July 2018 Development Paper

MariEMS Learning Material

This is the 24th compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material extracted from the IMO TTT Course. The material is composed from Chapter 24 of the learning material. Readers are also advised to refer to the papers on IdeaPort and IdealShip projects led by C4FF and published by MariFuture.

24. EEDI calculation

24.1 Concept of EEDI

The Attained EEDI is the actual value of EEDI for a ship and represents the amount of CO_2 generated by a ship while doing one tonne-mile of transport work. In simple term, it may be represented by equation (1):

$$EEDI = \frac{CO_2\ emission}{transport\ work} \quad = \quad EEDI = \frac{\text{Engine power x SFC x } C_F}{\text{DWT x speed}}\ (gCO_2/\text{ton-mile}) \quad (1)$$

It is argued that EEDI represents the ratio of a ship's "cost to society" in the form of its CO_2 emissions, divided by its "benefit to the society" represented by the transport work done by the ship as shown in (1). The above concept then translated into a more vigorous calculation method as represented by EEDI formula in equation (2) to account for diversity of ship types, ship sizes, alternative propulsion technologies, alternative fuels and future renewable technologies.

24.2 EEDI formula

Attained EEDI is calculated using the "EEDI formula" as shown below:

$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)}\cdot C_{FME(i)}\cdot SFC_{ME(i)}\right)+\left(P_{AE}\cdot C_{FAE}\cdot SFC_{AE}*\right)+\left(\left(\prod_{j=1}^{n} f_j\cdot\sum_{i=1}^{nPTI}P_{PTI(i)}-\sum_{i=1}^{neff}f_{eff(i)}\cdot P_{AEeff(i)}\right)C_{FAE}\cdot SFC_{AE}\right)-\left(\sum_{i=1}^{neff}f_{eff(i)}\cdot P_{eff(i)}\cdot C_{FME}\cdot SFC_{ME}**\right)}{f_i\cdot f_c\cdot Capacity\cdot f_w\cdot V_{ref}} \quad (2)$$

Figure 24.2.1 shows the main terms of the formula indicating that all relevant ship technologies will influence the EEDI level.

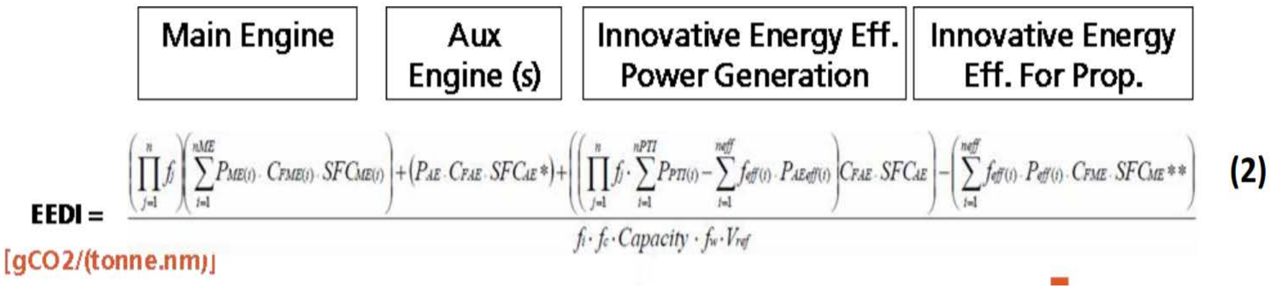


Figure 24.2.1: Main terms in EEDI formula

The items that primarily influence EEDI are:

