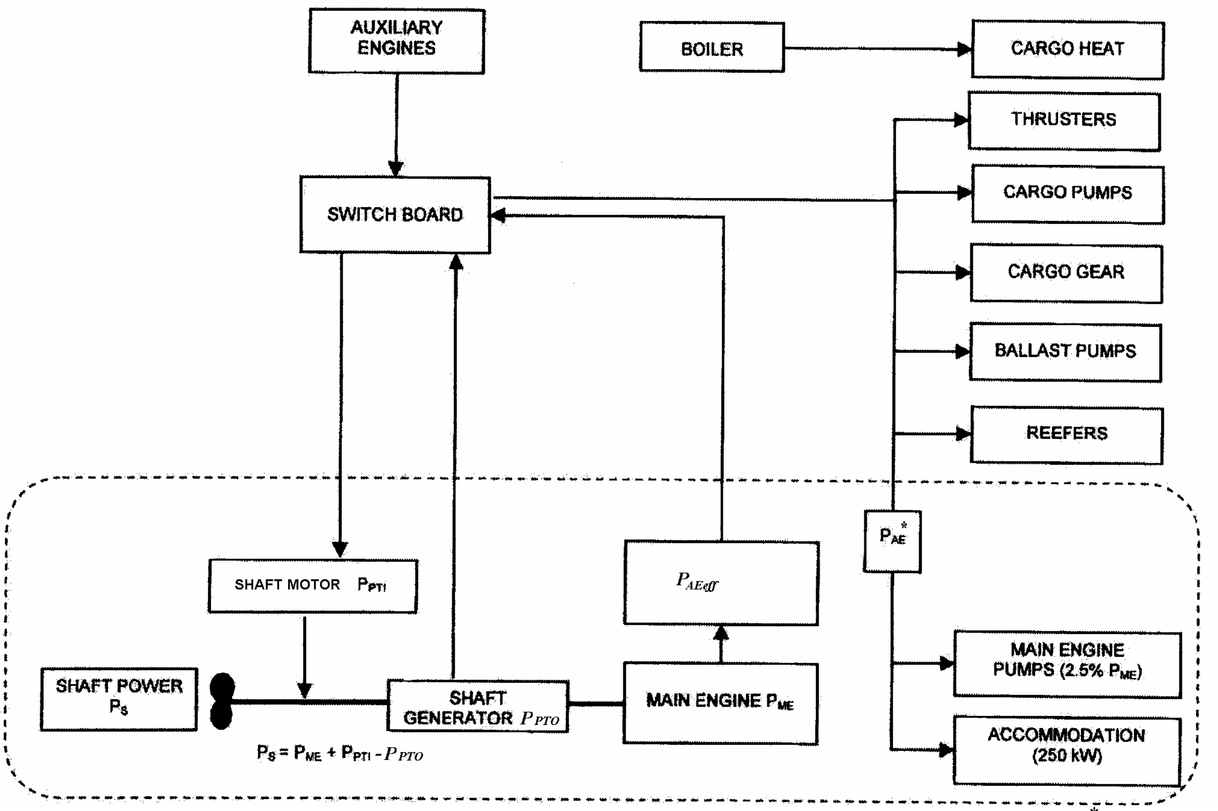

* see 2.5.6.3

Action requested of the Committee

29 The Committee is invited to consider the refinements to the annex 2 to GHG-WG 2/WP.1 "Draft interim guidelines on the method of calculation of the energy efficiency design index for new ships" as detailed above in paragraphs 6, 9, 10, 14, 15, 20, 23, 25 and 26 of this document and take action as appropriate.

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