Polski Rejestr Statków

RULES

PUBLICATION NO. 103/P

GUIDLINES OF ENERGY EFFICIENCY OF SHIPS

2018

January

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK
Publication No. 103/P – Guidelines for energy efficiency of ships – January 2018 was approved by PRS Executive Board on 21 December 2017 and enters into force on 1 January 2018.
1 INTRODUCTION

In July 2012 IMO introduced, by Resolution MEPC.203(62), amendments to Annex VI to MARPOL, thus implementing mandatory requirements for energy efficiency aimed to reduce the greenhouse gas emissions by worldwide shipping in the forthcoming years. Chapter 4 on ship energy efficiency was introduced thereto.

These regulations (with a further amendments) took effect on 1 January 2013 and apply to all ships of gross tonnage 400 and above engaged on international voyages who are subject to statutory survey.

As a result, the following two instruments ensuring ship energy efficiency entered into force as mandatory requirements: Energy Efficiency Design Index (EEDI) – for new ships and the ships who have undergone substantial modification, and Ship Energy Efficiency Management Plan (SEEMP) – for all ships who are subject to statutory survey.

Also a number of guidelines were developed to supplement MARPOL requirements on ship energy efficiency whereas shipbuilding industry issued their independent guidelines in this respect.

This Publication contains the above mentioned guidelines on ship energy efficiency and complements PRS Rules.
2014 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS, AS AMENDED (RESOLUTION MEPC.245(66), AS AMENDED BY RESOLUTIONS MEPC.263(68) AND MEPC.281(70))

1. The Marine Environment Protection Committee, at its seventieth session (24 to 28 October 2016), adopted resolution MEPC.281(70) on Amendments to the 2014 Guidelines on the method of calculation of the attained EEDI for new ships (resolution MEPC.245(66), as amended by resolution MEPC.263(68)) (MEPC 70/18, paragraph 5.69).

2. A consolidated text of the Guidelines, as requested by the Committee (MEPC 70/18, paragraph 5.69), is set out in the annex.

3. Member Governments are invited to bring the annexed 2014 Guidelines on the method of calculation of the attained EEDI for new ships, as amended by resolutions MEPC.263(68) and MEPC.281(70), to the attention of Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

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ANNEX

2014 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS, AS AMENDED

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1 Definitions


1.2 For the purpose of these Guidelines, the definitions in chapter 4 of MARPOL Annex VI, as amended, apply.

2 Energy Efficiency Design Index (EEDI)

The attained new ship Energy Efficiency Design Index (EEDI) is a measure of ships’ energy efficiency (g/t·nm) and calculated by the following formula:

\[
\text{EEDI} = \frac{1}{f_i} \left( \sum_{i=1}^{n} P_{\text{ME}(i)} \cdot C_{\text{ME}(i)} \cdot S\text{FC}_{\text{ME}(i)} \right) + \left( \sum_{i=1}^{n} P_{\text{AE}(i)} \cdot C_{\text{AE}(i)} \cdot S\text{FC}_{\text{AE}(i)} \right) \\
\left( \sum_{i=1}^{n} f_i \cdot f_j \cdot f\text{-Capacity} \cdot f\text{-V}_{\text{el}} \right)
\]

* If part of the Normal Maximum Sea Load is provided by shaft generators, \( S\text{FC}_{\text{ME}} \) and \( C_{\text{ME}} \) may – for that part of the power – be used instead of \( S\text{FC}_{\text{AE}} \) and \( C_{\text{AE}} \).

** In case of \( P_{\text{PTI}(i)} > 0 \), the average weighted value of \( (S\text{FC}_{\text{ME}} \cdot C_{\text{ME}}) \) and \( (S\text{FC}_{\text{AE}} \cdot C_{\text{AE}}) \) to be used for calculation of \( P_{\text{eff}} \).

Note: This formula may not be applicable to a ship having diesel-electric propulsion, turbine propulsion or hybrid propulsion system, except for cruise passenger ships and LNG carriers.

Where:

\( C_F \) 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 \( \text{ME}(i) \) and \( \text{AE}(i) \) refer to the main and auxiliary engine(s) respectively. \( C_F \) corresponds to the fuel used when determining \( S\text{FC} \) listed in the applicable test report included in a Technical File as defined in paragraph 1.3.15 of the NO\(_X\) Technical Code ("test report included in a NO\(_X\) technical file" hereafter). The value of \( C_F \) is as follows:

<table>
<thead>
<tr>
<th>Type of fuel</th>
<th>Reference</th>
<th>Lower calorific value (kJ/kg)</th>
<th>Carbon content</th>
<th>( C_F ) (t-CO(_2)/t-Fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Diesel/Gas Oil</td>
<td>ISO 8217 Grades DMX through DMB</td>
<td>42,700</td>
<td>0.8744</td>
<td>3.206</td>
</tr>
<tr>
<td>2 Light Fuel Oil (LFO)</td>
<td>ISO 8217 Grades RMA through RMD</td>
<td>41,200</td>
<td>0.8594</td>
<td>3.151</td>
</tr>
<tr>
<td>3 Heavy Fuel Oil (HFO)</td>
<td>ISO 8217 Grades RME through RMK</td>
<td>40,200</td>
<td>0.8493</td>
<td>3.114</td>
</tr>
<tr>
<td>4 Liquefied Petroleum Gas (LPG)</td>
<td>Propane</td>
<td>46,300</td>
<td>0.8182</td>
<td>3.000</td>
</tr>
<tr>
<td></td>
<td>Butane</td>
<td>45,700</td>
<td>0.8264</td>
<td>3.030</td>
</tr>
<tr>
<td>5 Liquefied Natural Gas (LNG)</td>
<td>Propane</td>
<td>48,000</td>
<td>0.7500</td>
<td>2.750</td>
</tr>
<tr>
<td>6 Methanol</td>
<td></td>
<td>19,900</td>
<td>0.3750</td>
<td>1.375</td>
</tr>
<tr>
<td>7 Ethanol</td>
<td></td>
<td>26,800</td>
<td>0.5217</td>
<td>1.913</td>
</tr>
</tbody>
</table>
In case of a ship equipped with a dual-fuel main or auxiliary engine, the $C_F$-factor for gas fuel and the $C_F$-factor for fuel oil should apply and be multiplied with the specific fuel oil consumption of each fuel at the relevant EEDI load point. Meanwhile, gas fuel should be identified whether it is regarded as the "primary fuel" in accordance with the formula below:

$$f_{DFgas} = \frac{\sum_{i=1}^{n_{gasfuel}} V_{gas(i)} \times \rho_{gas(i)} \times LCV_{gas(i)} \times K_{gas(i)}}{\sum_{i=1}^{n_{total}} \left( \sum_{i=1}^{n_{liquid}} V_{liquid(i)} \times \rho_{liquid(i)} \times LCV_{liquid(i)} \times K_{liquid(i)} \right) + \sum_{i=1}^{n_{total}} \left( V_{gas(i)} \times \rho_{gas(i)} \times LCV_{gas(i)} \times K_{gas(i)} \right)}$$

$$f_{DFliquid} = 1 - f_{DFgas}$$

where,

- $f_{DFgas}$ is the fuel availability ratio of gas fuel corrected for the power ratio of gas engines to total engines, $f_{DFgas}$ should not be greater than 1;
- $V_{gas}$ is the total net gas fuel capacity on board in $m^3$. If other arrangements, like exchangeable (specialized) LNG tank-containers and/or arrangements allowing frequent gas refuelling are used, the capacity of the whole LNG fuelling system should be used for $V_{gas}$. The boil-off rate (BOR) of gas cargo tanks can be calculated and included to $V_{gas}$ if it is connected to the fuel gas supply system (FGSS);
- $V_{liquid}$ is the total net liquid fuel capacity on board in $m^3$ of liquid fuel tanks permanently connected to the ship’s fuel system. If one fuel tank is disconnected by permanent sealing valves, $V_{liquid}$ of the fuel tank can be ignored;
- $\rho_{gas}$ is the density of gas fuel in $kg/m^3$;
- $\rho_{liquid}$ is the density of each liquid fuel in $kg/m^3$;
- $LCV_{gas}$ is the low calorific value of gas fuel in $kJ/kg$;
- $LCV_{liquid}$ is the low calorific value of liquid fuel in $kJ/kg$;
- $K_{gas}$ is the filling rate for gas fuel tanks;
- $K_{liquid}$ is the filling rate for liquid fuel tanks;
- $P_{total}$ is the total installed engine power, $P_{ME}$ and $P_{AE}$ in kW;
- $P_{gasfuel}$ is the dual fuel engine installed power, $P_{ME}$ and $P_{AE}$ in kW;

.1 If the total gas fuel capacity is at least 50% of the fuel capacity dedicated to the dual fuel engines, namely $f_{DFgas} \geq 0.5$, then gas fuel is regarded as the "primary fuel," and $f_{DFgas} = 1$ and $f_{DFliquid} = 0$ for each dual fuel engine.

.2 If $f_{DFgas} < 0.5$, gas fuel is not regarded as the "primary fuel." The $C_F$ and $SFC$ in the EEDI calculation for each dual fuel engine (both main and auxiliary engines) should be calculated as the weighted average of $C_F$ and $SFC$ for liquid and gas mode, according to $f_{DFgas}$.
and \( f_{DF\text{liquid}} \), such as the original item of \( P_{\text{ME}(i)} \cdot C_{\text{FME}(i)} \cdot SFC_{\text{ME}(i)} \) in the EEDI calculation is to be replaced by the formula below.

\[
P_{\text{ME}(i)} \cdot (f_{DF\text{gas}(i)} \cdot (C_{\text{FME pilot fuel}(i)} \cdot SFC_{\text{ME pilot fuel}(i)} + C_{\text{FME gas}(i)} \cdot SFC_{\text{ME gas}(i)}) + f_{DF\text{liquid}(i)} \cdot C_{\text{FME liquid}(i)} \cdot SFC_{\text{ME liquid}(i)})
\]

2 \( V_{ref} \) is the ship speed, measured in nautical miles per hour (knot), on deep water in the condition corresponding to the capacity as defined in paragraphs 2.3.1 and 2.3.3 (in case of passenger ships and cruise passenger ships, this condition should be summer load draught as provided in paragraph 2.4) at the shaft power of the engine(s) as defined in paragraph 2.5 and assuming the weather is calm with no wind and no waves.

3 \( \text{Capacity} \) is defined as follows:

1 For bulk carriers, tankers, gas carriers, LNG carriers, ro-ro cargo ships (vehicle carriers), ro-ro cargo ships, ro-ro passenger ships, general cargo ships, refrigerated cargo carrier and combination carriers, deadweight should be used as capacity.

2 For passenger ships and cruise passenger ships, gross tonnage in accordance with the International Convention of Tonnage Measurement of Ships 1969, annex I, regulation 3, should be used as capacity.

3 For containerships, 70\% of the deadweight (DWT) should be used as capacity. EEDI values for containerships are calculated as follows:

1 attained EEDI is calculated in accordance with the EEDI formula using 70\% deadweight for capacity.

2 estimated index value in the Guidelines for calculation of the reference line is calculated using 70\% deadweight as:

\[
Estimated \ Index \ Value = 3.1144 \cdot \left( \frac{190 \cdot \sum_{i=1}^{NME} P_{\text{ME}i} + 215 \cdot P_{\text{AE}}}{70\% \text{DWT} \cdot V_{\text{ref}}} \right)
\]

3 parameters \( a \) and \( c \) for containerships in table 2 of regulation 21 of MARPOL Annex VI are determined by plotting the estimated index value against 100\% deadweight i.e. \( a = 174.22 \) and \( c=0.201 \) were determined.

4 required EEDI for a new containership is calculated using 100\% deadweight as:

\[
\text{Required EEDI} = (1-X/100) \cdot a \cdot 100\% \text{ deadweight} \quad ^c
\]

Where \( X \) is the reduction factor (in percentage) in accordance with table 1 in regulation 21 of MARPOL Annex VI relating to the applicable phase and size of new containership.
.4 Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1,025 kg/m³ at the summer load draught and the lightweight of the ship. The summer load draught should be taken as the maximum summer draught as certified in the stability booklet approved by the Administration or an organization recognized by it.

.5 $P$ is the power of the main and auxiliary engines, measured in kW. The subscripts $\text{ME}(i)$ and $\text{AE}(i)$ refer to the main and auxiliary engine(s), respectively. The summation on $i$ is for all engines with the number of engines ($n_{\text{ME}}$) (see diagram in appendix 1).

.1 $P_{\text{ME}(i)}$ is 75% of the rated installed power ($\text{MCR}^1$) for each main engine ($i$).

For LNG carriers having diesel electric propulsion system, $P_{\text{ME}(i)}$ should be calculated by the following formula:

$$P_{\text{ME}(i)} = 0.83 \times \frac{MPP_{\text{Motor}(i)}}{\eta_{(i)}}$$

Where:

$MPP_{\text{Motor}(i)}$ is the rated output of motor specified in the certified document.

$\eta_{(i)}$ is to be taken as the product of electrical efficiency of generator, transformer, converter, and motor, taking into consideration the weighted average as necessary.

The electrical efficiency, $\eta_{(i)}$, should be taken as 91.3% for the purpose of calculating attained EEDI. Alternatively, if the value more than 91.3% is to be applied, the $\eta_{(i)}$ should be obtained by measurement and verified by method approved by the verifier.

For LNG carriers having steam turbine propulsion systems, $P_{\text{ME}(i)}$ is 83% of the rated installed power ($\text{MCR}_{\text{SteamTurbine}}$) for each steam turbine($i$).

The influence of additional shaft power take off or shaft power take in is defined in the following paragraphs.

.2 Shaft generator

In case where shaft generator(s) are installed, $P_{\text{PTO}(i)}$ is 75% of the rated electrical output power of each shaft generator. In case that shaft generator(s) are installed to steam turbine, $P_{\text{PTO}(i)}$ is 83% of the rated electrical output power and the factor of 0.75 should be replaced to 0.83.

For calculation of the effect of shaft generators two options are available:

---

1 The value of MCR specified on the EIAPP certificate should be used for calculation. If the main engines are not required to have an EIAPP certificate, the MCR on the nameplate should be used.
Option 1:

.1 The maximum allowable deduction for the calculation of $\Sigma P_{ME(i)}$ is to be no more than $P_{AE}$ as defined in paragraph 2.5.6. For this case, $\Sigma P_{ME(i)}$ is calculated as:

$$\sum_{i=1}^{n_{ME}} P_{ME(i)} = 0.75 \times \left( \sum MCR_{ME(i)} - \sum P_{PTO(i)} \right) \quad \text{with} \quad 0.75 \times \sum P_{PTO(i)} \leq P_{AE}$$

or

Option 2:

.2 Where an engine is installed with a higher rated power output than that which the propulsion system is limited to by verified technical means, then the value of $\Sigma P_{ME(i)}$ is 75% of that limited power for determining the reference speed, $V_{ref}$ and for EEDI calculation. The following figure gives guidance for determination of $\Sigma P_{ME(i)}$:

Shaft motor

.3 In case where shaft motor(s) are installed, $P_{PTO(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted average efficiency of the generator(s), as follows:

$$\sum P_{PTO(i)} = \sum \frac{0.75 \cdot P_{SM,max(i)}}{\eta_{Gen}}$$

Where:

- $P_{SM,max(i)}$ is the rated power consumption of each shaft motor
- $\eta_{Gen}$ is the weighted average efficiency of the generator(s)
In case that shaft motor(s) are installed to steam turbine, $P_{PTI(i)}$ is 83% of the rated power consumption and the factor of 0.75 should be replaced to 0.83.

The propulsion power at which $V_{ref}$ is measured, is:

$$\sum P_{ME(i)} + \sum P_{PTI(i), Shaft}$$

Where:

$$\sum P_{PTI(i), Shaft} = \sum (0.75 \cdot P_{SM, max(i)} \cdot \eta_{PTI(i)})$$

$\eta_{PTI(i)}$ is the efficiency of each shaft motor installed

Where the total propulsion power as defined above is higher than 75% of the power the propulsion system is limited to by verified technical means, then 75% of the limited power is to be used as the total propulsion power for determining the reference speed, $V_{ref}$ and for EEDI calculation.

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

**Note:** The shaft motor's chain efficiency may be taken into consideration to account for the energy losses in the equipment from the switchboard to the shaft motor, if the chain efficiency of the shaft motor is given in a verified document.

.4 $P_{eff(i)}$ is the output of the innovative mechanical energy efficient technology for propulsion at 75% main engine power.

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

In case of a ship equipped with a number of engines, the $C_F$ and $SFC$ should be the power weighted average of all the main engines.

In case of a ship equipped with dual-fuel engine(s), the $C_F$ and $SFC$ should be calculated in accordance with paragraphs 2.1 and 2.7.

.5 $P_{AEeff(i)}$ is the auxiliary power reduction due to innovative electrical energy efficient technology measured at $P_{ME(i)}$.

.6 $P_{AE}$ is the required auxiliary engine power to supply normal maximum sea load including necessary power for propulsion machinery/systems and accommodation, e.g. main engine pumps, navigational systems and equipment and living on board, but excluding the power not for propulsion machinery/systems, e.g. thrusters, cargo pumps, cargo gear, ballast pumps, maintaining cargo, e.g. reefers and cargo hold fans, in the condition where the
ship engaged in voyage at the speed \((V_{ref})\) under the condition as mentioned in paragraph 2.2.

1. For ships with a total propulsion power
\[
\left( \sum ME_{MCR(i)} + \frac{\sum P_{PTI(i)}}{0.75} \right) \text{ of } 10,000 \text{ kW or above, } P_{AE} \text{ is defined as:}
\]

\[
P_{AE} \left( \sum ME_{MCR(i)} \geq 10,000 \text{ kW} \right) = 0.025 \times \left( \sum_{i=1}^{nME} ME_{MCR(i)} + \frac{\sum^{nPTI}_{i=1} P_{PTI(i)}}{0.75} \right) + 250
\]

2. For ships with a total propulsion power
\[
\left( \sum ME_{MCR(i)} + \frac{\sum P_{PTI(i)}}{0.75} \right) \text{ below } 10,000 \text{ kW, } P_{AE} \text{ is defined as:}
\]

\[
P_{AE} \left( \sum ME_{MCR(i)} < 10,000 \text{ kW} \right) = 0.05 \times \left( \sum_{i=1}^{nME} ME_{MCR(i)} + \frac{\sum^{nPTI}_{i=1} P_{PTI(i)}}{0.75} \right)
\]

3. For LNG carriers with a reliquiefaction system or compressor(s), designed to be used in normal operation and essential to maintain the LNG cargo tank pressure below the maximum allowable relief valve setting of a cargo tank in normal operation, the following terms should be added to above \(P_{AE}\) formula in accordance with 1, 2 or 3 as below:

1. For ships having re-liquefaction system:
\[
+ \text{CargoTankCapacity}_{LNG} \times BOR \times COP_{reliquefy} \times R_{reliquefy}
\]

Where:

\text{CargoTankCapacity}_{LNG}\text{ is the LNG Cargo Tank Capacity in m}^3.

\text{BOR}\text{ is the design rate of boil-off gas of entire ship per day, which is specified in the specification of the building contract.}
COP\textsubscript{reliquefy} is the coefficient of design power performance for reliquefying boil-off gas per unit volume, as follows:

\[
\text{COP}_{\text{reliquefy}} = \frac{425 (kg/m^3) \times 511 (kJ/kg)}{24 (h) \times 3600 (sec) \times \text{COP}_{\text{cooling}}}
\]

COP\textsubscript{cooling} is the coefficient of design performance of reliquefaction and 0.166 should be used. Another value calculated by the manufacturer and verified by the Administration or an organization recognized by the Administration may be used.

\(R_{\text{reliquefy}}\) is the ratio of boil-off gas (BOG) to be re-liquefied to entire BOG, calculated as follows.

\[
R_{\text{reliquefy}} = \frac{\text{BOG}_{\text{reliquefy}}}{\text{BOG}_{\text{total}}}
\]

.2 For LNG carriers with direct diesel driven propulsion system or diesel electric propulsion system, having compressor(s) which are used for supplying high-pressured gas derived from boil-off gas to the installed engines (typically intended for 2-stroke dual fuel engines):

\[
+ \text{COP}_{\text{comp}} \times \sum_{i=1}^{n\text{ME}} \frac{\text{SFC}_{\text{ME}(i)\text{, gasmode}} \times P_{\text{ME}(i)}}{1000}
\]

Where:

\text{COP}_{\text{comp}} is the design power performance of compressor and 0.33 (kWh/kg) should be used. Another value calculated by the manufacturer and verified by the Administration or an organization recognized by the Administration may be used.

.3 For LNG carriers with direct diesel driven propulsion system or diesel electric propulsion system, having compressor(s) which are used for supplying low-pressured gas derived from boil-off gas to the installed engines (typically intended for 4-stroke dual fuel engines):

\[
+ 0.02 \times \sum_{i=1}^{n\text{ME}} P_{\text{ME}(i)}^2
\]

For LNG carriers having diesel electric propulsion system, \(MPP_{\text{Motor}(i)}\) should be used instead \(MCR_{\text{ME}(i)}\) for \(P_{\text{AE}}\) calculation.

For LNG carriers having steam turbine propulsion system and of which electric power is primarily supplied by turbine generator closely integrated into the steam and feed water

\[2\text{ With regard to the factor of 0.02, it is assumed that the additional energy needed to compress BOG for supplying to a 4-stroke dual fuel engine is approximately equal to 2\% of } P_{\text{ME}} \text{ compared to the energy needed to compress BOG for supplying to a steam turbine.} \]
systems, \( P_{AE} \) may be treated as 0(zero) instead of taking into account electric load in calculating \( SFC_{SteamTurbine} \).

.4 For ship where the \( P_{AE} \) value calculated by paragraphs 2.5.6.1 to 2.5.6.3 is significantly different from the total power used at normal seagoing, e.g. in cases of passenger ships (see NOTE under the formula of EEDI), the \( P_{AE} \) value should be estimated by the consumed electric power (excluding propulsion) in conditions when the ship is engaged in a voyage at reference speed (\( V_{ref} \)) as given in the electric power table\(^3\), divided by the average efficiency of the generator(s) weighted by power (see appendix 2).

.6 \( V_{ref}, \) Capacity and \( P \) should be consistent with each other. As for LNG carries having diesel electric or steam turbine propulsion systems, \( V_{ref} \) is the relevant speed at 83% of \( MPP_{Motor} \) or \( MCR_{SteamTurbine} \) respectively.

.7 \( SFC \) is the certified specific fuel consumption, measured in g/kWh, of the engines or steam turbines.

.1 The subscripts \( ME(i) \) and \( AE(i) \) refer to the main and auxiliary engine(s), respectively. For engines certified to the E2 or E3 test cycles of the NO\(_X\) Technical Code 2008, the engine Specific Fuel Consumption (\( SFC_{ME(i)} \)) is that recorded in the test report included in a NO\(_X\) technical file for the engine(s) at 75% of MCR power of its torque rating. For engines certified to the D2 or C1 test cycles of the NO\(_X\) Technical Code 2008, the engine Specific Fuel Consumption (\( SFC_{AE(i)} \)) is that recorded on the test report included in a NO\(_X\) technical file at the engine(s) 50% of MCR power or torque rating. If gas fuel is used as primary fuel in accordance with paragraph 4.2.3 of the Guidelines on survey and certification of the energy efficiency design index (EEDI), \( SFC \) in gas mode should be used. In case that installed engine(s) have no approved NO\(_X\) Technical File tested in gas mode, the \( SFC \) of gas mode should be submitted by the manufacturer and confirmed by the verifier.

The \( SFC \) should be corrected to the value corresponding to the ISO standard reference conditions using the standard lower calorific value of the fuel oil (42,700kJ/kg), referring to ISO 15550:2002 and ISO 3046-1:2002.

For ships where the \( P_{AE} \) value calculated by paragraphs 2.5.6.1 to 2.5.6.3 is significantly different from the total power used at normal seagoing, e.g. conventional passenger ships, the Specific Fuel Consumption (\( SFC_{AE} \)) of the auxiliary generators is that recorded in the test report included in a NO\(_X\) technical file for the engine(s) at 75% of MCR power of its torque rating.

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\(^3\) The electric power table should be examined and validated by the verifier. Where ambient conditions affect any electrical load in the power table, such as that for heating ventilation and air conditioning systems, the contractual ambient conditions leading to the maximum design electrical load of the installed system for the ship in general should apply.
$SFC_{AE}$ is the power-weighted average among $SFC_{AE(i)}$ of the respective engines $i$.

For those engines which do not have a test report included in a NO$_X$ technical file because its power is below 130 kW, the $SFC$ specified by the manufacturer and endorsed by a competent authority should be used.

At the design stage, in case of unavailability of test report in the NO$_X$ file, the $SFC$ specified by the manufacturer and endorsed by a competent authority should be used.

For LNG driven engines of which $SFC$ is measured in kJ/kWh should be corrected to the $SFC$ value of g/kWh using the standard lower calorific value of the LNG (48,000 kJ/kg), referring to the 2006 IPCC Guidelines.

Reference lower calorific values of additional fuels are given in the table in paragraph 2.1 of these Guidelines. The reference lower calorific value corresponding to the conversion factor of the respective fuel should be used for calculation.

The $SFC_{SteamTurbine}$ should be calculated by manufacturer and verified by the Administration or an organization recognized by the Administration as follows:

$$SFC_{SteamTurbine} = \frac{\text{FuelConsumption}}{\sum_{i=1}^{n_{ME}} P_{ME(i)}}$$

Where:

.1 *Fuel consumption* is fuel consumption of boiler per hour (g/h). For ships of which electric power is primarily supplied by Turbine Generator closely integrated into the steam and feed water systems, not only $P_{ME}$ but also *electric loads* corresponding to paragraph 2.5.6 should be taken into account.

.2 The $SFC$ should be corrected to the value of LNG using the standard lower calorific value of the LNG (48,000 kJ/kg) at SNAME Condition (condition standard; air temperature $24^\circ$C, inlet temperature of fan $38^\circ$C, sea water temperature $24^\circ$C).

.3 In this correction, the difference of the boiler efficiency based on lower calorific value between test fuel and LNG should be taken into account.
.8 $f_j$ is a correction factor to account for ship specific design elements:

.1 The power correction factor, $f_j$, for ice-classed ships should be taken as the greater value of $f_{j0}$ and $f_{j,min}$ as tabulated in table 1 but not greater than $f_{j,max} = 1.0$.

For further information on approximate correspondence between ice classes, see HELCOM Recommendation 25/7.

<table>
<thead>
<tr>
<th>Ship type</th>
<th>$f_{j0}$</th>
<th>$f_{j,min}$ depending on the ice class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>IA Super</td>
</tr>
<tr>
<td>Tanker</td>
<td>$\frac{0.308 L_{pp}}{\sum_{i=1}^{nME} P_{ME(i)}}$</td>
<td>0.15$L_{pp}$</td>
</tr>
<tr>
<td>Bulk carrier</td>
<td>$\frac{0.639 L_{pp}}{\sum_{i=1}^{nME} P_{ME(i)}}$</td>
<td>0.47$L_{pp}$</td>
</tr>
<tr>
<td>General cargo ship</td>
<td>$\frac{0.0227 \cdot L_{pp}}{\sum_{i=1}^{nME} P_{ME(i)}}$</td>
<td>0.31$L_{pp}$</td>
</tr>
<tr>
<td>Refrigerated cargo ships</td>
<td>$\frac{0.639 L_{pp}}{\sum_{i=1}^{nME} P_{ME(i)}}$</td>
<td>0.47$L_{pp}$</td>
</tr>
</tbody>
</table>

.2 The factor $f_j$ for shuttle tankers with propulsion redundancy should be $f_j = 0.77$. This correction factors applies to shuttle tankers with propulsion redundancy between 80,000 and 160,000 dwt. Shuttle tankers with propulsion redundancy are tankers used for loading of crude oil from offshore installations equipped with dual-engine and twin-propellers need to meet the requirements for dynamic positioning and redundancy propulsion class notation.

.3 For ro-ro cargo and ro-ro passenger ships $f_{jRoRo}$ is calculated as follows:

$$f_{jRoRo} = \frac{1}{F_{n_k}^\alpha \left( \frac{L_{pp}}{B_k} \right)^\beta \left( \frac{B_k}{d_k} \right)^\gamma \left( \frac{L_{pp}}{V^{1/3}} \right)^\delta}; \quad \text{If } f_{jRoRo} > 1 \text{ then } f_j = 1$$

where the Froude number, $F_{n_k}$, is defined as:

$$F_{n_k} = \frac{0.5144 \cdot V_{ref}}{\sqrt{L_{pp} \cdot g}}$$

---

4 HELCOM Recommendation 25/7 may be found at [http://www.helcom.fi](http://www.helcom.fi).
and the exponents $\alpha$, $\beta$, $\gamma$ and $\delta$ are defined as follows:

<table>
<thead>
<tr>
<th>Ship type</th>
<th>Exponent:</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
<th>$\delta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ro-ro cargo ship</td>
<td></td>
<td>2.00</td>
<td>0.50</td>
<td>0.75</td>
<td>1.00</td>
</tr>
<tr>
<td>Ro-ro passenger ship</td>
<td></td>
<td>2.50</td>
<td>0.75</td>
<td>0.75</td>
<td>1.00</td>
</tr>
</tbody>
</table>

.4 The factor $f_j$ for general cargo ships is calculated as follows:

$$f_j = \frac{0.174}{F_{n_V}^{2.3} \cdot C_b^{0.3}}$$

; If $f_j > 1$ then $f_j = 1$

Where

$$F_{n_V} = \frac{0.5144 \cdot V_{ref}}{\sqrt{g \cdot \nabla^2}}$$

; If $F_{n_V} > 0.6$ then $F_{n_V} = 0.6$

and

$$C_b = \frac{\nabla}{L_{pp} \cdot B_s \cdot d_s}$$

.5 For other ship types, $f_j$ should be taken as 1.0.

.9 $f_w$ 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 determined as follows:

.1 for the attained EEDI calculated under regulations 20 and 21 of MARPOL Annex VI, $f_w$ is 1.00;

.2 when $f_w$ is calculated according to the subparagraph .2.1 or .2.2 below, the value for attained EEDI calculated by the formula in paragraph 2 using the obtained $f_w$ should be referred to as "attained EEDI weather";

.1 $f_w$ can be determined by conducting the ship specific simulation on its performance at representative sea conditions. The simulation methodology should be based on the Guidelines developed by the Organization and the method and outcome for an individual ship should be verified by the Administration or an organization recognized by the Administration; and
in cases where a simulation is not conducted, \( f_w \) should be taken from the "Standard \( f_w \)" table/curve. A "Standard \( f_w \)" table/curve is provided in the Guidelines\(^5\) for each ship type defined in regulation 2 of MARPOL Annex VI, and expressed as a function of capacity (e.g. deadweight). The "Standard \( f_w \)" table/curve is based on data of actual speed reduction of as many existing ships as possible under the representative sea condition.

\( f_w \) and attained \( EEDI_{\text{weather}} \), if calculated, with the representative sea conditions under which those values are determined, should be indicated in the EEDI Technical File to distinguish it from the attained EEDI calculated under regulations 20 and 21 of MARPOL Annex VI.

\( f_{\text{eff}(i)} \) is the availability factor of each innovative energy efficiency technology. \( f_{\text{eff}(i)} \) for waste energy recovery system should be one (1.0)\(^6\).

\( f_i \) is the capacity factor for any technical/regulatory limitation on capacity, and should be assumed to be one (1.0) if no necessity of the factor is granted.

The capacity correction factor, \( f_i \) for ice-classed ships should be taken as the lesser value of \( f_{i0} \) and \( f_{i,\text{max}} \) as tabulated in Table 2, but not less than \( f_{i,\text{min}} = 1.0 \). For further information on approximate correspondence between ice classes, see HELCOM Recommendation 25/7\(^7\).

### Table 2: Capacity correction factor \( f_i \) for ice-classed ships

<table>
<thead>
<tr>
<th>Ship type</th>
<th>( f_{i0} )</th>
<th>( f_{i,\text{max}} ) depending on the ice class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>IA Super</td>
</tr>
<tr>
<td>Tanker</td>
<td>( \frac{0.00138 \cdot L_{pp}}{\text{capacity}} )</td>
<td>2.10(L_{pp} )−0.11</td>
</tr>
<tr>
<td>Bulk carrier</td>
<td>( \frac{0.00403 \cdot L_{pp}}{\text{capacity}} )</td>
<td>2.10(L_{pp} )−0.11</td>
</tr>
<tr>
<td>General cargo ship</td>
<td>( \frac{0.0377 \cdot L_{pp}}{\text{capacity}} )</td>
<td>2.18(L_{pp} )−0.11</td>
</tr>
<tr>
<td>Containership</td>
<td>( \frac{0.1033 \cdot L_{pp}}{\text{capacity}} )</td>
<td>2.10(L_{pp} )−0.11</td>
</tr>
<tr>
<td>Gas carrier</td>
<td>( \frac{0.0474 \cdot L_{pp}}{\text{capacity}} )</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Note:** Containership capacity is defined as 70% of the DWT.

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\(^5\) Refer to Interim Guidelines for the calculation of the coefficient \( f_w \) for decrease in ship speed in a representative sea condition for trial use, approved by the Organization and circulated by MEPC.1/Circ.796.

\(^6\) EEDI calculation should be based on the normal seagoing condition outside Emission Control Area designated under regulation 13.6 of MARPOL ANNEX VI.

\(^7\) HELCOM Recommendation 25/7 may be found at [http://www.helcom.fi](http://www.helcom.fi).
.2 \( f_{VSE} \) for ship specific voluntary structural enhancement is expressed by the following formula:

\[
f_{VSE} = \frac{DWT_{\text{reference design}}}{DWT_{\text{enhanced design}}}
\]

where:

\[
DWT_{\text{reference design}} = \Delta_{\text{ship}} - t_{\text{lightweight}}_{\text{reference design}}
\]

\[
DWT_{\text{enhanced design}} = \Delta_{\text{ship}} - t_{\text{lightweight}}_{\text{enhanced design}}
\]

For this calculation the same displacement (\( \Delta \)) for reference and enhanced design should be taken.

DWT before enhancements (\( DWT_{\text{reference design}} \)) is the deadweight prior to application of the structural enhancements. DWT after enhancements (\( DWT_{\text{enhanced design}} \)) is the deadweight following the application of voluntary structural enhancement. A change of material (e.g. from aluminum alloy to steel) between reference design and enhanced design should not be allowed for the \( f_{VSE} \) calculation. A change in grade of the same material (e.g. in steel type, grades, properties and condition) should also not be allowed.

In each case, two sets of structural plans of the ship should be submitted to the verifier for assessment. One set for the ship without voluntary structural enhancement; the other set for the same ship with voluntary structural enhancement (alternatively, one set of structural plans of the reference design with annotations of voluntary structural enhancement should also be acceptable). Both sets of structural plans should comply with the applicable regulations for the ship type and intended trade.

.3 for bulk carriers and oil tankers, built in accordance with the Common Structural Rules (CSR) of the classification societies and assigned the class notation CSR, the following capacity correction factor \( f_{CSR} \) should apply:

\[
f_{CSR} = 1 + (0.08 \cdot \frac{LWT_{CSR}}{DWT_{CSR}})
\]

Where \( DWT_{CSR} \) is the deadweight determined by paragraph 2.4 and \( LWT_{CSR} \) is the light weight of the ship.

.4 for other ship types, \( f_i \) should be taken as one (1.0).

.12 \( f_c \) is the cubic capacity correction factor and should be assumed to be one (1.0) if no necessity of the factor is granted.

.1 for chemical tankers, as defined in regulation 1.16.1 of MARPOL Annex II, the following cubic capacity correction factor \( f_c \) should apply:

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8 Structural and/or additional class notations such as, but not limited to, "strengthened for discharge with grabs" and "strengthened bottom for loading/unloading aground", which result in a loss of deadweight of the ship, are also seen as examples of "voluntary structural enhancements".
\( f_c = R^{-0.7} - 0.014, \) where \( R \) is less than 0.98
or
\( f_c = 1.000, \) where \( R \) is 0.98 and above;

where: \( R \) is the capacity ratio of the deadweight of the ship (tonnes) as determined by paragraph 2.4 divided by the total cubic capacity of the cargo tanks of the ship (m\(^3\)).

for gas carriers having direct diesel driven propulsion system constructed or adapted and used for the carriage in bulk of liquefied natural gas, the following cubic capacity correction factor \( f_{cLNG} \) should apply:

\[ f_{cLNG} = R^{-0.56} \]

where: \( R \) is the capacity ratio of the deadweight of the ship (tonnes) as determined by paragraph 2.4 divided by the total cubic capacity of the cargo tanks of the ship (m\(^3\)).

Note: This factor is applicable to LNG carriers defined as gas carriers in regulation 2.26 of MARPOL Annex VI and should not be applied to LNG carriers defined in regulation 2.38 of MARPOL Annex VI.

For ro-ro passenger ships having a DWT/GT-ratio of less than 0.25, the following cubic capacity correction factor, \( f_{cRopax} \), should apply:

\[ f_{cRopax} = \left( \frac{DWT}{GT} \right)^{-0.8} \]

Where DWT is the Capacity and GT is the gross tonnage in accordance with the International Convention of Tonnage Measurement of Ships 1969, annex I, regulation 3.

For bulk carriers having \( R \) of less than 0.55 (e.g. wood chip carriers), the following cubic capacity correction factor, \( f_{c bulk carriers designed to carry light cargoes} \), should apply:

\[ f_{c bulk carriers designed to carry light cargoes} = R^{-0.15} \]

where: \( R \) is the capacity ratio of the deadweight of the ship (tonnes) as determined by paragraph 2.4 divided by the total cubic capacity of the cargo holds of the ship (m\(^3\)).

Length between perpendiculars, \( L_{pp} \), means 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that were greater. In ships designed with a rake of keel the waterline on which this length is measured should be parallel to the designed waterline. \( L_{pp} \) should be measured in metres.

\( f_i \) is the factor for general cargo ships equipped with cranes and other cargo-related gear to compensate in a loss of deadweight of the ship.
\[ f_t = f_{\text{cranes}} \cdot f_{\text{sideloader}} \cdot f_{\text{ro-ro}} \]

- \( f_{\text{cranes}} \) = 1 if no cranes are present.
- \( f_{\text{sideloader}} \) = 1 if no side loaders are present.
- \( f_{\text{ro-ro}} \) = 1 if no ro-ro ramp is present.

**Definition of \( f_{\text{cranes}} \):**

\[
f_{\text{cranes}} = 1 + \frac{\sum_{n=1}^{N}(0.0519 \cdot SWL_n \cdot Reach_n + 32.11)}{\text{Capacity}}
\]

where:

- \( SWL \) = Safe Working Load, as specified by crane manufacturer in metric tonnes
- \( Reach \) = Reach at which the Safe Working Load can be applied in metres
- \( N \) = Number of cranes

For other cargo gear such as side loaders and ro-ro ramps, the factor should be defined as follows:

\[
f_{\text{sideloader}} = \frac{\text{Capacity}_{\text{No sideloader}}}{\text{Capacity}_{\text{sideloader}}}
\]

\[
f_{\text{ro-ro}} = \frac{\text{Capacity}_{\text{No ro-ro}}}{\text{Capacity}_{\text{ro-ro}}}
\]

The weight of the side loaders and ro-ro ramps should be based on a direct calculation, in analogy to the calculations as made for factor \( f_{\text{vase}} \).

.15 Summer load line draught, \( d_s \), is the vertical distance, in metres, from the moulded baseline at mid-length to the waterline corresponding to the summer freeboard draught to be assigned to the ship.

.16 Breadth, \( B_s \), is the greatest moulded breadth of the ship, in metres, at or below the load line draught, \( d_s \).

.17 Volumetric displacement, \( \nabla \), in cubic metres \( (m^3) \), is the volume of the moulded displacement of the ship, excluding appendages, in a ship with a metal shell, and is the volume of displacement to the outer surface of the hull in a ship with a shell of any other material, both taken at the summer load line draught, \( d_s \), as stated in the approved stability booklet/loading manual.

.18 \( g \) is the gravitational acceleration, \( 9.81 \text{m/s}^2 \).
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.
APPENDIX 2

GUIDELINES FOR THE DEVELOPMENT OF ELECTRIC POWER TABLES FOR EEDI (EPT-EEDI)

1 Introduction

This appendix contains a guideline for the document "Electric power table for EEDI" which is similar to the actual shipyards' load balance document, utilizing well defined criteria, providing standard format, clear loads definition and grouping, standard load factors, etc. A number of new definitions (in particular the "groups") are introduced, giving an apparent greater complexity to the calculation process. However, this intermediate step to the final calculation of $P_{AE}$ stimulates all the parties to a deep investigation through the global figure of the auxiliary load, allowing comparisons between different ships and technologies and eventually identifying potential efficiencies improvements.

2 Auxiliary load power definition

$P_{AE}$ is to be calculated as indicated in paragraph 2.5.6 of the Guidelines, together with the following additional three conditions:

.1 non-emergency situations (e.g. "no fire", "no flood", "no blackout", "no partial blackout");
.2 evaluation time frame of 24 hours (to account loads with intermittent use); and
.3 ship fully loaded with passengers and/or cargo and crew.

3 Definition of the data to be included in the electric power table for EEDI

The electric power table for EEDI calculation should contain the following data elements, as appropriate:

.1 Load's group;
.2 Load's description;
.3 Load's identification tag;
.4 Load's electric circuit Identification;
.5 Load's mechanical rated power $P_m$ (kW);
.6 Load's electric motor rated output power (kW);
.7 Load's electric motor efficiency $\eta$ (/);
.8 Load's Rated electric power $P_r$ (kW);
.9 Service factor of load $k_l$ (/);
.10 Service factor of duty $k_d$ (/);
.11 Service factor of time $k_t$ (/);
.12 Service total factor of use $k_u$ (/), where $k_u = k_l \cdot k_d \cdot k_t$;
.13 Load's necessary power $P_{load}$ (kW), where $P_{load} = P_r \cdot k_u$;
.14 Notes;
.15 Group's necessary power (kW); and
.16 Auxiliaries load's power $P_{AE}$ (kW).
4 Data to be included in the electric power table for EEDI

Load groups

4.1 The loads are divided into defined groups, allowing a proper breakdown of the auxiliaries. This eases the verification process and makes it possible to identify those areas where load reductions might be possible. The groups are listed below:

.1 A – Hull, deck, navigation and safety services;
.2 B – Propulsion service auxiliaries;
.3 C – Auxiliary engine and main engine services;
.4 D – Ship’s general services;
.5 E – Ventilation for engine-rooms and auxiliaries room;
.6 F – Air conditioning services;
.7 G – Galleys, refrigeration and laundries services;
.8 H – Accommodation services;
.9 I – Lighting and socket services;
.10 L – Entertainment services;
.11 N – Cargo loads; and
.12 M – Miscellaneous.