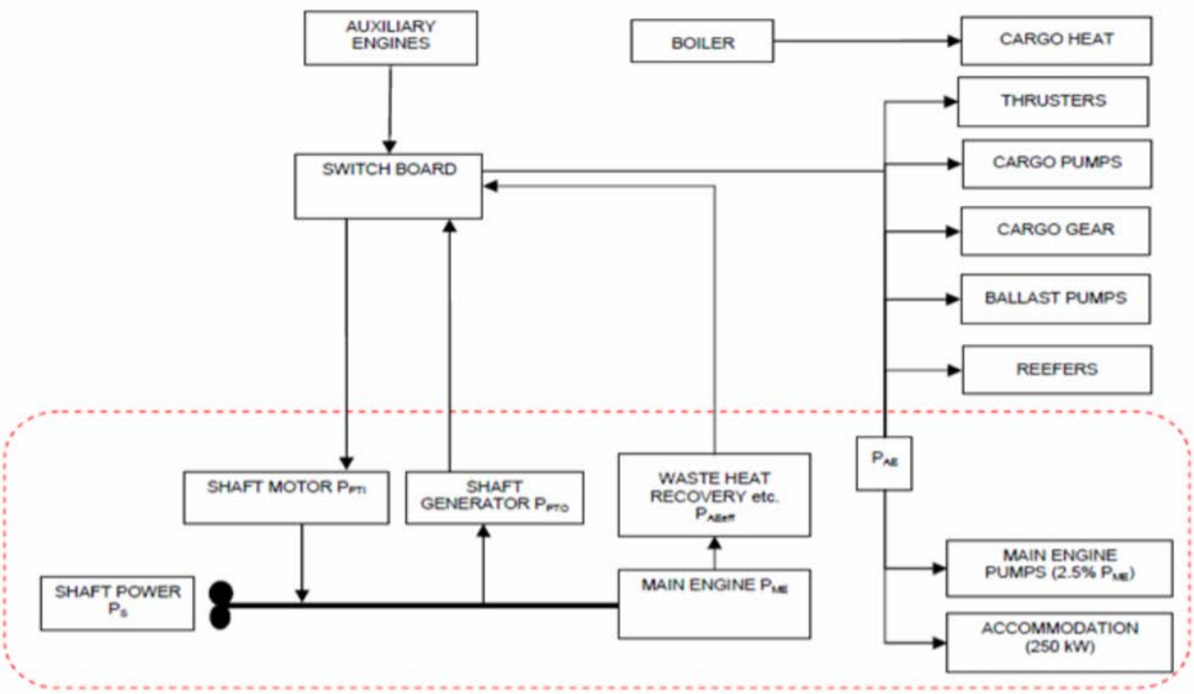
- Main engine and energy needed for propulsion; this represented by the first term in the nominator of the formula.
- Auxiliary power requirements of the ship; this is represented by the second term in the nominator.

- Any innovative power (electric) generation devices on board such as electricity from waste heat recovery or solar power. These are represented by the third term in the nominator.
- Innovative technologies that provide mechanical power for ship propulsion such as wind power (sails, kites, etc.). This is the last term in the nominator.
- In the denominator of the formula, ship capacity and ship speed are represented that together gives the value of transport work.

Figure 24.2.2 shows the scope of ship systems that are represented in equation (2). The items contained within the red dashed-line box are included in EEDI formula while everything outside the box is excluded.

APPENDIX 1

A GENERIC AND SIMPLIFIED MARINE POWER PLANT



Note 1: Mechanical recovered waste energy directly coupled to shafts need not be measured, since the effect of the technology is directly reflected in the V_{ref} .

Note 2: In case of combined PTI/PTO, the normal operational mode at sea will determine which of these to be used in the calculation.

Figure 24.2.2: Scope of ship systems included in EEDI formula [Resolution MEPC.245 (66)]

As a general rule:

- All the cargo-related energy uses on-board are outside the scope of the EEDI calculations (not included in the formula).
- Auxiliary boilers are also excluded from the formula; assuming that under normal sea-going conditions, boilers will not be operating.

Therefore, electricity needed for cargo pumps, cargo handling equipment, ship thrusters, etc. are out of scope of EEDI calculations.

24.3 Terms in the EEDI formula

Various terms in equation (2) are fully defined in the relevant IMO guidelines [Resolution MEPC.245 (66)], a summary of which is given in Table 24.3.1.

