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Background

Based on recent studies, indicating a dramatic development of climate change induced by human activities, the Marine Environment Protection Committee tasked the Working Group on Greenhouse Gas Emissions from Ships (GHG-WG 1) to develop design CO₂ index for new ships. This work resulted in developing Draft Interim Guidelines on the Method of Calculating the Energy Efficiency Design Index for new ships (MEPC 58/23, annex 11).

The purpose of the design CO₂ index is, according to document MEPC 58/4/8 (Denmark), “to provide a fair basis for comparison, to stimulate the development of more efficient engines and ships in general and to establish a minimum efficiency of ships depending on ship type and ship size”. It is further concluded that “a robust methodology for developing a baseline needs to be established”.

The proposed methodology entails the establishing of Energy Efficiency Design Index, EEDI, Baselines for the following ship types:

.1 Dry Bulk Carriers;
.2 Tankers;
.3 Gas Carriers;
.4 Containerships;
.5 General Cargo Ships;
.6 Ro-Ro Cargo Ships; and
.7 Passenger Ships, including Ro-Ro Passenger Ships (RoPax), but excluding High-Speed Craft.

Each respective baseline shall serve as a measure for the average of the index values for a large group of comparable existing ships applying a coherent calculation methodology; and shall demonstrate whether an individual ship “performs” above or below the average.

It is further stated in document MEPC 58/4/8 that “the variation of the index values compared to the baseline should not be too high, as a comparison would be inappropriate”.

The respective baselines as proposed are developed through regressions analysis using the Lloyd’s Register Fairplay (LRFP) database as primary source, applying the following criteria:

.1 New buildings in the period 1 January 1995 to 31 December 2004 (later 1 January 1998 to 31 December 2007);
.2 Number of ships in a selection, minimum 30 and preferably more than 100; and
.3 All relevant main parameters of selected ships to be given in the database.
Objective

As described in the above, the methodology for implementation of an EEDI as proposed by the GHG Working Group is based on two steps; first to establish baseline curves that can be mathematically expressed for a number of significant ship types and secondly to determine an attained EEDI for every future new building within each ship type segment, applying the same definition of the EEDI as applied for the establishing of the baselines. The intended use of the EEDI is then to approve only new ships showing an EEDI at or below the respective baseline. In a further perspective it can be presumed that the EEDI-baseline acceptance levels are reduced.

10 Having recognized the gravity of the development of the climate change and consequently the importance of the work carried out by the GHG Working Group, the Swedish Maritime Administration has, together with Swedish maritime industry, assessed the consequences of an implementation of a mandatory Energy Efficiency Design Index (EEDI) in general and the EEDI’s potential impact on Ro-Ro and Ro-Pax ships in particular. This document is intended to summarize the results derived and conclusions made within this study.

Evaluation of proposed baselines in general

Even though the same database volume, Lloyd’s Register Fairplay’s Sea-Web, and the same methodology for the determination of the EEDI as used within document MEPC 58/WP.8 have been applied, an absolute 100% match of the evaluated data has not been achieved. This may be the result of some minor discrepancies in the selected ships for evaluation. However, as each ship type segment is represented by more than 100 individuals, a fair common ground for comparison has been achieved.

As stated in document MEPC 58/4/8, the variation of individual index values compared to the baseline “should not be too high, as a comparison would become inappropriate”. Document MEPC 58/4/8 presented a table summarizing the coefficients for each baseline and also a so called correlation factor, $R^2$. This measure of variance gives an indication of how well the regression line represents the selected data. A resulting $R^2$ value close to 1.0 signifies a high degree of correlation.

In order to increase the accuracy, each baseline has been recalculated after having omitted any data falling more than two standard deviations off the original regression line. The obtained $R^2$ values as presented in document MEPC 58/4/8 for the various ship types ranges from 0.42 for container ships to 0.97 for tankers. The rather poor correlation of the data for the container ship fleet is assigned to the lack of consistent data for this segment. Hence, a parallel EEDI calculation has been executed based on data from the Germanisher Lloyd’s database, SIS, in which an $R^2$ value of 0.72 was achieved.

However, no overall regression convergence acceptance criterion has yet been defined.

Assessment of the Proposed Ro-Ro Cargo Ship Baseline

The present study shows a Ro-Ro Cargo Ships data, filtered to exclude off-set data of two standard deviations, built between 1998 and 2007 and having a service speed of 15 knots or more for 412 Ships. A regressions analysis of this data, in correspondence with document MEPC 58/WP.8 applying deadweight (DWT) as Capacity in the calculation of respective EEDI, a correlation factor $R^2$ of 0.79 is achieved (see annex – Figure 2).
16 However, a review of Ro-Ro Cargo Ship data reveals that the predominant sector is composed of Vehicle Carriers, 286 ships, which are mainly engaged in trans-ocean trades where seagoing transit is the absolute dominating mode in an operation profile. It should also be noted that the majority of these ships must carry a significant amount of permanent ballast, in many cases exceeding 3,000 tonnes, which is per definition included in the deadweight.