All the ship's loads should be delineated in the document, excluding only $PA_{eff}$, the shaft motors and shaft motors chain (while the propulsion services auxiliaries are partially included below in paragraph 4.1.2 B). Some loads (i.e. thrusters, cargo pumps, cargo gear, ballast pumps, maintaining cargo, reefers and cargo hold fans) still are included in the group for sake of transparency, however their service factor is zero in order to comply with rows 4 and 5 of paragraph 2.5.6 of the Guidelines, therefore making it easier to verify that all the loads have been considered in the document and there are no loads left out of the measurement.

4.1.1 A – Hull, deck, navigation and safety services

.1 loads included in the hull services typically are: ICCP systems, mooring equipment, various doors, ballasting systems, bilge systems, stabilizing equipment, etc. Ballasting systems are indicated with service factor equal to zero to comply with row 5 of paragraph 2.5.6 of the Guidelines;

.2 loads included in the deck services typically are: deck and balcony washing systems, rescue systems, cranes, etc.;

.3 loads included in the navigation services typically are: navigation systems, navigation's external and internal communication systems, steering systems, etc.; and

.4 loads included in the safety services typically are: active and passive fire systems, emergency shutdown systems, public address systems, etc.

4.1.2 B – Propulsion service auxiliaries

This group typically includes: propulsion secondary cooling systems such as LT cooling pumps dedicated to shaft motors, LT cooling pumps dedicated to propulsion converters, propulsion UPSs, etc. Propulsion service loads do not include shaft motors ($PT_{ii}$) and the auxiliaries which are part of them (shaft motor own cooling fans and pump, etc.) and the shaft motor chain losses and auxiliaries which are part of them (i.e. shaft motor converters including relevant
auxiliaries such as converter own cooling fans and pumps, shaft motor transformers including relevant auxiliaries losses such as propulsion transformer own cooling fans and pumps, shaft motor harmonic filter including relevant auxiliaries losses, shaft motor excitation system including the relevant auxiliaries consumed power, etc.). Propulsion service auxiliaries include manoeuvring propulsion equipment such as manoeuvring thrusters and their auxiliaries whose service factor is to be set to zero.

4.1.3 C – Auxiliary engine and main engine services

This group includes: cooling systems, i.e. pumps and fans for cooling circuits dedicated to alternators or propulsion shaft engines (seawater, technical water dedicated pumps, etc.), lubricating and fuel systems feeding, transfer, treatment and storage, ventilation system for combustion air supply, etc.

4.1.4 D – Ship’s general services

This group includes loads which provide general services which can be shared between shaft motor, auxiliary engines and main engine and accommodation support systems. Loads typically included in this group are: cooling systems, i.e. pumping seawater, technical water main circuits, compressed air systems, fresh water generators, automation systems, etc.

4.1.5 E – Ventilation for engine-rooms and auxiliaries room

This group includes all fans providing ventilation for engine-rooms and auxiliary rooms that typically are: engine-rooms cooling supply-exhaust fans, auxiliary rooms supply and exhaust fans. All the fans serving accommodation areas or supplying combustion air are not included in this group. This group does not include cargo hold fans and garage supply and exhaust fans.

4.1.6 F – Air conditioning services

All loads that make up the air conditioning service that typically are: air conditioning chillers, air conditioning cooling and heating fluids transfer and treatment, air conditioning's air handling units ventilation, air conditioning re-heating systems with associated pumping, etc. The air conditioning chillers service factor of load, service factor of time and service factor of duty are to be set as 1 ($k_l=1$, $k_t=1$ and $k_d=1$) in order to avoid the detailed validation of the heat load dissipation document (i.e. the chiller’s electric motor rated power is to be used). However, $k_d$ is to represent the use of spare chillers (e.g. four chillers are installed and one out four is spare then $k_d=0$ for the spare chiller and $k_d=1$ for the remaining three chillers), but only when the number of spare chillers is clearly demonstrated via the heat load dissipation document.

4.1.7 G – Galley, refrigeration and laundries services

All loads related to the galleys, pantries refrigeration and laundry services that typically are: galleys various machines, cooking appliances, galleys’ cleaning machines, galleys auxiliaries, refrigerated room systems including refrigeration compressors with auxiliaries, air coolers, etc.

4.1.8 H – Accommodation services

All loads related to the accommodation services of passengers and crew that typically are: crew and passengers' transportation systems, i.e. lifts, escalators, etc. environmental services, i.e. black and grey water collecting, transfer, treatment, storage, discharge, waste systems including collecting, transfer, treatment, storage, etc. accommodation fluids transfers, i.e. sanitary hot and cold water pumping, etc., treatment units, pools systems, saunas, gym equipment, etc.
4.1.9 I – Lighting and socket services

All loads related to the lighting, entertainment and socket services. As the quantity of lighting circuits and sockets within the ship may be significantly high, it is not practically feasible to list all the lighting circuits and points in the EPT for EEDI. Therefore circuits should be grouped into subgroups aimed to identify possible improvements of efficient use of power. The subgroups are:

.1 Lighting for 1) cabins, 2) corridors, 3) technical rooms/stairs, 4) public spaces/stairs, 5) engine-rooms and auxiliaries' room, 6) external areas, 7) garages and 8) cargo spaces. All should be divided by main vertical zones; and

.2 Power sockets for 1) cabins, 2) corridors, 3) technical rooms/stairs, 4) public spaces/stairs, 5) engine-rooms and auxiliaries' room, 6) garages and 7) cargo spaces. All should be divided by main vertical zones.

The calculation criteria for complex groups (e.g. cabin lighting and power sockets) subgroups are to be included via an explanatory note, indicating the load composition (e.g. lights of typical cabins, TV, hair dryer, fridge, etc., typical cabins).

4.1.10 L – Entertainment services

This group includes all loads related to entertainment services, typically: public spaces audio and video equipment, theatre stage equipment, IT systems for offices, video games, etc.

4.1.11 N – Cargo loads

This group will contain all cargo loads such as cargo pumps, cargo gear, maintaining cargo, cargo reefers loads, cargo hold fans and garage fans for sake of transparency. However, the service factor of this group is to be set to zero.

4.1.12 M – Miscellaneous

This group will contain all loads which have not been associated to the above-mentioned groups but still are contributing to the overall load calculation of the normal maximum sea load.

**Loads description**

4.2 This identifies the loads (for example "seawater pump").

**Loads identification tag**

4.3 This tag identifies the loads according to the shipyard’s standards tagging system. For example, the "PTI1 fresh water pump" identification tag is "SYYIA/C" for an example ship and shipyard. This data provides a unique identifier for each load.

**Loads electric circuit Identification**

4.4 This is the tag of the electric circuit supplying the load. Such information allows the data validation process.
Loads mechanical rated power "Pm"

4.5 This data is to be indicated in the document only when the electric load is made by an electric motor driving a mechanical load (for example a fan, a pump, etc.). This is the rated power of the mechanical device driven by an electric motor.

Loads electric motor rated output power (kW)

4.6 The output power of the electric motor as per maker's name plate or technical specification. This data does not take part of the calculation but is useful to highlight potential over rating of the combination motor-mechanical load.

Loads electric motor efficiency "e" (/)

4.7 This data is to be entered in the document only when the electric load is made by an electric motor driving a mechanical load.

Loads rated electric power "Pr" (kW)

4.8 Typically the maximum electric power absorbed at the load electric terminals at which the load has been designed for its service, as indicated on the maker's name plate and/or maker's technical specification. When the electric load is made by an electric motor driving a mechanical load the load's rated electric power is: $Pr = \frac{Pm}{e} \text{ (kW)}$.

Service factor of load "kl" (/)

4.9 Provides the reduction from the loads rated electric power to loads necessary electric power that is to be made when the load absorb less power than its rated power. For example, in case of electric motor driving a mechanical load, a fan could be designed with some power margin, leading to the fact that the fan rated mechanical power exceeds the power requested by the duct system it serves. Another example is when a pump rated power exceed the power needed for pumping in its delivery fluid circuit. Another example in case of electric self-regulating semi-conductors electric heating system is oversized and the rated power exceeds the power absorbed, according a factor $kl$.

Service factor of duty "kd" (/)

4.10 Factor of duty is to be used when a function is provided by more than one load. As all loads are to be included in the EPT for EEDI, this factor provides a correct summation of the loads. For example when two pumps serve the same circuit and they run in duty/stand-by their $Kd$ factor will be $\frac{1}{2}$ and $\frac{1}{2}$. When three compressors serves the same circuit and one runs in duty and two in stand-by, then $kd$ is $\frac{1}{3}$, $\frac{1}{3}$ and $\frac{1}{3}$.

Service factor of time "kt" (/)

4.11 A factor of time based on the shipyard's evaluation about the load duty along 24 hours of ship's navigation as defined at paragraph 3. For example the Entertainment loads operate at their power for a limited period of time, 4 hours out 24 hours; as a consequence $kt=\frac{4}{24}$. For example, the seawater cooling pumps operate at their power all the time during the navigation at $V_{ref}$. As a consequence $kt=1$. 

https://edocs.imo.org/Final Documents/English/MEPC.1-CIRC.866 (E).docx
Service total factor of use "ku" (/)

4.12 The total factor of use that takes into consideration all the service factors: \( ku=kl\cdot kd\cdot kt. \)

Loads necessary power "Pload" (kW)

4.13 The individual user contribution to the auxiliary load power is \( P_{load}=Pr\cdot ku. \)

Notes

4.14 A note, as free text, could be included in the document to provide explanations to the verifier.

Groups necessary power (kW)

4.15 The summation of the "Loads necessary power" from group A to N. This is an intermediate step which is not strictly necessary for the calculation of \( PAE. \) However, it is useful to allow a quantitative analysis of the \( PAE, \) providing a standard breakdown for analysis and potential improvements of energy saving.

Auxiliaries load's power \( PAE (kW) \)

4.16 Auxiliaries load's power \( PAE\) is the summation of the "Load's necessary power" of all the loads divided by the average efficiency of the generator(s) weighted by power.

\[
PAE=\sum \frac{P_{load}(i)}{\text{average efficiency of the generator(s) weighted by power}}
\]

Layout and organization of the data indicated in the electric power table for EEDI

5 The document "Electric power table for EEDI" is to include general information (i.e. ship's name, project name, document references, etc.) and a table with:

1. one row containing column titles;
2. one Column for table row ID;
3. one Column for the groups identification ("A", "B", etc.) as indicated in paragraphs 4.1.1 to 4.1.12 of this guideline;
4. one Column for the group descriptions as indicated in paragraphs 4.1.1 to 4.1.12 of this guideline;
5. one column each for items in paragraphs 4.2 to 4.14 of this guideline (e.g. "load tag", etc.);
6. one row dedicated to each individual load;
7. the summation results (i.e. summation of powers) including data from paragraphs 4.15 to 4.16 of this guideline; and
8. explanatory notes.

An example of an electric power table for EEDI for a cruise postal ship which transports passengers and has a car garage and reefer holds for fish trade transportation is indicated below. The data indicated and the type of ship is for reference only.
<table>
<thead>
<tr>
<th>ID</th>
<th>Load description</th>
<th>Load Identification</th>
<th>Load electric circuit rated power [kW]</th>
<th>Load mechanical input rated power [kW]</th>
<th>Load electric motor efficiency [%]</th>
<th>Load Rated power [kW]</th>
<th>service factor of load “Fm”</th>
<th>service factor of duty “Fd”</th>
<th>service factor of use “Fu”</th>
<th>service factor of use “Fp”</th>
<th>Load necessary for “Phat” [kW]</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>A. High pressure water feed</td>
<td>WW</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

PAE = 3764/[weighted average efficiency of generator(s)] [kW]

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APPENDIX 3

A GENERIC AND SIMPLIFIED MARINE POWER PLANT
FOR A CRUISE PASSENGER SHIPS HAVING NON-CONVENTIONAL PROPULSION

Note: Symbols for plus (+) and minus (−) indicate CO₂ contribution to EEDI formula.
APPENDIX 4

EEDI CALCULATION EXAMPLES FOR USE OF DUAL FUEL ENGINES

Case 1: Standard Kamsarmax ship, one main engine (MDO), standard auxiliary engines (MDO), no shaft generator:

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>MCR rating of main engine</td>
<td>kW</td>
<td>9930</td>
</tr>
<tr>
<td>2</td>
<td>Capacity</td>
<td>Deadweight of the ship at summer load draft</td>
<td>DWT</td>
<td>81200</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;ref&lt;/sub&gt;</td>
<td>Ships speed as defined in EEDI regulation</td>
<td>kn</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>0.75 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>7447.5</td>
</tr>
<tr>
<td>5</td>
<td>P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>0.05 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>496.5</td>
</tr>
<tr>
<td>6</td>
<td>C&lt;sub&gt;FM&lt;/sub&gt;E</td>
<td>C&lt;sub&gt;f&lt;/sub&gt; factor of Main engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>7</td>
<td>C&lt;sub&gt;FAE&lt;/sub&gt;</td>
<td>C&lt;sub&gt;f&lt;/sub&gt; factor of Auxiliary engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>8</td>
<td>SFC&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>Specific fuel consumption of at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>165</td>
</tr>
<tr>
<td>9</td>
<td>SFC&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>Specific fuel consumption of at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>210</td>
</tr>
<tr>
<td>10</td>
<td>EEDI</td>
<td>((P&lt;sub&gt;ME&lt;/sub&gt; x C&lt;sub&gt;FME&lt;/sub&gt; x SFC&lt;sub&gt;ME&lt;/sub&gt;) + (P&lt;sub&gt;AE&lt;/sub&gt; x C&lt;sub&gt;FAE&lt;/sub&gt; x SFC&lt;sub&gt;AE&lt;/sub&gt;)) / (V&lt;sub&gt;ref&lt;/sub&gt; x Capacity)</td>
<td>gCO&lt;sub&gt;2&lt;/sub&gt;/tnm</td>
<td>3.76</td>
</tr>
</tbody>
</table>

Case 2: LNG is regarded as the "primary fuel" if dual-fuel main engine and dual-fuel auxiliary engine (LNG, pilot fuel MDO; no shaft generator) are equipped with bigger LNG tanks:
### Table 1: Calculations and Parameters

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>MCR rating of main engine</td>
<td>kW</td>
<td>9930</td>
</tr>
<tr>
<td>2</td>
<td>Capacity</td>
<td>Deadweight of the ship at summer load draft</td>
<td>DWT</td>
<td>81200</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;ref&lt;/sub&gt;</td>
<td>Ships speed as defined in EEDI regulation</td>
<td>kn</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>0.75 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>7447.5</td>
</tr>
<tr>
<td>5</td>
<td>P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>0.05 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>496.5</td>
</tr>
<tr>
<td>6</td>
<td>CF_Pilotfuel</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of pilot fuel for dual fuel ME using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>7</td>
<td>CF_AE_Pilotfuel</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of pilot fuel for Auxiliary engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>8</td>
<td>CF_LNG</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of dual fuel engine using LNG</td>
<td>-</td>
<td>2.75</td>
</tr>
<tr>
<td>9</td>
<td>SFC&lt;sub&gt;ME_Pilotfuel&lt;/sub&gt;</td>
<td>Specific fuel consumption of pilot fuel for dual fuel ME at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>SFC&lt;sub&gt;AE_Pilotfuel&lt;/sub&gt;</td>
<td>Specific fuel consumption of pilot fuel for dual fuel AE at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>SFC&lt;sub&gt;ME_LNG&lt;/sub&gt;</td>
<td>Specific fuel consumption of ME using LNG at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>136</td>
</tr>
<tr>
<td>12</td>
<td>SFC&lt;sub&gt;AE_LNG&lt;/sub&gt;</td>
<td>Specific fuel consumption of AE using LNG at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>160</td>
</tr>
<tr>
<td>13</td>
<td>V&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>LNG tank capacity on board</td>
<td>m³</td>
<td>3100</td>
</tr>
<tr>
<td>14</td>
<td>V&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Heavy fuel oil tank capacity on board</td>
<td>m³</td>
<td>1200</td>
</tr>
<tr>
<td>15</td>
<td>V&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Marine diesel oil tank capacity on board</td>
<td>m³</td>
<td>400</td>
</tr>
<tr>
<td>16</td>
<td>ρ&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Density of LNG</td>
<td>kg/m³</td>
<td>450</td>
</tr>
<tr>
<td>17</td>
<td>ρ&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Density of heavy fuel oil</td>
<td>kg/m³</td>
<td>991</td>
</tr>
<tr>
<td>18</td>
<td>ρ&lt;sub&gt;DDO&lt;/sub&gt;</td>
<td>Density of Marine diesel oil</td>
<td>kg/m³</td>
<td>900</td>
</tr>
<tr>
<td>19</td>
<td>LCV&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Low calorific value of LNG</td>
<td>kJ/kg</td>
<td>48000</td>
</tr>
<tr>
<td>20</td>
<td>LCV&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Low calorific value of heavy fuel oil</td>
<td>kJ/kg</td>
<td>40200</td>
</tr>
<tr>
<td>21</td>
<td>LCV&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Low calorific value of marine diesel oil</td>
<td>kJ/kg</td>
<td>42700</td>
</tr>
<tr>
<td>22</td>
<td>K&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Filling rate of LNG tank</td>
<td>-</td>
<td>0.95</td>
</tr>
<tr>
<td>23</td>
<td>K&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Filling rate of heavy fuel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>24</td>
<td>K&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Filling rate of marine diesel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>25</td>
<td>f&lt;sub&gt;Dgas&lt;/sub&gt;</td>
<td>( \frac{\text{P}<em>{\text{ME}} + \text{P}</em>{\text{AE}}}{\text{P}<em>{\text{ME}} + \text{P}</em>{\text{AE}} + \text{V}<em>{\text{ref}} \times \text{SFC}\text{ME_Pilotfuel} + \text{V}</em>{\text{ref}} \times \text{SFC}\text{AE_Pilotfuel} + \text{V}<em>{\text{ref}} \times \text{SFC}\text{ME_LNG} + \text{V}</em>{\text{ref}} \times \text{SFC}\text{AE_LNG}} )</td>
<td>-</td>
<td>0.5068</td>
</tr>
<tr>
<td>26</td>
<td>EEDI</td>
<td>( \frac{(\text{P}_{\text{ME}} \times (\text{C}_F \text{Pilotfuel} \times \text{SFC}\text{ME_Pilotfuel} + \text{C}<em>F \text{LNG} \times \text{SFC}\text{ME_LNG}) + \text{P}</em>{\text{AE}} \times (\text{C}_F \text{Pilotfuel} \times \text{SFC}\text{AE_Pilotfuel} + \text{C}<em>F \text{LNG} \times \text{SFC}\text{AE_LNG}))}{(\text{V}</em>{\text{ref}} \times \text{Capacity})} )</td>
<td>gCO&lt;sub&gt;2&lt;/sub&gt;/tnm</td>
<td>2.78</td>
</tr>
</tbody>
</table>
Case 3: LNG is not regarded as the "primary fuel" if dual-fuel main engine and dual-fuel auxiliary engine (LNG, pilot fuel MDO; no shaft generator) are equipped with smaller LNG tanks:

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>MCR rating of main engine</td>
<td>kW</td>
<td>9930</td>
</tr>
<tr>
<td>2</td>
<td>Capacity</td>
<td>Deadweight of the ship at summer load draft</td>
<td>DWT</td>
<td>81200</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;ref&lt;/sub&gt;</td>
<td>Ships speed as defined in EEDI regulation</td>
<td>kn</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>0.75 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>7447.5</td>
</tr>
<tr>
<td>5</td>
<td>P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>0.05 x MCR&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>kW</td>
<td>496.5</td>
</tr>
<tr>
<td>6</td>
<td>C&lt;sub&gt;FP Pilot fuel&lt;/sub&gt;</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of pilot fuel for dual fuel ME using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>7</td>
<td>C&lt;sub&gt;FAE Pilot fuel&lt;/sub&gt;</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of pilot fuel for Auxiliary engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>8</td>
<td>C&lt;sub&gt;FLNG&lt;/sub&gt;</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of dual fuel engine using LNG</td>
<td>-</td>
<td>2.75</td>
</tr>
<tr>
<td>9</td>
<td>C&lt;sub&gt;FMDO&lt;/sub&gt;</td>
<td>C&lt;sub&gt;F&lt;/sub&gt; factor of dual fuel ME/AE engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>10</td>
<td>SFC&lt;sub&gt;ME Pilot fuel&lt;/sub&gt;</td>
<td>Specific fuel consumption of pilot fuel for dual fuel ME at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>SFC&lt;sub&gt;AE Pilot fuel&lt;/sub&gt;</td>
<td>Specific fuel consumption of pilot fuel for dual fuel AE at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>SFC&lt;sub&gt;ME LNG&lt;/sub&gt;</td>
<td>Specific fuel consumption of ME using LNG at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>136</td>
</tr>
<tr>
<td>13</td>
<td>SFC&lt;sub&gt;AE LNG&lt;/sub&gt;</td>
<td>Specific fuel consumption of AE using LNG at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>160</td>
</tr>
<tr>
<td>14</td>
<td>SFC&lt;sub&gt;ME MDO&lt;/sub&gt;</td>
<td>Specific fuel consumption of dual fuel ME using MDO at P&lt;sub&gt;ME&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>165</td>
</tr>
<tr>
<td>15</td>
<td>SFC&lt;sub&gt;AE MDO&lt;/sub&gt;</td>
<td>Specific fuel consumption of dual fuel AE using MDO at P&lt;sub&gt;AE&lt;/sub&gt;</td>
<td>g/kWh</td>
<td>187</td>
</tr>
<tr>
<td>16</td>
<td>V&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>LNG tank capacity on board</td>
<td>m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>600</td>
</tr>
<tr>
<td>17</td>
<td>V&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Heavy fuel oil tank capacity on board</td>
<td>m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1800</td>
</tr>
<tr>
<td>18</td>
<td>V&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Marine diesel oil tank capacity on board</td>
<td>m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>400</td>
</tr>
<tr>
<td>19</td>
<td>ρ&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Density of LNG</td>
<td>kg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>450</td>
</tr>
<tr>
<td>20</td>
<td>ρ&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Density of heavy fuel oil</td>
<td>kg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>991</td>
</tr>
<tr>
<td>21</td>
<td>ρ&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Density of Marine diesel oil</td>
<td>kg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>900</td>
</tr>
<tr>
<td>22</td>
<td>LCV&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Low calorific value of LNG</td>
<td>kJ/kg</td>
<td>48000</td>
</tr>
<tr>
<td>23</td>
<td>LCV&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Low calorific value of heavy fuel oil</td>
<td>kJ/kg</td>
<td>40200</td>
</tr>
<tr>
<td>24</td>
<td>LCV&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Low calorific value of marine diesel oil</td>
<td>kJ/kg</td>
<td>42700</td>
</tr>
<tr>
<td>25</td>
<td>K&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Filling rate of LNG tank</td>
<td>-</td>
<td>0.95</td>
</tr>
<tr>
<td>26</td>
<td>K&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Filling rate of heavy fuel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
</tbody>
</table>
### S/N Parameter  Formula or Source  Unit  Value

#### 28 $K_{\text{MDO}}$  Filling rate of marine diesel tank  -  0.98

#### 29 $f_{\text{DFgas}}$  
$$f_{\text{DFgas}} = \frac{P_{\text{ME}} \times (C_{\text{F Pilotfuel}} \times SFC_{\text{ME Pilotfuel}} + C_{\text{F LNG}} \times SFC_{\text{ME LNG}}) + f_{\text{DFliquid}} \times C_{\text{FMDO}} \times SFC_{\text{ME MDO}} + P_{\text{AE}} \times (f_{\text{DFgas}} \times (C_{\text{FAE Pilotfuel}} \times SFC_{\text{AE Pilotfuel}} + C_{\text{F LNG}} \times SFC_{\text{AE LNG}}) + f_{\text{DFliquid}} \times C_{\text{FMDO}} \times SFC_{\text{AE MDO}}))}{(V_{\text{ref}} \times \text{Capacity})}$$  gCO$_2$/tnm  3.61

#### Case 4: One dual-fuel main engine (LNG, pilot fuel MDO) and one main engine (MDO) and dual-fuel auxiliary engine (LNG, pilot fuel MDO, no shaft generator) which LNG could be regarded as "primary fuel" only for the dual-fuel main engine:

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCR$_{\text{MEMDO}}$</td>
<td>MCR rating of main engine using only MDO</td>
<td>kW</td>
<td>5000</td>
</tr>
<tr>
<td>2</td>
<td>MCR$_{\text{MELNG}}$</td>
<td>MCR rating of main engine using dual fuel</td>
<td>kW</td>
<td>4000</td>
</tr>
<tr>
<td>3</td>
<td>Capacity</td>
<td>Deadweight of the ship at summer load draft</td>
<td>DWT</td>
<td>81200</td>
</tr>
<tr>
<td>4</td>
<td>$V_{\text{ref}}$</td>
<td>Ships speed</td>
<td>kn</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>$P_{\text{MEMDO}}$</td>
<td>0.75 x MCR$_{\text{MEMDO}}$</td>
<td>kW</td>
<td>3750</td>
</tr>
<tr>
<td>6</td>
<td>$P_{\text{MELNG}}$</td>
<td>0.75 x MCR$_{\text{MELNG}}$</td>
<td>kW</td>
<td>3000</td>
</tr>
<tr>
<td>7</td>
<td>$P_{\text{AE}}$</td>
<td>0.05 x (MCR$<em>{\text{MEMDO}}$ + MCR$</em>{\text{MELNG}}$)</td>
<td>kW</td>
<td>450</td>
</tr>
<tr>
<td>8</td>
<td>$C_{\text{FPilotfuel}}$</td>
<td>$C_{\text{F}}$ factor of pilot fuel for dual fuel ME using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>9</td>
<td>$C_{\text{FAE Pilotfuel}}$</td>
<td>$C_{\text{F}}$ factor of pilot fuel for Auxiliary engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>10</td>
<td>$C_{\text{FLNG}}$</td>
<td>$C_{\text{F}}$ factor of dual fuel engine using LNG</td>
<td>-</td>
<td>2.75</td>
</tr>
<tr>
<td>11</td>
<td>$C_{\text{FMDO}}$</td>
<td>$C_{\text{F}}$ factor of dual fuel ME/AE engine using MDO</td>
<td>-</td>
<td>3.206</td>
</tr>
<tr>
<td>12</td>
<td>SFC$_{\text{ME Pilotfuel}}$</td>
<td>Specific fuel consumption of pilot fuel for dual fuel ME at $P_{\text{ME}}$</td>
<td>g/kWh</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>SFC$_{\text{AE Pilotfuel}}$</td>
<td>Specific fuel consumption of pilot fuel for dual fuel AE at $P_{\text{AE}}$</td>
<td>g/kWh</td>
<td>7</td>
</tr>
<tr>
<td>14</td>
<td>SFC$_{\text{DF LNG}}$</td>
<td>Specific fuel consumption of dual fuel ME using LNG at $P_{\text{ME}}$</td>
<td>g/kWh</td>
<td>158</td>
</tr>
<tr>
<td>15</td>
<td>SFC$_{\text{AE LNG}}$</td>
<td>Specific fuel consumption of AE using LNG at $P_{\text{AE}}$</td>
<td>g/kWh</td>
<td>160</td>
</tr>
<tr>
<td>16</td>
<td>SFC$_{\text{ME MDO}}$</td>
<td>Specific fuel consumption of single fuel ME at $P_{\text{ME}}$</td>
<td>g/kWh</td>
<td>180</td>
</tr>
<tr>
<td>17</td>
<td>$V_{\text{LNG}}$</td>
<td>LNG tank capacity on board</td>
<td>m$^3$</td>
<td>1000</td>
</tr>
<tr>
<td>18</td>
<td>$V_{\text{HFO}}$</td>
<td>Heavy fuel oil tank capacity on board</td>
<td>m$^3$</td>
<td>1200</td>
</tr>
</tbody>
</table>

https://edocs.imo.org/Final Documents/English/MEPC.1-CIRC.866 (E).docx
### Table

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>V&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Marine diesel oil tank capacity on board</td>
<td>m³</td>
<td>400</td>
</tr>
<tr>
<td>20</td>
<td>ρ&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Density of LNG</td>
<td>kg/m³</td>
<td>450</td>
</tr>
<tr>
<td>21</td>
<td>ρ&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Density of heavy fuel oil</td>
<td>kg/m³</td>
<td>991</td>
</tr>
<tr>
<td>22</td>
<td>ρ&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Density of Marine diesel oil</td>
<td>kg/m³</td>
<td>900</td>
</tr>
<tr>
<td>23</td>
<td>LCV&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Low calorific value of LNG</td>
<td>kJ/kg</td>
<td>48000</td>
</tr>
<tr>
<td>24</td>
<td>LCV&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Low calorific value of heavy fuel oil</td>
<td>kJ/kg</td>
<td>40200</td>
</tr>
<tr>
<td>25</td>
<td>LCV&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Low calorific value of marine diesel oil</td>
<td>kJ/kg</td>
<td>42700</td>
</tr>
<tr>
<td>26</td>
<td>K&lt;sub&gt;LNG&lt;/sub&gt;</td>
<td>Filling rate of LNG tank</td>
<td>-</td>
<td>0.95</td>
</tr>
<tr>
<td>27</td>
<td>K&lt;sub&gt;HFO&lt;/sub&gt;</td>
<td>Filling rate of heavy fuel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>28</td>
<td>K&lt;sub&gt;MDO&lt;/sub&gt;</td>
<td>Filling rate of Lmarine diesel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>29</td>
<td>f&lt;sub&gt;Dfgas&lt;/sub&gt;</td>
<td></td>
<td></td>
<td>0.5195</td>
</tr>
<tr>
<td>30</td>
<td>EEDI</td>
<td>(P&lt;sub&gt;MELNG&lt;/sub&gt; x (C&lt;sub&gt;F&lt;/sub&gt; Pilotfuel x SFC&lt;sub&gt;ME Pilotfuel&lt;/sub&gt; + C&lt;sub&gt;F&lt;/sub&gt; LNG x SFC&lt;sub&gt;DF LNG&lt;/sub&gt;) + P&lt;sub&gt;MEMDO&lt;/sub&gt; x C&lt;sub&gt;F&lt;/sub&gt; MDO x SFC&lt;sub&gt;ME MDO&lt;/sub&gt; + P&lt;sub&gt;AE&lt;/sub&gt; x (C&lt;sub&gt;FAE&lt;/sub&gt; Pilotfuel x SFC&lt;sub&gt;AE Pilotfuel&lt;/sub&gt; + C&lt;sub&gt;F&lt;/sub&gt; LNG x SFC&lt;sub&gt;AE LNG&lt;/sub&gt;)) / (V&lt;sub&gt;ref&lt;/sub&gt; x Capacity)</td>
<td>gCO₂/tnm</td>
<td>3.28</td>
</tr>
</tbody>
</table>

### Case 5

One dual-fuel main engine (LNG, pilot fuel MDO) and one main engine (MDO) and dual-fuel auxiliary engine (LNG, pilot fuel MDO, no shaft generator) which LNG could not be regarded as "primary fuel" for the dual-fuel main engine:

![Diagram](https://edocs.imo.org/Final Documents/English/MEPC.1-CIRC.866 (E).docx)
<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter</th>
<th>Formula or Source</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>SFC_{AE Pilotfuel}</td>
<td>Specific fuel consumption of pilot fuel for dual fuel AE at P_{AE}</td>
<td>g/kWh</td>
<td>7</td>
</tr>
<tr>
<td>14</td>
<td>SFC_{DF LNG}</td>
<td>Specific fuel consumption of dual fuel ME using LNG at P_{ME}</td>
<td>g/kWh</td>
<td>158</td>
</tr>
<tr>
<td>15</td>
<td>SFC_{AE LNG}</td>
<td>Specific fuel consumption of AE using LNG at P_{AE}</td>
<td>g/kWh</td>
<td>160</td>
</tr>
<tr>
<td>16</td>
<td>SFC_{DF MDO}</td>
<td>Specific fuel consumption of dual fuel ME using MDO at P_{ME}</td>
<td>g/kWh</td>
<td>185</td>
</tr>
<tr>
<td>17</td>
<td>SFC_{ME MDO}</td>
<td>Specific fuel consumption of single fuel ME at P_{ME}</td>
<td>g/kWh</td>
<td>180</td>
</tr>
<tr>
<td>18</td>
<td>SFC_{AE MDO}</td>
<td>Specific fuel consumption of AE using MDO at P_{AE}</td>
<td>g/kWh</td>
<td>187</td>
</tr>
<tr>
<td>19</td>
<td>V_{LNG}</td>
<td>LNG tank capacity on board</td>
<td>m³</td>
<td>600</td>
</tr>
<tr>
<td>20</td>
<td>V_{HFO}</td>
<td>Heavy fuel oil tank capacity on board</td>
<td>m³</td>
<td>1200</td>
</tr>
<tr>
<td>21</td>
<td>V_{MDO}</td>
<td>Marine diesel oil tank capacity on board</td>
<td>m³</td>
<td>400</td>
</tr>
<tr>
<td>22</td>
<td>p_{LNG}</td>
<td>Density of LNG</td>
<td>kg/m³</td>
<td>450</td>
</tr>
<tr>
<td>23</td>
<td>p_{HFO}</td>
<td>Density of heavy fuel oil</td>
<td>kg/m³</td>
<td>991</td>
</tr>
<tr>
<td>24</td>
<td>p_{MDO}</td>
<td>Density of Marine diesel oil</td>
<td>kg/m³</td>
<td>900</td>
</tr>
<tr>
<td>25</td>
<td>LCV_{LNG}</td>
<td>Low calorific value of LNG</td>
<td>kJ/kg</td>
<td>48000</td>
</tr>
<tr>
<td>26</td>
<td>LCV_{HFO}</td>
<td>Low calorific value of heavy fuel oil</td>
<td>kJ/kg</td>
<td>40200</td>
</tr>
<tr>
<td>27</td>
<td>LCV_{MDO}</td>
<td>Low calorific value of marine diesel oil</td>
<td>kJ/kg</td>
<td>42700</td>
</tr>
<tr>
<td>28</td>
<td>K_{LNG}</td>
<td>Filling rate of LNG tank</td>
<td>-</td>
<td>0.95</td>
</tr>
<tr>
<td>29</td>
<td>K_{HFO}</td>
<td>Filling rate of heavy fuel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>30</td>
<td>K_{MDO}</td>
<td>Filling rate of marine diesel tank</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>31</td>
<td>f_{DFgas}</td>
<td>1 - f_{DFgas}</td>
<td>-</td>
<td>0.6538</td>
</tr>
<tr>
<td>32</td>
<td>f_{DFliquid}</td>
<td>1 - f_{DFgas}</td>
<td>-</td>
<td>0.3462</td>
</tr>
<tr>
<td>33</td>
<td>EEDI</td>
<td>( \frac{(P_{ME \text{LNG}} \times (f_{DFgas} \times (C_{F \text{Pilotfuel}} \times SFC_{\text{ME Pilotfuel}} + C_{F \text{LNG}} \times SFC_{\text{DF LNG}}) + f_{DFliquid} \times C_{\text{F MDO}} \times SFC_{\text{DF MDO}})) + P_{\text{MEMDO}} \times C_{\text{F MDO}} \times SFC_{\text{ME MDO}} + P_{\text{AE}} \times (f_{DFgas} \times (C_{\text{FAE Pilotfuel}} \times SFC_{\text{AE Pilotfuel}} + C_{F \text{LNG}} \times SFC_{\text{AE LNG}}) + f_{DFliquid} \times C_{\text{F MDO}} \times SFC_{\text{AE MDO}}))}{(V_{\text{ref}} \times \text{Capacity})} )</td>
<td>gCO₂/tnm</td>
<td>3.54</td>
</tr>
</tbody>
</table>
ANNEX 10

RESOLUTION MEPC.282(70)
(Adopted on 28 October 2016)

2016 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 from ships,

RECALLING ALSO that it 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 that the aforementioned amendments to MARPOL Annex VI, which included a new chapter 4 on regulations on energy efficiency for ships in Annex VI, entered into force on 1 January 2013,

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,

NOTING FURTHER that it adopted, by resolution MEPC.278(70), amendments to MARPOL Annex VI related to the data collection system for fuel oil consumption which are expected to enter into force on 1 March 2018 upon their deemed acceptance on 1 September 2017,

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

HAVING CONSIDERED, at its seventieth session, draft 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP),

1 ADOPTS the 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) (the 2016 Guidelines), as set out in the annex to the present resolution;

2 INVITES Administrations to take the annexed 2016 Guidelines into account when developing and enacting national laws which give force to and implement requirements set forth in regulations 22 and 22A of MARPOL Annex VI, as amended;

3 REQUESTS the Parties to MARPOL Annex VI and other Member Governments to bring the annexed 2016 Guidelines to the attention of masters, seafarers, shipowners, ship operators and any other interested groups;

4 AGREES to keep the 2016 Guidelines under review in light of the experience gained with their implementation;

ANNEX

2016 GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

CONTENTS

1 INTRODUCTION
2 DEFINITIONS

PART I OF THE SEEMP: SHIP MANAGEMENT PLAN TO IMPROVE ENERGY EFFICIENCY

3 GENERAL
4 FRAMEWORK AND STRUCTURE OF PART I OF THE SEEMP
5 GUIDANCE ON BEST PRACTICES FOR FUEL-EFFICIENT OPERATION OF SHIPS

PART II OF THE SEEMP: SHIP FUEL OIL CONSUMPTION DATA COLLECTION PLAN

6 GENERAL
7 GUIDANCE ON METHODOLOGY FOR COLLECTING DATA ON FUEL OIL CONSUMPTION, DISTANCE TRAVELLED AND HOURS UNDERWAY
8 DIRECT CO₂ EMISSIONS MEASUREMENT

APPENDIX 1 – SAMPLE FORM OF SHIP MANAGEMENT PLAN TO IMPROVE ENERGY EFFICIENCY

APPENDIX 2 – SAMPLE FORM OF SHIP FUEL OIL CONSUMPTION DATA COLLECTION PLAN

APPENDIX 3 – STANDARDIZED DATA REPORTING FORMAT FOR THE DATA COLLECTION SYSTEM
1 INTRODUCTION

1.1 The Guidelines for the development of a Ship Energy Efficiency Management Plan have been developed to assist with the preparation of the Ship Energy Efficiency Management Plan (SEEMP) required by regulation 22 of MARPOL Annex VI.

1.2 There are two parts to a SEEMP. Part I 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. Part II provides the methodologies ships of 5,000 gross tonnage and above should use to collect the data required pursuant to regulation 22A of MARPOL Annex VI and the processes that the ship should use to report the data to the ship’s Administration or any organization duly authorized by it.

1.3 A sample form of the SEEMP is presented in appendices 1 and 2 for illustrative purposes. A standardized data reporting format for the data collection system is presented in appendix 3.

2 DEFINITIONS

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

2.2 "Ship fuel oil consumption data" means the data required to be collected on an annual basis and reported as specified in appendix IX to MARPOL Annex VI.

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.

PART I OF THE SEEMP: SHIP MANAGEMENT PLAN TO IMPROVE ENERGY EFFICIENCY

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 part I of the SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship’s operation. Preferably, this aspect of 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 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 ISO 14001 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, part I of the SEEMP may form part of the ship’s Safety Management System.
3.5 This section provides guidance for the development of part I of the SEEMP that should be adjusted to the characteristics and needs of individual companies and ships. Part I 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 on-board administrative burden to the minimum necessary.

3.6 Part I of the SEEMP should be developed as a ship-specific plan by the company, and should reflect efforts 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 efficiency management. With each iteration of the cycle, some elements of part I 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. For example, ships that perform services at sea (pipe laying, seismic survey, OSVs, dredgers, etc.) may choose different methods of improving energy efficiency when compared to conventional cargo carriers. The nature of operations and influence of prevailing weather conditions, tides and currents combined with the necessity of maintaining safe operations may require adjustment of general procedures to maintain the efficiency of the operation, for example the ships which are dynamically positioned. The length of voyage may also be an important parameter as may trade specific safety considerations.

4 FRAMEWORK AND STRUCTURE OF PART I OF THE SEEMP

4.1 Planning

4.1.1 Planning is the most crucial stage of part I 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. Part I of the SEEMP should identify energy-saving measures that have been undertaken, and should determine how effective these measures are in terms of improving energy efficiency. Part I also should identify 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 part I.
4.1.4 Guidance on best practices for fuel-efficient operation of ships, set out in chapter 5, can be used to facilitate this part of the planning phase. Also, in the planning process, particular consideration should be given to minimize any on-board 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 paragraph 5.2.4 – 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, part I of the SEEMP should describe how each measure should be implemented and who the responsible person(s) is. The implementation period (start and end dates) of each selected measure should be indicated. 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, it is recommended that the EEOI is calculated in accordance with the Guidelines for the development of a Ship Energy Efficiency Management Plan (MEPC.1/Circ.684) developed by the Organization, adjusted, as necessary, to a specific ship and trade.

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 management plan 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

5.1 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.

5.2 Fuel-efficient operations

Improved voyage planning

5.2.1 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.

5.2.2 The Guidelines for voyage planning, adopted by resolution A.893(21), provide essential guidance for the ship's crew and voyage planners.

Weather routeing

5.2.3 Weather routeing 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 routeing may also increase fuel consumption for a given voyage.

Just in time

5.2.4 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.

5.2.5 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

5.2.6 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 problems with soot deposits in combustion chambers and exhaust systems. These possible consequences should be taken into account.

5.2.7 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.

5.2.8 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.

5.2.9 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**

5.2.10 Operation at constant shaft RPM can be more efficient than continuously adjusting speed through engine power (see paragraph 5.7). The use of automated engine management systems to control speed rather than relying on human intervention may be beneficial.

5.3 Optimized ship handling

**Optimum trim**

5.3.1 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**

5.3.2 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.

5.3.3 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.

5.3.4 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

5.3.5 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.

5.3.6 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)

5.3.7 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.