Term	Unit	Brief description
Capacity	[Tonne]	Ship capacity in deadweight or gross tonnage at summer load line draught (for container ships, 70% of deadweight applies).
C_{FAE}	[gCO_2/gfuel]	Carbon factor for fuel for auxiliary engines.
C_{FME}	[gCO_2/gfuel]	Carbon factor for fuel for main engines.
f_{eff}	[-]	Correction factor for availability of innovative technologies.
f_i	[-]	Correction factor for capacity of ships with technical/regulatory elements that influence ship capacity.
f_c	[-]	Correction factor for capacity of ships with alternative cargo types that impact the deadweight-capacity relationship (e.g. LNG ships in gas carrier segment).
f_j	[-]	Correction factor for ship specific design features (e.g. ice-class ships).
f_w	[-]	Correction factor for speed reduction due to representative sea conditions.
n_{eff}	[-]	Number of innovative technologies.
n_{ME}	[-]	Number of main engines.
n_{PTI}	[-]	Number of power take-in systems (e.g. shaft motors).
P_{ME}	[kW]	Ship propulsion power that is 75% of main engine Maximum Continuous Rating (MCR) or shaft motor (where applicable); also taking into account the shaft generator. This will be influenced by alternative propulsion configurations.
P_{AE}	[kW]	Ship auxiliary power requirements at normal sea going conditions.
P_{AEeff}	[kW]	Auxiliary power reduction due to use of innovative electric power generation technologies.
P_{eff}	[kW]	75% of installed power for each innovative technology that contributes to ship propulsion.
P_{PTI}	[kW]	75% of installed power for each power take-in system (e.g. propulsion shaft motors).
SFC_{AE}	[g/kWh]	Specific fuel consumption for auxiliary engines as per NOx certification values.
SFC_{ME}	[g/kWh]	Specific fuel consumption for main engines as per NOx certification values.
V_{ref}	[knots]	Reference ship speed attained at propulsion power equal to P_{ME} and under clam sea and deep water operation at summer load line draught.

Table 24.3.1: Parameters for EEDI formula

More details of the important parameters are given below:

- SFC (Specific Fuel Consumption): The specific fuel consumption (SFC) is for engines and represents their fuel efficiency (fuel used) in g/kWh. The value for SFC is determined from the results recorded in the engine's NOx Technical File; determined as part of the engine NOx certification. The SFC for main engine is generally taken at 75% load and for auxiliary engines is generally taken at 50% load.

- CF (Carbon Factor): This factor specifies the amount of CO_2 generated per unit mass of fuel used. Table xx provides the standard value for marine fuels. The type of fuel used for the

NOx Certification test (to be taken from NOx Technical File) should be used to determine the value of the CF conversion factor.

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1 Diesel/Gas Oil	ISO 8217 Grades DMX through DMB	0.8744	3.206
2 Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.8594	3.151
3 Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.8493	3.114
4 Liquefied Petroleum Gas (LPG)	Propane	0.8182	3.000
	Butane	0.8264	3.030
5 Liquefied Natural Gas (LNG)		0.7500	2.750
6 Methanol		0.3750	1.375
7 Ethanol		0.5217	1.913

Table 24.3.2: Standard values of CF for marine fuels [Resolution MEPC.245 (66)]

- **Capacity:** The Capacity of the ship is the deadweight or gross tonnage based on summer load line draught. The calculation of the deadweight is based on the lightweight of the ship, and the displacement at the summer load line draught. At the design stage, for EEDI preliminary verification, the lightweight and the displacement may be calculated using the provisional ship's stability documentation. For containerships, capacity is taken as 70% of the capacity at summer load line draught.

- **Power (propulsion – P_{ME})**: The term "P" for power is used in different places in the formula for main engine, auxiliary power (electrical), shaft motor, shaft generator, renewable energy devices, etc. Power for shaft propulsion PME, generally is calculated at 75% MCR (Maximum Continuous Rating) of the main engine. Depending on various options of the propulsion line (shaft generator, shaft motor, limited power, etc.) different formulas are used for this purpose. For details, refer to the IMO guidelines (e.g. Resolution MEPC.245 (66)).

- **Power (auxiliary – P_{AE}):** For auxiliary power (electrical), also different formulation to calculate the auxiliary power applies. PAE generally includes the power consumed by the main engine pumps, navigational systems and equipment as well as accommodation but excludes other power used not for propulsion machinery/systems, e.g. thrusters, cargo pumps, cargo gear, ballast pumps, maintaining cargo, e.g. reefers and cargo hold fans (see also Figure 24.3.2). In the IMO guidelines [Resolution MEPC.245 (66)], there are specific formulas for calculation of P_{AE}. It should be noted that P_{AE} is not linked to the actual installed power of ship auxiliary engines.

- **Reference Speed (V_{ref}):** The reference speed V_{ref} is the ship speed as measured and verified during sea trials and corrected to the following conditions:
    - Deep water operation
    - Calm weather including no wind and waves
    - Loading condition corresponding to the Capacity
    - Total shaft propulsion power at corresponding value of P_{ME}

- **Weather factor f_w:** f_w is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed (e.g. Beaufort Scale 6), and is taken as 1.0 for the calculation of the Attained EEDI. Efforts are underway to define how this factor can be estimated for various ships but effort so far has not led to any agreed solution.