17 A regression analysis of “Pure” Ro-Ro Carriers, i.e. excluding Vehicle Carriers, depicts a poor convergence resulting in a correlation factor of $R^2 = 0.47$ (see annex – Figure 3), whereas the corresponding analysis of exclusively Vehicle Carriers indicates a more homogenous fleet resulting in a correlation factor of $R^2 = 0.85$ (see annex – Figure 4).

18 In order to enhance the statistical volume of the “Pure” Ro-Ro Ships, data for this type of ships has been extracted to include all new building projects having received an IMO number at the end of 2008, (see annex – Figure 5). Even though the amount of data constituting the basis for a regression analysis has been increased to include also late series of sister ships, the now enhanced “Pure” Ro-Ro fleet actually does not improve in terms of convergence; $R^2 = 0.46$. Moreover, even when undertaking a regression analysis of the same data volume, carried out while applying a filter only excluding ships which are found to fall one standard deviation off the regression baseline results in a poor correlation factor of $R^2 = 0.62$, (see annex – Figure 6).

19 Based on the above summarized assessment, it is hence concluded that “a fair basis for comparison” cannot be achieved for a collective Ro-Ro and Vehicle Carrier baseline. It is furthermore concluded that the “Pure” Ro-Ro fleet for various reasons does not show an index/capacity relation homogenous enough to facilitate an acceptable regression line convergence. Additional time is required in order to assess individual ship features, and hence identify various index driving factors. Such work would be helped by establishing what level of $R^2$ is acceptable for a statistical population of ships to jointly be allowed to form the dataset for a baseline. Thereafter, revised regression analyses could establish if an enhanced resolution of the fleet could meet pre-defined statistical criteria$^1$.

Assessment of the Proposed Passenger Ship Baseline

20 According to document MEPC 58/4/8, one common baseline was initially proposed to constitute the ground for comparison of all types of passenger ships including Cruise Vessels and Ro-Ro Passenger (Ro-Pax) ships larger than 400 GT. It was further decided to apply as Capacity the ships gross tonnage (GT), as defined in accordance with the International Convention on Tonnage measurements of ships 1969, when calculating the EEDI.

21 As no approach for the handling of diesel-electric (DE) propulsion drives had been defined in document MEPC 58/WP.8, the majority of the cruise fleet had to be excluded in the establishing of the passenger ship regression baseline. Hence, also “Pure” Ro-Pax baselines have later been prepared by the GHG Working Group, one baseline applying DWT as Capacity and another baseline applying GT as Capacity.

22 As Ro-Ro Passenger ships are in principle engaged in short sea shipping, providing line services dictated by time table traffic, these ships show immensely different features and characteristics than the cruise ship fleet. Hence, for the purpose of this assessment only Passenger Ro-Ro Ship data has been extracted and evaluated. When applying DWT as Capacity, 

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$^1$ E.g., size segmentation or lane meter vs. dead weight ratios could be evaluated in order to ascertain whether stronger correlations within the “Pure” Ro-Ro population do exist.

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the filtered “Pure” Ro-Pax data volume encompasses 287 ships which result in a regression line correlation factor of $R^2 = 0.78$, (see Appendix – Figure 7); and when applying GT, in total 286 ships provide a correlation factor of $R^2 = 0.79$, (see annex – Figure 8).

23 In conclusion to the above, regression baselines established for DWT-capacity as well as for GT-capacity, both provide similar basis for comparison, but as earlier noted, the correlation is not very strong in either case.

24 However, as Ro-Pax ships to a varying degree combine the features of Passenger ships and Ro-Ro ships, a “Pure” Ro-Pax baseline should be defined for ships having a minimum lane-meter capacity as well as a minimum passenger capacity. Hereby the extreme values influencing the regression analysis will be excluded.

**Regulatory aspects**

25 Prior to implementation of a mandatory Energy Efficiency Design Index (EEDI) it must be clearly defined at what stage of a new building project an attained index shall apply. Since an authority approval based on results obtained during sea trials may impose an undesired margin of installed power, it is recommended that authority approval must be granted in due time prior to commencing steel cutting at the ship yard; and hence based on results obtained from model tests or equivalent speed-power predictions performed by a renowned testing facility.