5.3.8 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 stages of the voyage it may have to be deactivated or very carefully adjusted, i.e. heavy weather and approaches to ports.

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

Hull maintenance

5.3.10 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.

5.3.11 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.

5.3.12 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.

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

Propulsion system

5.3.14 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**

5.3.15 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.

5.3.16 Additional means to improve engine efficiency might include use of fuel additives; adjustment of cylinder lubrication oil consumption; valve improvements; torque analysis; and automated engine monitoring systems.

5.4 **Waste heat recovery**

5.4.1 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.

5.4.2 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.

5.5 **Improved fleet management**

5.5.1 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.

5.5.2 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.

5.6 **Improved cargo handling**

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

5.7 **Energy management**

5.7.1 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.

5.7.2 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.

5.8 **Fuel type**

The use of emerging alternative fuels may be considered as a CO₂ reduction method but availability will often determine the applicability.
5.9 Other measures

5.9.1 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.

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

5.9.3 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.

5.9.4 Even wind assisted propulsion may be worthy of consideration.

5.9.5 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.

5.10 Compatibility of measures

5.10.1 These Guidelines indicate a wide variety of possibilities for energy efficiency improvements for the existing fleet. While there are many options available, they are not necessarily 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

5.10.2 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

5.10.3 The feasibility of many of the measures described in this guidance will be dependent on the trade and sailing area of the ship. 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.

5.10.4 The trade a ship is engaged in may determine the feasibility of the efficiency measures under consideration. For example, ships that perform services at sea (pipe laying, seismic survey, OSVs, dredgers, etc.) may choose different methods of improving energy efficiency when compared to conventional cargo carriers. The length of voyage may also be an important parameter as may trade specific safety considerations. The pathway to the most efficient combination of measures will be unique to each vessel within each shipping company.
PART II OF THE SEEMP: SHIP FUEL OIL CONSUMPTION DATA COLLECTION PLAN

6 GENERAL

6.1 Regulation 22.2 of MARPOL Annex VI specifies that, "On or before 31 December 2018, in the case of a ship of 5,000 gross tonnage and above, the SEEMP shall include a description of the methodology that will be used to collect the data required by regulation 22A.1 of this Annex and the processes that will be used to report the data to the ship's Administration." Part II of the SEEMP, the Ship Fuel Oil Consumption Data Collection Plan (hereinafter referred to as "Data Collection Plan") contains such methodology and processes.

6.2 With respect to part II of the SEEMP, these Guidelines provide guidance for developing a ship-specific method to collect, aggregate, and report ship data with regard to annual fuel oil consumption, distance travelled, hours underway and other data required by regulation 22A of MARPOL Annex VI to be reported to the Administration.

6.3 Pursuant to regulation 5.4.5 of MARPOL Annex VI, the Administration should ensure that each ship's SEEMP complies with regulation 22.2 of MARPOL Annex VI prior to collecting any data.

7 GUIDANCE ON METHODOLOGY FOR COLLECTING DATA ON FUEL OIL CONSUMPTION, DISTANCE TRAVELLED AND HOURS UNDERWAY

Fuel oil consumption

7.1 Fuel oil consumption should include all the fuel oil consumed on board including but not limited to the fuel oil consumed by the main engines, auxiliary engines, gas turbines, boilers and inert gas generator, for each type of fuel oil consumed, regardless of whether a ship is underway or not. Methods for collecting data on annual fuel oil consumption in metric tonnes include (in no particular order):

.1 method using bunker delivery notes (BDNs):

This method determines the annual total amount of fuel oil used based on BDNs, which are required for fuel oil for combustion purposes delivered to and used on board a ship in accordance with regulation 18 of MARPOL Annex VI; BDNs are required to be retained on board for three years after the fuel oil has been delivered. The Data Collection Plan should set out how the ship will operationalize the summation of BDN information and conduct tank readings. The main components of this approach are as follows:

.1 annual fuel oil consumption would be the total mass of fuel oil used on board the vessel as reflected in the BDNs. In this method, the BDN fuel oil quantities would be used to determine the annual total mass of fuel oil consumption, plus the amount of fuel oil left over from the last calendar year period and less the amount of fuel oil carried over to the next calendar year period;

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1 Regulation 2.9 of MARPOL Annex VI defines "fuel oil" as "fuel oil means any fuel delivered to and intended for combustion purposes for propulsion or operation on board a ship, including gas, distillate and residual fuels."
to determine the difference between the amount of remaining tank oil before and after the period, the tank reading should be carried out at the beginning and the end of the period;

in the case of a voyage that extends across the data reporting period, the tank reading should occur by tank monitoring at the ports of departure and arrival of the voyage and by statistical methods such as rolling average using voyage days;

fuel oil tank readings should be carried out by appropriate methods such as automated systems, soundings and dip tapes. The method for tank readings should be specified in the Data Collection Plan;

the amount of any fuel oil offloaded should be subtracted from the fuel oil consumption of that reporting period. This amount should be based on the records of the ship's oil record book; and

any supplemental data used for closing identified difference in bunker quantity should be supported with documentary evidence;

method using flow meters:
This method determines the annual total amount of fuel oil consumption by measuring fuel oil flows on board by using flow meters. In case of the breakdown of flow meters, manual tank readings or other alternative methods will be conducted instead. The Data Collection Plan should set out information about the ship’s flow meters and how the data will be collected and summarized, as well as how necessary tank readings should be conducted:

annual fuel oil consumption may be the sum of daily fuel oil consumption data of all relevant fuel oil consuming processes on board measured by flow meters;

the flow meters applied to monitoring should be located so as to measure all fuel oil consumption on board. The flow meters and their link to specific fuel oil consumers should be described in the Data Collection Plan;

note that it should not be necessary to correct this fuel oil measurement method for sludge if the flow meter is installed after the daily tank as sludge will be removed from the fuel oil prior to the daily tank;

the flow meters applied to monitoring fuel oil flow should be identified in the Data Collection Plan. Any consumer not monitored with a flow meter should be clearly identified, and an alternative fuel oil consumption measurement method should be included; and

calibration of the flow meters should be specified. Calibration and maintenance records should be available on board;
method using bunker fuel oil tank monitoring on board:

.1 to determine the annual fuel oil consumption, the amount of daily fuel oil consumption data measured by tank readings which are carried out by appropriate methods such as automated systems, soundings and dip tapes will be aggregated. The tank readings will normally occur daily when the ship is at sea and each time the ship is bunkering or de-bunkering; and

.2 the summary of monitoring data containing records of measured fuel oil consumption should be available on board.

7.2 Any corrections, e.g. density, temperature, if applied, should be documented\(^2\).

Conversion factor \( C_F \)

7.3 If fuel oils are used that do not fall into one of the categories as described in the 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.245(66)), as amended, and have no \( C_F \)-factor assigned (e.g. some "hybrid fuel oils"), the fuel oil supplier should provide a \( C_F \)-factor for the respective product supported by documentary evidence.

Distance travelled

7.4 Appendix IX of MARPOL Annex VI specifies that distance travelled should be submitted to the Administration and:

.1 distance travelled over ground in nautical miles should be recorded in the log-book in accordance with SOLAS regulation V/28.1\(^3\);

.2 the distance travelled while the ship is underway under its own propulsion should be included into the aggregated data of distance travelled for the calendar year; and

.3 other methods to measure distance travelled accepted by the Administration may be applied. In any case, the method applied should be described in detail in the Data Collection Plan.

Hours underway

7.5 Appendix IX of MARPOL Annex VI specifies that hours underway should be submitted to the Administration. Hours underway should be an aggregated duration while the ship is underway under its own propulsion.

Data quality

7.6 The Data Collection Plan should include data quality control measures which should be incorporated into the existing shipboard safety management system. Additional measures to be considered could include:

.1 the procedure for identification of data gaps and correction thereof; and

\(^2\) For example, ISO 8217 provides a method for liquid fuel.
\(^3\) Distance travelled measured using satellite data is distance travelled over the ground.
the procedure to address data gaps if monitoring data is missing, for example, flow meter malfunctions.

**A standardized data reporting format**

7.7 Regulation 22A.3 of MARPOL Annex VI states that the data specified in appendix IX of the Annex are to be communicated electronically using a standardized form developed by the Organization. The collected data should be reported to the Administration in the standardized format shown in appendix 3.

8 **DIRECT CO₂ EMISSIONS MEASUREMENT**

8.1 Direct CO₂ emission measurement is not required by regulation 22A of MARPOL Annex VI.

8.2 Direct CO₂ emissions measurement, if used, should be carried out as follows:

.1 this method is based on the determination of CO₂ emission flows in exhaust gas stacks by multiplying the CO₂ concentration of the exhaust gas with the exhaust gas flow. In case of the absence or/and breakdown of direct CO₂ emissions measurement equipment, manual tank readings will be conducted instead;

.2 the direct CO₂ emissions measurement equipment applied to monitoring is located exhaustively so as to measure all CO₂ emissions in the ship. The locations of all equipment applied are described in this monitoring plan; and

.3 calibration of the CO₂ emissions measurement equipment should be specified. Calibration and maintenance records should be available on board.
APPENDIX 1

SAMPLE FORM OF SHIP MANAGEMENT PLAN TO IMPROVE ENERGY EFFICIENCY (PART I OF THE SEEMP)

<table>
<thead>
<tr>
<th>Name of ship:</th>
<th>Gross tonnage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship type:</td>
<td>Capacity:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of development:</th>
<th>Developed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation period:</td>
<td>From:</td>
</tr>
<tr>
<td></td>
<td>Until:</td>
</tr>
<tr>
<td>Planned date of next evaluation:</td>
<td></td>
</tr>
</tbody>
</table>

1 MEASURES

<table>
<thead>
<tr>
<th>Energy efficiency measures</th>
<th>Implementation (including the starting date)</th>
<th>Responsible personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather routing</td>
<td>&lt;Example&gt; Contracted with (Service providers) to use their weather routing system and start using on trial basis as of 1 July 2012.</td>
<td>&lt;Example&gt; The master is responsible for selecting the optimum route based on the information provided by (Service providers).</td>
</tr>
<tr>
<td>Speed optimization</td>
<td>While the design speed (85% MCR) is 19.0 kt, the maximum speed is set at 17.0 kt as of 1 July 2012.</td>
<td>The master is responsible for keeping the ship’s speed. The log-book entry should be checked every day.</td>
</tr>
</tbody>
</table>

2 MONITORING

Description of monitoring tools

3 GOAL

Measurable goals

4 EVALUATION

Procedures of evaluation
APPENDIX 2

SAMPLE FORM OF SHIP FUEL OIL CONSUMPTION DATA COLLECTION PLAN
(PART II OF THE SEEMP)

1 Ship particulars

<table>
<thead>
<tr>
<th>Name of ship</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO number</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>Flag</td>
<td></td>
</tr>
<tr>
<td>Ship type</td>
<td></td>
</tr>
<tr>
<td>Gross tonnage</td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>DWT</td>
<td></td>
</tr>
<tr>
<td>EEDI (if applicable)</td>
<td></td>
</tr>
<tr>
<td>Ice class</td>
<td></td>
</tr>
</tbody>
</table>

2 Record of revision of Fuel Oil Consumption Data Collection Plan

<table>
<thead>
<tr>
<th>Date of revision</th>
<th>Revised provision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Ship engines and other fuel oil consumers and fuel oil types used

<table>
<thead>
<tr>
<th>Engines or other fuel oil consumers</th>
<th>Power (kW)</th>
<th>Fuel oil types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Type/model of main engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Type/model of auxiliary engine</td>
<td>(kW)</td>
<td></td>
</tr>
<tr>
<td>3 Boiler</td>
<td>(...)</td>
<td></td>
</tr>
<tr>
<td>4 Inert gas generator</td>
<td>(...)</td>
<td></td>
</tr>
</tbody>
</table>

4 Emission factor

$C_F$ is a non-dimensional conversion factor between fuel oil consumption and CO$_2$ emission in the 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.245(66)), as amended. The annual total amount of CO$_2$ is calculated by multiplying annual fuel oil consumption and $C_F$ for the type of fuel.

<table>
<thead>
<tr>
<th>Fuel oil Type</th>
<th>$C_F$ (t-CO$_2$/t-Fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel/Gas oil (e.g. ISO 8217 grades DMX through DMB)</td>
<td>3.206</td>
</tr>
<tr>
<td>Light fuel oil (LFO) (e.g. ISO 8217 grades RMA through RMD)</td>
<td>3.151</td>
</tr>
<tr>
<td>Heavy fuel oil (HFO) (e.g. ISO 8217 grades RME through RMK)</td>
<td>3.114</td>
</tr>
<tr>
<td>Liquefied petroleum gas (LPG) (Propane)</td>
<td>3.000</td>
</tr>
<tr>
<td>Liquefied petroleum gas (LPG) (Butane)</td>
<td>3.030</td>
</tr>
<tr>
<td>Liquefied natural gas (LNG)</td>
<td>2.750</td>
</tr>
</tbody>
</table>
### Table: Fuel oil Type and $C_F$ (t-CO$_2$/t-Fuel)

<table>
<thead>
<tr>
<th>Fuel oil Type</th>
<th>$C_F$ (t-CO$_2$/t-Fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>1.375</td>
</tr>
<tr>
<td>Ethanol</td>
<td>1.913</td>
</tr>
<tr>
<td>Other (………)</td>
<td></td>
</tr>
</tbody>
</table>

5 **Method to measure fuel oil consumption**

The applied method for measurement for this ship is given below. The description explains the procedure for measuring data and calculating annual values, measurement equipment involved, etc.

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>

6 **Method to measure distance travelled**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>

7 **Method to measure hours underway**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>

8 **Processes that will be used to report the data to the Administration**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>

9 **Data quality**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>
## APPENDIX 3

### STANDARDIZED DATA REPORTING FORMAT FOR THE DATA COLLECTION SYSTEM

<table>
<thead>
<tr>
<th>Method used to measure fuel oil consumption</th>
<th>Fuel oil consumption</th>
<th>Hours underway (h)</th>
<th>Distance Traveled (nm)</th>
<th>Power output (rated power) (kW)</th>
<th>EEDI (if applicable) (gCO₂/t.nm)</th>
<th>DWT (t)</th>
<th>NT (t)</th>
<th>Gross Tonnage (t)</th>
<th>Ship type</th>
<th>IMO number</th>
<th>End date (dd/mm/yyyy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>Ethanol (C: 1.913)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>Methanol (C: 1.376)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>LNG (C: 2.750)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>LPG (Butane) (C: 0.030)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>LPG (Propane) (C: 1.000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>HFO (C: 5.14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>LPG (C: 3.151)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(C: ...); Other (C: ...)</td>
<td>Diesel/Gas Oil (C: 2.260)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. In accordance with the *IMO Ship Identification Number Scheme*, adopted by the Organization by resolution A.1078(28).
2. As defined in regulation 2 of MARPOL Annex VI or other (to be stated).
4. NT should be calculated in accordance with the International Convention on Tonnage Measurement of Ships, 1969. If not applicable, note "N/A".
5. DWT means the difference in tonnes between the displacement of a ship in water of relative density of 1025 kg/m³ at the summer load draught and the lightweight of the ship. The summer load draught should be taken as the maximum summer draught as certified in the stability booklet approved by the Administration or an organization recognized by it.
6. EEDI should be calculated in accordance with the *2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, as amended, adopted by resolution MEPC.245(66). If not applicable, note "N/A".
7. Ice class should be consistent with the definition set out in the International Code for ships operating in polar waters (Polar Code), adopted by resolutions MEPC.264(68) and MSC.385(94). If not applicable, note "N/A".
8. Power output (rated power) of main and auxiliary reciprocating internal combustion engines over 130 kW (to be stated in kW). Rated power means the maximum continuous rated power as specified on the nameplate of the engine.
2014 GUIDELINES ON SURVEY AND CERTIFICATION OF THE ENERGY EFICIENT DESIGN INDEX (EEDI), AS AMENDED (RESOLUTION MEPC.254(67), AS AMENDED BY RESOLUTION MEPC.261(68))

1 The Marine Environment Protection Committee, at its sixty-eighth session (11 to 15 May 2015), adopted, by resolution MEPC.261(68), amendments to the 2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI) (resolution MEPC.254(67)). A consolidated text of the guidelines, as requested by the Committee (MEPC 68/21, paragraph 3.99), is set out in the annex.

2 The Committee also endorsed the use of ISO standard 15016:2015 for ships for which the sea trial is conducted on or after 1 September 2015 and encouraged the application of the standard prior to that date (MEPC 68/21, paragraph 3.100).

3 Member Governments are invited to bring the annexed 2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI), as amended, to the attention of Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

4 The 2014 Guidelines revoke the 2012 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI) (resolution MEPC.214(63), as amended by resolution MEPC.234(65)). Consequently, this circular revokes MEPC.1/Circ.816.

***
ANNEX

2014 GUIDELINES ON SURVEY AND CERTIFICATION OF
THE ENERGY EFFICIENCY DESIGN INDEX (EEDI), AS AMENDED
(RESOLUTION MEPC.254 (67), AS AMENDED BY RESOLUTION MEPC.261 (68))

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Appendix 1 Sample of EEDI Technical File
Appendix 2 Guidelines for validation of electric power tables for EEDI (EPT-EEDI)
Appendix 3 Electric power table form for EEDI (EPT-EEDI Form) and statement of validation
1 GENERAL

The purpose of these guidelines is to assist verifiers of the Energy Efficiency Design Index (EEDI) of ships in conducting the survey and certification of the EEDI, in accordance with regulations 5, 6, 7, 8 and 9 of MARPOL Annex VI, and assist shipowners, shipbuilders, manufacturers and other interested parties in understanding the procedures for the survey and certification of the EEDI.

2 DEFINITIONS

2.1 Verifier means an Administration, or organization duly authorized by it, which conducts the survey and certification of the EEDI in accordance with regulations 5, 6, 7, 8 and 9 of MARPOL Annex VI and these guidelines.

2.2 Ship of the same type means a ship the hull form (expressed in the lines such as sheer plan and body plan), excluding additional hull features such as fins, and principal particulars of which are identical to that of the base ship.

2.3 Tank test means model towing tests, model self-propulsion tests and model propeller open water tests. Numerical calculations may be accepted as equivalent to model propeller open water tests or used to complement the tank tests conducted (e.g. to evaluate the effect of additional hull features such as fins, etc. on ships’ performance) with the approval of the verifier.

3 APPLICATION

These guidelines should be applied to new ships for which an application for an initial survey or an additional survey specified in regulation 5 of MARPOL Annex VI has been submitted to a verifier.

4 PROCEDURES FOR SURVEY AND CERTIFICATION

4.1 General

4.1.1 The attained EEDI should be calculated in accordance with regulation 20 of MARPOL Annex VI and the 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, as amended (resolution MEPC.245(66), as amended by resolution MEPC.263(68)) (EEDI Calculation Guidelines). Survey and certification of the EEDI should be conducted in two stages: preliminary verification at the design stage and final verification at the sea trial. The basic flow of the survey and certification process is presented in figure 1.

4.1.2 The information used in the verification process may contain confidential information of submitters which requires Intellectual Property Rights (IPR) protection. In the case where the submitter wants a non-disclosure agreement with the verifier, the additional information should be provided to the verifier upon mutually agreed terms and conditions.

---

1 Other terms used in these guidelines have the same meaning as those defined in the 2014 Guidelines on the method of calculation of the attained EEDI for new ships, as amended (resolution MEPC.245(66), as amended by resolution MEPC.263(68)).
4.2 Preliminary verification of the attained EEDI at the design stage

4.2.1 For the preliminary verification at the design stage, an application for an initial survey and an EEDI Technical File containing the necessary information for the verification and other relevant background documents should be submitted to a verifier.

4.2.2 The EEDI Technical File should be written at least in English. The EEDI Technical File should include as a minimum, but not limited to:

1. deadweight (DWT) or gross tonnage (GT) for passenger and ro-ro passenger ships, the maximum continuous rating (MCR) of the main and auxiliary engines, the ship speed ($V_{ref}$), as specified in paragraph 2.2 of the EEDI Calculation Guidelines, type of fuel, the specific fuel consumption ($SFC$) of the main engine at 75% of MCR power, the $SFC$ of the auxiliary engines at 50% MCR power, and the electric power table for certain ship types, as necessary, as defined in the EEDI Calculation Guidelines.

2. Electric power tables should be validated separately, taking into account the guidelines set out in appendix 2.

*To be conducted by a test organization or a submitter.

Figure 1: Basic flow of survey and certification process
.2 power curve(s) (kW – knot) estimated at design stage under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines, and, in the event that the sea trial is carried out in a condition other than the above condition, also a power curve estimated under the sea trial condition;

.3 principal particulars, ship type and the relevant information to classify the ship as such a ship type, classification notations and an overview of the propulsion system and electricity supply system on board;

.4 estimation process and methodology of the power curves at design stage;

.5 description of energy saving equipment;

.6 calculated value of the attained EEDI, including the calculation summary, which should contain, at a minimum, each value of the calculation parameters and the calculation process used to determine the attained EEDI;

.7 calculated values of the attained EEDI^weather and f_w value (not equal to 1.0), if those values are calculated, based on the EEDI Calculation Guidelines; and

.8 for LNG carriers:

.1 type and outline of propulsion systems (such as direct drive diesel, diesel electric, steam turbine);

.2 LNG cargo tank capacity in m^3 and BOR as defined in paragraph 2.5.6.3 of the EEDI Calculation Guidelines;

.3 shaft power of the propeller shaft after transmission gear at 100% of the rated output of motor (MPP\textsubscript{Motor}) and \( \eta_{(i)} \) for diesel electric;

.4 maximum continuous rated power (MCR\textsubscript{SteamTurbine}) for steam turbine; and

.5 SFC\textsubscript{SteamTurbine} for steam turbine, as specified in paragraph 2.5.7 of the EEDI Calculation Guidelines.

A sample of an EEDI Technical File is provided in appendix 1.

4.2.3 For ships equipped with dual-fuel engine(s) using LNG and fuel oil, the C_F-factor for gas (LNG) and the specific fuel consumption (SFC) of gas fuel should be used by applying the following criteria as a basis for the guidance of the Administration:

.1 final decision on the primary fuel rests with the Administration;

.2 the ratio of calorific value of gas fuel (LNG) to total marine fuels (HFO/MGO), including gas fuel (LNG) at design conditions should be equal to or larger than 50% in accordance with the formula below. However, the Administration can accept a lower value of the percentage taking into account the intended voyages:
\[
\frac{V_{\text{gas}} \times \rho_{\text{gas}} \times LCV_{\text{gas}} \times K_{\text{gas}}}{\left( \sum_{i=1}^{n_{\text{Liquid}}} V_{\text{liquid(i)}} \times \rho_{\text{liquid(i)}} \times LCV_{\text{liquid(i)}} \times K_{\text{liquid(i)}} \right) + V_{\text{gas}} \times \rho_{\text{gas}} \times LCV_{\text{gas}} \times K_{\text{gas}}} \geq 50\%
\]

whereby:

- \(V_{\text{gas}}\) is the total net tank volume of gas fuel on board in m\(^3\);
- \(V_{\text{liquid}}\) is the total net tank volume of every liquid fuel on board in m\(^3\);
- \(\rho_{\text{gas}}\) is the density of gas fuel in kg/m\(^3\);
- \(\rho_{\text{liquid}}\) is the density of every liquid fuel in kg/m\(^3\);
- \(LCV_{\text{gas}}\) is the low calorific value of gas fuel in kJ/kg;
- \(LCV_{\text{liquid}}\) is the low calorific value of liquid fuel in kJ/kg;
- \(K_{\text{gas}}\) is the filling rate for gas fuel tanks;
- \(K_{\text{liquid}}\) is the filling rate for liquid fuel tanks.

Normal density, Low Calorific Value and filling rate for tanks of different kinds of fuel are listed below.

<table>
<thead>
<tr>
<th>Type of fuel</th>
<th>Density (kg/m(^3))</th>
<th>Low Calorific Value (kJ/kg)</th>
<th>Filling rate for tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel/Gas Oil</td>
<td>900</td>
<td>42700</td>
<td>0.98</td>
</tr>
<tr>
<td>Heavy Fuel Oil</td>
<td>991</td>
<td>40200</td>
<td>0.98</td>
</tr>
<tr>
<td>Liquefied Natural Gas (LNG)</td>
<td>450</td>
<td>48000</td>
<td>0.95*</td>
</tr>
</tbody>
</table>

* Subject to verification of tank filling limit.

.3 in case the ship is not fully equipped with dual-fuel engines, the CF-factor for gas (LNG) should apply only for those installed engines that are of dual-fuel type and sufficient gas fuel supply should be available for such engines; and

.4 LNG fuelling solutions with exchangeable (specialized) LNG tank-containers should also fall under the terms of LNG as primary fuel.

4.2.4 The SFC of the main and auxiliary engines should be quoted from the approved NO\(_x\) Technical File and should be corrected to the value corresponding to the ISO standard reference conditions using the standard lower calorific value of the fuel oil (42,700 kJ/kg), referring to ISO 15550:2002 and ISO 3046-1:2002. For the confirmation of the SFC, a copy of the approved NO\(_x\) Technical File and documented summary of the correction calculations should be submitted to the verifier. In cases where the NO\(_x\) Technical File has not been
approved at the time of the application for initial survey, the test reports provided by manufacturers should be used. In this case, at the time of the sea trial verification, a copy of the approved NO\textsubscript{x} Technical File and documented summary of the correction calculations should be submitted to the verifier. In the case that gas fuel is determined as primary fuel in accordance with paragraph 4.2.3 and that installed engine(s) have no approved NO\textsubscript{x} Technical File tested in gas mode, the SFC of gas mode should be submitted by the manufacturer and confirmed by the verifier.

**Note:** SFC in the NO\textsubscript{x} Technical File are the values of a parent engine, and the use of such value of SFC for the EEDI calculation for member engines may have the following technical issues for further consideration:

1. the definition of "member engines" given in the NO\textsubscript{x} Technical File is broad and specification of engines belonging to the same group/family may vary; and

2. the rate of NO\textsubscript{x} emission of the parent engine is the highest in the group/family – i.e. CO\textsubscript{2} emission, which is in the trade-off relationship with NO\textsubscript{x} emission, can be lower than the other engines in the group/family.

4.2.5 For ships to which regulation 21 of MARPOL Annex VI applies, the power curves used for the preliminary verification at the design stage should be based on reliable results of tank tests. A tank test for an individual ship may be omitted based on technical justifications such as availability of the results of tank tests for ships of the same type. In addition, the omission of tank tests is acceptable for a ship for which sea trials will be carried out under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines, upon agreement of the shipowner and shipbuilder and with the approval of the verifier. To ensure the quality of tank tests, the ITTC quality system should be taken into account. Model tank tests should be witnessed by the verifier.

**Note:** It would be desirable in the future that an organization conducting a tank test be authorized.

4.2.6 The verifier may request further information from the submitter, in addition to that contained in the EEDI Technical File, as necessary, to examine the calculation process of the attained EEDI. For the estimation of the ship speed at the design stage much depends on each shipbuilder’s experience, and it may not be practicable for any person/organization other than the shipbuilder to fully examine the technical aspects of experience-based parameters, such as the roughness coefficient and wake scaling coefficient. Therefore, the preliminary verification should focus on the calculation process of the attained EEDI to ensure that it is technically sound and reasonable and follows regulation 20 of MARPOL Annex VI and the EEDI Calculation Guidelines.

**Note 1:** A possible way forward for more robust verification is to establish a standard methodology of deriving the ship speed from the outcome of tank tests, by setting standard values for experience-based correction factors such as roughness coefficient and wake scaling coefficient. In this way, ship-by-ship performance comparisons could be made more objectively by excluding the possibility of arbitrary setting of experience-based parameters. If such standardization is sought, this would have an implication on how the ship speed adjustment based on sea trial results should be conducted, in accordance with paragraph 4.3.8 of these guidelines.

**Note 2:** A joint industry standard to support the method and role of the verifier is expected to be developed.
4.2.7 Additional information that the verifier may request the submitter to provide includes, but is not limited to:

.1 descriptions of a tank test facility; this should include the name of the facility, the particulars of tanks and towing equipment, and the records of calibration of each monitoring equipment;

.2 lines of a model ship and an actual ship for the verification of the appropriateness of the tank test; the lines (sheer plan, body plan and half-breadth plan) should be detailed enough to demonstrate the similarity between the model ship and the actual ship;

.3 lightweight of the ship and displacement table for the verification of the deadweight;

.4 detailed report on the method and results of the tank test; this should include at least the tank test results at sea trial condition and under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines;

.5 detailed calculation process of the ship speed, which should include the basis for the estimation of experience-based parameters such as roughness coefficient and wake scaling coefficient;

.6 reasons for exempting a tank test, if applicable; this should include lines and tank test results of ships of the same type, and the comparison of the principal particulars of such ships and the ship in question. Appropriate technical justification should be provided, explaining why the tank test is unnecessary; and

.7 for LNG carriers, detailed calculation process of $P_{AE}$ and $SFC_{SteamTurbine}$.

4.2.8 The verifier should issue the report on the Preliminary Verification of the EEDI after it has verified the attained EEDI at the design stage, in accordance with paragraphs 4.1 and 4.2 of these guidelines.

4.3 Final verification of the attained EEDI at sea trial

4.3.1 Sea trial conditions should be set as the conditions specified in paragraph 2.2 of the EEDI Calculation Guidelines, if possible.

4.3.2 Prior to the sea trial, the following documents should be submitted to the verifier: a description of the test procedure to be used for the speed trial, the final displacement table and the measured lightweight, or a copy of the survey report of deadweight, as well as a copy of the NOx Technical File, as necessary. The test procedure should include, as a minimum, descriptions of all necessary items to be measured and corresponding measurement methods to be used for developing power curves under the sea trial condition.

4.3.3 The verifier should attend the sea trial and confirm:

.1 propulsion and power supply system, particulars of the engines or steam turbines, and other relevant items described in the EEDI Technical File;

.2 draught and trim;

.3 sea conditions;
4.3.4 Draught and trim should be confirmed by the draught measurements taken prior to the sea trial. The draught and trim should be as close as practical to those at the assumed conditions used for estimating the power curves.

4.3.5 Sea conditions should be measured in accordance with ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials Part 1; 2014 or ISO 15016:2015.

4.3.6 Ship speed should be measured in accordance with ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials Part 1; 2014 or ISO 15016:2015, and at more than two points of which range includes the power of the main engine as specified in paragraph 2.5 of the EEDI Calculation Guidelines.

4.3.7 The main engine output, shaft power of propeller shaft (for LNG carriers having diesel electric propulsion system) or steam turbine output (for LNG carrier having steam turbine propulsion system) should be measured by shaft power meter or a method which the engine manufacturer recommends and the verifier approves. Other methods may be acceptable upon agreement of the shipowner and shipbuilder and with the approval of the verifier.

4.3.8 The submitter should develop power curves based on the measured ship speed and the measured output of the main engine at sea trial. For the development of the power curves, the submitter should calibrate the measured ship speed, if necessary, by taking into account the effects of wind, current, waves, shallow water, displacement, water temperature and water density in accordance with ITTC Recommended Procedure 7.5-04-01-01.2 Speed and Power Trials Part 2; 2014 or ISO 15016:2015. Upon agreement with the shipowner, the submitter should submit a report on the speed trials including details of the power curve development to the verifier for verification.

4.3.9 The submitter should compare the power curves obtained as a result of the sea trial and the estimated power curves at the design stage. In case differences are observed, the attained EEDI should be recalculated, as necessary, in accordance with the following:

1. for ships for which sea trial is conducted under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines: the attained EEDI should be recalculated using the measured ship speed at sea trial at the power of the main engine as specified in paragraph 2.5 of the EEDI Calculation Guidelines; and

2. for ships for which sea trial cannot be conducted under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines: if the measured ship speed at the power of the main engine as specified in paragraph 2.5 of the EEDI Calculation Guidelines at the sea trial conditions is different from the expected ship speed on the power curve at the corresponding condition, the shipbuilder should recalculate the attained EEDI by adjusting ship speed under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines by an appropriate correction method that is agreed by the verifier.
An example of the scheme of conversion from trial condition to EEDI condition at EEDI power is given as follows:

\[ V_{\text{ref}} \] is obtained from the results of the sea trials at trial condition using the speed-power curves predicted by the tank tests. The tank tests shall be carried out at both draughts: trial condition corresponding to that of the S/P trials and EEDI condition. For trial conditions the power ratio \( \alpha_P \) between model test prediction and sea trial result is calculated for constant ship speed. Ship speed from model test prediction for EEDI condition at EEDI power multiplied with \( \alpha_P \) is \( V_{\text{ref}} \).

\[
\alpha_P = \frac{P_{\text{Trial,P}}}{P_{\text{Trial,S}}}
\]

where:

- \( P_{\text{Trial,P}} \) : power at trial condition predicted by the tank tests
- \( P_{\text{Trial,S}} \) : power at trial condition obtained by the S/P trials
- \( \alpha_P \) : power ratio

Figure 2 shows an example of the scheme of conversion to derive the resulting ship speed at EEDI condition (\( V_{\text{ref}} \)) at EEDI power.

**Figure 2: An example of scheme of conversion from trial condition to EEDI condition at EEDI power**

**Note:** Further consideration would be necessary for speed adjustment methodology in paragraphs 4.3.9.2 to 4.3.9.4 of these guidelines. One of the concerns relates to a possible situation where the power curve for sea trial condition is estimated in an excessively conservative manner (i.e. power curve is shifted in a leftward direction) with the intention to get an upward adjustment of the ship speed by making the measured ship speed at sea trial easily exceed the lower-estimated speed for sea trial condition at design stage.
4.3.10 In cases where the finally determined deadweight/gross tonnage differs from the designed deadweight/gross tonnage used in the EEDI calculation during the preliminary verification, the submitter should recalculate the attained EEDI using the finally determined deadweight/gross tonnage. The finally determined gross tonnage should be confirmed in the Tonnage Certificate of the ship.

4.3.11 The electrical efficiency $\eta_{(i)}$ should be taken as 91.3% for the purpose of calculating the attained EEDI. Alternatively, if a value of more than 91.3% is to be applied, $\eta_{(i)}$ should be obtained by measurement and verified by a method approved by the verifier.

4.3.12 In case where the attained EEDI is calculated at the preliminary verification by using $SFC$ based on the manufacturer's test report, due to the non-availability at that time of the approved NO$_x$ Technical File, the EEDI should be recalculated by using $SFC$ in the approved NO$_x$ Technical File. Also, for steam turbines, the EEDI should be recalculated by using $SFC$ confirmed by the Administration, or an organization recognized by the Administration, at the sea trial.

4.3.13 The EEDI Technical File should be revised, as necessary, by taking into account the results of sea trials. Such revision should include, as applicable, the adjusted power curve based on the results of sea trials (namely, modified ship speed under the condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines), the finally determined deadweight/gross tonnage, $\eta$ for LNG carriers having diesel electric propulsion system and $SFC$ described in the approved NO$_x$ Technical File, and the recalculated attained EEDI based on these modifications.

4.3.14 The EEDI Technical File, if revised, should be submitted to the verifier for confirmation that the (revised) attained EEDI is calculated in accordance with regulation 20 of MARPOL Annex VI and the EEDI Calculation Guidelines.

4.4 Verification of the attained EEDI in case of major conversion

4.4.1 In cases of a major conversion of a ship, the shipowner should submit to a verifier an application for an additional survey with the EEDI Technical File duly revised, based on the conversion made and other relevant background documents.

4.4.2 The background documents should include as a minimum, but are not limited to:

1. details of the conversion;
2. EEDI parameters changed after the conversion and the technical justifications for each respective parameter;
3. reasons for other changes made in the EEDI Technical File, if any; and
4. calculated value of the attained EEDI with the calculation summary, which should contain, as a minimum, each value of the calculation parameters and the calculation process used to determine the attained EEDI after the conversion.

4.4.3 The verifier should review the revised EEDI Technical File and other documents submitted and verify the calculation process of the attained EEDI to ensure that it is technically sound and reasonable and follows regulation 20 of MARPOL Annex VI and the EEDI Calculation Guidelines.

4.4.4 For verification of the attained EEDI after a conversion, speed trials of the ship are required, as necessary.
APPENDIX 1
SAMPLE OF EEDI TECHNICAL FILE

1 Data

1.1 General information

<table>
<thead>
<tr>
<th>Shipbuilder</th>
<th>JAPAN Shipbuilding Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull no.</td>
<td>12345</td>
</tr>
<tr>
<td>IMO no.</td>
<td>94111XX</td>
</tr>
<tr>
<td>Ship type</td>
<td>Bulk carrier</td>
</tr>
</tbody>
</table>

1.2 Principal particulars

| Length overall                     | 250.0 m                   |
| Length between perpendiculars     | 240.0 m                   |
| Breadth, moulded                   | 40.0 m                    |
| Depth, moulded                     | 20.0 m                    |
| Summer load line draught, moulded | 14.0 m                    |
| Deadweight at summer load line draught | 150,000 tons            |

1.3 Main engine

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>JAPAN Heavy Industries Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>6J70A</td>
</tr>
<tr>
<td>Maximum continuous rating (MCR)</td>
<td>15,000 kW x 80 rpm</td>
</tr>
<tr>
<td>SFC at 75% MCR</td>
<td>165.0 g/kWh</td>
</tr>
<tr>
<td>Number of sets</td>
<td>1</td>
</tr>
<tr>
<td>Fuel type</td>
<td>Diesel Oil</td>
</tr>
</tbody>
</table>

1.4 Auxiliary engine

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>JAPAN Diesel Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>5J-200</td>
</tr>
<tr>
<td>Maximum continuous rating (MCR)</td>
<td>600 kW x 900 rpm</td>
</tr>
<tr>
<td>SFC at 50% MCR</td>
<td>220.0 g/kWh</td>
</tr>
<tr>
<td>Number of sets</td>
<td>3</td>
</tr>
<tr>
<td>Fuel type</td>
<td>Diesel Oil</td>
</tr>
</tbody>
</table>

1.5 Ship speed

| Ship speed in deep water at summer load line draught at 75% of MCR | 14.25 knots |
2 Power curves

The power curves estimated at the design stage and modified after the speed trials are shown in figure 2.1.

![Power curves](image-url)
3 Overview of propulsion system and electric power supply system

3.1 Propulsion system

3.1.1 Main engine
Refer to paragraph 1.3 of this appendix.

3.1.2 Propeller

<table>
<thead>
<tr>
<th>Type</th>
<th>Fixed pitch propeller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>7.0 m</td>
</tr>
<tr>
<td>Number of blades</td>
<td>4</td>
</tr>
<tr>
<td>Number of sets</td>
<td>1</td>
</tr>
</tbody>
</table>

3.2 Electric power supply system

3.2.1 Auxiliary engines
Refer to paragraph 1.4 of this appendix.

3.2.2 Main generators

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>JAPAN Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output</td>
<td>560 kW (700 kVA) x 900 rpm</td>
</tr>
<tr>
<td>Voltage</td>
<td>AC 450 V</td>
</tr>
<tr>
<td>Number of sets</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 3.1: Schematic figure of propulsion and electric power supply system
4  Estimation process of power curves at design stage

Power curves are estimated based on model test results. The flow of the estimation process is shown below.

**Figure 4.1: Flow-chart of process for estimating power curves**

5  Description of energy saving equipment

5.1  Energy saving equipment the effects of which are expressed as $P_{AEeff(i)}$ and/or $P_{eff(i)}$ in the EEDI calculation formula

N/A

5.2  Other energy saving equipment

(Example)

5.2.1  Rudder fins

5.2.2  Propeller boss cap fins

(Specifications, schematic figures and/or photos, etc., for each piece of equipment or device should be indicated. Alternatively, attachment of a commercial catalogue may be acceptable.)
6 Calculated value of attained EEDI

6.1 Basic data

<table>
<thead>
<tr>
<th>Type of ship</th>
<th>Capacity DWT</th>
<th>Speed $V_{ref}$ (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Carrier</td>
<td>150,000</td>
<td>14.25</td>
</tr>
</tbody>
</table>

6.2 Main engine

<table>
<thead>
<tr>
<th>$MCR_{ME}$ (kW)</th>
<th>Shaft gen.</th>
<th>$P_{ME}$ (kW)</th>
<th>Type of fuel</th>
<th>$C_{FME}$</th>
<th>$SFC_{ME}$ (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>N/A</td>
<td>11,250</td>
<td>Diesel Oil</td>
<td>3.206</td>
<td>165.0</td>
</tr>
</tbody>
</table>

6.3 Auxiliary engines

<table>
<thead>
<tr>
<th>$P_{AE}$ (kW)</th>
<th>Type of fuel</th>
<th>$C_{FAE}$</th>
<th>$SFC_{AE}$ (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>625</td>
<td>Diesel Oil</td>
<td>3.206</td>
<td>220.0</td>
</tr>
</tbody>
</table>

6.4 Ice class

N/A

6.5 Innovative electrical energy efficient technology

N/A

6.6 Innovative mechanical energy efficient technology

N/A

6.7 Cubic capacity correction factor

N/A

6.8 Calculated value of attained EEDI

$$EEDI = \frac{\sum_{i=1}^{nPTI} \left( \prod_{j=1}^{M} f_j \right) \left( \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \right) + \left( P_{AE} \cdot C_{FAE} \cdot SFC_{AE} \right)}{f_i \cdot f_c \cdot \text{Capacity} \cdot f_\nu \cdot V_{ref}}$$

$$+ \frac{\left( \prod_{j=1}^{M} f_j \right) \left( \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot f_{eff(i)} \cdot P_{AEeff(i)} \right) \cdot C_{FAE} \cdot SFC_{AE}}{f_i \cdot f_c \cdot \text{Capacity} \cdot f_\nu \cdot V_{ref}}$$

EEDI = \frac{1 \times (11250 \times 3.206 \times 165.0) + (625 \times 3.206 \times 220.0) + 0 - 0}{1 \cdot 1.150000 \cdot 1 \cdot 14.25}

EEDI = 2.99 \ (g - CO_2/\text{ton} \cdot \text{mile})

attained EEDI: 2.99 g-CO_2/ton mile
7 Calculated value of attained EEDI_{weather}

7.1 Representative sea conditions

<table>
<thead>
<tr>
<th></th>
<th>Mean wind speed</th>
<th>Mean wind direction</th>
<th>Significant wave height</th>
<th>Mean wave period</th>
<th>Mean wave direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF6</td>
<td>12.6 (m/s)</td>
<td>0 (deg.)*</td>
<td>3.0 (m)</td>
<td>6.7 (s)</td>
<td>0 (deg.)*</td>
</tr>
</tbody>
</table>

* Heading direction of wind/wave in relation to the ship's heading, i.e. 0 (deg.) means the ship is heading directly into the wind.