- **Ship design related correction factors that influence propulsion power f_j:** There are a host of correction factors that are used to differentiate ships of same type and size if their basic design requirements are different. For example a tanker with ice-class as against same tanker without ice-class will have a correction factor to cater for their design differences. Design related correction factor f_j for the following ships are specified (see relevant IMO guidelines [Resolution MEPC.245(66)] for calculation process, formula and values); otherwise it is 1.0:

    - Ice-classed ships o Shuttle tankers with propulsion redundancy (80,000~160,000 DWT)
    - Ro-Ro ships, all types
    - General cargo ships

- **Design factor that impact ship Capacity fi:** These are a set of correction factors that are used to differentiate ships of same type and size if their cargo capacity is influenced by design or type of cargo. For example a tanker with ice-class as against same tanker without ice-class will have a smaller capacity that needs to be taken into account. Other examples are when an owner decides to voluntarily strengthen the ship structure via use of thicker still plates or when a ship is classed according to Common Structural Rules. Capacity related correction factors are (for details of calculation of each, see Resolution MEPC.245(66) and relevant formulas for each factor below):

    - **Ice-class capacity factor fi:** This is the factor used for ice-class ships.
    - **Voluntary Structural Enhancement f_{iVSE}:** For a ship with voluntary structural enhancement, the f_{iVSE} factor is to be computed according to according to formulation provided in the IMO guidelines.
    - **Common Structural Rules f_{iCSR}:** For bulk carriers and oil tankers built in accordance with the Common Structural Rules and assigned the class notation CSR, the f_{iCSR} factor is to be computed according to formulation provided in the IMO guidelines.

- **Cubic capacity correction factor f_c:** This refers to correction factors that are used to differentiate various types of cargos. Except in the cases listed below, the value of the fc factor is 1.0.
    - For a number of chemical tankers as defined under MARPOL Annex II, the f_c factor is to be computed according to formulation provided in the IMO guidelines [Resolution MEPC.245 (66)].
    - For gas carriers as defined in certain regulation of IGC Code (*International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*) having direct diesel driven propulsion. In such cases, the fc factor is computed according to formulation provided in the IMO guidelines [Resolution MEPC.245 (66)].

24.4 EEDI Condition

It is important to note that EEDI is calculated for a single ship's operating condition. This single operating condition is referred to as "EEDI Condition". The EEDI Condition is as follows:

- **Draught:** Summer load line draught.
- **Capacity:** Deadweight (or gross tonnage for passenger ships, etc.) for the above draught (container ship will be 70% value).
- **Weather condition:** Calm with no wind and no waves.
- **Propulsion shaft power:** 75% of main engine MCR (conventional ships) with some amendments for shaft motor or shaft generator or shaft-limited power cases, where applicable.
- **Reference speed (V_{ref}):** Is the ship speed when measured/estimated under the above conditions.

To calculate EEDI, all the measurements and data used should be corrected to the above conditions.

24.5 EEDI Technical File

Calculation of Attained EEDI involves the determination / measurement / calculation of all the terms as identified in Table 24.3.1 and their verification. Also, determination of Required EEDI is done via formulations provided in Section 23.4.

For verification purposes and subsequent implementation and enforcement purposes by flag and port States, it is a requirement that all the relevant terms and their values shall be recorded in an "EEDI Technical File" and then submitted to the verifiers (normally Recognized Organization on behalf of flag State) that will carry out the certification on behalf of flag Administration. Also, the "EEDI Technical File" needs to be kept on board and forms a supplement to International Energy Efficiency Certificate.

IMO in its EEDI survey and verification guidelines [Resolution MEPC.254 (67)] have provided a sample "EEDI Technical File". This sample indicates that all data necessary for verification purposes including all the terms defined in Section 24.3 need to be recorded in this technical file.

24.6 References and Further Readings

1. IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation. http://www.imo.org/en/ourwork/environment/pollutionprevention/airpollution/pages/imo-train-the-trainer-course.aspx viewed Dec 2016.
2. Resolution MEPC.231 (65): 2013 Guidelines for calculation of reference lines for use with the energy efficiency design index (EEDI), adopted in 2013.
3. Resolution MEPC.263 (68), "Amendments to the 2014 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for New Ships, (Resolution MEPC.245 (66)), adopted on 15 May 2015.
4. MariEMS Train the trainees Course for seafarers and cadets – www.mariems.com