26 Having acknowledged that for practical reasons, when establishing the baseline curves for the various ship types, all coefficients and reduction factors have been set to 1.0, it can be assumed that also when calculating an attained index, the use of still undefined coefficients applied in order to account for ship specific features ($f_j$), seagoing conditions ($f_w$) and technical/regulatory limitation on capacity ($f_i$) may result in a significant divergence of the index. The intended robustness of the index determination methodology which, according to document MEPC 58/4/8, shall constitute a fair basis for comparison may be lost. In detail:

1. $f_j, f_i$ Safety aspects such as redundant propulsion systems, “take me home” capacity and power capacity as required for safe navigation in ice must be given special consideration. The ship specific design coefficient, $f_j$, cannot be expressed by a “standard table/curve”. For ice-strengthened ships both the numerator and denominator of document MEPC 58/4/8 formula are negatively impacted by the special requirements on power and the increased light ship weight;

2. $f_w$ Environmental loads such as sea states, wind and current may show significant fluctuations and seasonal variations also when regarding one and the same route; and

3. $f_j, f_w$ For some segments prevailing market conditions may require a flexibility in the deployed fleet. Moreover, seasonal variations in the demand for transportation services may impose dual Load Line certificates.

**Proposal**

27 As a more robust approach, it is therefore recommended that $P_{MEI}$ is to be taken as predicted total brake power ($P_B$) required to propel the ship at service speed ($V_s$) in calm and deep water at the load condition corresponding to the Capacity. Hereby the coefficients $f_j$ and $f_w$ can be omitted, providing an uncomplicated methodology for the calculation of the attained index.
It should be noted that this methodology aligns perfectly with the primary intention of the design index to “stimulate the development of more efficient engines and ships in general”, since the influence of the index on speed/power curve will be equivalent regardless of whether a specified power or a specified speed is applied, both points need to fall on one and the same curve, see figure 1:

.1 If the required power \( (P_B) \) to meet the defined service speed should coincide with 75% of MCR – and all correction factors in document MEPC 58/4/8 methodology are set to 1.0 – then the resulting EEDI would be the same with this approach as it would with the methodology set out in document MEPC 58/4/8;

.2 The main advantage of utilizing \( (P_B) \) as above, is that any excess power needed for ice class and/or for redundant propulsion, or similar, will not have to be compensated for by employing any corrections factor(s); and

.3 Further work is needed in order to establish a robust correction factor to account for decreased Capacity due to increased light ship weight in ice-strengthened ships.

Moreover, the proposal also allows for implementation of future rules and regulations having an impact on the installed engine power, e.g., Safe Return to Port or stricter air emission regulations such as the announced NO\(_x\) requirements. An adequate installed power margin could be verified against requirements as dictated by designated class notation.

In order to fulfil the objective of the implementation of an EEDI as given in document MEPC 58/4/8 and to provide “a fair basis for comparison” it is recommended that a correlation factor \( R^2 \) must reach a value of at least [0.XY] within reasonable filtering of off-set data resulting in the inclusion of at least [100] modern ships.
31 In a future perspective, if the baselines levels are to be lowered, the consequences on safe navigation, taking into consideration relevant environmental loads representative for a specific service, must be carefully evaluated.

32 Implementation of a mandatory design index shall be preceded by a trial period and evaluated in order to validate that the intent of the index has been fulfilled. The assessment shall furthermore address any indication of sub optimization of ship design in order to meet the required index; and any indication of a compromised degree of safety.

33 Provisions shall be made to allow for alternative methods for a comprehensive determination of attained index by means of calculations and/or tests executed and presented to the satisfaction of the Authority.

**Action requested of the Intersessional Meeting**

34 The Intersessional Meeting is invited to consider the information and proposals above and decide as appropriate.

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ANNEX

FIGURES

Figure 2  Ro-Ro Cargo Ship Baseline Filtered by +/- 2 Standard Deviations

Figure 3  “Pure” Ro-Ro Carriers Baseline Filtered +/- 2 Standard Deviations
Figure 4  “Pure” Vehicle Carriers Baseline Filtered +/- 2 Standard Deviation

Figure 5  “Pure” Ro-Ro Ships Baseline (1998-2013) Filtered +/- 2 Standard Deviations
“Pure” Ro-Ro Ships Baseline (1998-2013), Filtered +/- 1 Standard Deviation

Figure 6

“Pure” Ro-Pax Ships Baseline, applying DWT as Capacity

Figure 7
RoPax GT Base Line (Jan. 1998-Dec. 2007)
Filtered +/- 2xStdDev

$y = 2437x^{0.4665}$
$R^2 = 0.7902$

**Figure 8**  “Pure” Ro-Pax Ships Baseline, applying GT as Capacity