7.2 Calculated weather factor, $f_w$

$f_w$ 0.900

7.3 Calculated value of attained EEDI_{weather}

attained EEDI_{weather}: 3.32 g-CO$_2$/ton mile
APPENDIX 2

GUIDELINES FOR VALIDATION OF ELECTRIC POWER TABLES FOR EEDI (EPT-EEDI)

1 INTRODUCTION

The purpose of these guidelines is to assist recognized organizations in the validation of Electric Power Tables (EPT) for the calculation of the Energy Efficiency Design Index (EEDI) for ships. As such, these guidelines support the implementation of the EEDI Calculation Guidelines and the Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI). These guidelines will also assist shipowners, shipbuilders, ship designers and manufacturers in relation to aspects of the development of more energy efficient ships and also in understanding the procedures for the EPT-EEDI validation.

2 OBJECTIVES

These guidelines provide a framework for the uniform application of the EPT-EEDI validation process for ships for which required auxiliary engine power is calculated under paragraph 2.5.6.4 of the EEDI Calculation Guidelines.

3 DEFINITIONS

3.1 Applicant means an organization, primarily a shipbuilder or a ship designer, which requests the EPT-EEDI validation in accordance with these guidelines.

3.2 Validator means a recognized organization which conducts the EPT-EEDI validation in accordance with these guidelines.

3.3 Validation for the purpose of these guidelines means review of submitted documents and survey during construction and sea trials.

3.4 Standard EPT-EEDI-Form refers to the layout given in appendix 3, containing the EPT-EEDI results that will be the subject of validation. Other supporting documents submitted for this purpose will be used as reference only and will not be subject to validation.

3.5 $P_{AE}$ herein is defined as per the definition in paragraph 2.5.6 of the EEDI Calculation Guidelines.

3.6 Ship service and engine-room loads refer to all the load groups which are needed for the hull, deck, navigation and safety services, propulsion and auxiliary engine services, engine-room ventilation and auxiliaries and ship's general services.

3.7 Diversity factor is the ratio of the "total installed load power" and the "actual load power" for continuous loads and intermittent loads. This factor is equivalent to the product of service factors for load, duty and time.

4 APPLICATION

4.1 These guidelines are applicable to ships as stipulated in paragraph 2.5.6.4 of the EEDI Calculation Guidelines.

4.2 These guidelines should be applied to new ships for which an application for an EPT-EEDI validation has been submitted to a validator.
4.3 The steps of the validation process include:

.1 review of documents during the design stage:
   .1 check if all relevant loads are listed in the EPT;
   .2 check if reasonable service factors are used; and
   .3 check the correctness of the $P_{AE}$ calculation based on the data given in the EPT;

.2 survey of installed systems and components during construction stage:
   .1 check if a randomly selected set of installed systems and components are correctly listed with their characteristics in the EPT;
   .3 survey of sea trials:
      .1 check if selected units/loads specified in EPT are observed.

5 SUPPORTING DOCUMENTS

5.1 The applicant should provide as a minimum the ship electric balance load analysis.

5.2 Such information may contain shipbuilders' confidential information. Therefore, after the validation, the validator should return all or part of such information to the applicant at the applicant's request.

5.3 A special EEDI condition during sea trials may be needed and defined for each ship and included in the sea trial schedule. For this condition, a special column should be inserted into the EPT.

6 PROCEDURES FOR VALIDATION

6.1 General

$P_{AE}$ should be calculated in accordance with the EPT-EEDI Calculation Guidelines. EPT-EEDI validation should be conducted in two stages: preliminary validation at the design stage and final validation during sea trials. The validation process is presented in figure 6.1.
6.2 Preliminary validation at the design stage

6.2.1 For the preliminary validation at the design stage, the applicant should submit to a validator an application for the validation of EPT-EEDI, inclusive of the EPT-EEDI Form, and all the relevant and necessary information for the validation as supporting documents.

6.2.2 The applicant should supply as a minimum the supporting data and information, as specified in appendix A (to be developed).

6.2.3 The validator may request from the applicant additional information to that contained in these guidelines, as necessary, to enable the validator to examine the calculation process of the EPT-EEDI. The estimation of the ship EPT-EEDI at the design stage depends on each applicant's experience, and it may not be practicable to fully examine the technical aspects and details of each machinery component. Therefore, the preliminary validation should focus on the calculation process of the EPT-EEDI that should follow best marine practices.

Note: A possible way forward for more robust validation is to establish a standard methodology of deriving the ship EPT by setting standard formats as agreed and used by industry.
6.3 Final validation

6.3.1 The final validation process should as a minimum include a check of the ship electric load analysis to ensure that all electric consumers are listed. Their specific data and the calculations in the power table itself are correct and are supported by sea trial results. If necessary, additional information has to be requested.

6.3.2 For the final validation, the applicant should revise the EPT-EEDI Form and supporting documents as necessary, by taking into account the characteristics of the machinery and other electrical loads actually installed on board the ship. The EEDI condition at sea trials should be defined and the expected power requirements in these conditions documented in the EPT. Any changes within the EPT from design stage to construction stage should be highlighted by the shipyard.

6.3.3 The preparation for the final validation includes a desk top check comprising:

1. consistency of preliminary and final EPT;
2. changes of service factors (compared to the preliminary validation);
3. all electric consumers are listed;
4. their specific data and the calculations in the power table itself are correct; and
5. in case of doubt, component specification data is checked in addition.

6.3.4 A survey prior to sea trials is performed to ensure that machinery characteristics and data as well as other electric loads comply with those recorded in the supporting documents. This survey does not cover the complete installation but selects randomly a number of samples.

6.3.5 For the purpose of sea trial validation, the surveyor will check the data of selected systems and/or components given in the special column added to the EPT for this purpose or the predicted overall value of electric load by means of practicable measurements with the installed measurement devices.

7 ISSUANCE OF THE EPT-EEDI STATEMENT OF VALIDATION

7.1 The validator should stamp the EPT-EEDI Form as "Noted" having validated the EPT-EEDI in the preliminary validation stage, in accordance with these guidelines.

7.2 The validator should stamp the EPT-EEDI Form as "Endorsed" having validated the final EPT-EEDI in the final validation stage in accordance with these guidelines.
APPENDIX 3

ELECTRIC POWER TABLE FORM FOR ENERGY EFFICIENCY DESIGN INDEX (EPT-EEDI FORM) AND STATEMENT OF VALIDATION

Ship ID:
IMO no.: ________________
Ship's name: ________________
Shipyard: ________________
Hull no.: ________________

Applicant:  Validation stage:
Name: ________________  ☐ Preliminary validation
Address: ________________

Final validation

Summary results of EPT-EEDI

<table>
<thead>
<tr>
<th>Load group</th>
<th>Seagoing condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EEDI Calculation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>guidelines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuous load (kW)</td>
<td>Intermittent load (kW)</td>
</tr>
<tr>
<td>Ship service and engine-room loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accommodation and cargo loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total installed load</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal seagoing load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted average efficiency of generators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{AE}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supporting documents

<table>
<thead>
<tr>
<th>Title</th>
<th>ID or remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Validator details:
Organization: ________________
Address: ________________

This is to certify that the above-mentioned electrical loads and supporting documents have been reviewed in accordance with EPT-EEDI Validation Guidelines and the review shows a reasonable confidence for use of the above $P_{AE}$ in EEDI calculations.

Date of review: ________________  Statement of validation no. ________________

This statement is valid on condition that the electric power characteristics of the ship do not change.

Signature of Validator

___________________________________________

Printed name: ________________
ANNEX 14

RESOLUTION MEPC. 231(65)

Adopted on 17 May 2013

2013 GUIDELINES FOR CALCULATION OF REFERENCE LINES FOR USE WITH THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)

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 that regulation 21 (required EEDI) of MARPOL Annex VI, as amended, requires reference lines to be established for each ship type to which regulation 21 is applicable,

NOTING ALSO that Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) were adopted at its sixty-third session,

HAVING CONSIDERED, at its sixty-fifth session, the draft amendments to Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for extension of the application of the EEDI to LNG carrier, ro-ro cargo ship (vehicle carrier), ro-ro cargo ship and ro-ro passenger ship,

1. ADOPTS the 2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI), as set out at annex to the present resolution;

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

3. REVOCKES the Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI), adopted by resolution MEPC.215(63), as from this date.
The reference lines are established for each ship type to which regulation 21 (Required EEDI) of MARPOL Annex VI is applicable. The purpose of the EEDI is to provide a fair basis for comparison, to stimulate the development of more efficient ships in general and to establish the minimum efficiency of new ships depending on ship type and size. Hence, the reference lines for each ship type is calculated in a transparent and robust manner.

Ship types are defined in regulation 2 of MARPOL Annex VI. The reference line for each ship type is used for the determination of the required EEDI as defined in regulation 21 of MARPOL Annex VI.

These guidelines apply to the following ships types: bulk carrier, gas carrier, tanker, containership, general cargo ship, refrigerated cargo carrier, combination carrier, ro-ro cargo ship, ro-ro cargo ship (vehicle), ro-ro passenger ship and LNG carrier. It is noted that a method of calculating reference lines has not been established for passenger ships other than cruise passenger ship having non-conventional propulsion.

Definition of a reference line

A reference line is defined as a curve representing an average index value fitted on a set of individual index values for a defined group of ships.

One reference line is developed for each ship type to which regulation 21 of MARPOL Annex VI is applicable, ensuring that only data from comparable ships are included in the calculation of each reference line.

The reference line value is formulated as $Reference\ line\ value = a (100\%\ deadweight)^{-c}$ where "a" and "c" are parameters determined from the regression curve fit.

Input data for the calculation of the reference lines is filtered through a process where data deviating more than two standard deviations from the regression line are discarded. The regression is then applied again to generate a corrected reference line. For the purpose of documentation, discarded data is listed with the ships IMO number.

Data sources

IHS Fairplay (IHSF) database is selected as the standard database delivering the primary input data for the reference line calculation. For the purpose of the EEDI reference line calculations, a defined version of the database is archived as agreed between the Secretariat and IHSF.

For the purpose of calculating the reference lines, data relating to existing ships of 400 GT and above from the IHSF database delivered in the period from 1 January 1999 to 1 January 2009 are used. For ro-ro cargo and ro-ro passenger ships, data relating to existing ships of 400 GT and above from the IHSF database delivered in the period from 1 January 1998 to 1 January 2010 are used.
The following data from the IHSF database on ships with conventional propulsion systems is used when calculating the reference lines:

.1 data on the ships' capacity is used as Capacity for each ship type as defined in MEPC.212(63);

.2 data on the ships' service speed is used as reference speed \(V_{ref}\), and

.3 data on the ships' total installed main power is used as \(MCR_{ME(i)}\).

For some ships, some data entries may be blank or contain a zero (0) in the database. Datasets with blank power, capacity and/or speed data should be removed from the reference line calculations. For the purpose of later references, the omitted ships should be listed with their IMO number.

To ensure a uniform interpretation, the association of ship types defined in regulation 2 of MARPOL Annex VI, with the ship types given by the IHSF database and defined by the so-called Stat codes, is shown in the appendix to this guideline. Table 1 in the appendix 1 lists the ship types from IHSF used for the calculation of reference lines. Table 2 lists the IHSF ship types not used when calculating the reference lines.

**Calculation of reference lines**

To calculate the reference line, an estimated index value for each ship contained in the set of ships per ship type is calculated using the following assumptions:

.1 the carbon emission factor is constant for all engines, i.e. \(C_{F,ME}=C_{F,AE}=CF=3.1144\ \text{g CO}_2/\text{g fuel};\)

.2 the specific fuel consumption for all ship types is constant for all main engines, i.e. \(SFC_{ME}=190\ \text{g/kWh};\)

.3 \(P_{ME(i)}\) is 75% of the total installed main power (\(MCR_{ME(i)}\));

.4 the specific fuel consumption for all ship types is constant for all auxiliary engines, i.e. \(SFC_{AE}=215\ \text{g/kWh};\)

.5 \(P_{AE}\) is the auxiliary power and is calculated according to paragraphs 2.5.6.1 and 2.5.6.2 of the annex to MEPC.212(63);

.6 for ro-ro passenger ships, \(P_{AE}\) is calculated as follows:

\[
P_{AE} = 0.866 \cdot CT^{0.732}
\]

.7 no correction factors are used except for \(f_{RoRo}\) and \(f_{RoPaPax}\) and

.8 innovative mechanical energy efficiency technology, shaft motors and other innovative energy efficient technologies are all excluded from the reference line calculation, i.e. \(P_{AE\text{eff}}=0\, \text{, } P_{PTI}=0\, \text{, } P_{\text{eff}}=0\).
14 The equation for calculating the estimated index value for each ship (excluding containerships and ro-ro cargo ships (vehicle carrier) – see paragraph 15) is as follows:

\[
Estimated \ Index \ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{n_{ME}} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}
\]

15 For containerships, 70 per cent of the deadweight (70% DWT) is used as capacity for calculating the estimated index value for each containership as follows:

\[
Estimated \ Index \ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{n_{ME}} P_{MEi} + 215 \cdot P_{AE}}{70\% \text{DWT} \cdot V_{ref}}
\]

16 For ro-ro cargo ship (vehicle carrier), the following equation is used:

\[
Estimated \ Index \ Value = f_{roro} \cdot 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{n_{ME}} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}
\]

Where:

\[
f_{roro} = \frac{-15571 \cdot F_{n}^2 + 5538.4 \cdot F_{n} - 132.67}{287}
\]

17 For ro-ro cargo ships the estimated index value for each individual ship is calculated as follows:

\[
Estimated \ Index \ Value = \frac{3.1144 \cdot (f_{roro} \cdot 190 \cdot \sum_{i=1}^{n_{ME}} P_{MEi} + 215 \cdot P_{AE})}{Capacity \cdot V_{ref}}
\]

18 For ro-ro passenger ships the estimated index value for each individual ship is calculated as follows:

\[
Estimated \ Index \ Value = \frac{3.1144 \cdot (f_{roro} \cdot 190 \cdot \sum_{i=1}^{n_{ME}} P_{MEi} + 215 \cdot P_{AE})}{f_{c\text{RoPax}} \cdot Capacity \cdot V_{ref}}
\]

19 For LNG carriers, the equation set out in appendix 2 is used.

**Calculation of reference line parameters "a" and "c"**

20 For all ship types to which these guidelines apply except for ro-ro passenger ships, parameters "a" and "c" are determined from a regression analysis undertaken by plotting the calculated estimated index values against 100 per cent deadweight (100% DWT).

21 For ro-ro passenger ships, parameters "a" and "c" are determined from a regression analysis undertaken by plotting the calculated estimated index values against corrected deadweight, DWT, for ships to which the capacity correction factor, \( f_{c\text{RoPax}} \), applies and against 100 per cent deadweight (100% DWT) for ships to which the capacity correction factor does not apply.
Documentation

22 For purposes of transparency, the ships used in the calculation of the reference lines should be listed with their IMO numbers and the numerator and denominator of the index formula, as given in paragraphs 14 to 19. The documentation of the aggregated figures preserves the individual data from direct access but offers sufficient information for possible later scrutiny.

***
Appendix 1

1 To ensure a uniform interpretation, ship types defined in regulation 2 of MARPOL Annex VI are compared to the ship types given in the IHSF database.

2 The IHSF Stat code system provides several levels of definition as follows:

.1 Highest level:

- A Cargo carrying
- B Work vessel
- W Non-seagoing merchant ships
- X Non-merchant
- Y Non-propelled
- Z Non-ship structures

For the purpose of the EEDI, only group "A cargo carrying" needs to be considered. A graphical representation of this is given below.

.2 The next level comprises:

- A1 Tankers
- A2 Bulk carriers
- A3 Dry cargo/passenger

There are further differentiations until level five, e.g. "A31A2GX General Cargo Ship", and each category is described.

The complete list is attached.
3 The ship types from the IHSF Stat code 5 (Statcode5v1075) used for the calculation of reference lines for the following ship types: bulk carrier, gas carrier, tanker, containership, general cargo ship, refrigerated cargo carrier and combination carrier, are set out in table 1. The IHSF database ship types, not used in the calculation of reference lines for the specific ship types, are set out in table 2, e.g. ships built for sailing on the Great Lakes and landing craft.

**Table 1: Ship types from IHSF used for the calculation of reference lines for use with the EEDI**

<table>
<thead>
<tr>
<th>Ship Type</th>
<th>Stat Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>.1 Bulk carrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk dry</td>
<td>A21A2BC</td>
<td>Bulk carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel with an arrangement of topside ballast tanks for the carriage of bulk dry cargo of a homogeneous nature.</td>
</tr>
<tr>
<td>Bulk dry</td>
<td>A21B2BO</td>
<td>Ore carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo ship fitted with two longitudinal bulkheads. Ore is carried in the centreline holds only.</td>
</tr>
<tr>
<td>Self-discharging bulk dry</td>
<td>A23A2BD</td>
<td>Bulk cargo carrier, self-discharging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A bulk carrier fitted with self-trimming holds, a conveyor belt (or similar system) and a boom which can discharge cargo alongside or to shore without the assistance of any external equipment.</td>
</tr>
<tr>
<td>Other dry bulk</td>
<td>A24A2BT</td>
<td>Cement carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel fitted with pumping arrangements for the carriage of cement in bulk. There are no weather deck hatches. May be self-discharging.</td>
</tr>
<tr>
<td></td>
<td>A24B2BW</td>
<td>Wood chips carrier, self-unloading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel with high freeboard for the carriage of wood chips. May be self-discharging.</td>
</tr>
<tr>
<td></td>
<td>A24C2BU</td>
<td>Urea carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel for the carriage of urea in bulk. May be self-discharging.</td>
</tr>
<tr>
<td></td>
<td>A24D2BA</td>
<td>Aggregates carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel for the carriage of aggregates in bulk. Also known as a sand carrier. May be self-discharging.</td>
</tr>
<tr>
<td></td>
<td>A24E2BL</td>
<td>Limestone carrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A single deck cargo vessel for the carriage of limestone in bulk. There are no weather deck hatches. May be self-discharging.</td>
</tr>
<tr>
<td><strong>.2 Gas carrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquefied gas</td>
<td>A11A2TN</td>
<td>LNG tanker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A tanker for the bulk carriage of liquefied natural gas (primarily methane) in independent insulated tanks. Liquefaction is achieved at temperatures down to -163 deg C.</td>
</tr>
<tr>
<td></td>
<td>A11B2TG</td>
<td>LPG tanker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A tanker for the bulk carriage of liquefied petroleum gas in insulated tanks, which may be independent or integral. The cargo is pressurized (smaller vessels), refrigerated (larger vessels) or both (&quot;semi-pressurized&quot;) to achieve liquefaction.</td>
</tr>
<tr>
<td></td>
<td>A11C2LC</td>
<td>CO2 tank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A tanker for the bulk carriage of liquefied carbon dioxide.</td>
</tr>
<tr>
<td></td>
<td>A11A2TQ</td>
<td>CNG tanker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A tanker for the bulk carriage of compressed natural gas. Cargo remains in gaseous state but is highly compressed.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Type Description</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>A12A2LP</td>
<td>Molten sulphur tanker</td>
<td>A tanker for the bulk carriage of molten sulphur in insulated tanks at a high temperature.</td>
</tr>
<tr>
<td>A12A2TC</td>
<td>Chemical tanker</td>
<td>A tanker for the bulk carriage of chemical cargoes, lube oils, vegetable/animal oils and other chemicals as defined in the International Bulk Chemical Code. Tanks are coated with suitable materials which are inert to the cargo.</td>
</tr>
<tr>
<td>A12B2TR</td>
<td>Chemical/products tanker</td>
<td>A chemical tanker additionally capable of the carriage of clean petroleum products.</td>
</tr>
<tr>
<td>A12C2LW</td>
<td>Wine tanker</td>
<td>A cargo ship designed for the bulk transport of wine in tanks. Tanks will be stainless steel or lined. New vessels will be classified as chemical carriers.</td>
</tr>
<tr>
<td>A12D2LV</td>
<td>Vegetable oil tanker</td>
<td>A cargo ship designed for the bulk transport of vegetable oils in tanks. Tanks will be stainless steel or lined. New vessels will be classified as chemical carriers.</td>
</tr>
<tr>
<td>A12E2LE</td>
<td>Edible oil tanker</td>
<td>A cargo ship designed for the bulk transport of edible oils in tanks. Tanks will be stainless steel or lined. New vessels will be classified as chemical carriers.</td>
</tr>
<tr>
<td>A12F2LB</td>
<td>Beer tanker</td>
<td>A tanker for the bulk carriage of beer.</td>
</tr>
<tr>
<td>A12G2LT</td>
<td>Latex tanker</td>
<td>A tanker for the bulk carriage of latex.</td>
</tr>
<tr>
<td>A12H2LJ</td>
<td>Fruit juice tanker</td>
<td>A tanker for the bulk carriage of fruit juice concentrate in insulated tanks.</td>
</tr>
<tr>
<td>A13A2TV</td>
<td>Crude oil tanker</td>
<td>A tanker for the bulk carriage of crude oil.</td>
</tr>
<tr>
<td>A13A2TW</td>
<td>Crude/oil products tanker</td>
<td>A tanker for the bulk carriage of crude oil but also for carriage of refined oil products.</td>
</tr>
<tr>
<td>A13B2TP</td>
<td>Products tanker</td>
<td>A tanker for the bulk carriage of refined petroleum products, either clean or dirty.</td>
</tr>
<tr>
<td>A13B2TU</td>
<td>Tanker (unspecified)</td>
<td>A tanker whose cargo is unspecified.</td>
</tr>
<tr>
<td>A13C2LA</td>
<td>Asphalt/Bitumen tanker</td>
<td>A tanker for the bulk carriage of asphalt/bitumen at temperatures between 150 and 200 deg C.</td>
</tr>
<tr>
<td>A13E2LD</td>
<td>Coal/oil mixture tanker</td>
<td>A tanker for the bulk carriage of a cargo of coal and oil mixed as a liquid and maintained at high temperatures.</td>
</tr>
<tr>
<td>A14A2LO</td>
<td>Water tanker</td>
<td>A tanker for the bulk carriage of water.</td>
</tr>
<tr>
<td>A14F2LM</td>
<td>Molasses tanker</td>
<td>A tanker for the bulk carriage of molasses.</td>
</tr>
<tr>
<td>A14G2LG</td>
<td>Glue tanker</td>
<td>A tanker for the bulk carriage of glue.</td>
</tr>
<tr>
<td>A14H2LH</td>
<td>Alcohol tanker</td>
<td>A tanker for the bulk carriage of alcohol.</td>
</tr>
<tr>
<td>A14N2LL</td>
<td>Caprolactam tanker</td>
<td>A tanker for the bulk carriage of caprolactam, a chemical used in the plastics industry for the production of polyamides.</td>
</tr>
<tr>
<td>A12A2TL</td>
<td>Parcels tanker</td>
<td>A chemical tanker with many segregated cargo tanks to carry multiple grades of chemicals as defined in the International Bulk Chemical Code. Typically these can have between 10 and 60 different tanks.</td>
</tr>
<tr>
<td>.4 Containership</td>
<td>Container</td>
<td>A33A2CC</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>.5 General cargo ship</td>
<td>General cargo</td>
<td>A31A2GX</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38H2GU</td>
<td>Pulp carrier</td>
</tr>
<tr>
<td>.6 Refrigerated cargo carrier</td>
<td>Refrigerated cargo</td>
<td>A34A2GR</td>
</tr>
<tr>
<td>.7 Combination carrier</td>
<td>Bulk dry/oil</td>
<td>A22A2BB</td>
</tr>
<tr>
<td></td>
<td>Bulk dry/oil</td>
<td>A22B2BR</td>
</tr>
<tr>
<td></td>
<td>Bulk dry/oil</td>
<td>A22A2BP</td>
</tr>
</tbody>
</table>
Table 2: Ship types from IHSF not included in the calculation of reference lines for use with the EEDI

<table>
<thead>
<tr>
<th>Category</th>
<th>Type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0.1 Bulk carrier</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk dry</td>
<td>A21A2BG</td>
<td>Bulk carrier, laker only</td>
<td>A single deck cargo vessel with dimensions suited to the limitations of Great Lakes of North America trade, unsuitable for open sea navigation. Hatches are more numerous than standard bulk carriers, and much wider than they are long.</td>
</tr>
<tr>
<td>Bulk dry</td>
<td>A21A2BV</td>
<td>Bulk carrier (with vehicle decks)</td>
<td>A bulk carrier with movable decks for the additional carriage of new vehicles.</td>
</tr>
<tr>
<td>Bulk dry/oil</td>
<td>A22A2BB</td>
<td>Bulk/oil carrier (OBO)</td>
<td>A bulk carrier arranged for the alternative (but not simultaneous) carriage of crude oil.</td>
</tr>
<tr>
<td>Bulk dry/oil</td>
<td>A22B2BR</td>
<td>Ore/oil carrier</td>
<td>An ore carrier arranged for the alternative (but not simultaneous) carriage of crude oil.</td>
</tr>
<tr>
<td>Bulk dry/oil</td>
<td>A22A2BP</td>
<td>Ore/bulk/products carrier</td>
<td>A bulk carrier arranged for the alternative (but not simultaneous) carriage of oil products.</td>
</tr>
<tr>
<td>Self-discharging bulk dry</td>
<td>A23A2BK</td>
<td>Bulk cargo carrier, self-discharging, laker</td>
<td>A Great Lakes bulk carrier fitted with a conveyor belt (or similar system) and a boom which can discharge cargo alongside or to shore without the assistance of any external equipment.</td>
</tr>
<tr>
<td>Other bulk dry</td>
<td>A24H2BZ</td>
<td>Powder carrier</td>
<td>A single deck cargo vessel for the carriage of fine powders such as fly ash. There are no weather deck hatches.</td>
</tr>
<tr>
<td>Other bulk dry</td>
<td>A24G2BS</td>
<td>Refined sugar carrier</td>
<td>A single deck cargo vessel for the carriage of refined sugar. Sugar is loaded in bulk and bagged in transit (BIBO – Bulk In – Bag Out).</td>
</tr>
<tr>
<td><strong>0.2 Gas carrier</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquefied gas</td>
<td>A11B2TH</td>
<td>LPG/chemical tanker</td>
<td>An LPG tanker additionally capable of the carriage of chemical products as defined in the International Bulk Chemical Code.</td>
</tr>
<tr>
<td><strong>0.3 Tanker</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td>A13A2TS</td>
<td>Shuttle tanker</td>
<td>A tanker for the bulk carriage of crude oil specifically for operation between offshore terminals and refineries. Is typically fitted with bow loading facilities.</td>
</tr>
<tr>
<td><strong>0.4 Containership</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container</td>
<td>A33B2CP</td>
<td>Passenger/containership</td>
<td>A containership with accommodation for the carriage of more than 12 passengers.</td>
</tr>
<tr>
<td>Class</td>
<td>Code</td>
<td>Description</td>
<td>Details</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>General cargo ship</td>
<td>A31A2GO</td>
<td>Open hatch cargo ship</td>
<td>A large single deck cargo vessel with full width hatches and boxed holds for the carriage of unitized dry cargo such as forest products and containers. Many are fitted with a gantry crane.</td>
</tr>
<tr>
<td>General cargo</td>
<td>A31A2GS</td>
<td>General cargo/tanker (container/oil/bulk – COB ship)</td>
<td>A general cargo ship with reversible hatch covers; one side is flush and the other is fitted with baffles for use with liquid cargoes. Containers can be carried on the hatch covers in dry cargo mode.</td>
</tr>
<tr>
<td>General cargo</td>
<td>A31A2GT</td>
<td>General cargo/tanker</td>
<td>A general cargo ship fitted with tanks for the additional carriage of liquid cargo.</td>
</tr>
<tr>
<td>General cargo</td>
<td>A31C2GD</td>
<td>Deck cargo ship</td>
<td>A vessel arranged for carrying unitized cargo on deck only. Access may be by use of a ro-ro ramp.</td>
</tr>
<tr>
<td>Passenger/general cargo</td>
<td>A32A2GF</td>
<td>General cargo/ passenger ship</td>
<td>A general cargo ship with accommodation for the carriage of more than 12 passengers.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38A2GL</td>
<td>Livestock carrier</td>
<td>A cargo vessel arranged for the carriage of livestock.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38B2GB</td>
<td>Barge carrier</td>
<td>A cargo vessel arranged for the carriage of purpose built barges (lighters) loaded with cargo. Typically loading is by way of a gantry crane. Also known as Lighter Aboard SHip vessels (LASH).</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38C2GH</td>
<td>Heavy load carrier, semi-submersible</td>
<td>A heavy load carrier which is semi-submersible for the float on loading/unloading of the cargoes.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38C3GY</td>
<td>Yacht carrier, semi-submersible</td>
<td>A semi-submersible heavy load carrier specifically arranged for the carriage of yachts.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38D2GN</td>
<td>Nuclear fuel carrier</td>
<td>A cargo vessel arranged to carry nuclear fuel in flasks.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38D2GZ</td>
<td>Nuclear fuel carrier (with ro-ro facility)</td>
<td>A nuclear fuel carrier which is loaded and unloaded by way of a ro-ro ramp.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38B3GB</td>
<td>Barge carrier, semi-submersible</td>
<td>A barge carrier which is semi-submersible for the float on loading/unloading of the barges.</td>
</tr>
<tr>
<td>Other dry cargo</td>
<td>A38C2GH</td>
<td>Heavy load carrier</td>
<td>A cargo vessel able to carry heavy and/or outsized individual cargoes. Cargo may be carried on deck or in holds and may be loaded by crane and/or ro-ro ramps.</td>
</tr>
</tbody>
</table>
### Appendix 2

**EQUATION FOR CALCULATING THE INDEX VALUE OF REFERENCE LINE FOR LNG CARRIERS**

<table>
<thead>
<tr>
<th></th>
<th>Direct Drive Diesel</th>
<th>Dual Fuel Diesel – Electronic (DFDE)</th>
<th>Steam Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Margins</strong></td>
<td><strong>Engine : 10%</strong></td>
<td><strong>Engine : –</strong></td>
<td><strong>Engine : –</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Sea : 20%</strong></td>
<td><strong>Sea : 20%</strong></td>
<td><strong>Sea : 20%</strong></td>
</tr>
<tr>
<td><strong>Design Margin</strong></td>
<td><strong>$M_{arg in} = 0.9 \over 1.2$</strong></td>
<td><strong>$M_{arg in} = \frac{1}{1.2}$</strong></td>
<td><strong>$M_{arg in} = \frac{1}{1.2}$</strong></td>
</tr>
<tr>
<td></td>
<td><strong>$M_{arg in} = 75%$</strong></td>
<td><strong>$M_{arg in} = 83%$</strong></td>
<td><strong>$M_{arg in} = 83%$</strong></td>
</tr>
<tr>
<td><strong>$P_{ME}$ Formula$^1$</strong></td>
<td>$P_{ME(i)} = 0.75 \cdot (MCR_{ME(i)} - P_{PTO(i)})$</td>
<td>$P_{ME(i)} = 0.83 \cdot \frac{MPP_{(i)}}{\eta_{Electrical(i)}}$</td>
<td>$P_{ME(i)} = 0.83 \cdot (MCR_{ME(i)} - P_{PTO(i)})$</td>
</tr>
<tr>
<td><strong>SFC$_{ME}$ in g/kWh (Fuel)</strong></td>
<td>190 (HFO)</td>
<td>175 (FBO)</td>
<td>285 (FBO)</td>
</tr>
<tr>
<td><strong>$P_{AE}$ Formula$^2$</strong></td>
<td>$P_{AE} = 0.025 \cdot \sum_{i=1}^{n_{ME}} MCR_{ME(i)} + 250 + \text{Capacity} \cdot BOR \cdot 15$</td>
<td>$P_{AE} = (0.025 + 0.02) \cdot \sum_{i=1}^{n_{ME}} P_{ME(i)} + 250$</td>
<td>$P_{AE} = 0$</td>
</tr>
<tr>
<td><strong>Index Formulae</strong></td>
<td>$\frac{190 \cdot \sum_{i=1}^{n_{ME}} P_{ME(i)} + 215 \cdot P_{AE}}{\text{Capacity} \cdot V_{ref}}$</td>
<td>$\frac{175 \cdot \sum_{i=1}^{n_{ME}} P_{ME(i)} + 175 \cdot P_{AE}}{\text{Capacity} \cdot V_{ref}}$</td>
<td>$\frac{285 \cdot \sum_{i=1}^{n_{ME}} P_{ME(i)}}{\text{Capacity} \cdot V_{ref}}$</td>
</tr>
</tbody>
</table>

**NOTES:**

1. MPP$_{(i)}$ of DFDE is calculated as 66% of MCR of engines.
2. BOR of Direct Drive Diesel is 0.15 (%/day).

***
2013 INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS, AS AMENDED (RESOLUTION MEPC.232(65), AS AMENDED BY RESOLUTIONS MEPC.255(67) AND MEPC.262(68))

1. The Marine Environment Protection Committee, at its sixty-eighth session (11 to 15 May 2015), adopted, by resolution MEPC.262(68), amendments to the 2013 Interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions (resolution MEPC.232(65), as amended by resolution MEPC.255(67)) and agreed to a phase-in period of six months for the application of the amendments. A consolidated text of the Guidelines, as requested by the Committee (MEPC 68/21, paragraph 3.101), is set out in the annex.

2. The Marine Environment Protection Committee, at its seventy-first session (3 to 7 July 2017), agreed to extend the validity of the 2013 Interim Guidelines to EEDI phase 2 and requested the Secretariat to revise MEPC.1/Circ.850/Rev.1 accordingly, for dissemination as MEPC.1/Circ.850/Rev.2 (MEPC 71/17, paragraph 5.47.1).

3. Member Governments are invited to bring the annexed 2013 Interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions, as amended, and the decision taken by MEPC 71 to the attention of Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

***
ANNEX

2013 INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS, AS AMENDED (RESOLUTION MEPC.232(65), AS AMENDED BY RESOLUTIONS MEPC.255(67) AND MEPC.262(68))

0 Purpose

The purpose of these interim guidelines is to assist Administrations and recognized organizations in verifying that ships complying with EEDI requirements set out in regulations on energy efficiency for ships have sufficient installed propulsion power to maintain the manoeuvrability in adverse conditions, as specified in regulation 21.5 of chapter 4 of MARPOL Annex VI.

1 Definition

1.1 "Adverse conditions" mean sea conditions with the following parameters:

<table>
<thead>
<tr>
<th>Significant wave height $h_s$, m</th>
<th>Peak wave period $T_p$, s</th>
<th>Mean wind speed $V_w$, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>7.0 to 15.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

JONSWAP sea spectrum with the peak parameter of 3.3 is to be considered for coastal waters.

1.2 The following adverse condition should be applied to ships defined by the following threshold values of ship size.

<table>
<thead>
<tr>
<th>Ship length, m</th>
<th>Significant wave height $h_s$, m</th>
<th>Peak wave period $T_p$, s</th>
<th>Mean wind speed $V_w$, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 200</td>
<td>4.0</td>
<td>7.0 to 15.0</td>
<td>15.7</td>
</tr>
<tr>
<td>$200 \leq L_{pp} \leq 250$</td>
<td>Parameters linearly interpolated depending on ship’s length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than $L_{pp} = 250$</td>
<td>Refer to paragraph 1.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 Applicability*

2.1 These guidelines should be applied in the case of all new ships of types as listed in table 1 of the appendix required to comply with regulations on energy efficiency for ships according to regulation 21 of MARPOL Annex VI.

2.2 Notwithstanding the above, these guidelines should not be applied to ships with non-conventional propulsion systems, such as pod propulsion.

2.3 These guidelines are intended for ships in unrestricted navigation; for other cases, the Administration should determine appropriate guidelines, taking the operational area and relevant restrictions into account.

* These interim guidelines are applied to ships required to comply with regulations on energy efficiency for ships according to regulation 21 of MARPOL Annex VI during phase 0 and phase 1 (i.e. for those ship types as in table 1 of appendix with a size of equal or more than 20,000 DWT).
3 **Assessment procedure**

3.1 The assessment can be carried out at two different levels as listed below:

- .1 minimum power lines assessment; and
- .2 simplified assessment.

3.2 The ship should be considered to have sufficient power to maintain the manoeuvrability in adverse conditions if it fulfils one of these assessment levels.

4 **Assessment level 1 – minimum power lines assessment**

4.1 If the ship under consideration has installed power not less than the power defined by the minimum power line for the specific ship type, the ship should be considered to have sufficient power to maintain manoeuvrability in adverse conditions.

4.2 The minimum power lines for the different types of ships are provided in the appendix.

5 **Assessment level 2 – simplified assessment**

5.1 The methodology for the simplified assessment is provided in the appendix.

5.2 If the ship under consideration fulfils the requirements as defined in the simplified assessment, the ship should be considered to have sufficient power to maintain manoeuvrability in adverse conditions.

6 **Documentation**

Test documentation should include at least, but not be limited to, a:

- .1 description of the ship’s main particulars;
- .2 description of the ship’s relevant manoeuvring and propulsion systems;
- .3 description of the assessment level used and results; and
- .4 description of the test method(s) used with references, if applicable.
APPENDIX

ASSESSMENT PROCEDURES TO MAINTAIN THE MANOEUVRABILITY
UNDER ADVERSE CONDITIONS, APPLICABLE DURING PHASE 0
AND PHASE 1 OF THE EEDI IMPLEMENTATION

1 Scope

1.1 The procedures as described below are applicable during phase 0 and phase 1 of the EEDI implementation as defined in regulation 21 of MARPOL Annex VI (see also paragraph 0 – Purpose of these interim guidelines).

2 Minimum power lines

2.1 The minimum power line values of total installed MCR, in kW, for different types of ships should be calculated as follows:

Minimum Power Line Value = \( a \times (DWT) + b \)

where:

\( DWT \) is the deadweight of the ship in metric tons; and
\( a \) and \( b \) are the parameters given in table 1 for tankers, bulk carriers and combination carriers.

<table>
<thead>
<tr>
<th>Ship type</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk carrier which DWT is less than 145,000</td>
<td>0.0763</td>
<td>3374.3</td>
</tr>
<tr>
<td>Bulk carrier which DWT is 145,000 and over</td>
<td>0.0490</td>
<td>7329.0</td>
</tr>
<tr>
<td>Tanker</td>
<td>0.0652</td>
<td>5960.2</td>
</tr>
<tr>
<td>Combination carrier</td>
<td>see tanker above</td>
<td></td>
</tr>
</tbody>
</table>

2.2 The total installed MCR of all main propulsion engines should not be less than the minimum power line value, where MCR is the value specified on the EIAPP Certificate.

3 Simplified assessment

3.1 The simplified assessment procedure is based on the principle that, if the ship has sufficient installed power to move with a certain advance speed in head waves and wind, the ship will also be able to keep course in waves and wind from any other direction. The minimum ship speed of advance in head waves and wind is thus selected depending on ship design, in such a way that the fulfilment of the ship speed of advance requirements means fulfilment of course-keeping requirements. For example, ships with larger rudder areas will be able to keep course even if the engine is less powerful; similarly, ships with a larger lateral windage area will require more power to keep course than ships with a smaller windage area.

3.2 The simplification in this procedure is that only the equation of steady motion in longitudinal direction is considered; the requirements of course-keeping in wind and waves are taken into account indirectly by adjusting the required ship speed of advance in head wind and waves.
3.3 The assessment procedure consists of two steps:

.1 definition of the required advance speed in head wind and waves, ensuring course-keeping in all wave and wind directions; and

.2 assessment whether the installed power is sufficient to achieve the required advance speed in head wind and waves.

**Definition of required ship speed of advance**

3.4 The required ship advance speed through the water in head wind and waves, $V_s$, is set to the larger of:

.1 minimum navigational speed, $V_{nav}$; or

.2 minimum course-keeping speed, $V_{ck}$.

3.5 The minimum navigational speed, $V_{nav}$, facilitates leaving coastal area within a sufficient time before the storm escalates, to reduce navigational risk and risk of excessive motions in waves due to unfavourable heading with respect to wind and waves. The minimum navigational speed is set to 4.0 knots.

3.6 The minimum course-keeping speed in the simplified assessment, $V_{ck}$, is selected to facilitate course-keeping of the ships in waves and wind from all directions. This speed is defined on the basis of the reference course-keeping speed $V_{ck, ref}$, related to ships with the rudder area $A_R$ equal to 0.9% of the submerged lateral area corrected for breadth effect, and an adjustment factor taking into account the actual rudder area:

$$V_{ck} = V_{ck, ref} - 10.0 \times (A_{R\%} - 0.9)$$  \hspace{1cm} (1)

where $V_{ck}$ in knots, is the minimum course-keeping speed, $V_{ck, ref}$ in knots, is the reference course-keeping speed, and $A_{R\%}$ is the actual rudder area, $A_R$, as percentage of the submerged lateral area of the ship corrected for breadth effect, $A_{LS, cor}$, calculated as $A_{R\%} = A_R/A_{LS, cor} \cdot 100\%$. The submerged lateral area corrected for breadth effect is calculated as $A_{LS, cor} = L_{pp} T_m (1.0+25.0(B_{wl}/L_{pp})^2)$, where $L_{pp}$ is the length between perpendiculars in m, $B_{wl}$ is the water line breadth in m and $T_m$ is the draft a midship in m. In case of high-lift rudders or other alternative steering devices, the equivalent rudder area to the conventional rudder area is to be used.

3.7 The reference course-keeping speed $V_{ck, ref}$ for bulk carriers, tankers and combination carriers is defined, depending on the ratio $A_{FW}/A_{LW}$ of the frontal windage area, $A_{FW}$, to the lateral windage area, $A_{LW}$, as follows:

.1 9.0 knots for $A_{FW}/A_{LW} = 0.1$ and below and 4.0 knots for $A_{FW}/A_{LW} = 0.40$ and above; and

.2 linearly interpolated between 0.1 and 0.4 for intermediate values of $A_{FW}/A_{LW}$.

**Procedure of assessment of installed power**

3.8 The assessment is to be performed in maximum draught conditions at the required ship speed of advance, $V_s$, defined above. The principle of the assessment is that the required propeller thrust, $T$ in N, defined from the sum of bare hull resistance in calm water $R_{cw}$, resistance due to appendages $R_{app}$, aerodynamic resistance $R_{air}$, and added resistance in waves $R_{aw}$, can be provided by the ship’s propulsion system, taking into account the thrust deduction factor $t$:

$$T = (R_{cw} + R_{aw} + R_{air} + R_{app})/(1-t) \hspace{1cm} (2)$$
3.9 The calm-water resistance for bulk carriers, tankers and combination carriers can be calculated neglecting the wave-making resistance as \( R_{cw} = (1 + k)C_r \frac{1}{2} \rho S V_l^2 \), where \( k \) is the form factor, \( C_r = \frac{0.075}{(\log_{10} \text{Re} - 2)^2} \) is the frictional resistance coefficient, \( \text{Re} = \frac{V_l T_m}{\nu} \) is the Reynolds number, \( \rho \) is water density in kg/m\(^3\), \( S \) is the wetted area of the bare hull in m\(^2\), \( V_l \) is the ship advance speed in m/s, and \( \nu \) is the kinematic viscosity of water in m\(^2\)/s.

3.10 The form factor \( k \) should be obtained from model tests. Where model tests are not available the empirical formula below may be used:

\[
k = -0.095 + 25.6 \frac{C_B}{(L_{pp}/B_{sh})^{1.5}} \sqrt{B_{sh}/T_m}
\]

(3)

where \( C_B \) is the block coefficient based on \( L_{pp} \).

3.11 Aerodynamic resistance can be calculated as \( R_{air} = C_{air} \frac{1}{2} \rho_A A_F V_{w,rel}^2 \), where \( C_{air} \) is the aerodynamic resistance coefficient, \( \rho_A \) is the density of air in kg/m\(^3\), \( A_F \) is the frontal windage area of the hull and superstructure in m\(^2\), and \( V_{w,rel} \) is the relative wind speed in m/s, defined by the adverse conditions in paragraph 1.1 of the interim guidelines, \( V_s \), added to the ship advance speed, \( V_s \). The coefficient \( C_{air} \) can be obtained from model tests or empirical data. If none of the above is available, the value 1.0 is to be assumed.

3.12 The added resistance in waves, \( R_{aw} \), defined by the adverse conditions and wave spectrum in paragraph 1 of the interim guidelines, is calculated as:

\[
R_{aw} = 2 \int_0^{\infty} \frac{R_{aw}(V_s, \omega)}{(2 \pi)^2} S_{aw}(\omega) d\omega
\]

(4)

where \( R_{aw}(V_s, \omega) \) is the quadratic transfer function of the added resistance, depending on the advance speed \( V_s \) in m/s, wave frequency \( \omega \) in rad/s, the wave amplitude, \( \zeta_a \) in m and the wave spectrum, \( S_{aw} \) in m\(^2\)/s. The quadratic transfer function of the added resistance can be obtained from the added resistance test in regular waves at the required ship advance speed \( V_s \) as per ITTC procedures 7.5-02 07-02.1 and 7.5-02 07-02.2, or from equivalent method verified by the Administration.

3.13 The thrust deduction factor \( t \) can be obtained either from model tests or empirical formula. Default conservative estimate is \( t = 0.7w \), where \( w \) is the wake fraction. Wake fraction \( w \) can be obtained from model tests or empirical formula; default conservative estimates are given in table 2.

<table>
<thead>
<tr>
<th>Block coefficient</th>
<th>One propeller</th>
<th>Two propellers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>0.6</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>0.7</td>
<td>0.29</td>
<td>0.19</td>
</tr>
<tr>
<td>0.8 and</td>
<td>0.35</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Table 2: Recommended values for wake fraction $w$

<table>
<thead>
<tr>
<th>Block coefficient above</th>
<th>One propeller</th>
<th>Two propellers</th>
</tr>
</thead>
</table>

3.14 The required advance coefficient of the propeller is found from the equation:

$$T = \rho u_a^2 D_P^2 K_T (J)/J^2$$  \hspace{1cm} (5)

where $D_P$ is the propeller diameter, $K_T (J)$ is the open water propeller thrust coefficient, $J = u_a/nD_P$, and $u_a = V_a/(1 - w)$. $J$ can be found from the curve of $K_T (J)/J^2$.

3.15 The required rotation rate of the propeller, $n$, in revolutions per second, is found from the relation:

$$n = u_a/(JD_P)$$  \hspace{1cm} (6)

3.16 The required delivered power to the propeller at this rotation rate $n$, $P_D$ in watt, is then defined from the relation:

$$P_D = 2\pi n^3 D_P^2 K_Q (J)$$  \hspace{1cm} (7)

where $K_Q (J)$ is the open water propeller torque coefficient curve. Relative rotative efficiency is assumed to be close to 1.0.

3.17 For diesel engines, the available power is limited because of the torque-speed limitation of the engine, $Q \leq Q_{\text{max}}(n)$, where $Q_{\text{max}}(n)$ is the maximum torque that the engine can deliver at the given propeller rotation rate $n$. Therefore, the required minimum installed MCR is calculated taking into account:

.1 torque-speed limitation curve of the engine which is specified by the engine manufacturer; and

.2 transmission efficiency $\eta_s$ which is to be assumed 0.98 for aft engine and 0.97 for midship engine, unless exact measurements are available.
ANNEX 17

RESOLUTION MEPC.233(65)

Adopted on 17 May 2013

2013 GUIDELINES FOR CALCULATION OF REFERENCE LINES FOR USE WITH THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)
FOR CRUISE PASSENGER SHIPS HAVING NON-CONVENTIONAL PROPULSION

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 that regulation 21 (required EEDI) of MARPOL Annex VI, as amended, requires reference lines to be established for each ship type to which regulation 21 is applicable,

HAVING CONSIDERED, at its sixty-fifth session, the draft 2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for cruise passenger ships having non-conventional propulsion for extension of the application of the EEDI to these ship type,

1. ADOPTS the 2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for cruise passenger ships having non-conventional propulsion, as set out at annex to the present resolution; and

2. AGREES to keep these Guidelines under review in light of the experience gained.
2013 GUIDELINES FOR CALCULATION OF REFERENCE LINES FOR USE WITH THE ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR CRUISE PASSENGER SHIPS HAVING NON-CONVENTIONAL PROPULSION

Introduction

1 Reference lines are established for each ship type to which regulation 21 (required EEDI) of MARPOL Annex VI is applicable.

2 A reference line is defined as a curve representing an average index value fitted on a set of individual index values for a defined group of ships. One reference line will be developed for each ship type to which regulation 21 of MARPOL Annex VI is applicable, ensuring that only data from comparable ships are included in the calculation of each reference line.

3 The purpose of the EEDI is to provide a fair basis for comparison, to stimulate development of more efficient ships in general and to establish the minimum efficiency of new ships depending on ship type and size. Hence, the reference lines for each ship type must be calculated in a transparent and robust manner.

4 Ship types are defined in regulation 2 of MARPOL Annex VI. The reference line for each ship type is used for calculation of the required EEDI as defined in regulation 21 of MARPOL Annex VI.

Applicability

5 These guidelines apply to cruise passenger ships having non-conventional propulsion, including diesel-electric propulsion, turbine propulsion, and hybrid propulsion systems.

6 For other ship types, refer to the Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) in resolution MEPC.215(63).

Reference line value

7 The reference line value for cruise passenger ships having non-conventional propulsion is formulated as

\[
\text{Reference line value} = 170.84 \cdot b^{-0.214}
\]

where \( b \) is the gross tonnage of the ship.

Calculating the reference line

8 To calculate the reference line, an index value for each cruise passenger ship having non-conventional propulsion is calculated using the following assumption:

.1 The carbon emission factor is constant for all engines, including engines for diesel-electric and hybrid propulsion cruise passenger ships, i.e. \( C_{F,ME} = C_{F,AE} = C_F = 3.1144 \text{ g CO}_2/\text{g fuel} \).
The carbon factor for hybrid propulsion ships equipped with gas turbines $C_{F,AE}$ is calculated as an average of the carbon factors of auxiliary engines (i.e. 3.1144 g CO$_2$/g fuel) and the carbon factor of gas turbines (i.e. 3.206 g CO$_2$/g fuel) weighted with their installed rated power.

\[ P_{ME(i)} \text{ is reflected as 75 \% of the rated installed main power (} MCR_{ME(i)}). \]

Where a ship only has electric propulsion $P_{ME(i)}$ is zero (0).

The specific fuel consumption for all ship types, including diesel-electric and hybrid propulsion cruise passenger ships, is constant for all auxiliary engines, i.e. $SFC_{AE}=215$ g/kWh.

The specific fuel consumption for hybrid propulsion cruise passenger ships equipped with gas turbines $SFC_{AE}$ is calculated as an average of the specific fuel oil consumption of the auxiliary engines (i.e. 215 g/kWh) and the specific fuel oil consumption of the gas turbines (i.e. 250 g/kWh) weighted according to their installed rated power.

$P_{AE}$ is calculated according to paragraph 2.5.6.3 of the 2012 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.212(63)) considering a given average efficiency of generator(s) weighted by power of 0.95.

Innovative mechanical energy efficiency technology, shaft generators and other innovative energy efficient technologies are all excluded from the reference line calculation, i.e. $P_{AE,eff} = 0$ and $P_{eff} = 0$.

$P_{PTI(i)}$ is 75\% of the rated power consumption of each shaft motor divided by a given efficiency of generators of 0.95 and divided by a given propulsion chain efficiency of 0.92.

The equation for calculating the index value for cruise passenger ships having non-conventional propulsion is as follows:

\[
\text{Estimated Index Value} = \frac{3.1144 \cdot 190 \cdot \sum_{i=1}^{n\text{ME}} P_{ME(i)} + C_{F,AE} \cdot SFC_{AE} \cdot (P_{AE} + \sum_{i=1}^{n\text{PTI}} P_{PTI(i)})}{\text{Gross tonnage} \cdot V_{ref}}
\]
Procedure for calculation and verification of the Energy Efficiency Design Index (EEDI)

Introduction

This procedure applies to all cases of Class Societies’ involvement in conducting the survey and certification of EEDI in accordance with regulations 5, 6, 7, 8 and 9 of MARPOL Annex VI as a Verifier defined in the IMO “2014 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)” as amended in MEPC.1/Circ.855.

1 Definitions

“Industry Guidelines” means the “2015 Industry Guidelines for calculation and verification of the Energy Efficiency Design Index (EEDI)” as submitted to MEPC 68 that may be revised in order to remain in line with the relevant IMO Guidelines.

“Verifying Society” is a Society which conducts the survey and verification of EEDI of a ship.

“Witnessing Society” is a Society which has witnessed the towing tank test of a ship of the same type as the ship whose EEDI is verified by the Verifying Society. “Ship of the same type” is defined in IMO “2014 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)”.

“Witnessing protocol” is a document showing evidence of the witnessing and acceptance of the towing tank test by the Witnessing Society, with indication such as date, signature and possible remarks of the attending surveyor.

2 Scope of the Procedure

The scope of this procedure is defined in Part I of the Industry Guidelines.

Note:

1. This Procedural Requirement applies from 1 July 2013.

2. Rev.1 of this Procedural Requirement applies from 1 July 2016.
3 Calculation of EEDI

The procedure to compute the EEDI is documented in Part II of the Industry Guidelines. For the purpose of this Procedural Requirement, calculation of the EEDI is to be performed in accordance with IMO “2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships” and Part II of the Industry Guidelines, as amended.

4 Verification of EEDI

The procedure to verify the EEDI is documented in Part III of the Industry Guidelines, together with Appendixes 1, 3, 4 and 5. For the purpose of this Procedural Requirement, verification of the EEDI is to be performed in accordance with IMO “2014 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)” and Part III of the Industry Guidelines, as amended.

A sample of document to be submitted to the Verifier including additional information for verification is provided in Appendix 2 of the Industry Guidelines.

5 Acceptance of towing tank tests witnessed by another Society

Further to the agreement of the submitter of the EEDI Technical File and the Shipowner, a Verifying Society may accept towing tank tests reports witnessed by another Society if the towing tank tested ship is of the same type as the ship of which the EEDI is verified.

Copies of the following documents are to be provided to the Verifying Society, with due consideration given to the protection of the Intellectual Property Rights (IPR) as indicated under paragraph 14 of the Industry Guidelines:

- Calculation of the reference speed of the verified ship explicitly making reference to the speed power curves of the tank tested ship model
- Witnessing protocol of the tank tested ship endorsed by the surveyor of the Witnessing Society
- Towing tank test report of the tank tested ship

On specific request of the Verifying Society, the following additional information is to be submitted:

- Ship lines and model particulars, loading and operating conditions of the tank tested ship as described in 4.2.7.2 of IMO “2014 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)” as amended, showing that the verified ship and the tank tested ship are of the same type

If some of the relevant information is held by the original Witnessing Society, the submitter should authorize the Witnessing Society to make the information available to the Verifying Society.

6 New ship (as per MARPOL Annex VI Regulation 2) designed before the entry into force of the MARPOL Annex VI amendments introducing the EEDI

It is expected that the towing tank tests of a new ship performed before the entry into force of MARPOL Annex VI amendments introducing the EEDI have not been witnessed by a Verifier. In this case, towing tank test results provided by a tank test organization with quality control
No. 38 (cont)

certified according to a recognized scheme or with experience acceptable to the Verifying Society may be accepted by the Verifying Society.

Attached:

2015 Industry Guidelines for calculation and verification of the Energy Efficiency Design Index (EEDI)
# 2015 Industry Guidelines for Calculation and Verification of EEDI

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Part I - Scope of the Industry Guidelines

1 Scope of the Guidelines

1.1 Objective

The objective of these Industry Guidelines for calculation and verification of the Energy Efficiency Design Index (EEDI), hereafter designated as "the Industry Guidelines", is to provide details and examples of calculation of attained EEDI and to support the method and role of the verifier in charge of conducting the survey and certification of EEDI in compliance with the following IMO Resolutions:

- 2014 Guidelines on the method of calculation of EEDI for new ships, Res. MEPC.245(66) adopted on 4 April 2014, as amended, referred to as the "IMO Calculation Guidelines" in the present document
- 2014 Guidelines on survey and certification of EEDI, Res. MEPC.254(67) adopted on 17 October 2014, as amended, referred to as the "IMO Verification Guidelines" in the present document
- 2013 interim Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions, Res. MEPC.232(65) as amended
- 2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI, MEPC.1/Circ.815

In the event that the IMO Guidelines are amended, then pending amendment of these Industry Guidelines, calculation and verification of EEDI are to be implemented in compliance with the amended IMO Guidelines.

1.2 Application

These Guidelines apply to new ships as defined in regulation 2.23 of MARPOL Annex VI of 400 gross tonnage and above of the types defined in regulations 2.25 to 2.31, 2.33 to 2.35, 2.38 and 2.39, as follows:

- Bulk carrier
- Gas carrier
- LNG carrier (contracted on or after 1 September 2015)
- Cruise passenger ship having non-conventional propulsion (contracted on or after 1 September 2015)
- Tanker
- Container ship
- General cargo ship
- Ro-ro cargo ship (vehicle carrier) (contracted on or after 1 September 2015)
- Ro-ro cargo ship (contracted on or after 1 September 2015)
- Ro-ro passenger ship (contracted on or after 1 September 2015)
- Refrigerated cargo carrier
- Combination carrier

The calculation and verification of EEDI shall be performed for each:
1. new ship before ship delivery
2. new ship in service which has undergone a major conversion
3. new or existing ship which has undergone a major conversion that is so extensive that the ship is regarded by the Administration as a newly constructed ship
The Industry Guidelines shall not apply to ships which have non-conventional propulsion, such as diesel-electric propulsion, turbine propulsion or hybrid propulsion systems, with the exception of cruise passenger ships with diesel-electric propulsion and LNG carriers having diesel-electric or steam turbine propulsion systems.

The Industry Guidelines shall not apply to cargo ships having ice-breaking capability as defined in regulation 2.42 of MARPOL Annex VI. As a consequence, the Industry Guidelines apply to cargo vessels with ice class up to and including Finnish-Swedish ice class 1A Super or equivalent unless they qualify as a ship with ice-breaking capability in which case they are exempt. The intermediate Polar Classes, namely PC4 and PC5, need to demonstrate ice-breaking capability through ice trials to qualify. In the initial stages, ice-breaking capability can be demonstrated based on ice tank tests.
Part II - Explanatory notes on calculation of EEDI

2 Introduction

The attained Energy Efficiency Design Index (EEDI) is a measure of a ship’s energy efficiency determined as follows:

\[ \text{EEDI} = \frac{\text{CO}_2 \text{ emission}}{\text{Transport work}} \]

The CO2 emission is computed from the fuel consumption taking into account the carbon content of the fuel. The fuel consumption is based on the power used for propulsion and auxiliary power measured at defined design conditions.

The transport work is estimated by multiplying the ship capacity as defined under 2.3 of the IMO Calculation Guidelines by the ship’s reference speed at the corresponding draft. The reference speed is determined at 75% of the rated installed power in general and 83% of the rated installed propulsion power for LNG carriers having diesel electric or steam turbine propulsion systems.

3 EEDI formula

The EEDI is provided by the following formula:

\[ \left( \prod_{i=1}^{n} \left( P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \right) + \sum_{i=1}^{n} P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \right) \frac{1}{F_{c} \cdot F_{r} \cdot \text{Capacity} \cdot V_{m}} \]

With the following notes:

The global fi factor may also be written:

\[ f_{i} = \left( \prod_{i=1}^{n} f_{i} \right) \]

where each individual fi factor is explained under section 9 of this document.

If part of the normal maximum sea load is provided by shaft generators, the term \( P_{AR} \cdot C_{FAR} \cdot SFC_{AR} \) may be replaced by:

\[ (P_{AE} - 0.75 \cdot \sum_{i=1}^{n} P_{PTO(i)} \cdot C_{FAB} \cdot SFC_{AB} + 0.75 \cdot \sum_{i=1}^{n} P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}) \]

with the condition \( 0.75 \cdot \sum_{i=1}^{n} P_{PTO(i)} \leq P_{AE} \).

Where the total propulsion power is limited by verified technical means as indicated under section 6, the term \( \left( \sum_{i=1}^{n} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} + \sum_{i=1}^{n} P_{PTT(i)} \cdot C_{FAC} \cdot SFC_{AE(i)} \right) \) is to be replaced by 75 percent of the limited total propulsion power multiplied by the average weighted value of \((SFC_{ME} \cdot C_{FME})\) and \((SFC_{AE} \cdot C_{FAE})\).

Due to the uncertainties in the estimation of the different parameters, the accuracy of the calculation of the attained EEDI cannot be better than 1%.

Therefore, the values of attained and required EEDI have to be reported with no more than three significant figures (for instance, 2.23 or 10.3) and the checking of Regulation 20, chapter 4 of MARPOL Annex VI is to be verified in accordance with this accuracy.
4 Fuel consumption and Fuel Conversion Factor

4.1 General

The conversion factor CF and the specific fuel consumption, SFC, are determined from the results recorded in the parent engine NOx Technical File as defined in paragraph 1.3.15 of the NOx Technical Code 2008.

The fuel grade used during the test of the engine in the test bed measurement of SFC determines the value of the CF conversion factor according to the table under 2.1 of the IMO Calculation Guidelines.

SFC is the corrected specific fuel consumption, measured in g/kWh, of the engines. The subscripts ME(i) and AE(i) refer to the main and auxiliary engine(s), respectively. $SFC_{AE(i)}$ is the power-weighted average among $SFC_{AE(i)}$ of the respective engines $i$.

For main engines certified to the E2 or E3 test cycles of the NOx Technical Code 2008, the engine Specific Fuel Consumption ($SFC_{ME(i)}$) is that recorded in the test report included in a NOx Technical File for the parent engine(s) at 75% of MCR power.

For engines certified to the D2 or C1 test cycles of the NOx Technical Code 2008, the engine Specific Fuel Consumption ($SFC_{AE(i)}$) is that recorded in the test report included in a NOx Technical File for the parent engine(s) at 50% of MCR power or torque rating.

The SFC is to be corrected to the value corresponding to the ISO standard reference conditions using the standard lower calorific value of the fuel oil (42,700kJ/kg), referring to ISO 15550:2002 and ISO 3046-1:2002.

For LNG driven engines for which SFC is measured in kJ/kWh, the SFC value is to be converted to g/kWh using the standard lower calorific value of the LNG (48,000 kJ/kg), referring to the 2006 IPCC Guidelines.

For those engines which do not have a test report included in a NOx Technical File because its power is below 130 kW, the SFC specified by the manufacturer is to be used.

At the design stage, in case of unavailability of test reports in the NOx Technical File, the SFC value given by the manufacturer with the addition of the guarantee tolerance is to be used.

4.2 Dual-fuel engines

Gas fuel may be used as primary fuel for one or more of the main and auxiliary engine(s) in accordance with paragraph 4.2.3 of the IMO Verification Guidelines.

For these dual-fuel engines, the $C_F$ factor and the Specific Fuel Consumption for gas (LNG) and for pilot fuel should be combined at the relevant EEDI load point as described in 2.5.1 and Appendix 4 of the IMO Calculation Guidelines.

4.3 LNG carriers with steam turbine propulsion

The Specific Fuel Consumption of the steam turbine should be determined during the running tests of the main boilers and steam turbines on board under load during the sea trials. For preliminary estimate of EEDI, manufacturer’s certificate is to be used.
5 Capacity, power and speed

5.1 Capacity

The capacity of the ship is computed as a function of the gross tonnage for cruise passenger ships and of the deadweight for other types of ships as indicated under 2.3 of the IMO Calculation Guidelines.

For the computation of the deadweight according to 2.4 of the IMO Calculation Guidelines, the lightweight of the ship and the displacement at the summer load draught are to be based on the results of the inclining test or lightweight check provided in the final stability booklet. At the design stage, the deadweight may be taken in the provisional documentation.

5.2 Power

The installed power for EEDI determination is taking into account the propulsion power and in general a fixed part of the auxiliary power, measured at the output of the crankshaft of main or auxiliary engine.

The power $P_{ME}$ is defined as 75% MCR of all main engines in general.

For LNG carriers having diesel electric propulsion system, the power $P_{ME}$ is 83% of the rated output of the electrical propulsion motor(s) divided by the electrical chain efficiency from the output of the auxiliary engines to the output of the propulsion motor(s).

For LNG carriers having steam turbine propulsion system, the power $P_{ME}$ is 83% of the rated installed power of steam turbines.

The total propulsion power is conventionally taken as follows:

$$\sum_{i=1}^{n_{ME}} P_{ME(i)} + \sum_{i=1}^{n_{PTI}} (P_{PTI(i)} \cdot \eta_{PTI(i)} \cdot \eta_{EPT})$$

In this formula:

- The value of PME(i) may be limited by verified technical means (see 6 below)
- The total propulsion power may be limited by verified technical means. In particular an electronic engine control system may limit the total propulsion power, whatever the number of engines in function (see 6 below)

The auxiliary power can be nominally defined as a specified proportion of main engine power aiming to cover normal maximum sea load for propulsion and accommodation\(^1\). The nominal values are 2.5% of main engine power plus 250 kW for installed main engine power equal to or above 10 MW. 5% of main engine power will be accounted if less than 10 MW main engine power is installed. Alternatively, as explained below, the value for auxiliary power can be taken from the electric power table (EPT) of the ship.

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\(^1\) by paragraphs 2.5.6.1 to 2.5.6.3 of the IMO Calculation Guidelines.
In addition, if shaft motors are installed, then in principle 75% of the shaft motor power is accounted for in the EEDI calculation. Detailed explanation about this is given in section 6.

For a ship where the \( P_{AE} \) value calculated by paragraphs 2.5.6.1 to 2.5.6.3 of the IMO Calculation Guidelines is significantly different from the total power used at normal seagoing operations, e.g. for cruise passenger ships, and as an option if the difference leads to a variation of the computed value of the EEDI exceeding 1%, the \( P_{AE} \) value could be estimated by the electric power (excluding propulsion) in conditions when the ship is engaged in a voyage at reference speed \( (V_{ref}) \) as given in the electric power table (EPT), divided by the average efficiency of the generator(s) weighted by power.

5.3 Speed \( V_{ref} \)

The speed \( V_{ref} \) is the ship speed, measured in knots, verified during sea trials and corrected to be given in the following ideal conditions:
- in deep water of 15°C
- assuming the weather is calm with no wind, no current and no waves
- in the loading condition corresponding to the Capacity
- at the total propulsion power defined in 5.2 taking into account shaft generators and shaft motors

6 Shaft generator and shaft motor

6.1 Introduction and background

As for 2.5.2 and 2.5.3 of IMO Calculation Guidelines, content of this section applies to ships other than LNG carriers having diesel-electric propulsion system. For LNG carriers with diesel-electric propulsion, the factor 0.75 between the propulsion power and the rated power is to be replaced by 0.83.

Ships need electrical power for the operation of engine auxiliary systems, other systems, crew accommodation and for any cargo purposes. This electrical power can be generated by diesel-generator sets (gen-sets), shaft generators, waste heat recovery systems driving a generator and possibly by new innovative technologies, e.g. solar panels.

Diesel-generator sets and shaft generators are the most common systems. While diesel-generator sets use a diesel engine powering a generator, a shaft generator is driven by the main engine. It is considered that due to the better efficiency of the main engine and efficiency of the shaft generator less CO\(_2\) is emitted compared to gen-set operation.

The EEDI formula expresses the propulsion power of a vessel as 75% of the main engine power \( P_{ME} \). It is also termed shaft power \( P_S \), which corresponds to the ship’s speed \( V_{ref} \) in the EEDI formula.

\( P_{AE} \) - the auxiliary power - is also included in the EEDI formula. However, this power demand is largely dependent on loading and trading patterns and it must also incorporate safety aspects, for example, the provision of a spare generator set. As noted in section 5, the auxiliary power can generally be taken into account as a fixed proportion of the main engine power (i.e. nominally 2.5% plus 250kW)\(^2\).

\(^2\) c.f.: precise instruction in IMO Calculation Guidelines.
The use of shaft generators is a well proven and often applied technology, particularly for high electrical power demands related to the payload e.g. reefer containers. Usually a ship design implements a main engine to reach the envisaged speed with some provision of sea margin. For the use of a shaft generator past practice and understanding was to install a bigger main engine to reach the same speed compared to the design without a shaft generator and to then have the excess power available from the main engine at any time for generation of electrical power. As a rule of thumb, one more cylinder was added to the main engine to cover this additional power demand.

The difficulty with this issue for calculation of the EEDI is that the excess power could be used to move the ship faster in the case where the shaft generator is not in use which would produce a distortion between ship designs which are otherwise the same.

The IMO Calculation Guidelines take these circumstances into account and offer options for the use of shaft generators. These options are described in detail, below.

Further, electric shaft motors operate similarly to shaft generators; sometimes a shaft generator can act as a shaft motor. The possible influence of shaft motors has also been taken into account in the IMO Calculation Guidelines and is also illustrated, below.

6.2 Main engine power without shaft generators

The main engines are solely used for the ship’s propulsion. For the purpose of the EEDI, the main engine power is 75 % of the rated installed power \( MCR_{ME(i)} \) for each main engine:

\[
P_{ME(i)} = 0.75 \times MCR_{ME(i)}
\]

6.3 Main engine power with shaft generators

Shaft generators produce electric power using power from the prime mover (main engine). Therefore the power used for the shaft generator is not available for the propulsion. Hence \( MCR_{ME} \) is the sum of the power needed for propulsion and the power needed for the shaft generator. Thus at least a part of the shaft generator’s power should be deductible from the main engine power (\( P_{ME} \)).

The power driving the shaft generator is not only deducted in the calculation. As this power is not available for propulsion this yields a reduced reference speed. The speed is to be determined from the power curve obtained at the sea trial as explained in the schematic figure provided in paragraph 2.5 of the IMO Calculation Guidelines.

It has been defined that 75% of the main engine power is entered in the EEDI calculation. To induce no confusion in the calculation framework, it has therefore also been defined to take into account 75% of the shaft power take off.

For the calculation of the effect of shaft generators, two options are available.

6.3.1 Option 1

For this option, \( P_{PTO(i)} \) is defined as 75% of the rated electrical output power \( MCR_{PTO} \) of each shaft generator. The maximum allowable deduction is limited by the auxiliary power \( P_{AE} \) as described in Paragraph 2.6 in the IMO Calculation Guidelines.

Then the main engine power \( P_{ME} \) is:
\[ P_{PTO(i)} = 0.75 \times MCR_{PTO(i)} \]
\[ \sum P_{ME(i)} = 0.75 \times \sum (MCR_{ME(i)} - P_{PTO(i)}) \text{ with } 0.75 \times \sum P_{PTO(i)} \leq P_{AE} \]

This means, that only the maximum amount of shaft generator power that is equal to \( P_{AE} \) is deductible from the main engine power. In doing so, 75% of the shaft generator power must be greater than the auxiliary power calculated in accordance to Para. 2.5.6 of the IMO Calculation Guidelines.

Higher shaft generators output than \( P_{AE} \) will not be accounted for under option 1.

### 6.3.2 Option 2

The main engine power \( P_{ME} \) to be considered for the calculation of the EEDI is defined as 75% of the power to which the propulsion system is limited. This can be achieved by any verified technical means, e.g. by electronic engine controls.

\[ P_{ME(i)} = 0.75 \times P_{\text{Shaft,limit}} \]

This option is to cover designs with the need for very high power requirements (e.g., pertaining to the cargo). With this option it is ensured that the higher main engine power cannot be used for a higher ship speed. This can be safeguarded by the use of verified technical devices limiting the power to the propulsor.

For example, consider a ship having a 15 MW main engine with a 3 MW shaft generator. The shaft limit is verified to 12 MW. The EEDI is then calculated with only 75% of 12 MW as main engine power as, in any case of operation, no more power than 12 MW can be delivered to the propulsor, irrespective of whether a shaft generator is in use or not.

It is to be noted that the guidelines do not stipulate any limits as to the value of the shaft limit in relation to main engine power or shaft generator power.

### 6.3.3 The use of specific fuel oil consumption and CF-factor

Shaft generators are driven by the main engine, therefore the specific fuel oil consumption of the main engine is allowed to be used to the full extent if 75% of the shaft generator power is equal to \( P_{AE} \).

In the case shaft generator power is less than \( P_{AE} \) then 75% of the shaft generator power is calculated with the main engine's specific fuel oil consumption and the remaining part of the total \( P_{AE} \) power is calculated with SFC of the auxiliaries (SFC\(_{AE}\)).

The same applies to the conversion factor \( C_F \), if different fuels are used in the EEDI calculation.

### 6.4 Total shaft power with shaft motors

In the case where shaft motor(s) are installed, the same guiding principles as explained for shaft generators, above, apply. But in contrast to shaft generators, motors do increase the total power to the propulsor and do increase ships’ speed and therefore must be included in the total shaft power within the EEDI calculation. The total shaft power is thus main engine(s) power plus the additional shaft motor(s) power:

\[ \sum P_{ME(i)} + \sum P_{PTI(i),Shaft} \]
Where:

\[ \sum P_{PTI(i),Shaft} = \sum \left( 0.75 \cdot P_{SM,max(i)} \cdot \eta_{PTI(i)} \right) \]

and \( \Sigma P_{ME} \) may be 0(zero) if the ship is a diesel-electric cruise passenger ship.

Similar to the shaft generators, only 75% of the rated power consumption \( P_{SM,max} \) (i.e. rated motor output divided by the motor efficiency) of each shaft motor divided by the weighted average efficiency of the generator(s) \( \eta_{Gen} \) is taken into account for EEDI calculation\(^3\).

\[ \sum P_{PTI(i)} = \sum \left( \frac{0.75 \cdot P_{SM,max(i)}}{\eta_{Gen}} \right) \]

Figure 1.1 provides the notations used for the power and efficiencies used in IMO Calculation Guidelines and the present document.

Figure 1.1: flow of power in a generic shaft motor installation

A power limitation similar to that described above for shaft generators can also be used for shaft motors. So if a verified technical measure is in place to limit the propulsion output, only 75% of limited power is to be used for EEDI calculation and also for that limited power \( V_{ref} \) is determined.

A diagram is inserted to highlight where the mechanical and electrical efficiencies or the related devices (PTI and Generator’s) are located:

---

\(^3\) The efficiency of shaft generators in the previous section has consciously not been taken into account in the denominator as inefficient generator(s) would increase the deductible power.
6.5 Calculation examples

For these calculation examples the ships’ following main parameters are set as:

\[ MCR_{ME} = 20,000 \text{ kW} \]
\[ \text{Capacity} = 20,000 \text{ DWT} \]
\[ C_{F,ME} = 3.206 \]
\[ C_{F,AE} = 3.206 \]
\[ SFC_{ME} = 190 \text{ g/kWh} \]
\[ SFC_{AE} = 215 \text{ g/kWh} \]
\[ v_{\text{ref}} = 20 \text{ kn (without shaft generator/motor)} \]

### 6.5.1 One main engine, no shaft generator

\[ MCR_{ME} = 20,000 \text{ kW} \]
\[ P_{ME} = 0.75 \times MCR_{ME} = 0.75 \times 20,000 \text{ kW} = 15,000 \text{ kW} \]
\[ v_{\text{ref}} = 20 \text{ kn (without shaft generator/motor)} \]

\[ EEDI = \frac{((15,000 \times 3.206 \times 190) + (750 \times 3.206 \times 215))}{(20 \times 20,000)} \]
\[ = 24.1 \text{ g CO}_2/\text{t nm} \]

### 6.5.2 One main engine, 0.75 × P_{PTO} < P_{AE}, option 1

\[ MCR_{PTO} = 500 \text{ kW} \]
\[ P_{PTO} = 500 \text{ kW} \times 0.75 = 375 \text{ kW} \]
\[ MCR_{ME} = 20,000 \text{ kW} \]
\[ P_{ME} = 0.75 \times (MCR_{ME} - P_{PTO}) = 0.75 \times (20,000 \text{ kW} - 375 \text{ kW}) = 14,719 \text{ kW} \]
\[ P_{AE} = (0.025 \times MCR_{ME}) + 250 \text{ kW} = 750 \text{ kW} \]
\[ v_{\text{ref}} = 19.89 \text{ kn} \]

\[ EEDI = \frac{((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME}) + (P_{AE} - 0.75 \times P_{PTO} \times C_{F,AE} \times SFC_{AE}))}{(DWT \times v_{\text{ref}})} \]
\[ = 23.8 \text{ g CO}_2/\text{t nm} \approx 1\% \]
6.5.3 One main engine, 0.75 x $P_{PTO}=P_{AE}$, option 1

$MCR_{PTO} = 1,333 kW$

$P_{PTO} = 1,333 kW \times 0.75 = 1,000 kW$

$MCR_{ME} = 20,000 kW$

$P_{ME} = 0.75 \times (MCR_{ME} - P_{PTO}) = 0.75 \times (20,000 kW - 1,000 kW) = 14,250 kW$

$P_{AE} = (0.025 \times MCR_{ME}) + 250 kW = 750 kW$

$v_{ref} = 19.71 km$: The speed at $P_{ME}$ determined from the power curve

$EEDI = \left( P_{ME} \times C_{F,ME} \times SCF_{ME} \right) \div \left( DWT \times v_{ref} \right)$

$= 23.2 \text{ g } CO_2 / \text{t nm} \approx 4\%$

6.5.4 One main engine with shaft generator, 0.75 x $P_{PTO}>P_{AE}$, option 1

$MCR_{PTO} = 2,000 kW$

$0.75 \times P_{PTO} = 0.75 \times 2,000 kW \times 0.75 = 1,125 kW > P_{AE} \Rightarrow P_{PTO} = P_{AE} / 0.75 = 1,000 kW$

$MCR_{ME} = 20,000 kW$

$P_{ME} = 0.75 \times (MCR_{ME} - P_{PTO}) = 0.75 \times (20,000 kW - 1,000 kW) = 14,250 kW$

$P_{AE} = (0.025 \times MCR_{ME}) + 250 kW = 750 kW$

$v_{ref} = 19.71 km$: The speed at $P_{ME}$ determined from the power curve

$EEDI = \left( P_{ME} \times C_{F,ME} \times SCF_{ME} \right) \div \left( DWT \times v_{ref} \right)$

$= 23.2 \text{ g } CO_2 / \text{t nm} \approx 4\%$

6.5.5 One main engine with shaft generator, 0.75 x $P_{PTO}>P_{AE}$, option 2

$MCR_{PTO} = 2,000 kW$

$MCR_{ME} = 20,000 kW$

$P_{shaft,lim} = 18,000 kW$

$P_{ME} = 0.75 \times (P_{shaft,lim}) = 0.75 \times (18,000 kW) = 13,500 kW$

$P_{AE} = (0.025 \times MCR_{ME}) + 250 kW = 750 kW$

$v_{ref} = 19.71 km$: The speed at $P_{ME}$ determined from the power curve

$EEDI = \left( P_{AE} \times C_{F,ME} \times SCF_{ME} \right) \div \left( DWT \times v_{ref} \right)$

$= 22.4 \text{ g } CO_2 / \text{t nm} \approx 7\%$

6.5.6 One main engine, one shaft motor

$MCR_{ME} = 18,000 kW$

$P_{ME} = 0.75 \times MCR_{ME} = 0.75 \times 18,000 kW = 13,500 kW$

$P_{AE} = \left( 0.025 \times (MCR_{ME} + P_{PTI} / 0.75) \right) + 250 kW = \left( 0.025 \times \left( 18,000 + \frac{1612.9}{0.75} \right) \right) + 250 kW = 754 kW$

$P_{SM,max} = 2,000 kW$

$P_{PTI} = 0.75 \times P_{SM,max} \div \eta_{PTI} = 1,612.9 kW$

$\eta_{PTI} = 0.97$

$\eta_{Gen} = 0.93$

$P_{shaft} = P_{ME} + P_{PTI,shaft} = P_{ME} + (P_{PTI} \cdot \eta_{PTI}) \cdot \eta_{Gen} = 13,500 kW + (1612.9 \cdot 0.97) \cdot 0.93 = 14,955 kW$

$v_{ref} = 20 km$

$EEDI = \left( P_{ME} \times C_{F,ME} \times SCF_{ME} \right) + \left( P_{AE} \times C_{F,AE} \times SCF_{AE} \right) + \left( P_{PTI} \times C_{F,PTI} \times SCF_{PTI} \right) \div \left( DWT \times v_{ref} \right)$

$= 24.6 \text{ g } CO_2 / \text{t nm} \approx -2\%$
7  **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 attained EEDI.

When a calculated $f_w$ factor is used, the attained EEDI using calculated $f_w$ shall be presented as "attained EEDI\textsubscript{weather}" in order to clearly distinguish it from the attained EEDI under regulations 20 in MARPOL Annex VI.

Guidelines for the calculation of the coefficient $f_w$ for the decrease of ship speed in respective sea conditions are provided in MEPC.1/Circ.796.

8  **Correction factor for ship specific design elements $f_j$**

Except in the cases listed below, the value of the $f_j$ factor is 1.0.

For Finnish-Swedish ice class notations or equivalent notations of the Classification Societies, the $f_j$ correction factor is indicated in 2.8.1 of the IMO Calculation Guidelines.

For shuttle tankers with propulsion redundancy defined as oil tankers between 80,000 and 160,000 deadweight equipped with dual-engines and twin-propellers and assigned the class notations covering dynamic positioning and propulsion redundancy, the $f_j$ factor is 0.77.

The total shaft propulsion power of shuttle tankers with redundancy is usually not limited by verified technical means.

For ro-ro cargo and ro-ro passenger ships, the factor $f_{j\text{RoRo}}$ is to be computed according to 2.8.3 of the IMO calculation Guidelines.

For general cargo ships, the factor $f_j$ is to be computed according to 2.8.4 of the IMO Calculation Guidelines.

$f_j$ factors for ice-class and for ship’s type can be cumulated (multiplied) for ice-classed general cargo ships or ro-ro cargo or ro-ro passenger ships.

9  **Capacity factor $f_i$**

Except in the cases listed below, the value of the $f_i$ factor is 1.0.

For Finnish-Swedish ice class notations or equivalent notations of the Classification Societies, the $f_i$ correction factor is indicated in 2.11.1 of the IMO Calculation Guidelines.

For a ship with voluntary structural enhancement, the $f_{i\text{VSE}}$ factor is to be computed according to 2.11.2 of the IMO Calculation Guidelines.

For bulk carriers and oil tankers built in accordance with the Common Structural Rules and assigned the class notation CSR, the $f_{i\text{CSR}}$ factor is to be computed according to 2.11.3 of the IMO Calculation Guidelines.

---

4 Tables 1 and 2 in IMO Calculation Guidelines refer to Finnish/Swedish ice classed ships usually trading in the Baltic Sea. Justified alternative values for $f_i$ and $f_j$ factors may be accepted for ice-classed ships outside this scope of application (e.g. very large ships or POLAR CLASS)
f_i capacity factors can be cumulated (multiplied), but the reference design for calculation of \( f_{\text{VSE}} \) is to comply with the ice notation and/or Common Structural Rules as the case may be.

10  Cubic capacity correction factor \( f_c \) and cargo gears factor \( f_l \)

Except in the cases listed below, the value of the \( f_c \) and \( f_l \) factors is 1.0.

For chemical tankers as defined in regulation 1.16.1 of MARPOL Annex II, the \( f_c \) factor is to be computed according to 2.12.1 of the IMO Calculation Guidelines.

For gas carriers having direct diesel driven propulsion constructed or adapted and used for the carriage in bulk of liquefied natural gas, the \( f_c \) factor is to be computed according to 2.12.2 of the IMO Calculation Guidelines. This factor is not to be applied to LNG carriers defined in regulation 2.38 of MARPOL Annex VI.

For ro-ro passenger ships having a DWT/GT-ratio of less than 0.25, the cubic capacity correction factor \( f_{\text{RoPax}} \) is to be computed according to 2.12.3 of the IMO Calculation Guidelines.

For general cargo ships only equipped with cranes, side loaders or ro-ro ramps, the \( f_l \) correction factor is to be computed according to 2.14 of the IMO Calculation Guidelines.

11  Innovative energy efficient technologies

Innovative energy efficient technologies are to be taken into account according to the 2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI, MEPC.1/Circ.815.

12  Example of calculation

12.1  List of input parameters for calculation of EEDI

The input parameters used in the calculation of the EEDI are provided in Table 1.

The values of all these parameters are to be indicated in the EEDI Technical File and the documents listed in the “source” column are to be submitted to the verifier.

For electrical generator, the rated electrical output in kW is related to the rated apparent power output in kVA by the following relation: \( \text{MCR}_{\text{PTO}} \text{(kW)} = \text{KVA}_{\text{PTO}} \times 0.8 \) where 0.8 is the conventional power factor.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Usage</th>
<th>Source</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service notation</td>
<td>Capacity, ( f_i, f_j ) and ( f_c ) factors</td>
<td></td>
<td>For the ship</td>
<td></td>
</tr>
<tr>
<td>Class notations</td>
<td>( f_j ) for shuttle tanker, ( f_{\text{CSR}} )</td>
<td>Classification file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice notation</td>
<td>( f_i ), ( f_j ) for ice class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lpp</td>
<td>Length between perpendiculars (m)</td>
<td>( f_i ), ( f_j ) for ice class, ( f_{\text{RoRop}} ), ( f_i ) for general cargo ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bs</td>
<td>Breadth (m)</td>
<td>( f_{\text{RoRop}} ), ( f_i ) for general cargo ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbol</td>
<td>Name</td>
<td>Usage</td>
<td>Source</td>
<td>Scope</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>$d_S$</td>
<td>Summer load line draught (m)</td>
<td>$f_{f_{RoRo}}, f_i$ for general cargo ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\nabla$</td>
<td>Volumetric displacement</td>
<td>$f_{f_{RoRo}}, f_i$ for general cargo ships</td>
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</tr>
<tr>
<td>$\Delta$</td>
<td>Displacement @ summer load draught (t)</td>
<td>deadweight, $f_{VSE}$, $f_{CSR}, f_{f_{RoPax}}, f_i$ for general cargo ships</td>
<td>final stability file</td>
<td></td>
</tr>
<tr>
<td>LWT</td>
<td>Ligthweight (t)</td>
<td>deadweight, $f_{VSE}$, $f_{CSR}, f_{f_{RoPax}}, f_i$ for general cargo ships</td>
<td>Sheets of Submitter calculation for lightweight referencedesign</td>
<td></td>
</tr>
<tr>
<td>GT</td>
<td>Gross tonnage Capacity</td>
<td>$f_{f_{RoPax}}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{AE}$</td>
<td>Auxiliary engine power (kW)</td>
<td>EEDI</td>
<td>Note: Computed from engines &amp; PTIs powers or electric power table</td>
<td></td>
</tr>
<tr>
<td>$V_{ref}$</td>
<td>Reference speed (knot)</td>
<td>EEDI, $f_{f_{RoRo}}, f_i$ for general cargo ships</td>
<td>Sea trial report</td>
<td></td>
</tr>
<tr>
<td>Cube</td>
<td>Total cubic capacity of the cargo tanks (m³)</td>
<td>$f_c$ for chemical tankers and gas carriers</td>
<td>Tonnage file</td>
<td></td>
</tr>
<tr>
<td>SWL</td>
<td>Safe working load of the crane (t)</td>
<td>$f_i$ for general cargo ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reach</td>
<td>Reach of the crane (m)</td>
<td>$f_i$ for general cargo ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCR</td>
<td>Rated installed power (kW)</td>
<td>$P_{ME}$</td>
<td>EIAPP certificate or nameplate (if less than 130 kW)</td>
<td>Per engine (nME + nGEN)</td>
</tr>
<tr>
<td>$MCR_{lim}$</td>
<td>Limited rated output power after PTO in (kW)</td>
<td>$P_{ME}$ with PTO option 2</td>
<td>Verification file</td>
<td></td>
</tr>
<tr>
<td>$MPP_{Motor}$</td>
<td>Rated output of motor (kW)</td>
<td>$P_{ME}$ for LNG carriers having diesel electric propulsion system</td>
<td>Certificate of the product</td>
<td></td>
</tr>
<tr>
<td>$\eta$</td>
<td>Electrical efficiency</td>
<td>$P_{ME}$ for LNG carriers having diesel electric propulsion system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MCR_{SteamTurbine}$</td>
<td>Rated installed power (kW)</td>
<td>$P_{ME}$ for LNG carriers having steam turbine propulsion system</td>
<td>Certificate of the product</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel grade</td>
<td>$C_r, SFC$</td>
<td>NOx Technical File of the parent engine</td>
<td></td>
</tr>
<tr>
<td>SFC</td>
<td>Corrected specific fuel consumption (g/kWh)</td>
<td>EEDI</td>
<td>NOx Technical File of the parent engine</td>
<td></td>
</tr>
</tbody>
</table>
Symbol | Name | Usage | Source | Scope
---|---|---|---|---
$KVA_{PTO}$ | Rated electrical apparent output power (kVA) | $P_{ME}$ | Nameplate of the shaft generator | Per shaft generator (nPTO)
$P_{PTI,Shaft}$ | Mechanical output power (kW) | EEDI | Nameplate of the shaft motor | Per shaft motor (nPTI)
$\eta_{PTI}$ | efficiency | power | Per generator (nGEN)
$\eta_{GEN}$ | efficiency | power | Per generator (nGEN)
$P_{SHAFTlim}$ | Limited shaft propulsion power (kW) | Limited power where means of limitation are fitted | Verification file | Per shaftline (nSHAFT)

### 12.2 Sample calculation of EEDI

A sample of document to be submitted to the verifier is provided in Appendix 2.

In addition, Appendix 6 contains a list of sample calculations of EEDI, as follows:

- Appendix 6.1: Cruise passenger ship with diesel-electric propulsion
- Appendix 6.2: LNG carrier with diesel-electric propulsion
- Appendix 6.3: Diesel-driven LNG carrier with re-liquefaction system
- Appendix 6.4: LNG carrier with steam turbine propulsion
Part III - Verification of EEDI

13 Verification process

Attained EEDI is to be computed in accordance with the IMO Calculation Guidelines and Part II of the present Industry Guidelines. Survey and certification of the EEDI are to be conducted on two stages:

1. preliminary verification at the design stage
2. final verification at the sea trial

The flow of the survey and certification process is presented in Figure 2.

![Flow of survey and certification process by verifier](image)

14 Documents to be submitted

A sample of documents to be submitted to the verifier including additional information for verification is provided in Appendix 2.

The following information is to be submitted by the submitter to the verifier at the design stage:

<table>
<thead>
<tr>
<th>Table 2: documents to be submitted at the design stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEDI Technical File</td>
</tr>
</tbody>
</table>
### NOx Technical File
Copy of the NOx Technical File and documented summary of the SFC correction for each type of main and auxiliary engine with copy of EIAPP certificate.

Note: if the NOx Technical File has not been approved at the time of the preliminary verification, the SFC value with the addition of the guarantee tolerance is to be provided by Manufacturer. In this case, the NOx Technical File is to be submitted at the final verification stage.

### Electric Power Table
If $P_{AE}$ is significantly different from the values computed using the formula in 2.5.6.1 or 2.5.6.2 of the IMO Calculation Guidelines

### Ship lines and model particulars
- Lines of ship
- Report including the particulars of the ship model and propeller model

### Verification file of power limitation technical arrangement
If the propulsion power is voluntarily limited by verified technical means

### Power curves
Power-speed curves predicted at full scale in sea trial condition and EEDI condition

### Description of the towing tank test facility and towing tank test organisation quality manual
If the verifier has no recent experience with the towing tank test facility and the towing tank test organization quality system is not ISO 9001 certified.
- Quality management system of the towing tank test including process control, justifications concerning repeatability and quality management processes
- Records of measuring equipment calibration as described in Appendix 3
- Standard model-ship extrapolation and correlation method (applied method and tests description)

### Gas fuel oil general arrangement plan
If gas fuel is used as the primary fuel of the ship fitted with dual fuel engines. Gas fuel storage tanks (with capacities) and bunkering facilities are to be described.

### Towing Tank Tests Plan
Plan explaining the different steps of the towing tank tests and the scheduled inspections allowing the verifier to check compliance with the items listed in Appendix 1 concerning tank tests

### Towing Tank Tests Report
- Report of the results of the towing tank tests at sea trial and EEDI condition as required in Appendix 4
- Values of the experience-based parameters defined in the standard model-ship correlation method used by the towing tank test organization/shipyard
- Reasons for exempting a towing tank test, only if applicable
- Numerical calculations report and validation file of these calculations, only if calculations are used to derive power curves

### Ship reference speed $V_{ref}$
Detailed calculation process of the ship speed, which is to include the estimation basis of experience-based parameters such as roughness coefficient, wake scaling coefficient

The following information is to be submitted by the submitter to the verifier at the final verification stage (and before the sea trials for the programme of sea trials):
Table 3: documents to be submitted at the final verification stage

<table>
<thead>
<tr>
<th>Programme of sea trials</th>
<th>Description of the test procedure to be used for the speed trial, with number of speed points to be measured and indication of PTO/PTI to be in operation, if any.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea trials report</td>
<td>Report of sea trials with detailed computation of the corrections allowing determination of the reference speed $V_{ref}$</td>
</tr>
<tr>
<td>Final stability file</td>
<td>Final stability file including lightweight of the ship and displacement table based on the results of the inclining test or the lightweight check</td>
</tr>
<tr>
<td>Final power curves</td>
<td>Final power curve in the EEDI condition showing the speed adjustment methodology</td>
</tr>
<tr>
<td>Revised EEDI Technical File</td>
<td>Including identification of the parameters differing from the calculation performed at the initial verification stage</td>
</tr>
<tr>
<td>Ship lines</td>
<td>Lines of actual ship</td>
</tr>
</tbody>
</table>

In line with the IMO Verification Guidelines (4.1.2), it is recognized that the documents listed above may contain confidential information of submitters, which requires Intellectual Property Rights (IPR) protection. In the case where the submitter wants a non-disclosure agreement with the verifier, the additional information is to be provided to the verifier upon mutually agreed terms and conditions.

15 Preliminary verification at the design stage

15.1 Scope of the verifier work

For the preliminary verification of the EEDI at the design stage, the verifier:

- Review the EEDI Technical File, check that all the input parameters (see 12.1 above) are documented and justified and check that the possible omission of a towing tank test has been properly justified
- Check that the ITTC procedures and quality system are implemented by the organization conducting the towing tank tests. The verifier should possibly audit the quality management system of the towing tank if previous experience is insufficiently demonstrated
- Witness the towing tank tests according to a test plan initially agreed between the submitter and the verifier
- Check that the work done by the towing tank test organisation is consistent with the present Guidelines. In particular, the verifier will check that the power curves at full scale are determined in a consistent way between sea trials and EEDI loading conditions, applying the same calculation process of the power curves and considering justifiable differences of experience based parameters between the two conditions
- Issue a pre-verification report

15.2 Definitions

*Experience-based parameters* means parameters used in the determination of the scale effects coefficients of correlation between the towing tank model scale results and the full scale predictions of power curves. This may include:

1. Hull roughness correction
2. Wake correction factor
3. Air resistance correction factor (due to superstructures and deck load)
4. Appendages correction factor (for appendages not present at model scale)
5. Propeller cavitation correction factor
6. Propeller open-water characteristics correction
7. \( C_p \) and \( C_N \) (see below)
8. \( \Delta C_{FC} \) and \( \Delta w_C \) (see below)

*Ship of the same type* means a ship of which hull form (expressed in the lines such as sheer plan and body plan) excluding additional hull features such as fins and of which principal particulars are identical to that of the base ship.

Definition of survey methods directly involving the verifier: Review and Witness.

**Review** means the act of examining documents in order to determine identification and traceability and to confirm that requested information are present and that EEDI calculation process conforms to relevant requirements.

**Witness** means the attendance at scheduled key steps of the towing tank tests in accordance with the agreed Test Plan to the extent necessary to check compliance with the survey and certification requirements.

### 15.3 Towing tank tests and numerical calculations

There are two loading conditions to be taken into account for EEDI: EEDI loading condition and sea trial condition.

The speed power curves for these two loading conditions are to be based on towing tank test measurements. Towing tank test means model towing tests, model self-propulsion tests and model propeller open water tests.

Numerical calculations may be accepted as equivalent to model propeller open water tests.

A towing tank test for an individual ship may be omitted based on technical justifications such as availability of the results of towing tank tests for ships of the same type according to 4.2.5 of the IMO Verification Guidelines.

Numerical calculations may be submitted to justify derivation of speed power curves, where only one parent hull form have been verified with towing tank tests, in order to evaluate the effect of additional hull features such as fore bulb variations, fins and hydrodynamic energy saving devices.

These numerical tests may include CFD calculation of propulsive efficiency at reference speed \( V_{ref} \) as well as hull resistance variations and propeller open water efficiency.

In order to be accepted, these numerical tests are to be carried out in accordance with defined quality and technical standards (ITTC 7.5-03-01-04 at its latest revision or equivalent). The comparison of the CFD-computed values of the unmodified parent hull form with the results of the towing tank tests must be submitted for review.

### 15.4 Qualification of verifier personnel

Surveyors of the verifier are to confirm through review and witness as defined in 15.2 that the calculation of EEDI is performed according to the relevant requirements listed in 1.1. The surveyors are to be qualified to be able to carry out these tasks and procedures are to be in place to ensure that their activities are monitored.

### 15.5 Review of the towing tank test organisation quality system
The verifier is to familiarize with the towing tank test organization test facilities, measuring equipment, standard model-ship extrapolation and correlation method (applied method and tests description) and quality system for consideration of complying with the requirements of 15.6 prior to the test attendance when the verifier has no recent experience of the towing tank test facilities.

When in addition the towing tank test organization quality control system is not certified according to a recognized scheme (ISO 9001 or equivalent) the following additional information relative to the towing tank test organization is to be submitted to the verifier:

1. descriptions of the towing tank test facility; this includes the name of the facility, the particulars of towing tanks and towing equipment, and the records of calibration of each monitoring equipment as described in Appendix 3

2. quality manual containing at least the information listed in the ITTC Sample quality manual (2002 issue) Records of measuring equipment calibration as described in Appendix 3

15.6 Review and Witness

The verifier is to review the EEDI Technical File, using also the other documents listed in table 2 and submitted for information in order to verify the calculation of EEDI at design stage. This review activity is described in Appendix 1. Since detailed process of the towing tank tests depends on the practice of each submitter, sufficient information is to be included in the document submitted to the verifier to show that the principal scheme of the towing tank test process meets the requirements of the reference documents listed in Appendix 1 and Appendix 4.

Prior to the start of the towing tank tests, the submitter is to submit a test plan to the verifier. The verifier reviews the test plan and agrees with the submitter which scheduled inspections will be performed with the verifier surveyor in attendance in order to perform the verifications listed in Appendix 1 concerning the towing tank tests.

Following the indications of the agreed test plan, the submitter will notify the verifier for the agreed tests to be witnessed. The submitter will advise the verifier of any changes to the activities agreed in the Test Plan and provide the submitter with the towing tank test report and results of trial speed prediction.

15.7 Model-ship correlation

Model-ship correlation method followed by the towing tank test organization or shipyard is to be properly documented with reference to the 1978 ITTC Trial prediction method given in ITTC Recommended Procedure 7.5-02-03-1.4 rev.02 of 2011 or subsequent revision, mentioning the differences between the followed method and the 1978 ITTC trial prediction method and their global equivalence.

Considering the formula giving the total full scale resistance coefficient of the ship with bilge keels and other appendages:

$$C_{TS} = \frac{S_y + S_{BK}}{S_y} \cdot \left[ (1 + k) \cdot C_{PS} + \Delta C_F + C_A \right] + C_R + C_{AAS} + C_{AppS}$$

The way of calculating the form factor k, the roughness allowance $\Delta C_F$, the correlation allowance $C_A$, the air resistance coefficient $C_{AAS}$ and the appendages coefficient $C_{AppS}$ are to
be documented (if they are taken as 0, this has to be indicated also), as indicated in Appendix 4.

The correlation method used is to be based on thrust identity and the correlation factors is to be according to method 1 \((C_p - C_N)\) or method 2 \((\Delta C_{FC} - \Delta w_C)\) of the 1978 ITTC Trial prediction method. If the standard method used by the towing tank test organization doesn’t fulfil these conditions, an additional analysis based on thrust identity is to be submitted to the verifier.

The verifier will check that the power-speed curves obtained for the EEDI condition and sea trial condition are obtained using the same calculation process and properly documented as requested in Appendix 4 “Witnessing of model test procedures”. In particular, the verifier will compare the differences between experience based coefficients \(C_p\) and \(\Delta C_{FC}\) between the EEDI condition \(\left(\nabla_{\text{full}}\right)\) and sea trial condition if different from EEDI condition \(\left(\nabla\right)\) with the indications given in Figures 3.1 and 3.2 extracted from a SAJ-ITTC study on a large number of oil tankers. If the difference is significantly higher than the values reported in the Figures, a proper justification of the values is to be submitted to the verifier.

NB: The trends in Figures 3.1 and 3.2 are based on limited data and may be revised in the future. The displayed trends depend on the method used to analyze the model tests behind the data including the form factor and other correlation factor relations. Other values may be accepted if based on sufficient number of data.

\[\delta C_p = C_p - C_{PF,full}\]

\[\nabla / \nabla_{\text{Full}}\]

**Figure 3.1: Variation of \(C_p\) - \(C_{PF,full}\) as a function of the displacement ratio**
15.8 Pre-verification report

The verifier issues the report on the "Preliminary Verification of EEDI" after it has verified the attained EEDI at the design stage in accordance with paragraphs 4.1 and 4.2 of the IMO Verification Guidelines.

A sample of the report on the “Preliminary Verification of EEDI” is provided in Appendix 5.

16 Final verification at sea trial

16.1 Sea trial procedure

For the verification of the EEDI at sea trial stage, the verifier shall:
- Examine the programme of the sea trial to check that the test procedure and in particular that the number of speed measurement points comply with the requirements of the IMO Verification Guidelines (see note below).
- Perform a survey to ascertain the machinery characteristics of some important electric load consumers and producers included in the EPT, if the power $P_{AE}$ is directly computed from the EPT data’s.
- Attend the sea trial and notes the main parameters to be used for the final calculation of the EEDI, as given under 4.3.3 of the IMO Verification Guidelines.

Figure 3.2: Variation of $\Delta C_{FC}$ as a function of the displacement ratio
- Review the sea trial report provided by the submitter and check that the measured power and speed have been corrected accordingly (see note below).
- Check that the power curve estimated for EEDI condition further to sea trial is obtained by power adjustment.
- Review the revised EEDI Technical File.
- Issue or endorse the International Energy Efficiency Certificate.

Note: For application of the present Guidelines, sea conditions and ship speed should be measured in accordance with ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials Part 1; 2014 or ISO 15016:2015.

Table 4 lists the data which are to be measured and recorded during sea trials:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Measurement</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time and duration of sea trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Draft marks readings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air and sea temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Main engine setting</td>
<td>Machinery log</td>
<td></td>
</tr>
<tr>
<td>( \Psi_0 )</td>
<td>Course direction (rad)</td>
<td>Compass</td>
<td></td>
</tr>
<tr>
<td>( V_G )</td>
<td>Speed over ground (m/s)</td>
<td>GPS</td>
<td></td>
</tr>
<tr>
<td>( n )</td>
<td>Propeller rpm (rpm)</td>
<td>Tachometer</td>
<td></td>
</tr>
<tr>
<td>( P_S )</td>
<td>Power measured (kW)</td>
<td>Torsion meter or strain gauges (for torque measurement) or any alternative method that offer an equivalent level of precision and accuracy of power measurement</td>
<td></td>
</tr>
<tr>
<td>( V_{WR} )</td>
<td>Relative wind velocity (m/s)</td>
<td>Wind indicator</td>
<td></td>
</tr>
<tr>
<td>( \Psi_{WR} )</td>
<td>Relative wind direction (rad)</td>
<td>See above</td>
<td></td>
</tr>
<tr>
<td>( T_m )</td>
<td>Mean wave period (seas and swell) (s)</td>
<td>Visual observation by multiple observers supplemented by hindcast data or wave measuring devices (wave buoy, wave radar, etc.)</td>
<td></td>
</tr>
<tr>
<td>( H_{1/3} )</td>
<td>Significant wave height (seas and swell) (m)</td>
<td>See above</td>
<td></td>
</tr>
<tr>
<td>( \chi )</td>
<td>Incident angle of waves (seas and swell) (rad)</td>
<td>See above</td>
<td></td>
</tr>
<tr>
<td>( \delta_R )</td>
<td>Rudder angle (rad)</td>
<td>Rudder</td>
<td></td>
</tr>
<tr>
<td>( \beta )</td>
<td>Drift angle (rad)</td>
<td>GPS</td>
<td></td>
</tr>
</tbody>
</table>

Prior to the sea trial, the programme of the sea trials and, if available, additional documents listed in table 3 are to be submitted to the verifier in order for the verifier to check the procedure and to attend the sea trial and perform the verifications included in Appendix 1 concerning the sea trial.

The ship speed is to be measured at sea trial for at least three power settings of which range includes the total propulsion power defined in 5.2 according to the requirements of the IMO Verification Guidelines 4.3.6. This requirement applies individually to each ship, even if the ship is a sister ship of a parent vessel.

If it is physically impossible to meet the conditions in the ISO15016:2015 or ITTC Recommended Procedure 7.5-04-01-01, a practical treatment shall be allowed based on the documented mutual agreement among the owner, the verifier and the shipbuilder.
16.2 Estimation of the EEDI reference speed $V_{\text{Ref}}$

The adjustment procedure is applicable to the most complex case where sea trials cannot be conducted in EEDI loading condition. It is expected that this will be usually the case for cargo ships like bulk carriers for instance.

Ship speed should be measured in accordance with ISO 15016:2015 or ITTC Recommended Procedure 7.5-04-01-01.1, including the accuracy objectives under paragraph 1 of ITTC Recommended Procedure 7.5-04-01-01.2. In particular, if the shaft torque measurement device cannot be installed near the output flange of main engine, then the efficiency from the measured shaft power to brake horse power should be taken into account.

Using the speed-power curve obtained from the sea trials in the trial condition, the conversion of ship’s speed from the trial condition to the EEDI condition shall be carried out by power adjustment as defined in Annex I of ISO 15016:2015.

The reference speed $V_{\text{Ref}}$ should be determined based on sea trials which have been carried out and evaluated in accordance with ISO 15016:2015 or equivalent (see note in 16.1).

Reference is made to paragraph 3 of Appendix 2 (Figure 3.1) where an example is provided.

16.3 Revision of EEDI Technical File

The EEDI Technical File is to be revised, as necessary, by taking into account the results of sea trials. Such revision is to include, as applicable, the adjusted power curve based on the results of sea trial (namely, modified ship speed under the condition as specified in paragraph 2.2 of the IMO Calculation Guidelines), the finally determined deadweight/gross tonnage and the recalculated attained EEDI and required EEDI based on these modifications.

The revised EEDI Technical File is to be submitted to the verifier for the confirmation that the revised attained EEDI is calculated in accordance with regulation 20 of MARPOL Annex VI and the IMO Calculation Guidelines.

17 Verification of the EEDI in case of major conversion

In this section, a major conversion is defined as in MARPOL Annex VI regulation 2.24 and interpretations in MEPC.1/Circ.795/Rev2, subject to the approval of the Administration.

For verification of the attained EEDI after a major conversion, no speed trials are necessary if the conversion or modifications don’t involve a variation in reference speed.

In case of conversion, the verifier will review the modified EEDI Technical File. If the review leads to the conclusion that the modifications couldn’t cause the ship to exceed the applicable required EEDI, the verifier will not request speed trials.

If such conclusion cannot be reached, like in the case of a lengthening of the ship, or increase of propulsion power of 10% or more, speed trials will be required.

If an Owner voluntarily requests re-certification of EEDI with IEE Certificate reissuance on the basis of an improvement to the ship efficiency, the verifier may request speed trials in order to validate the attained EEDI value improvement.

If speed trials are performed after conversion or modifications changing the attained EEDI value, tank tests verification is to be requested if the speed trials conditions differ from the
EEDI condition. In this case, numerical calculations performed in accordance with defined quality and technical standards (ITTC 7.5-03-01-04 at its latest revision or equivalent) replacing tank tests may be accepted by the verifier to quantify influence of the hull modifications.

In case of major conversion of a ship without prior EEDI, EEDI computation is not required, except if the Administration considers that due to the extensive character of the conversion, the ship is to be considered as a new one.
# APPENDIX 1

## Review and witness points

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Function</th>
<th>Survey method</th>
<th>Reference document</th>
<th>Documentation available to verifier</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>EEDI Technical File</td>
<td>Review</td>
<td>IMO Verification Guidelines This document</td>
<td>Documents in table 2</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>Limitation of power</td>
<td>Review</td>
<td>IMO Calculation Guidelines</td>
<td>Verification file of limitation technical means</td>
<td>Only if means of limitation are fitted</td>
</tr>
<tr>
<td>03</td>
<td>Electric Power Table</td>
<td>Review</td>
<td>Appendix 2 to IMO Calculation Guidelines Appendix 2 to IMO Verification Guidelines</td>
<td>EPT EPT-EEDI form</td>
<td>Only if PAE is significantly different from the values computed using the formula in 2.5.6.1 to 2.5.6.3 of the IMO Calculation Guidelines</td>
</tr>
<tr>
<td>04</td>
<td>Calibration of towing tank test measuring equipment</td>
<td>Review &amp; witness</td>
<td>Appendix 3</td>
<td>Calibration reports</td>
<td>Check at random that measuring devices are well identified and that calibration reports are currently valid</td>
</tr>
<tr>
<td>05</td>
<td>Model tests – ship model</td>
<td>Review &amp; witness</td>
<td>Appendix 4</td>
<td>Ship lines plan &amp; offsets table Ship model report</td>
<td>Checks described in Appendix 4.1</td>
</tr>
<tr>
<td>06</td>
<td>Model tests – propeller model</td>
<td>Review &amp; witness</td>
<td>Appendix 4</td>
<td>Propeller model report</td>
<td>Checks described in Appendix 4.2</td>
</tr>
<tr>
<td>07</td>
<td>Model tests – Resistance test, Propulsion test, Propeller open water test</td>
<td>Review &amp; witness</td>
<td>Appendix 4</td>
<td>Towing tank tests report</td>
<td>Checks described in Appendix 4.3 Note: propeller open water test is not needed if a stock propeller is used. In this case, the open water characteristics of the stock propeller are to be annexed to the towing tank tests report.</td>
</tr>
<tr>
<td>Ref.</td>
<td>Function</td>
<td>Survey method</td>
<td>Reference document</td>
<td>Documentation available to verifier</td>
<td>Remarks</td>
</tr>
<tr>
<td>------</td>
<td>---------------------------------------</td>
<td>---------------</td>
<td>--------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>08</td>
<td>Model-ship extrapolation and correlation</td>
<td>Review</td>
<td>ITTC 7.5-02-03-01.4 1978 ITTC performance prediction method (rev.02 of 2011 or subsequent revision) Appendix 4 This document 15.7</td>
<td>Documents in table 2</td>
<td>Check that the ship-model correlation is based on thrust identity with correlation factor according to method 1 ($C_P - C_N$) or method 2 ($\Delta C_{FC} - \Delta w_C$) Check that the power-speed curves obtained for the EEDI condition and sea trial condition are obtained using the same calculation process with justified values of experience-based parameters</td>
</tr>
<tr>
<td>09</td>
<td>Numerical calculations replacing towing tank tests</td>
<td>Review</td>
<td>ITTC 7.5-03-01-04 (latest revision) or equivalent</td>
<td>Report of calculations</td>
<td>For justification of calculations replacing model tests refer to 15.3.</td>
</tr>
<tr>
<td>10</td>
<td>Electrical machinery survey prior to sea trials</td>
<td>Witness</td>
<td>Appendix 2 to IMO Verification Guidelines</td>
<td>Only if $P_{AE}$ is computed from EPT</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Programme of sea trials</td>
<td>Review</td>
<td>IMO Verification Guidelines</td>
<td>Programme of sea trials</td>
<td>Check minimum number of measurement points (3) Check the EEDI condition in EPT (if $P_{AE}$ is computed from EPT)</td>
</tr>
<tr>
<td>12</td>
<td>Sea trials</td>
<td>Witness</td>
<td>ISO 15016:2015 or ITTC 7.5-04-01-01.1 (latest revision)</td>
<td>Check: • Propulsion power, particulars of the engines • Draught and trim • Sea conditions • Ship speed • Shaft power &amp; rpm Check operation of means of limitations of engines or shaft power (if fitted) Check the power consumption of selected consumers included in sea trials condition EPT (if $P_{AE}$ is computed from EPT)</td>
<td></td>
</tr>
<tr>
<td>Ref.</td>
<td>Function</td>
<td>Survey method</td>
<td>Reference document</td>
<td>Documentation available to verifier</td>
<td>Remarks</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------</td>
<td>---------------</td>
<td>--------------------------------------------------------</td>
<td>---------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>13</td>
<td>Sea trials – corrections calculation</td>
<td>Review</td>
<td>ISO 15016:2015 or ITTC Recommended Procedure 7.5-04-01-01.2</td>
<td>Sea trials report</td>
<td>Check that the displacement and trim of the ship in sea trial condition has been obtained with sufficient accuracy. Check that the power curve estimated for EEDI condition is obtained by power adjustment.</td>
</tr>
<tr>
<td>14</td>
<td>Sea trials – adjustment from trial condition to EEDI condition</td>
<td>Review</td>
<td>This document 16.2</td>
<td>Power curves after sea trial</td>
<td>Check that the power curve estimated for EEDI condition is obtained by power adjustment.</td>
</tr>
<tr>
<td>15</td>
<td>EEDI Technical File – revised after sea trials</td>
<td>Review</td>
<td>IMO Verification Guidelines</td>
<td>Revised EEDI Technical File</td>
<td>Check that the file has been updated according to sea trials results</td>
</tr>
</tbody>
</table>
APPENDIX 2

Sample of document to be submitted to the verifier including additional information for verification

Caution
Protection of Intellectual Property Rights

This document contains confidential information (defined as additional information) of submitters. Additional information should be treated as strictly confidential by the verifier and failure to do so may lead to penalties. The verifier should note following requirements of IMO Verification Guidelines:

“4.1.2 The information used in the verification process may contain confidential information of submitters, which requires Intellectual Property Rights (IPR) protection. In the case where the submitter want a non-disclosure agreement with the verifier, the additional information should be provided to the verifier upon mutually agreed terms and conditions.”

Revision list

<table>
<thead>
<tr>
<th>REV.</th>
<th>ISSUE DATE</th>
<th>DESCRIPTION</th>
<th>DRAWN</th>
<th>CHECKED</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>01/05/2014</td>
<td>Final stage: sections 1 to 16</td>
<td>XYZ</td>
<td>YYY</td>
<td>ZZZ</td>
</tr>
<tr>
<td>A</td>
<td>01/01/2013</td>
<td>Design stage: sections 1 to 13</td>
<td>XXX</td>
<td>YYY</td>
<td>ZZZ</td>
</tr>
</tbody>
</table>
1 General

This calculation of the Energy Efficiency Design Index (EEDI) is based on:

- Resolution MEPC.203(62) and MEPC.251(66) amendments to include regulations on energy efficiency in MARPOL Annex VI
- Resolution MEPC. 245(66) 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships

Calculations are being dealt with according to the Industry Guidelines on calculation and verification of EEDI, 2015 issue.

2 Data

2.1 Main parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
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<td>OWNER</td>
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</tr>
<tr>
<td>IMO No.</td>
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<td>Ship's type</td>
<td>Bulk carrier</td>
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<td>Ship classification notations</td>
<td>I HULL, MACH, Bulk Carrier CSR BC-A (holds 2 and 4 may be empty) ESP GRAB[20] Unrestricted Navigation AUT-UMS, GREEN PASSPORT, INWATERSURVEY, MON-SHAFT</td>
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<tr>
<td>Length between perpendiculars</td>
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<td>Breadth, moulded</td>
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<td>Depth, moulded</td>
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<tr>
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<td>Owner’s voluntary structural enhancements</td>
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<td>MAIN ENGINE</td>
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<tr>
<td>Type &amp; manufacturer</td>
<td>BUILDER 6SRT60ME</td>
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<tr>
<td>Specified Maximum Continuous Rating (SMCR)</td>
<td>9200 kW x 105 rpm</td>
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<tr>
<td>SFC at 75% SMCR</td>
<td>171 g/kWh</td>
<td>See paragraph 10.1</td>
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<tr>
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<td>Fuel type</td>
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<td>AUXILIARY ENGINES</td>
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### 2.2 Preliminary verification of attained EEDI

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<td>TEST corp.</td>
<td>See section 6.</td>
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<td>ISO Certification or previous experience?</td>
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2.3 Final verification of attained EEDI

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<td>See section 3</td>
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<td>Sea trial report with corrections</td>
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<td>Ship Reference speed</td>
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<td>FINAL DEADWEIGHT</td>
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<td>FINAL ATTAINED EEDI</td>
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3 Power curves

The power curves estimated at the design stage and modified after the sea trials are given in Figure 3.1.
4 Overview of propulsion system and electric power system

Figure 4.1 shows the connections within the propulsion and electric power supply systems.

The characteristics of the main engines, auxiliary engines, electrical generators and propulsion electrical motors are given in table 2.1.
5 Electric power table

The electric power for the calculation of EEDI is provided in table 5.1.

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<thead>
<tr>
<th>Id</th>
<th>Group</th>
<th>Description</th>
<th>Mech. Power $P_{m}$</th>
<th>El. Motor output</th>
<th>Efficie n. $e$</th>
<th>Rated el. Power $P_{r}$</th>
<th>load factor $k_{l}$</th>
<th>duty factor $k_{d}$</th>
<th>time factor $k_{t}$</th>
<th>use factor $k_{u}$</th>
<th>Necessary power $P_{load}$</th>
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<td>Rated el. Power &quot;Pr&quot;</td>
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<td>42</td>
<td>C</td>
<td>M/E L.O. SEPARATOR</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>6.5</td>
<td>0.9</td>
<td>1</td>
<td>0.2</td>
<td>0.18</td>
<td>1.2</td>
</tr>
<tr>
<td>43</td>
<td>C</td>
<td>G/E L.O. SEPARATOR</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>6.5</td>
<td>0.9</td>
<td>1</td>
<td>0.2</td>
<td>0.18</td>
<td>1.2</td>
</tr>
<tr>
<td>44</td>
<td>D</td>
<td>HYDROPHORE PUMP NO.1</td>
<td>2.8</td>
<td>4</td>
<td>0.84</td>
<td>3.3</td>
<td>1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>45</td>
<td>D</td>
<td>HYDROPHORE PUMP NO.2</td>
<td>2.8</td>
<td>4</td>
<td>0.84</td>
<td>3.3</td>
<td>1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>46</td>
<td>D</td>
<td>HOT WATER CIRCULATING PUMP NO.1</td>
<td>0.5</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
<td>1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>47</td>
<td>D</td>
<td>HOT WATER CIRCULATING PUMP NO.2</td>
<td>0.5</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
<td>1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.10</td>
<td>0.1</td>
</tr>
<tr>
<td>48</td>
<td>E</td>
<td>E/R WORKSHOP WELDING SPACE EXH.</td>
<td>0.5</td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
<td>0.9</td>
<td>1</td>
<td>1</td>
<td>0.90</td>
<td>0.6</td>
</tr>
<tr>
<td>49</td>
<td>F</td>
<td>ECR COOLER UNIT</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>4.2</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.50</td>
<td>2.1</td>
</tr>
<tr>
<td>50</td>
<td>F</td>
<td>FAN FOR AIR CONDITIONING PLANT</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>8.0</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
<td>0.45</td>
<td>3.6</td>
</tr>
<tr>
<td>51</td>
<td>F</td>
<td>COMP. AIR CONDITIONING PLANT NO.1</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>10.0</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
<td>0.45</td>
<td>4.5</td>
</tr>
<tr>
<td>52</td>
<td>F</td>
<td>COMP. AIR CONDITIONING PLANT NO.2</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>10.0</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
<td>0.45</td>
<td>4.5</td>
</tr>
<tr>
<td>53</td>
<td>F</td>
<td>COMP. AIR CONDITIONING PLANT NO.3</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>10.0</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
<td>0.45</td>
<td>4.5</td>
</tr>
<tr>
<td>54</td>
<td>F</td>
<td>COMP. AIR CONDITIONING PLANT NO.4</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>10.0</td>
<td>0.9</td>
<td>1</td>
<td>0.5</td>
<td>0.45</td>
<td>4.5</td>
</tr>
</tbody>
</table>
6 Towing Tank test organization quality system

Towing tank tests will be performed in TEST corp.

The quality control system of the towing tank test organization TEST corp. has been documented previously (see report 100 for the ship hull No. 12345) and the quality manual and calibration records are available to the verifier.

The measuring equipment has not been modified since the issue of report 100 and is listed in table 6.1.

Table 6.1: List of measuring equipment

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Series</th>
<th>Lab. Id.</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propeller dynamometer</td>
<td>B&amp;N 6001</td>
<td>300</td>
<td>125-2</td>
<td>Calibrated 01/01/2011</td>
</tr>
</tbody>
</table>

7 Estimation process of power curves at design stage

7.1 Test procedure

The tests and their analysis are conducted by TEST corp. applying their standard correlation method (document is given in annex 1).

The method is based on thrust identity and references ITTC Recommended Procedure 7.5 - 02 - 03 -1.4 ITTC 1978 Trial Prediction Method (in its latest reviewed version of 2011), with prediction of the full scale rpm and delivered power by use of the CP – CN correction factors.

The results are based on a Resistance Test, a Propulsion Test and use the Open Water Characteristics of the model propeller used during the tests and the Propeller Open Water Characteristics of the final propeller given in 7.4.
Results of the resistance tests and propulsion tests of the ship model are given in the report of TEST corp. given in annex 2.

7.2 Speed prediction

The ship delivered power $P_D$ and rate of revolutions $n_S$ are determined from the following equations:

$$\begin{align*}
P_D &= C_P \cdot P_{DS} \\
n_S &= C_N \cdot n_S
\end{align*}$$

Where $C_N$ and $C_P$ are experience-based factors and $P_{DS}$ (resp. $n_S$) are the delivered power (resp. rpm) obtained from the analysis of the towing tank tests.

The ship total resistance coefficient $C_{TS}$ is given by:

$$C_{TS} = \frac{S_S + S_{BK} \cdot [(1 + k) \cdot C_{FS} + \Delta C_F]}{S_S} + C_R + C_{AAS} + C_{Apps}$$

Where:

- $S_S$: ship hull wetted surface, here 9886 m$^2$
- $S_{BK}$: wetted surface of bilge keels
- $k$: form factor. Here $1+k = 1.38$ over the speed range, determined according to ITTC standard procedure 7.5-02-01
- $C_{FS}$: ship frictional resistance coefficient (computed according to ITTC 1957 formula)
- $\Delta C_F$: roughness allowance, computed according to Bowden-Davison formula. Here $\Delta C_F = 0.000339$
- $C_R$: residual resistance coefficient
- $C_{AAS}$: air resistance coefficient
- $C_{Apps}$: ship appendages (propeller boss cap fins) resistance coefficient, computed as provided in annex 2.

The air resistance coefficient is computed according to the following formula:

$$C_{AAS} = C_{DA} \cdot \frac{\rho_A \cdot A_{VS}}{\rho_S \cdot S_S}$$

Where:

- $C_{DA}$ is the air drag coefficient, here 0.8
- $\rho_A$ and $\rho_S$ are the air density and water density, respectively
- $A_{VS}$ is the projected wind area, here 820 m$^2$
- $C_{AAS} = 7.9 \times 10^{-5}$

The delivered power $P_D$ results of the towing tank tests are summarized in table 7.1 for the EEDI condition (scantling draft) and in table 7.2 for the sea trial condition (light ballast draft).

<table>
<thead>
<tr>
<th>Table 7.1: results of trial prediction in EEDI condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model reference: SX100 - model scale: 40</td>
</tr>
<tr>
<td>Loading condition: EEDI loading condition (12.70 m draft)</td>
</tr>
<tr>
<td>Resistance test: R001</td>
</tr>
<tr>
<td>Ship speed $V$ (knot)</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>12.5</td>
</tr>
</tbody>
</table>
Table 7.2: results of trial prediction in sea trial condition

<table>
<thead>
<tr>
<th>Ship speed V (knot)</th>
<th>Wake factor w_{TM}-w_{TS}</th>
<th>Propeller thrust T_S (kN)</th>
<th>Propeller torque Q_S (kNm)</th>
<th>rpm on ship n_S</th>
<th>Delivered Power P_D (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.079</td>
<td>406</td>
<td>379</td>
<td>72</td>
<td>2974</td>
</tr>
<tr>
<td>12.5</td>
<td>0.081</td>
<td>451</td>
<td>418</td>
<td>76</td>
<td>3445</td>
</tr>
<tr>
<td>13</td>
<td>0.083</td>
<td>500</td>
<td>459</td>
<td>79</td>
<td>3968</td>
</tr>
<tr>
<td>13.5</td>
<td>0.085</td>
<td>551</td>
<td>503</td>
<td>83</td>
<td>4545</td>
</tr>
<tr>
<td>14</td>
<td>0.087</td>
<td>606</td>
<td>549</td>
<td>87</td>
<td>5181</td>
</tr>
<tr>
<td>14.5</td>
<td>0.088</td>
<td>664</td>
<td>597</td>
<td>90</td>
<td>5878</td>
</tr>
<tr>
<td>15</td>
<td>0.091</td>
<td>725</td>
<td>648</td>
<td>94</td>
<td>6641</td>
</tr>
<tr>
<td>15.5</td>
<td>0.089</td>
<td>790</td>
<td>701</td>
<td>98</td>
<td>7474</td>
</tr>
</tbody>
</table>

Experience-based factor C_P: 1.05
Experience based factor C_N: 1.03

The predicted results are represented on the speed curves given in Figure 3.1. The EEDI condition results are indexed (Full, p), the sea trial condition results (Ballast, p).

### 7.3 Ship and propeller models

The ship model is at scale λ = 40. The characteristics are given in table 7.3.

Table 7.3: characteristics of the ship model

<table>
<thead>
<tr>
<th>Identification (model number or similar)</th>
<th>SX 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of construction</td>
<td>Wood</td>
</tr>
<tr>
<td>Principal dimensions</td>
<td></td>
</tr>
<tr>
<td>Length between perpendiculars (L_{PP})</td>
<td>4.625 m</td>
</tr>
<tr>
<td>Length of waterline (L_{WL})</td>
<td>4.700 m</td>
</tr>
<tr>
<td>Breadth (B)</td>
<td>0.806 m</td>
</tr>
<tr>
<td>Draught (T)</td>
<td>0.317 m</td>
</tr>
<tr>
<td>Design displacement (Δ) (kg, fresh water)</td>
<td>1008.7 kg</td>
</tr>
<tr>
<td>Wetted surface area</td>
<td>6.25 m²</td>
</tr>
<tr>
<td>Details of turbulence stimulation</td>
<td>Sand strips</td>
</tr>
<tr>
<td>Details of appendages</td>
<td>rudder</td>
</tr>
</tbody>
</table>
| Tolerances of manufacture                | +/- 2.5 mm on length
|                                          | +/- 1 mm on breadth |
The propeller model used during the tests is a stock model with the following characteristics:

<table>
<thead>
<tr>
<th>Table 7.4: characteristics of the stock propeller used during the tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification (model number or similar)</td>
</tr>
<tr>
<td>Materials of construction</td>
</tr>
<tr>
<td>Blade number</td>
</tr>
<tr>
<td>Principal dimensions</td>
</tr>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Pitch-Diameter Ratio ( (P/D) )</td>
</tr>
<tr>
<td>Expanded blade Area Ratio ( (A_E/A_0) )</td>
</tr>
<tr>
<td>Thickness Ratio ( (t/D) )</td>
</tr>
<tr>
<td>Hub/Boss Diameter ( (d_h) )</td>
</tr>
<tr>
<td>Tolerances of manufacture</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

7.4 Open water characteristics of propeller

The open water characteristics of the stock model propeller are given in annex 2. The open water characteristics of the ship propeller are given in Figure 7.1.

![Figure 7.1: open water characteristics of ship propeller](image)
8 Lines and offsets of the ship
The ships lines and offsets table are given in Annex 3.

9 Description of energy saving equipment

9.1 Energy saving equipment of which effects are expressed as $P_{AE_{eff(i)}}$ and/or $P_{eff(i)}$ in the EEDI calculation formula

None here.

9.2 Other energy saving equipment
The propeller boss cap fins are described in annex 4.

10 Justification of SFC (documents attached to NOx technical file of the parent engine)

10.1 Main engine
The shop test report for the parent main engine is provided in annex 5.1. The SFOC has been corrected to ISO conditions.

10.2 Auxiliary engine
The technical file of the EIAPP certificate of the auxiliary engines is provided in annex 5.2. The SFOC has been corrected to ISO conditions.

11 Calculation of attained EEDI at design stage

11.1 Input parameters and definitions
The EEDI quantities and intermediate calculations are listed in table 11.1:

<table>
<thead>
<tr>
<th>Table 11.1: Parameters in attained EEDI calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EEDI quantity</strong></td>
</tr>
<tr>
<td>CF&lt;sub&gt;FME&lt;/sub&gt;</td>
</tr>
<tr>
<td>PME</td>
</tr>
<tr>
<td>SFC&lt;sub&gt;ME&lt;/sub&gt;</td>
</tr>
<tr>
<td>CF&lt;sub&gt;AЕ&lt;/sub&gt;</td>
</tr>
<tr>
<td>P&lt;sub&gt;PTI&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
| P<sub>AE</sub> | 381 kW | MCR of the engine is 9200 kW, less than 10000kW 

\[
P_{AE} = 0.05 \times \left( \sum_{i=1}^{n_{ME}} MCR_{ME(i)} \times \frac{\sum_{i=1}^{n_{PTI}} P_{PTI(i)}}{0.75} \right)
\]

\[
P_{AE} = 0.05 \times 9200 \times 0.75 = 460 kW
\]

According to electric power table included in table 5.1, $\sum P_{load(i)} = 354 kW$
The weighted average efficiency of generators = 0.93 (KWelec/kWmech)

\[
P_{AE} = \frac{\sum P_{load(i)}}{0.93} = 381 kW
\]

The difference (460 – 381) KW is expected to vary EEDI by slightly
2015 Industry Guidelines for calculation and verification of EEDI

<table>
<thead>
<tr>
<th>SFC_{AE} (at 75% MCR)</th>
<th>199 g/kWh</th>
<th>According to technical file of EIAPP certificate in ISO conditions (see 10.2). According to 2.7.1 of IMO EEDI Calculation Guidelines the SFC_{AE} at 75% MCR should be used as P_{AE} is significantly different from 2.5.6 of IMO EEDI Calculation Guidelines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEff</td>
<td>0</td>
<td>No mechanical energy efficient devices The propeller boss cap fins act by reducing ship resistance</td>
</tr>
<tr>
<td>PAE_{Eff}</td>
<td>0</td>
<td>No auxiliary power reduction</td>
</tr>
<tr>
<td>fEff</td>
<td>1.0</td>
<td>Not relevant here (see above)</td>
</tr>
<tr>
<td>fJ</td>
<td>1.0</td>
<td>The ship is a bulk carrier without ice notations. fJ = 1.0</td>
</tr>
<tr>
<td>fi</td>
<td>1.017</td>
<td>No ice notation f_{ICE} = 1.0 No voluntary structural enhancement for this ship f_{VSE} = 1.0 The ship has the notation Bulk carrier CSR: f_{CSR} = 1 + 0.08<em>LWT_{CSR}/DWT_{CSR} = 1+0.08</em>11590/55000 = 1.017 f_i = f_{ICE} x f_{VSE} x f_{CSR} = 1.017</td>
</tr>
<tr>
<td>fw</td>
<td>1.0</td>
<td>For attained EEDI calculation under regulation 20 and 21 of MARPOL Annex VI, f_w is 1.0</td>
</tr>
<tr>
<td>fc</td>
<td>1.0</td>
<td>The ship is a bulk carrier f_c = 1.0</td>
</tr>
<tr>
<td>Capacity</td>
<td>55000</td>
<td>For a bulk carrier, Capacity is deadweight = 55 000 tons</td>
</tr>
<tr>
<td>V_{ref}</td>
<td>14.25 knots</td>
<td>At design stage, reference speed is obtained from the towing tank test report and delivered power in scantling draft (EEDI) condition is given in table 7.1 In table 7.1 P_D = 1.0 x P_{ME} = 6900 kW The reference speed is read on the speed curve corresponding to table 7.1 at intersection between curve Full, p and 6900 kW V_{ref} = 14.25 knots</td>
</tr>
</tbody>
</table>

### 11.2 Result

For this vessel, Attained EEDI is:

\[
\text{Attained EEDI} = \frac{(6900\times3.206\times171+381\times3.206\times199)}{(1.017\times55000\times14.25)} = 5.05 \text{ g/t.nm}
\]

### 12 Required EEDI

According to MARPOL Annex VI, Chapter 4, Regulation 21, the required EIDI is:

\[
(1-x/100) \times \text{reference line value}
\]

The reference line value = \(a\times b^c\) where \(a\), \(b\), \(c\) are given for a bulk carrier as:

\[
a = 961.79 \quad b = \text{deadweight of the ship} \quad c = 0.477
\]

So reference line value = 5.27 g/t.nm

In Phase 0 (between 1 Jan 2013 and 31 Dec 2014) above 20000 DWT, \(x = 0\)

So Required EEDI = 5.27 g/t.nm

Figure 12.1 provides the relative position of attained EEDI with reference to required value.

As a conclusion, for this vessel:

- attained EEDI = 5.05 g/t.nm
- required EEDI = 5.27 g/t.nm
- Regulation criteria is satisfied with 4.2% margin

**Figure 12.1: Required EEDI value**

13 Calculation of attained EEDI\text{weather}

Not calculated.

14 Lightweight check report

The lightweight check report is provided in annex 6. The final characteristics of the ship are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>66171 tons</td>
</tr>
<tr>
<td>Lightweight</td>
<td>11621 tons</td>
</tr>
<tr>
<td>Deadweight</td>
<td>54550 DWT</td>
</tr>
</tbody>
</table>

15 Sea trial report with corrections

The sea trial report is provided in annex 7. The results of the sea trial after corrections by BSRA and ITTC standard methods are given on curve Ballast,\text{s on Figure 3.1.}

16 Calculation of attained EEDI at final stage

16.1 Recalculated values of parameters

The EEDI quantities and intermediate calculations are listed in table 16.1. Parameters which have not been modified from the preliminary verification stage are marked “no change”. 
Table 16.1: Parameters in attained EEDI calculation (final stage)

<table>
<thead>
<tr>
<th>EEDI quantity</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFME</td>
<td>3.206</td>
<td>No change</td>
</tr>
<tr>
<td>PME</td>
<td>6900 kW</td>
<td>No change</td>
</tr>
<tr>
<td>SFCME</td>
<td>171 g/kWh</td>
<td>No change</td>
</tr>
<tr>
<td>CFAE</td>
<td>3.206</td>
<td>No change</td>
</tr>
<tr>
<td>PPTI</td>
<td>0</td>
<td>No change</td>
</tr>
<tr>
<td>PAE</td>
<td>381 kW</td>
<td>The electric power table has been validated and endorsed (see the electric power table form in annex 8)</td>
</tr>
<tr>
<td>SFCAE at 75% MCR</td>
<td>199 g/kWh</td>
<td>No change</td>
</tr>
<tr>
<td>P_eff</td>
<td>0</td>
<td>No change</td>
</tr>
<tr>
<td>PAE_eff</td>
<td>0</td>
<td>No change</td>
</tr>
<tr>
<td>f_eff</td>
<td>1.0</td>
<td>No change</td>
</tr>
</tbody>
</table>
| f_i           | 1.017                  | Deadweight and lightweight are computed from lightweight check: \( f_{ICSR} = 1 + 0.08 \times \frac{LWT_{CSR}}{DWT_{CSR}} = 1 + 0.08 \times \frac{11621}{54550} = 1.017 \)
| f_c           | 1.0                    | No change                                                               |
| Capacity      | 54550 DWT              | Deadweight has been computed from the lightweight check. See 14.          |
| V_ref         | 14.65 knots            | The reference speed in EEDI condition has been adjusted according to the delivered power adjustment methodology defined in Industry Guidelines. The reference speed is read on the speed curves diagram in Figure 3.1 \( V_{ref} = 14.65 \) knots |

16.2 Final result

Attained EEDI = \( \frac{(6900 \times 3.206 \times 171 + 381 \times 3.206 \times 199)}{(1.017 \times 54550 \times 14.65)} \) = 4.95 g/t.nm

Required EEDI in Phase 0: \( 961.79 \times 54550^{0.477} = 5.29 \) g/t.nm

Regulation criteria is satisfied with 6.4% margin
List of annexes to the Document

Annex 1  Standard model-ship extrapolation and correlation method

Annex 2  Towing tank tests report

Annex 3  Ship lines and offsets table

Annex 4  Description of energy saving equipment

Annex 5  5.1 NOx Technical File of main engine(s)
          5.2 NOx Technical File of auxiliary engines

Annex 6  Lightweight check report

Annex 7  Sea trials report

Annex 8  EPT-EEDI form
APPENDIX 3
Verifying the calibration of model test equipment

Quality Control System

The existence of a Quality Control System is not sufficient to guarantee the correctness of the test procedures; QS, including ISO 9000, only give documentary evidence what is to be and has been done. Quality Control Systems do not evaluate the procedures as such.

The Test institute should have a quality control system (QS). If the QS is not certified ISO 9000 a documentation of the QS should be shown. A Calibration Procedure is given in ITTC Recommended Procedures 7.6-01-01.

1. Measuring Equipment

An important aspect of the efficient operation of Quality System according to measuring equipment is a full identification of devices used for the tests.

Measuring equipment instruments shall have their individual records in which the following data shall be placed:
- name of equipment
- manufacturer
- model
- series
- laboratory identification number ( optionally)
- status ( verified, calibration, indication )

Moreover the information about the date of last and next calibration or verification shall be placed on this record. All the data shall be signed by authorised officer.

2. Measuring Standards

Measuring standards used in laboratory for calibration purposes shall be confirmed (verified) by Weights and Measures Office at appropriate intervals (defined by the Weights and Measures Office).

All measuring standards used in laboratory for the confirmation purposes shall be supported by certificates, reports or data sheets for the equipment confirming the source, uncertainty and conditions under which the results were obtained.

3. Calibration

The calibration methods may differ from institution to institution, depending on the particular measurement equipment. The calibration shall comprise the whole measuring chain (gauge, amplifier, data acquisition system etc.).

The laboratory shall ensure that the calibration tests are carried out using certified measuring standards having a known valid relationship to international or nationally recognised standards.

a) Calibration Report

“Calibration reports” shall include:
- identification of certificate for measuring standards
- description of environmental conditions
- calibration factor or calibration curve
- uncertainty of measurement
- minimum and maximum capacity” for which the error of measuring instrument is within specified (acceptable) limits.

b) Intervals of Confirmation

The measuring equipment (including measuring standards) shall be confirmed at appropriate (usually periodical) intervals, established on the basis of their stability, purpose and wear. The intervals shall be such that confirmation is carried out again prior to any probable change in the equipment accuracy, which is important for the equipment reliability. Depending on the results of preceding calibrations, the confirmation period may be shortened, if necessary, to ensure the continuous accuracy of the measuring equipment.

The laboratory shall have specific objective criteria for decisions concerning the choice of intervals of confirmation.

c) Non-Conforming Equipment

Any item of measuring equipment
- that has suffered damage,
- that has been overloaded or mishandled,
- that shows any malfunction,
- whose proper functioning is subject to doubt,
- that has exceeded its designated confirmation interval, or
- the integrity of whose seal has been violated, shall be removed from service by segregation, clear labelling or cancelling.

Such equipment shall not be returned to service until the reasons for its nonconformity have been eliminated and it is confirmed again.

If the results of calibration prior to any adjustment or repair were such as to indicate a risk of significant errors in any of the measurements made with the equipment before the calibration, the laboratory shall take the necessary corrective action.

4. Instrumentation

Especially the documentation on the calibration of the following Instrumentation should be shown.

a) Carriage Speed

The carriage speed is to be calibrated as a distance against time. Period between the calibrations is to be in accordance with the internal procedure of the towing tank test organisation.

b) Water Temperature

Measured by calibrated thermometer with certificate (accuracy 0.1°C).

c) Trim Measurement

Calibrated against a length standard. Period between the calibrations is to be in accordance with the internal procedure of the towing tank test organisation.

d) Resistance Test
Resistance Test is a force measurement. It is to be calibrated against a standard weight. Calibration normally before each test series.

e) Propulsion Test
During Self Propulsion Test torque, thrust and rate of revolutions are measured. Thrust and Torque are calibrated against a standard weight. Rate of revolution is normally measured by a pulse tachometer and an electronic counter which can be calibrated e.g. by an oscillograph.

Period between the calibrations is to be in accordance with the internal procedure of the towing tank test organisation.

f) Propeller Open Water Test
During Propeller Open Water Test torque, thrust and rate of revolutions are measured. Thrust and Torque are calibrated against a standard weight. Rate of revolution is normally measured by a pulse tachometer and an electronic counter which can be calibrated e.g. by an oscillograph.

Period between the calibrations is to be in accordance with the internal procedure of the towing tank test organisation.

Examples of documentation sheets are given in the Annexes 1 and 2:
### ANNEX 1: SAMPLE OF MEASURING EQUIPMENT CARD

<table>
<thead>
<tr>
<th>QM 4.10.5.1</th>
<th>Measurement Equipment Card</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Manufacturer</th>
<th>Serial No.</th>
<th>Model</th>
<th>Date of Purchase</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Basic range</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibrated</td>
<td></td>
</tr>
<tr>
<td>Indication</td>
<td></td>
</tr>
<tr>
<td>Verified</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of Check</th>
<th>Certificate No.</th>
<th>Period</th>
<th>Date of Next Check</th>
<th>Responsible</th>
<th>Department</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>


# ANNEX 2: SAMPLE OF CALIBRATION CERTIFICATE.

<table>
<thead>
<tr>
<th>CALIBRATION CERTIFICATE for</th>
<th>NO.</th>
<th>LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROPELLER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calibration Instructions | Calibrated by: |
Date of calibration | Checked by: |

## Measurement combination

### DYNAMOMETER

<table>
<thead>
<tr>
<th>LIN</th>
<th>Manufacturer</th>
<th>Serial No</th>
<th>Model</th>
<th>Date of purchased</th>
<th>Last calibration</th>
</tr>
</thead>
</table>

Work instruction

### Cable

### AMPLIFIER

<table>
<thead>
<tr>
<th>LIN</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Date of purchased</th>
<th>Type of transducer</th>
<th>Frequency of excit.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Work instruction</th>
<th>Excitation</th>
<th>Amp. gain</th>
<th>Amp. gain</th>
<th>Thrust:</th>
<th>Torque:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero not load</td>
<td>Zero not load</td>
<td>Amp. gain</td>
<td>Amp. gain</td>
<td>Amp. gain</td>
<td>Amp. gain</td>
<td>Amp. gain</td>
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</table>

### Cable

### A/C TRANSDUCER

<table>
<thead>
<tr>
<th>LIN</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Date of purchased</th>
<th>Certificate No</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Work instruction</th>
<th>Certificate No</th>
</tr>
</thead>
</table>

### MEASUREMENT STANDARDS

<table>
<thead>
<tr>
<th>Mass</th>
<th>Certificate No</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Length arm of force</th>
<th>Certificate No</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Voltmeter</th>
<th>Certificate No</th>
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</table>
### CALIBRATION RESULTS

#### Environmental condition

<table>
<thead>
<tr>
<th>Place of test</th>
<th>Temperature</th>
<th>Dampness</th>
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<tbody>
<tr>
<td></td>
<td>initial</td>
<td>initial</td>
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</tbody>
</table>

#### Computation results of calibrations test

<table>
<thead>
<tr>
<th>Executed program</th>
<th>procedure</th>
<th>certificate NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

#### Thrust and Torque

<table>
<thead>
<tr>
<th>Drift</th>
<th>Non Linearity errors</th>
<th>Hysteresis</th>
<th>Precision errors</th>
<th>Total uncertainty</th>
<th>Calibration factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Calibration requests

<table>
<thead>
<tr>
<th>Specified limits of errors</th>
<th>Thrust</th>
<th>Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum capacity</th>
<th>Minimum capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** tests and computations results are included in report

Prepared by: ....................... Approved by: ....................... Date: ...................
APPENDIX 4  
Review and witnessing of model test procedures

The Model Tests is to be witnessed by the verifier. Special attention is to be given to the following items:

1. Ship Model

Hydrodynamic Criteria

a) Model Size: The model should generally be as large as possible for the size of the towing tank taking into consideration wall, blockage and finite depth effects, as well as model mass and the maximum speed of the towing carriage (ITTC Recommended Procedure 7.5-02-02-01 Resistance Test).

b) Reynolds Number: The Reynolds Number is to be, if possible, above $2.5 \times 10^5$.

c) Turbulence Stimulator: In order to ensure turbulent flow, turbulence stimulators have to be applied.

Manufacture Accuracy

With regard to accuracy the ship model is to comply with the criteria given in ITTC Recommended Procedure 7.5-01-01-01, Ship Models.

The following points are to be checked:

a) Main dimensions: $L_{PP}$, $B$.

b) Surface finish: Model is to be smooth. Particular care is to be taken when finishing the model to ensure that geometric features such as knuckles, spray rails, and boundaries of transom sterns remain well-defined.

c) Stations and Waterlines: The spacing and numbering of displacement stations and waterlines are to be properly defined and accurately marked on the model.

d) Displacement: The model is to be run at the correct calculated displacement. The model weight is to be correct to within 0.2% of the correct calculated weight displacement. In case the marked draught is not met when the calculated displacement has been established the calculation of the displacement and the geometry of the model compared to the ship has to be revised. (Checking the Offsets).

Documentation in the report

Identification (model number or similar)  
Materials of construction  
Principal dimensions  
Length between perpendiculars ($L_{PP}$)  
Length of waterline ($L_{WL}$)  
Breadth ($B$)  
Draught ($T$)  
For multihull vessels, longitudinal and transverse hull spacing  
Design displacement ($\Delta$) (kg, fresh water)
Hydrostatics, including water plane area and wetted surface area
Details of turbulence stimulation
Details of appendages
Tolerances of manufacture

2. Propeller Model

The Manufacturing Tolerances of Propellers for Propulsion Tests are given IN ITTC Recommended Procedures 7.5-01-01-01, Ship Models Chapter 3.1.2. Attention: Procedure 7.5 – 01-02-02 Propeller Model Accuracy is asking for higher standards which are applicable for cavitation tests and not required for self-propulsion tests.

Propeller Model Accuracy

Stock Propellers
During the “stock-propeller” testing phase, the geometrical particulars of the final design propeller are normally not known. Therefore, the stock propeller pitch (in case of CPP) is recommended to be adjusted to the anticipated propeller shaft power and design propeller revolutions. (ITTC Recommended Procedure 7.5-02-03-01.1 Propulsion/Bollard Pull Test).

Adjustable Pitch Propellers
Before the Tests the pitch adjustment is to be controlled.

Final Propellers
Propellers having diameter (D) typically from 150 mm to 300 mm is to be finished to the following tolerances:
- Diameter (D) ± 0.10 mm
- Thickness (t) ± 0.10 mm
- Blade width (c) ± 0.20 mm
- Mean pitch at each radius (P/D): ± 0.5% of design value.

Special attention is to be paid to the shaping accuracy near the leading and trailing edges of the blade section and to the thickness distributions. The propeller will normally be completed to a polished finish.

Documentation in the report
Identification (model number or similar)
Materials of construction
Principal dimensions
Diameter
Pitch-Diameter Ratio (P/D)
Expanded blade Area Ratio (Ae/A0)
Thickness Ratio (t/D)
Hub/Boss Diameter (dh)
Tolerances of manufacture

3. Model Tests

a) Resistance Test
The Resistance Test is to be performed acc. to ITTC Recommended Procedure 7.5-02-02-01 Resistance Test.

Documentation in the report
Model Hull Specification:
- Identification (model number or similar)
- Loading condition
- Turbulence stimulation method
- Model scale
- Main dimensions and hydrostatics (see ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 2 of this paper).

Particulars of the towing tank, including length, breadth and water depth
Test date
Parametric data for the test:
- Water temperature
- Water density
- Kinematic viscosity of the water
- Form factor (even if (1+k) = 1.0 is applicable, this is to be stated)
- $\Delta C_F$ or $C_A$

For each speed, the following measured and extrapolated data is to be given as a minimum:
- Model speed
- Resistance of the model
- Sinkage fore and aft, or sinkage and trim

**b) Propulsion Test**

The Propulsion Test is to be performed acc. to ITTC Recommended Procedure 7.5-02-03-01.1 Propulsion Test/Bollard Pull.

**Documentation in the report**

**Model Hull Specification:**
- Identification (model number or similar)
- Loading condition
- Turbulence stimulation method
- Model scale
- Main dimensions and hydrostatics (see ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 2 of this paper).

**Model Propeller Specification:**
- Identification (model number or similar)
- Model Scale
- Main dimensions and particulars (see ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 3 of this paper)

Particulars of the towing tank, including length, breadth and water depth
Test date
Parametric data for the test:
- Water temperature
- Water density
- Kinematic viscosity of the water
- Form factor (even if (1+k) = 1.0 is applicable, this is to be stated)
- $\Delta C_F$ or $C_A$
- Appendage drag scale effect correction factor (even if a factor for scale effect correction is not applied, this is to be stated).

For each speed the following measured data and extrapolated data is to be given as a minimum:
- Model speed
- External tow force
- Propeller thrust,
- Propeller torque
- Rate of revolutions.
- Sinkage fore and aft, or sinkage and trim
- The extrapolated values are also to contain the resulting delivered power $P_D$.

c) Propeller Open Water Test

In many cases the Propeller Open Water Characteristics of a stock propeller will be available and the Propeller Open Water Test need not be repeated for the particular project. A documentation of the Open Water Characteristics (Open Water Diagram) will suffice.

In case of a final propeller or where the Propeller Open Water Characteristics is not available the Propeller Open Water Test is to be performed acc. to ITTC Recommended Procedure 7.5-02-03-02.1 Open Water Test.

Documentation in the report
Model Propeller Specification:
- Identification (model number or similar)
- Model scale
- Main dimensions and particulars (see recommendations of ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 3 of this paper)
- Immersion of centreline of propeller shaft in the case of towing tank

Particulars of the towing tank or cavitation tunnel, including length, breadth and water depth or test section length, breadth and height.

Test date
Parametric data for the test:
- Water temperature
- Water density
- Kinematic viscosity of the water
- Reynolds Number (based on propeller blade chord at 0.7R)

For each speed the following data is to be given as a minimum:
- Speed
- Thrust of the propeller
- Torque of the propeller
- Rate of revolution
- Force of nozzle in the direction of the propeller shaft (in case of ducted propeller)

Propeller Open Water Diagram
4. **Speed Trial Prediction**

The principal steps of the Speed Trial Prediction Calculation are given in ITTC Recommended Procedure 7.5 - 02 - 03 -1.4 ITTC 1978 Trial Prediction Method (in its latest reviewed version of 2011). The main issue of a speed trial prediction is to get the loading of the propeller correct and also to assume the correct full scale wake. The right loading of the propeller can be achieved by increasing the friction deduction by the added resistance (e.g. wind resistance etc.) and run the self-propulsion test already at the right load or it can be achieved by calculation as given in Procedure 7.5-02-03-1.4.

A wake correction is always necessary for single screw ships. For twin screw ships it can be neglected unless the stern shape is of twin hull type or other special shape.

The following scheme indicates the main components of a speed trial prediction. It is to be based on a Resistance Test, a Propulsion Test and an Open Water Characteristics of the used model propeller during the tests and the Propeller Open Water Characteristics of the final propeller.

**Documentation**

Model Hull Specification:
- Identification (model number or similar)
- Loading condition
- Turbulence stimulation method
- Model scale
- Main dimensions and hydrostatics (see ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 2 of this paper).

Model Propeller Specification:
- Main dimensions and particulars (see ITTC Recommended Procedure 7.5-01-01-01 Ship Models and chapter 3 of this paper)

Particulars of the towing tank, including length, breadth and water depth
Resistance Test Identification (Test No. or similar)
Propulsion Test Identification (Test No. or similar)
Open Water Characteristics of the model propeller
Open Water Characteristics of ship propeller
Ship Specification:
- Projected wind area
- Wind resistance coefficient
- Assumed BF
- \( C_p \) and \( C_n \)
For each speed the following calculated data is to be given as a minimum:
- Ship speed
- Model wake coefficient
- Ship wake coefficient
- Propeller thrust on ship
- Propeller torque on ship
- Rate of revolutions on ship
- Predicted power on ship (delivered power on Propeller(s) \( P_b \))
- Sinkage fore and aft, or sinkage and trim
Scheme for review and witnessing Model Tests

Checking of Model Testing Procedure

1. Quality Control System
   - ISO9000?
     - Yes
     - Certification
     - Hydrodynamic Criteria
       - $Re_{above} \geq 2.5 \times 10^6$
       - Tank blockage
       - Turbulence Stimulators
       - Main Dimensions
       - Stations and Waterlines
       - Model Quality
       - Check accuracy by draught - displacement
         - correct?
           - Yes
           - No
             - Offsets

2. Ship Model
   - No
     - Other System
       - Documentation

3. Propeller Model
   - Final Propeller?
     - Yes
     - Documentation of Offsets
     - Propeller Characteristics
     - No
       - Stackpropeller
         - Adjustable Pitch?
           - Yes
             - Check Pitch adjustment
           - No
             - See scheme for Trial Prediction
       - No
         - See scheme for Trial Prediction
APPENDIX 5
Sample report “Preliminary Verification of EEDI”

ATTESTATION
PRELIMINARY VERIFICATION OF ENERGY EFFICIENCY DESIGN INDEX (EEDI)
by VERIFIER

Statement N° EEDI/2015/XXX

Ship particulars:
Ship Owner: ___________________
Shipyard: ___________________
Ship’s Name: ___________________
IMO Number: ___________________
Hull number: ___________________
Building contract date: ___________________
Type of ship: ___________________
Port of registry: ___________________
Deadweight: ___________________

Summary results of EEDI
Reference speed | VV.V knots
Attained EEDI | X.XX g/t.nm
Required EEDI | Y.YY g/t.nm

Supporting documents

<table>
<thead>
<tr>
<th>Title</th>
<th>ID and/or remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEDI Technical File</td>
<td>RRRR dated 01/01/2015</td>
</tr>
</tbody>
</table>

This is to certify:

1 That the attained EEDI of the ship has been calculated according to the 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, IMO resolution MEPC. 245(66).

2 That the preliminary verification of the EEDI shows that the ship complies with the applicable requirements in regulation 20 and regulation 21 of MARPOL Annex VI amended by resolutions MEPC.203(62) and MEPC. 251(66).

Completion date of preliminary verification of EEDI: xx/xx/xxxx

Issued at: _______________ on: _____________

Signature of the Verifier
APPENDIX 6
Sample calculations of EEDI

Content

Appendix 6.1: Cruise passenger ship with diesel-electric propulsion
Appendix 6.2: LNG carrier with diesel-electric propulsion
Appendix 6.3: Diesel-driven LNG carrier with re-liquefaction system
Appendix 6.4: LNG carrier with steam turbine propulsion
Appendix 6.1
Sample calculation for diesel-electric cruise passenger ship

1. Preliminary calculation of attained EEDI at design stage
Attained EEDI for cruise passenger ship having diesel electric propulsion system is calculated as follows at design stage.
For a diesel-electric cruise passenger ship:
\[ P_{ME} = 0, \quad P_{PTI} \neq 0, \quad P_{PTO} = 0 \]

1) Input
The table below lists the input information needed at the design stage and verified at the final stage:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPP</td>
<td>Rated output of electric propulsion motors</td>
<td>2 x 20000 kW</td>
<td>From EEDI technical file</td>
</tr>
<tr>
<td>( \eta_{PTI} )</td>
<td>Efficiency of transformer + converter + propulsion motor at 75% of rated motor output</td>
<td>0.945</td>
<td>From electric power table</td>
</tr>
<tr>
<td>( \eta_{GEN} )</td>
<td>Power-weighted average efficiency of generators</td>
<td>0.974</td>
<td>Calculation from individual generator efficiencies given in electric power table: 0.975<em>19000+0.972</em>14000/(14000+19000)</td>
</tr>
<tr>
<td>HLOAD(_{Max})</td>
<td>Consumed electric power excluding propulsion in cruise most demanding conditions</td>
<td>15 779 kW</td>
<td>From electric power table for the most demanding cruise contractual conditions (here extreme summer conditions 28°C during 80% of the time)</td>
</tr>
<tr>
<td>SFC(_{AE})</td>
<td>Power-weighted average of specific oil consumption among all engines at 75% of the MCR power</td>
<td>185 g/kWh</td>
<td>From NOx technical file</td>
</tr>
<tr>
<td>GT</td>
<td>Gross Tonnage</td>
<td>160000 ums</td>
<td>From EEDI technical file</td>
</tr>
</tbody>
</table>

\( MCR \) of auxiliary diesel engines \( 19,000 \text{ kW} \times 2 + 14,000 \text{ kW} \times 2 \)
\( MPP \) \( 20,000 \text{ kW} \times 2 \)
\( SFC_{AE} \) recorded in the test report annexed to the NOx technical file at 75% of MCR power and corrected to the ISO standard reference conditions.
185 g/kWh for both types of engines (19,000 kW and 14,000 kW)

2) Calculation of \( \Sigma P_{PTI} \)
The input is the rated output of the electric propulsion motors, MPP, which can be identified with the quantity noted \( P_{PTI,Shaft} \) in 2.5.3 of the "2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".
The term \( P_{PTI} \) is then computed as follows:
Where $\eta_{PTI}$ is the chain efficiency of the transformer, frequency converter and electric motor, as given by the manufacturer at 75% of the rated motor output and $\eta_{Gen}$ is the weighted average efficiency of the generators.

3) **Value of $P_{AE}$**

$P_{AE}$ is estimated by the consumed electric power, excluding propulsion, in most demanding (i.e. maximum electricity consumption) cruise conditions as given in the electric power table provided by the submitter, divided by the average efficiency of the generators.

The most demanding conditions maximise the design electrical load and correspond to contractual ambient conditions leading to the maximum consumption off heating ventilation and air conditioning systems, in accordance with Note 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

In this example, the most demanding condition corresponds to extreme summer conditions, where the external air temperature is 28°C during 80% of the time.

$$P_{AE} = \frac{\text{HLOAD}_{\text{Max}}}{\eta_{Gen}}$$

$$= \frac{15,779\text{kW}}{0.974}$$

$$= 16,200 \text{ kW}$$

4) **$V_{ref}$ at EEDI condition**

$V_{ref}$ is obtained by the preliminary speed-power curves as the model tank test results at EEDI condition at design stage. Suppose that $V_{ref}$ of 22.5 kn is obtained at 75% of $MPP$, in this example calculation at design stage.

5) **Calculation of the attained EEDI at design stage**

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is marine Gas Oil in this example.

$$EEDI = \frac{(P_{AE} + \sum_{i} P_{PTI}(i)) \cdot (C_{F,AE} \cdot SFC_{AE})}{\text{Capacity} \cdot V_{ref}}$$

$$= \frac{(16200 + 32593) \times 185 \times 3.206}{160,000(\text{UMS}) \times 22.5(\text{kn})} = 8.04$$

2. **Final calculation of attained EEDI at sea trial**

Attained EEDI at sea trial of cruise passenger ship having diesel electric propulsion system is calculated as follows.
1) Typical configuration and example of measurement points at sea trial

![Switch Board Diagram]

2) Specifications

Chain efficiency of the electric motor $\eta_{PTI}$ and generator efficiency $\eta_{Gen}$ can be confirmed during the sea trials at EEDI conditions (i.e. 75% of the rated motor output) taking into account the power factor $\cos\phi$ of the electric consumers.

$SFC_{AE}$ is computed from the NOx technical file if this file was not available at the preliminary stage.

Gross tonnage is confirmed at 160,000 ums.

Prior to sea trials, an on-board survey is performed to ensure that data read on the nameplates of the main electrical pieces of equipment comply with those recorded in the submitted electric power table.

3) $V_{ref}$ at EEDI condition

$V_{ref}$ is obtained by the speed-power curves as a result of the sea trial in accordance with paragraph 4.3.9 of the “2013 guidelines on survey and certification of the energy efficiency design index (EEDI)”. Suppose that $V_{ref}$ of 18.7kn is obtained at 75% of $MPP$, in this example calculation at sea trial.

During the sea trials, the shaft power transferred to the propellers $P_{PTI,shaft}$ must be obtained. It could be measured by a torsiometer fitted on the propeller shaft, or obtained from the computation of the power consumption of the motor $P_{SM}$ through the following relation:

$$P_{PTI,shaft} = P_{SM} \times \eta_{PTI}$$

4) Calculation of the attained EEDI at sea trial

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is marine Gas Oil in this example.
\[
EEDI = \frac{(P_{AE} + \sum_i P_{Pf}(i)) \cdot (C_{FAE} \cdot SFC_{AE})}{\text{Capacity} \cdot V_{ref}}
\]

\[
= \frac{(16200 + 32593) \times 185 \times 3.206}{160,000 \times 22.7} = 7.97
\]
Appendix 6.2  
Sample calculation for LNG carrier having diesel electric propulsion system

1. Preliminary calculation of attained EEDI at design stage
   Attained EEDI for LNG carrier having diesel electric propulsion system at design stage is calculated as follows.

1) Specifications

   - MCR of main engines: $10,000 \text{ (kW)} \times 3 + 6,400 \text{ (kW)} \times 1$
   - MPP\text{Motor}: 24,000 \text{ (kW)}$
   - SFC\text{ME(i),electric, gas mode at 75% of MCR}$: $162.0 \text{ (g/kWh)}$ (for 10,000 (kW)-Engines) (SFC with the addition of the guarantee tolerance)  
     $162.6 \text{ (g/kWh)}$ (for 6,400 (kW)-Engine) (Ditto)
   - SFC\text{ME(i),Pilotfuel}$: $6.0 \text{ (g/kWh)}$ (for 10,000 (kW)-Engines), $6.1 \text{ (g/kWh)}$ (for 6,400 (kW)-Engine)
   - Deadweight: 75,000 (ton)

2) $\eta_{\text{electrical}}$ at design stage

   $\eta_{\text{electrical}}$ is set as 0.913 in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

3) Calculation of $P_{\text{ME}}$

   $P_{\text{ME}}$ is calculated in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

   $$P_{\text{ME}} = 0.83 \times \frac{\text{MPP}\text{Motor}}{\eta_{\text{electrical}}} = 0.83 \times \frac{24,000}{0.913} = 21,818 \text{ (kW)}$$

4) Calculation of $P_{\text{AE}}$

   $P_{\text{AE}}$ is calculated in accordance with paragraph 2.5.6.1 and 2.5.6.3 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

   $$P_{\text{AE}} = \left[0.025 \times \left( \sum_{\text{m}} \frac{\text{MCR}\text{ME(i)}}{0.75} \right) + 250 \right] + \text{Cargo Tank Capacity}_{\text{LNG}} \times \text{BOR} \times \text{COP reekify} \times R_{\text{reliqify}}$$
   $$+ 0.33 \times \sum_{\text{m}} \frac{\text{SFC}\text{ME(i),gas mode} \times P_{\text{ME(i)}}}{1000}$$
   $$+ 0.02 \times \sum_{\text{m}} P_{\text{ME(i)}}$$

   $$= \left[0.025 \times 24,000 + 250\right] + 0 + 0 + \left(0.02 \times 21,818\right)$$
   $$= 1,286 \text{ (kW)}$$
5) \( V_{\text{ref}} \) at EEDI condition

\( V_{\text{ref}} \) is obtained by the preliminary speed-power curves as the model tank test results at EEDI condition at design stage. Suppose that \( V_{\text{ref}} \) of 18.4kn is obtained at 83% of \( MPP_{\text{Motor}} \), in this example calculation at design stage.

6) Calculation of the attained EEDI at design stage

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is LNG in this example calculation. In this case, \( SFC_{\text{AE(i)}_\text{electric, gas mode at 75% of MCR}} \) is equal to \( SFC_{\text{ME(i)}_\text{electric, gas mode at 75% of MCR}} \), and \( SFC_{\text{AE(i)}_\text{Pilotfuel}} \) is equal to \( SFC_{\text{ME(i)}_\text{Pilotfuel}} \).

\[
EEDI = \frac{P_{\text{ME}} \left( C_{\text{FME, gas}} \cdot SFC_{\text{ME, gas}} + C_{\text{FME, Pilotfuel}} \cdot SFC_{\text{ME, Pilotfuel}} \right) + P_{\text{AE}} \left( C_{\text{FAE, gas}} \cdot SFC_{\text{AE, gas}} + C_{\text{FAE, Pilotfuel}} \cdot SFC_{\text{AE, Pilotfuel}} \right)}{\text{Capacity} \cdot V_{\text{ref}}} 
\]

\[
= \frac{21.818 \times (2.750 \times 162.1 + 3.206 \times 6.0) + 1.286 \times (2.750 \times 162.1 + 3.206 \times 6.0)}{75,000 \times (18.4kn)} = 7.79
\]

Note:

*1: The average weighed value of \( SFC_{\text{ME(i)}_\text{electric, gas mode at 75% of MCR}} \) and \( SFC_{\text{AE(i)}_\text{electric, gas mode at 75% of MCR}} \) is used;

\[
\frac{162.0 \times 10,000 \times (kW) \times 3 + 162.6 \times 6,400 \times (kW)}{10,000 \times (kW) \times 3 + 6,400 \times (kW)} = 162.1 (g/kWh)
\]

*2: The average weighed value of \( SFC_{\text{ME(i)}_\text{Pilotfuel}} \) and \( SFC_{\text{AE(i)}_\text{Pilotfuel}} \) is used;

\[
\frac{6.0 \times 10,000 \times (kW) \times 3 + 6.1 \times 6,400 \times (kW)}{10,000 \times (kW) \times 3 + 6,400 \times (kW)} = 6.0 (g/kWh)
\]

2. Final calculation of attained EEDI at sea trial

Attained EEDI for LNG carrier having diesel electric propulsion system at sea trial is calculated as follows.

1) Typical configuration and example of measurement points at sea trial
2) Specifications

- **MCR of main engines**: 10,000 (kW) x 3 + 6,400 (kW) x 1
- **MPPMotor**: 24,000 (kW)
- **SFC\(_{ME(i),\text{electric, gas mode at 75\% of MCR}}\)**
  - 161.6 (g/kWh) (for 10,000 (kW)-Engines) (SFC of the test report in the NOx technical file)
  - 162.2 (g/kWh) (for 6,400 (kW)-Engine) (Ditto)
- **SFC\(_{ME(i),\text{Pilotfuel}}\)**
  - 6.0 (g/kWh) (for 10,000 (kW)-Engines), 6.1 (g/kWh) (for 6,400 (kW)-Engine)
- **Deadweight**: 75,500 (ton)

3) \(\eta_{\text{electrical}}\) at sea trial

\(\eta_{\text{electrical}}\) is set as 0.913 in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

4) Calculation of \(P_{ME}\)

\[ P_{\text{ME}} = 0.83 \times \frac{\text{MPP}_{\text{Motor}}}{\eta_{\text{electrical}}} \]

\[ = 0.83 \times \frac{24,000}{0.913} = 21,818 \text{(kW)} \]

5) Calculation of \(P_{AE}\)

\[ P_{\text{AE}} = \left\{ 0.025 \times \left( \sum_{i=1}^{\text{ME}} \text{MCR}_{\text{ME}(i)} \right) + \sum_{i=1}^{\text{PTI}} \frac{\text{PP}_{\text{PTI}(i)}}{0.75} \right\} + 250 \]

\[ + \text{CargoTankCapacity}_{\text{LNG}} \times \text{BOR} \times \text{COP}_{\text{liquefy}} \times \text{R}_{\text{liquefy}} \] \(\cdots (1)\) and/or; (Not Applicable)

\[ + 0.33 \times \sum_{i=1}^{\text{ME}} \text{SFC}_{\text{ME(i),gas mode}} \times \frac{\text{PP}_{\text{ME}(i)}}{1000} \] \(\cdots (2)\) and/or; (Not Applicable)

\[ + 0.02 \times \sum_{i=1}^{\text{ME}} \text{PP}_{\text{ME}(i)} \] \(\cdots (3)\)

\[ = \left[ 0.025 \times 24,000 \right] + 250 + 0 + 0 + \left( 0.02 \times 21,818 \right) \]

\[ = 1,286 \text{(kW)} \]

Note:
*1: The value of \(\text{MPP}_{\text{Motor}}\) is used instead of \(\text{MCR}_{\text{ME}}\) in accordance with paragraph 2.5.6.3.3.

6) \(V_{\text{ref}}\) at EEDI condition

\(V_{\text{ref}}\) is obtained by the speed-power curves as a result of the sea trial in accordance with paragraph 4.3.9 of the “2013 guidelines on survey and certification of the energy efficiency design index (EEDI)". Suppose that \(V_{\text{ref}}\) of 18.5kn is obtained at 83\% of \(\text{MPP}_{\text{Motor}}\), in this example calculation at sea trial.
7) Calculation of the attained EEDI at sea trial

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is LNG in this example calculation. In this case, $SFC_{AE\,(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$ and $SFC_{AE\,(i)\_Pilotfuel}$ is equal to $SFC_{ME\,(i)\_Pilotfuel}$.

$$
EEDI = \frac{P_{ME}(C_{FME\_Gen} \cdot SFC_{ME\_Gen} + C_{FME\_Pilotfuel} \cdot SFC_{ME\_Pilotfuel}) + P_{AE}(C_{FAE\_Gen} \cdot SFC_{AE\_Gen} + C_{FAE\_Pilotfuel} \cdot SFC_{AE\_Pilotfuel})}{Capacity \cdot V_{ref}}
$$

$$
= \frac{21,818 \times (2.750 \times 161.7 + 3.206 \times 6.0) + 1,286 \times (2.750 \times 161.7 + 3.206 \times 6.0)}{75,500(DWT) \times 18.5(kn)} = 7.67
$$

Note:

*1: The average weighed value of $SFC_{ME\,(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$ and $SFC_{AE\,(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$ is used;
$$
= \frac{161.6 \times 10,000(kW) \times 3 + 162.2 \times 6,400(kW)}{10,000(kW) \times 3 + 6,400(kW)} = 161.7(g/kWh)
$$

*2: The average weighed value of $SFC_{ME\,(i)\_Pilotfuel}$ and $SFC_{AE\,(i)\_Pilotfuel}$ is used;
$$
= \frac{6.0 \times 10,000(kW) \times 3 + 6.1 \times 6,400(kW)}{10,000(kW) \times 3 + 6,400(kW)} = 6.0(g/kWh)
$$
Appendix 6.3
Sample calculation for LNG carrier having diesel driven with re-liquefaction system

1. Preliminary calculation of attained EEDI at design stage
Attained EEDI for LNG carrier having diesel driven with re-liquefaction system at design stage is calculated as follows.

1) Specifications

- **MCR** \(_{ME(i)}\) = 18,660 x 2 (kW) = 37,320 (kW)
- **SFC\(_{ME(i)}\) at 75% of MCR** = 165.0 (g/kWh)
- **SFC\(_{AE(i)}\) at 50% of MCR** = 198.0 (g/kWh)
- **CargoTankCapacity\(_{LNG}\)** = 211,900 (m³)
- **BOR** = 0.15 (%/day)
- **COP\(_{cooling}\)** = 0.166
- **COP\(_{reliquefy}\)** = 15.142
- **Deadweight** = 109,000 (ton)

2) Calculation of \(P_{ME}\)

\(P_{ME}\) is calculated in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

\[
P_{ME(i)} = 0.75 \times MCR_{ME(i)} + 250 + CargoTankCapacity_{LNG} \times BOR \times COP_{reliquefy} \times R_{reliquefy}
\]

\[
= 0.75 \times (18,660 + 18,660) = 27,990 (kW)
\]

3) Calculation of \(P_{AE}\)

\(P_{AE}\) is calculated in accordance with paragraph 2.5.6.1 and 2.5.6.3 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

\[
P_{AE} = 0.025 \times \sum 0.0_{ME(i)} + 250 + CargoTankCapacity_{LNG} \times BOR \times COP_{reliquefy} \times R_{reliquefy}
\]

\[
= 0.025 \times 37,320 + 250 + 211,900 \times 0.15/100 \times 15.142 \times 1
\]

\[
= 5,996 (kW)
\]

4) \(V_{ref}\) at EEDI condition

\(V_{ref}\) is obtained by the preliminary speed-power curves as the model tank test results at EEDI condition at design stage.

Suppose that \(V_{ref}\) of 19.7kn is obtained at 75% of \(MCR_{ME(i)}\), in this example calculation at design stage.

5) Calculation of the attained EEDI on design stage

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”).
2. Final calculation of attained EEDI at sea trial

Attained EEDI for LNG carrier having diesel driven with re-liquefaction system at sea trial is calculated as follows.

1) Specifications

- **MCR**: \(18,660 \times 2 = 37,320\) (kW)
- **SFC\(_{ME(i)}\) at 75% of MCR**: 165.5 (g/kWh)
- **SFC\(_{AE(i)}\) at 50% of MCR**: 198.5 (g/kWh)
- **CargoTankCapacity\(_{LNG}\)**: 211,900 (m\(^3\))
- **BOR**: 0.15 (%/day)
- **COP\(_{cooling}\)**: 0.166
- **COP\(_{reliquefy}\)**: 15.142
- **Deadweight**: 109,255 (ton)

2) Measured values at sea trial

Relation between SHP\(_{seatrial}\) and Ship’s speed shall be measured and verified at sea trial.

3) Calculation of \(P_{ME}\)

\[ P_{ME} = 0.75 \times MCR_{ME(i)} \]
\[ = 0.75 \times (18,660 + 18,660) = 27,990\) (kW)

4) Calculation of \(P_{AE}\)

\[ P_{AE} = 0.025 \times \sum 0.0ME(i) + 250 \]
\[ + CargoTankCapacity\(_{LNG}\) \times BOR \times COP_{reliquefy} \times R_{reliquefy} \]
\[ = 0.025 \times 37,320 + 250 \]
\[ + 211,900 \times 0.15/100 \times 15.142 \times 1 \]
\[ = 5,996\) (kW)
5) \( V_{ref} \) at EEDI condition

\( V_{ref} \) is obtained by the speed-power curves as a result of the sea trial in accordance with paragraph 4.3.9 of the “2013 guidelines on survey and certification of the energy efficiency design index (EEDI)”. Suppose that \( V_{ref} \) of 19.8kn is obtained at 75% of \( MCR_{ME(i)} \), in this example calculation at sea trial.

6) Calculation of the attained EEDI at sea trial

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

\[
EEDI = \frac{P_{ME} \cdot C_{FME} \cdot SFC_{ME} + P_{AF} \cdot C_{FAE} \cdot SFC_{AE}}{Capacity \cdot V_{ref}}
\]

\[
= \frac{27,990 \times 3.206 \times 165.5 + 5,996 \times 3.206 \times 198.5}{109,255(DWT) \times 19.8(kn)} = 8.629
\]
Appendix 6.4
Sample calculation for LNG carrier having steam turbine propulsion system

1. Preliminary calculation of attained EEDI at design stage

Attained EEDI for LNG carrier having steam turbine propulsion system at design stage is calculated as follows.

1) Specifications

\[
\begin{align*}
MCR_{\text{Steam turbine}} & : 25,000 \text{ (kW)} \\
SFC_{\text{Steam turbine}} & : 241.0 \text{ (g/kWh)} \\
\text{Deadweight} & : 75,000 \text{ (ton)}
\end{align*}
\]

2) Calculation of \( P_{ME} \)

\( P_{ME} \) is calculated in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

\[
P_{ME} = 0.83 \times MCR_{\text{Steam Turbine}}
\]

\[
= 0.83 \times 25,000 = 20,750 \text{(kW)}
\]

3) Calculation of \( P_{AE} \)

\( P_{AE} \) is treated as 0 (zero) because electric load \( (P_{\text{generator, sea trial}}) \) is supposed to be included in \( SFC_{\text{Steam Turbine}} \), in accordance with paragraph 2.5.6.3 and 2.7.2.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

\[
P_{AE} = 0
\]

4) \( V_{\text{ref}} \) at EEDI condition

\( V_{\text{ref}} \) is obtained by the preliminary speed-power curves as the model tank test results at EEDI condition at design stage.

Suppose that \( V_{\text{ref}} \) of 18.7kn is obtained at 83\% of \( MCR_{\text{Steam Turbine}} \), in this example calculation at design stage.

5) Calculation of the attained EEDI on design stage

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is LNG in this example calculation.

\[
EEDI = \frac{P_{ME} \cdot C_{\text{FME}} \cdot SFC_{\text{ME}} + P_{AE} \cdot C_{\text{FAE}} \cdot SFC_{\text{AE}}}{\text{Capacity} \cdot V_{\text{ref}}}
\]

\[
= \frac{20,750 \times 2.750 \times 241.0 + 0}{75,000 \text{(DWT)} \times 18.7 \text{(kn)}} = 9.81
\]

2. Final calculation of attained EEDI at sea trial

Attained EEDI for LNG carrier having steam turbine propulsion system at sea trial is calculated as follows.
1) Typical configuration and example of measurement points at sea trial

In addition to the above, in order to correct measured Fuel Consumption to the design conditions corresponding to the SNAME condition, inlet air temperature, sea water temperature, steam temperature, steam pressure, etc. are measured, as appropriate.

\( P_{AE} \) is treated as 0(zero) because electric load \( P_{generator\_seatrial} \) is supposed to be included in \( SFC_{Steam\_Turbine} \), in accordance with paragraph 2.5.6.3 and 2.7.2.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

2) Specifications

- \( MCR_{Steam\_Turbine} \): 25,000 (kW)
- \( SFC_{Steam\_Turbine} \): 241.0 (g/kWh)
- \( Deadweight \): 75,000 (ton)

3) Measured values at sea trial

- \( P_{generator\_seatrial} \): 980 (kW)
- \( SHP_{seatrial} \): 21,520 (kW)
- \( Fuel\_Consumption\_seatrial \): 5.95 x 10^6 (g/hour)

Each Fuel Consumption\(_{(j)}\_seatrial \) should be corrected in accordance with paragraph 2.7.2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

- Coefficient of flow meter: 1.0010
- Steam temperature: 500 degree Celsius
- Steam pressure: 5.85 (MPaG)
Condenser vacuum  725 (mmHg)  
Dist. water production  28.5 (t/day)  
Inlet air temperature of FAN  45 degree Celsius  
Lower calorific value of fuel used at sea trial  42,030 (kJ/kg)

4) Calculation of $SFC_{\text{SteamTurbine at sea trial}}$

$SFC_{\text{SteamTurbine}}$ is calculated in accordance with paragraph 2.7.2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$SFC_{\text{SteamTurbine at sea trial}} = \frac{\text{Fuel Consumption}}{\text{SHP}} = \frac{5.95 \times 10^6 \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7}{21,520}$$

$$= \frac{5.95 \times 10^6 \times 0.9871 \times 0.8756 \times 1.0010 \times 1.0001 \times 1.0035 \times 0.9999 \times 1.0028}{21,520}$$

$$= 240.7 \text{ (g/kW/h)}$$

Note:

*1: $SFC$ should be corrected to the value corresponding to SNAME and EEDI conditions, in accordance with paragraph 2.7.2 .2 and .3 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. Coefficients from C1 to C7 represent as follows.

C1: Coefficient of electric power to the electric load equivalent to

$$P_{AE} = 0.025 \times MCR_{\text{Steam turbine}} + 250 = 875 \text{ (kW)}$$

C2: Coefficient of LCV to the standard LCV of 48,000 kJ/kg for LNG fuel

C3: Coefficient of flow meter

C4: Coefficient of steam temperature and steam pressure

C5: Coefficient of condenser vacuum for steam turbine

C6: Coefficient of water feed of condenser

C7: Coefficient of inlet air temperature

$SFC_{\text{SteamTurbine}}$ is calculated as the value to include all losses of machinery and, gears necessary for main propulsion system and the specified electric load of $P_{AE}$.

Minimum two $SFC_{\text{SteamTurbine}}$ at around the EEDI power are obtained at the sea trial. However in this example calculation, all $SFC_{\text{SteamTurbine}} (i)$ are supposed to the same value of 240.7 g/kWh.

5) Calculation of $P_{\text{ME}}$

$P_{\text{ME}}$ is calculated in accordance with paragraph 2.5.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{\text{ME}} = 0.83 \times MCR_{\text{SteamTurbine}}$$

$$= 0.83 \times 25,000 = 20,750 \text{ (kW)}$$
6) Calculation of $P_{AE}\$

$P_{AE}$ is treated as 0(zero) because electric load ($P_{\text{generator\_seatrial}}$) is supposed to be included in $SFC_{\text{SteamTurbine}}$, in accordance with paragraph 2.5.6.3 and 2.7.2.1 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$P_{AE} = 0$

7) $V_{ref}$ at EEDI condition

$V_{ref}$ is obtained by the speed-power curves as a result of the sea trial in accordance with paragraph 4.3.9 of the “2013 guidelines on survey and certification of the energy efficiency design index (EEDI)”.

Suppose that $V_{ref}$ of 18.8kn is obtained at 83% of $MCR_{\text{SteamTurbine}}$, in this example calculation at sea trial.

8) Calculation of the attained EEDI at sea trial

EEDI is calculated in accordance with paragraph 2 of the “2014 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

The primary fuel is LNG in this example calculation.

$$EEDI = \frac{P_{ME} \cdot C_{FAE} \cdot SFC_{ME} + P_{AE} \cdot C_{FAE} \cdot SFC_{AE}}{\text{Capacity} \cdot V_{ref}}$$

$$= \frac{20,750 \times 2.750 \times 240.7 + 0}{75,000(\text{DWT}) \times 18.8(\text{kn})} = 9.74$$

End of Document
1 The Marine Environment Protection Committee, at its sixty-fifth session (13 to 17 May 2013), agreed to circulate the 2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI, as set out in the annex (MEPC 65/22, paragraph 4.134.6).

2 Member Governments are invited to bring the annexed Guidance to the attention of their Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

***
ANNEX

2013 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI

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ANNEX 2 Guidance on calculation and verification of effects of Category (C) innovative technologies
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1 General

1.1 The purpose of this guidance is to assist manufacturers, shipbuilders, shipowners, verifiers and other interested parties related to Energy Efficiency Design Index (EEDI) of ships to treat innovative energy efficiency technologies for calculation and verification of the attained EEDI, in accordance with regulations 5, 6, 7, 8, 9 and 20 of Annex VI to MARPOL.

1.2 There are EEDI Calculation Guidelines and EEDI Survey Guidelines. This guidance does not intend to supersede those guidelines but provides the methodology of calculation, survey and certification of innovative energy efficiency technologies, which are not covered by those guidelines. In the case that there are inconsistencies between this guidance and these guidelines, those guidelines should take precedence.

1.3 This guidance might not provide sufficient measures of calculation and verification for ships with diesel-electric propulsion, turbine propulsion and hybrid propulsion system on the ground that the attained EEDI Formula shown in EEDI Calculation Guidelines may not be able to apply to such propulsion systems.

1.4 The guidance should be reviewed for the inclusion of new innovative technologies not yet covered by the guidance.

1.5 The guidance also should be reviewed, after accumulating the experiences of each innovative technology, in order to make it more robust and effective, using the feedback from actual operating data. Therefore, it is advisable that the effect of each innovative technology in actual operating conditions should be monitored and collected for future improvement of this guidance document.

2 Definitions

2.1 EEDI Calculation Guidelines means "2012 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships (resolution MEPC.212(63))".

2.2 EEDI Survey Guidelines means "2012 guidelines on survey and certification of the energy efficiency design index (EEDI) (resolution MEPC.214(63))".

2.3 $P_p$ is the propulsion power and is defined as $\Sigma P_M + \Sigma P_{PTI}(\text{shaft})$, as shown in paragraph 2.5.3 of EEDI Calculation Guidelines.

2.4 In addition to the above, definitions of the words in this guidance are same as those of MARPOL Annex VI, EEDI Calculation Guidelines and EEDI Survey Guidelines.

3 Categorizing of Innovative Energy Efficiency Technologies

3.1 Innovative energy efficiency technologies are allocated to category (A), (B) and (C), depending on their characteristics and effects to the EEDI formula. Furthermore, innovative energy efficiency technologies of category (B) and (C) are categorized to two sub-categories (category (B-1) and (B-2), and (C-1) and (C-2), respectively).

Category (A): Technologies that shift the power curve, which results in the change of combination of $P_p$ and $V_{ref}$; e.g. when $V_{ref}$ is kept constant, $P_p$ will be reduced and when $P_p$ is kept constant, $V_{ref}$ will be increased.
**Category (B):** Technologies that reduce the propulsion power, \( P_P \), at \( V_{ref} \), but not generate electricity. The saved energy is counted as \( P_{eff} \).

**Category (B-1):** Technologies which can be used at any time during the operation and thus the availability factor (\( f_{eff} \)) should be treated as 1.00.

**Category (B-2):** Technologies which can be used at their full output only under limited condition. The setting of availability factor (\( f_{eff} \)) should be less than 1.00.

**Category (C):** Technologies that generate electricity. The saved energy is counted as \( P_{AEeff} \).

**Category (C-1):** Technologies which can be used at any time during the operation and thus the availability factor (\( f_{eff} \)) should be treated as 1.00.

**Category (C-2):** Technologies which can be used at their full output only under limited condition. The setting of availability factor (\( f_{eff} \)) should be less than 1.00.

---

### Innovative Energy Efficiency Technologies

<table>
<thead>
<tr>
<th>Reduction of Main Engine Power</th>
<th>Reduction of Auxiliary Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category A</strong></td>
<td><strong>Category B-1</strong></td>
</tr>
<tr>
<td>Cannot be separated from overall performance of the vessel</td>
<td>Can be treated separately from the overall performance of the vessel</td>
</tr>
<tr>
<td>( f_{eff} = 1 )</td>
<td>( f_{eff} &lt; 1 )</td>
</tr>
<tr>
<td>- low friction coating</td>
<td>- hull air lubrication system (air cavity via air injection to reduce ship resistance) (can be switched off)</td>
</tr>
<tr>
<td>- bare optimization</td>
<td></td>
</tr>
<tr>
<td>- rudder resistance</td>
<td></td>
</tr>
<tr>
<td>- propeller design</td>
<td></td>
</tr>
</tbody>
</table>
4 Calculation and Verification of effects of Innovative Energy Efficiency Technologies

4.1 General

The evaluation of the benefit of any innovative technology is to be carried out in conjunction with the hull form and propulsion system with which it is intended to be used. Results of model tests or sea trials of the innovative technology in conjunction with different hull forms or propulsion systems may not be applicable.

4.2 Category (A) technology

Innovative energy efficiency technologies in category (A) affect \( P_p \) and/or \( V_{ref} \) and their effects cannot be measured in isolation. Therefore, these effects should not be calculated nor certified in isolation in this guidance but should be treated as a part of vessel in EEDI Calculation Guidelines and EEDI Survey Guidelines.

4.3 Category (B) technology

4.3.1 The effects of innovative energy technologies in category (B) are expressed as \( P_{eff} \) which would be multiplied by \( C_{FME} \) and \( SFC_{ME} \) (in the case of \( P_{PTI(i)}>0 \), the average weighted value of \( (SFC_{ME} \cdot C_{FME}) \) and \( (SFC_{AE} \cdot C_{FAE}) \) ) and \( f_{eff} \), and then be deducted from the EEDI formula. In the case of category (B-1) technology, \( f_{eff} \) is 1.00.

4.3.2 Guidance on calculation and verification of effects of Category (B) innovative technologies is given in annex 1.

4.4 Category (C) technology

4.4.1 The effects of innovative energy technologies in category (C) are expressed as \( P_{AEeff} \) which would be multiplied by \( C_{FAE} \), \( SFC_{AE} \) and \( f_{eff} \), and then be deducted from the EEDI formula. In the case of category (C-1) technology, \( f_{eff} \) is 1.00.

4.4.2 Guidance on calculation and verification of effects of Category (C) innovative technologies is given in annex 2.

5 Average weighted value in the case of \( P_{PTI(i)}>0 \)

In the case of \( P_{PTI(i)}>0 \), both Category (B) and Category (C) technologies might deduct the value of \( P_{PTI(i)} \). In such case, following values are to be used for average weighted value in calculating \( \Sigma (f_{eff(i)} \cdot P_{eff(i)} \cdot C_F \cdot SFC) \) in attained EEDI formula;

For shaft power(s):
\[
\frac{\left( \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right) \cdot \left( \Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right)}{\left( \Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right)},
\]
where, if \( \left( \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right) \) is taken negative value, the value \( \left( \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right) \) should be fixed to zero; and

For main engine(s):
\[
\frac{\Sigma P_{ME(i)}}{\left( \Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right)},
\]
where, if \( \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \) is taken negative value, the value \( \left( \Sigma P_{PTI(i),shaft} - \Sigma P_{AEeff(i)} \cdot \eta_{GEN} \cdot \eta_{PTI(i)} \right) \) should be fixed to zero.

* * *
ANNEX 1

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (B) INNOVATIVE TECHNOLOGIES

Appendix 1

AIR LUBRICATION SYSTEM (CATEGORY (B-1))

1 Summary of innovative energy efficient technology

An air lubrication system is one of the innovative energy efficiency technologies. Ship frictional resistance can be reduced by covering the ship surface with air bubbles, which is injected from the fore part of the ship bottom by using blowers, etc.

![Schematic illustration of an air lubrication system](image)

Figure 1 – Schematic illustration of an air lubrication system

2 Method of calculation

2.1 Power reduction due to air lubrication system

Power reduction factor $P_{eff}$ due to an air lubrication system as an innovative energy efficiency technology is calculated by the following formula. The first and second terms of the right hand side represent the reduction of propulsion power by the air lubrication system and the additional power necessary for running the system, respectively. For this system, $f_{eff}$ is 1.0 in EEDI formula.

$$
P_{eff} = P_{Peff\text{AL}} - P_{Aeff\text{AL}} \cdot \frac{C_{FAE}}{C_{FME}} \cdot \frac{SFC_{AE}}{SFC_{ME}} \cdot \ast
$$

* In the case of $P_{PTI(i)}>0$, the average weighted value of $(SFC_{ME} \cdot C_{FME})$ and $(SFC_{AE} \cdot C_{FAE})$

---

1 All examples in appendix are used solely to illustrate the proposed methods of calculation and verification.
2.1.1 \( P_{\text{eff}} \) is the effective power reduction in kW due to the air lubrication system at the 75 per cent of the rated installed power (MCR). In case that shaft generators are installed, \( P_{\text{eff}} \) should be calculated at the 75 per cent MCR having after deducted any installed shaft generators in accordance with paragraph 2.5 of EEDI Calculation Guidelines. \( P_{\text{eff}} \) should be calculated both in the fully loaded and the sea trial conditions.

2.1.2 \( P_{\text{PeffAL}} \) is the reduction of propulsion power due to the air lubrication system in kW. \( P_{\text{PeffAL}} \) should be calculated both in the condition corresponding to the Capacity as defined in EEDI Calculation Guidelines (hereinafter referred to as “fully loaded condition”) and the sea trial condition, taking the following items into account.

1. area of ship surface covered with air;
2. thickness of air layer;
3. reduction rate of frictional resistance due to the coverage of air layer;
4. change of propulsion efficiency due to the interaction with air bubbles (self propulsion factors and propeller open water characteristics); and
5. change of resistance due to additional device, if equipped.

2.1.3 \( P_{\text{AEffAL}} \) is additional auxiliary power in kW necessary for running the air lubrication system in the fully loaded condition. \( P_{\text{AEffAL}} \) should be calculated as 75 per cent of the rated output of blowers based on the manufacturer's test report. For a system where the calculated value above is significantly different from the output used at normal operation in the fully loaded condition, the \( P_{\text{AEffAL}} \) value may be estimated by an alternative method. In this case, the calculation process should be submitted to a verifier.

2.2 Points to keep in mind in calculation of attained EEDI with air lubrication system

2.2.1 \( V_{\text{ref}} \) in paragraph 2.2 of EEDI Calculation Guidelines should be calculated in the condition that the air lubrication system is OFF to avoid the double count of the effect of this system.

2.2.2 In accordance with EEDI Calculation Guidelines, the EEDI value for ships for the air lubrication system ON should be calculated in the fully loaded condition.

3 Method of verification

3.1 General

Attained EEDI for a ship with an innovative energy efficient technology should be verified in accordance with EEDI Survey Guidelines. Additional information on the application of air lubrication system, which is not given in the EEDI Survey Guidelines, is contained below.

3.2 Preliminary verification at the design stage

3.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by a shipowner or shipbuilder should include:
1 outline of the air lubrication system;

2 $P_{PEffAL}$: the reduction of propulsion power due to the air lubrication system at the ship speed of $V_{ref}$ both in the fully loaded and the sea trial conditions;

3 $EDR_{full}$: the reduction rate of propulsion power in the fully loaded condition due to the air lubrication system. $EDR_{full}$ is calculated by dividing $P_{MEeffAL}$ by $P_{ME}$ in EEDI Calculation Guidelines in the fully loaded condition (See Figure 2);

4 $EDR_{trial}$: the reduction rate of propulsion power in a sea trial condition due to the air lubrication system. $EDR_{trial}$ is calculated by dividing $P_{MEeffAL}$ by $P_{ME}$ in EEDI Calculation Guidelines in sea trial condition (see figure 2);

5 $P_{AEffAL}$: additional power necessary for running the air lubrication system; and

6 the calculated value of the EEDI for the air lubrication system ON in the fully loaded condition.

3.2.2 In addition with paragraph 4.2.7 of the EEDI Survey Guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

1 the detailed calculation process of the reduction of propulsion power due to the air lubrication system: $P_{PEffAL}$; and

2 the detailed calculation process of the additional power necessary for running the air lubrication system: $P_{AEffAL}$.
3.3 **Final verification of the attained EEDI at sea trial**

3.3.1 Final verification of the EEDI of ships due to the air lubrication system should be conducted at the sea trial. The procedure of final verification should be basically in accordance with paragraph 4.3 of the EEDI Survey Guidelines.

3.3.2 Prior to the sea trial, the following documents should be submitted to the verifier; a description of the test procedure that includes the measurement methods to be used at the sea trial of the ship with the air lubrication system.

3.3.3 The verifier should attend the sea trial and confirm the items described in paragraph 4.3.3 of the EEDI Survey Guidelines to be measured at the sea trial for the air lubrication system ON and OFF.

3.3.4 The main engine output at the sea trial for the air lubrication system ON and OFF should be set so that the range of the developed power curve includes the ship speed of $V_{ref}$.

3.3.5 The following procedure should be conducted based on the power curve developed for air lubrication system OFF.

1. ship speed at 75 per cent MCR of main engine in the fully loaded condition, $V_{ref}$, should be calculated. In case that shaft generators are installed, $V_{ref}$ should be calculated at 75 per cent MCR having after deducted any installed shaft generators in accordance with paragraph 2.5 of EEDI Calculation Guidelines.

2. In case that $V_{ref}$ obtained above is different from that estimated at the design stage, the reduction rate of main engine should be recalculated at new $V_{ref}$ both in the fully loaded and the sea trial conditions.

3.3.6 The shipbuilder should develop power curves for the air lubrication system ON based on the measured ship speed and output of the main engine at the sea trial. The following calculations should be conducted.

1. The actual reduction rate of propulsion power $ADR_{trial}$ at the ship speed of $V_{ref}$ at the sea trial.

2. If the sea trial is not conducted in the fully loaded condition, the reduction rate of propulsion power in this condition should be calculated by the following formula:

$$1 - ADR_{Full} = (1 - EDR_{Full}) \times \frac{1 - ADR_{trial}}{1 - EDR_{trial}},$$

i.e.

$$ADR_{Full} = 1 - (1 - EDR_{Full}) \times \frac{1 - ADR_{trial}}{1 - EDR_{trial}}$$

(2)
3.3.7 The reduction of propulsion power due to the air lubrication system $P_{MEeff\ AL}$ in the fully loaded and the sea trial conditions should be calculated as follows:

$$P_{eff\ AL_{\ Full}} = ADR_{Full} \times P_P$$  \hspace{1cm} (3)  

$$P_{eff\ AL_{\ Trial}} = ADR_{Trial} \times P_P$$  \hspace{1cm} (4)

3.3.8 The shipowner or the shipbuilder should revise the EEDI Technical File, as necessary, by taking the result of the sea trial into account. Such revision should include the following contents:

1. $V_{ref}$, in case that it is different from that estimated at the design stage;
2. the reduction of propulsion power $P_{eff\ AL}$ at the ship speed of $V_{ref}$ in the fully loaded and the sea trial conditions for the air lubrication system ON;
3. the reduction rate of propulsion power due to air lubrication system ($ADR_{full}$ and $ADR_{trial}$) in the fully loaded and the sea trial conditions.
4. the calculated value of the EEDI for the air lubrication system ON in the fully loaded condition.
Appendix 2

WIND PROPULSION SYSTEM (CATEGORY B-2)

1 Summary of innovative energy efficient technology

1.1 Wind propulsion systems belong to innovative mechanical energy efficient technologies which reduce the CO\textsubscript{2} emissions of ships. There are different types of wind propulsion technologies (sails, wings, kites, etc.) which generate forces dependent on wind conditions. This technical guidance defines the available effective power of wind propulsion systems as the product of the reference speed and the sum of the wind propulsion system force and the global wind probability distribution.

2 Definitions

2.1 For the purpose of these guidelines, the following definitions should apply:

.1 *Available effective power* is the multiplication of effective power $P_{\text{eff}}$ and availability factor $f_{\text{eff}}$ as defined in the EEDI calculation.

.2 *Wind propulsion systems* belong to innovative mechanical energy efficient technologies which reduce the CO\textsubscript{2} emissions of ships. These proposed guidelines apply to wind propulsion technologies that directly transfer mechanical propulsion forces to the ship's structure (sails, wings, kites, etc.).

.3 *Global wind probability matrix* contains data of the global wind power on the main global shipping routes based on a statistical survey of worldwide wind data. A detailed determination of the global wind probability matrix can be found in a separate submission (INF paper).

3 Available effective power of wind propulsion systems

3.1 The available effective power of wind propulsion systems as innovative energy efficient technology is calculated by the following formula:

\[
(f_{\text{eff}} \cdot P_{\text{eff}}) = \frac{0.5144 \cdot V_{\text{ref}}}{\eta_T} \sum_{i=1}^{m} \sum_{j=1}^{n} V_{\text{ref}}(i,j) \cdot W_{i,j} - \left( \sum_{i=1}^{m} \sum_{j=1}^{n} P(V_{\text{ref}})(i,j) \cdot W_{i,j} \right)
\]

Where:

.1 $(f_{\text{eff}} \cdot P_{\text{eff}})$ is the available effective power in kW delivered by the specified wind propulsion system. $f_{\text{eff}}$ and $P_{\text{eff}}$ are combined in the calculation because the product of availability and power is a result of a matrix operation, addressing each wind condition with a probability and a specific wind propulsion system force.

.2 The factor 0.5144 is the conversion factor from nautical miles per hour (knots) to metres per second (m/s).

.3 $V_{\text{ref}}$ is the ship reference speed measured in nautical miles per hour (knots), as defined in the EEDI calculation guidelines.
.4 \( \eta_T \) is the total efficiency of the main drive(s) at 75 per cent of the rated installed power (MCR) of the main engine(s). \( \eta_T \) shall be set to 0.7, if no other value is specified and verified by the verifier.

.5 \( F(V_{\text{ref}})_{ij} \) is the force matrix of the respective wind propulsion system for a given ship speed \( V_{\text{ref}} \).

.6 \( W_{ij} \) is the global wind probability matrix (see below).

.7 \( P(V_{\text{ref}})_{ij} \) is a matrix with the same dimensions as \( F(V_{\text{ref}})_{ij} \) and \( W_{ij} \) and represents the power demand in kW for the operation of the wind propulsion system.

3.2 The first term of the formula defines the additional propulsion power to be considered for the overall EEDI calculation. The term contains the product of the ship specific speed, the force matrix and the global wind probability matrix. The second term contains the power requirement for the operation of the specific wind propulsion system which has to be subtracted from the gained wind power.

4 Wind propulsion system force matrix \( F(V_{\text{ref}})_{ij} \)

4.1 Every wind propulsion system has a distinctive force characteristic dependent on ship speed, wind speed and the wind angle relative to heading. The force characteristic can be expressed in a two dimensional matrix, holding elements for any combination of wind speed and wind angle relative to heading for a given ship speed \( V_{\text{ref}} \).

4.2 Each matrix element represents the propulsion force in kilonewton (kN) for the respective wind speed and angle. The wind angle is given in relative bearings (with 0° on the bow). Table 1 gives guidance for the determination of the wind propulsion system force matrix \( F(V_{\text{ref}})_{ij} \). For the final determination of the CO\(_2\) reduction of a system the force matrix must be approved by the verifier.

<table>
<thead>
<tr>
<th>wind speed [m/s]</th>
<th>0</th>
<th>5</th>
<th>…</th>
<th>355</th>
</tr>
</thead>
<tbody>
<tr>
<td>( &lt;1 )</td>
<td>( f_{1,1} )</td>
<td>( f_{1,2} )</td>
<td>…</td>
<td>( f_{1,72} )</td>
</tr>
<tr>
<td>( &lt;2 )</td>
<td>( f_{2,1} )</td>
<td>( f_{2,2} )</td>
<td>…</td>
<td>( f_{2,72} )</td>
</tr>
<tr>
<td>( &lt;3 )</td>
<td>( f_{3,1} )</td>
<td>( f_{3,2} )</td>
<td>…</td>
<td>( f_{3,72} )</td>
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<tr>
<td>( … )</td>
<td>( … )</td>
<td>( … )</td>
<td>( … )</td>
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</tr>
<tr>
<td>( \geq 25 )</td>
<td>( f_{26,1} )</td>
<td>( f_{26,2} )</td>
<td>…</td>
<td>( f_{26,72} )</td>
</tr>
</tbody>
</table>

5 The global wind probability matrix \( W_{ij} \)

5.1 \( W_{ij} \) represents the probability of wind conditions. Each matrix element represents the probability of wind speed and wind angle relative to the ship coordinates. The sum over all matrix elements equals 1 and is non-dimensional. Table 2 shows the layout of the global wind probability matrix. The wind probability matrix shall be gained from the wind probability on the main global shipping routes\(^2\).

\(^2\) An example on a global wind probability matrix can be found in document MEPC 62/INF.34. This example should be subject to approval in a later session of MEPC.
Table 2: Lay-out of the global wind probability matrix

<table>
<thead>
<tr>
<th>Wind speed [m/s]</th>
<th>0</th>
<th>5</th>
<th>…</th>
<th>355</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind angle [°]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1</td>
<td>W1,1</td>
<td>W1,2</td>
<td>...</td>
<td>W1,72</td>
</tr>
<tr>
<td>&lt;2</td>
<td>W2,1</td>
<td>W2,2</td>
<td>...</td>
<td>W2,72</td>
</tr>
<tr>
<td>&lt;3</td>
<td>W3,1</td>
<td>W3,2</td>
<td>...</td>
<td>W3,72</td>
</tr>
<tr>
<td>≥25</td>
<td>W26,1</td>
<td>W26,2</td>
<td>...</td>
<td>W26,72</td>
</tr>
</tbody>
</table>

6 Effective CO₂ reduction by wind propulsion systems

6.1 For the calculation of the CO₂ reduction the resulting available effective power \((f_{eff} \times P_{eff})\) has to be multiplied with the conversion factor \(C_{FME}\) and \(SFC_{ME}\) as contained in the original EEDI formula.

7 Verification of wind propulsion systems in the EEDI certification process

7.1 General

Verification of EEDI with innovative energy efficient technologies should be conducted according to the EEDI Survey Guidelines. Additional items concerning innovative energy efficient technologies not contained in EEDI Survey Guidelines are described below.

7.2 Preliminary verification at the design stage

7.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 Outline of Wind propulsion systems; and

.2 Calculated value of EEDI due to the wind propulsion system.

7.2.2 In addition to paragraph 4.2.7 of the EEDI Survey Guidelines, additional information from the shipbuilder may be requested by the verifier. It includes:

.1 Detailed calculation process of the wind propulsion system force matrix \(F(V_{ref})_{ij}\) and results of performance tests\(^3\).

7.2.3 In order to prevent undesirable effects on the ship's structure or main drive, the influences of added forces on the ship should be determined during the EEDI certification process. Elements in the wind propulsion system force matrix may be limited to ship specific restrictions if necessary. The technical means to restrict the wind propulsion system's force should be verified as part of the performance test\(^4\).

\(^3\) Performance test for the specific type of wind propulsion system are required to determine the wind propulsion system force matrix. Technical guidance for the conduction of performance tests should be subject to approval in a later session of MEPC.

\(^4\) Technical guidance for the conduction of performance tests should be subject to approval in a later session of MEPC.
7.2.4 If more than one innovative energy efficient technology is subject to approval in the EEDI certification, interactions between these technologies should be considered. The appropriate technical papers should be included in the additional information submitted to the verifier in the certification process.

7.3 Final verification of the attained EEDI at sea trial

The total net power generated by wind propulsion systems should be confirmed based on the EEDI Technical File. In addition to the confirmation, it should be confirmed prior to the final verification, whether the configuration of the wind propulsion systems on the ship is the same as applied in the pre-verification.

***
ANNEX 2

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (C) INNOVATIVE TECHNOLOGIES

Appendix 1

WASTE HEAT RECOVERY SYSTEM FOR GENERATION OF ELECTRICITY (CATEGORY (C-1))

1 Summary of innovative energy efficient technology

This Appendix provides the guidance on the treatment of high temperature waste heat recovery systems (electric generation type) as innovative energy efficiency technologies related to the reduction of the auxiliary power (concerning $P_{AEff(i)}$). Mechanical recovered waste energy directly coupled to shafts need not be measured in this category, since the effect of the technology is directly reflected in the $V_{ref}$.

Waste heat energy technologies increase the efficiency utilization of the energy generated from fuel combustion in the engine through recovery of the thermal energy of exhaust gas, cooling water, etc., thereby generating electricity.

There are the following two methods of generating electricity by the waste heat energy technologies (electric generation type).

(A) Method to recover thermal energy by a heat exchanger and to drive the thermal engine which drives an electric generator.

(B) Method to drive directly an electric generator using power turbine, etc. Furthermore, there is a waste heat recovery system which combines both of the above methods.

5 All examples in appendix are used solely to illustrate the proposed methods of calculation and verification.
2 Method of calculation

2.1 Power reduction due to waste heating recovery system

The reduction of power by the waste heat recovery system is calculated by the following equation. For this system, \( f_{eff} \) is 1.00 in EEDI formula.

\[
P_{AEff} = P'_{AEff} - P_{AEff\_Loss}
\]  

(1)

In the above equation, \( P'_{AEff} \) is power produced by the waste heat recovery system. \( P_{AEff\_Loss} \) is the necessary power to drive the waste heat recovery system.

2.1.1 \( P_{AEff} \) is the reduction of the ship's total auxiliary power (kW) by the waste heat recovery system under the ship performance condition applied for EEDI calculation. The power generated by the system under this condition and fed into the main switch board is to be taken into account, regardless of its application on board the vessel (except for power consumed by machinery as described in paragraph 2.1.4).

2.1.2 \( P'_{AEff} \) is defined by the following equation.

\[
P'_{AEff} = \frac{W_e}{\eta_g}
\]  

(2)

where:

\( W_e \) : Calculated production of electricity by the waste heat recovery system
\( \eta_g \) : Weighted average generator efficiency
2.1.3 \( P_{AEff} \) is determined by the following factors:

.1 temperature and mass flow of exhaust gas of the engines, etc.;

.2 constitution of the waste heat recovery system; and

.3 efficiency and performances of the components of the waste heat recovery system.

2.1.4 \( P_{AEff, Loss} \) is the power (kW) for the pump, etc., necessary to drive the waste heat recovery system.

3 Method of verification

3.1 General

Verification of EEDI with innovative energy efficient technologies should be conducted according to the EEDI Survey Guidelines. Additional items concerning innovative energy efficient technologies not contained in EEDI Survey Guidelines are described below.

3.2 Preliminary verification at the design stage

3.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 diagrams, such as a plant diagram, a process flow diagram, or a piping and instrumentation diagram outlining the waste heat recovery system, and its related information such as specifications of the system components;

.2 deduction of the saved energy from the auxiliary engine power by the waste heat recovery system; and

.3 calculation result of EEDI.

3.2.2 In addition to paragraph 4.2.7 of the EEDI Survey Guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 exhaust gas data for the main engine at 75 per cent MCR (and/or the auxiliary engine at the measurement condition of SFC) at different ambient air inlet temperatures, e.g. 5°C, 25°C and 35°C; which consist of:

.1.1 exhaust gas mass flow for turbo charger (kg/h);

.1.2 exhaust gas temperatures after turbo charger (°C);

.1.3 exhaust gas bypass mass flow available for power turbine, if any (kg/h);

.1.4 exhaust gas temperature for bypass flow (°C); and

.1.5 exhaust gas pressure for bypass flow (bar).
in the case of system using heat exchanger, expected output steam flows and steam temperatures for the exchanger, based on the exhaust gas data from the main engine;

estimation process of the heat energy recovered by the waste heat recovery system; and

further details of the calculation method of $P_{AE_{eff}}$ defined in paragraph 2.1 of this appendix.

3.3 Final verification of the attained EEDI at sea trial

3.3.1 Deduction of the saved energy from the auxiliary engine power by the waste heat recovery system should be verified by the results of shop tests of the waste heat recovery system’s principal components and, where possible, at sea trials.

3.3.2 In the case of systems for which shop tests are difficult to be conducted, e.g. in case of the exhaust gas economizer, the performance of the waste heat recovery system should be verified by measuring the amount of the generated steam, its temperature, etc. at the sea trial. In that case, the measured vapour amount, temperature, etc. should be corrected to the value under the exhaust gas condition when they were designed, and at the measurement conditions of $SFC$ of the main/auxiliary engine(s). The exhaust gas condition should be corrected based on the atmospheric temperature in the engine-room (Measurement condition of $SFC$ of main/auxiliary engine(s); i.e. 25°C), etc.
Appendix 2

PHOTOVOLTAIC POWER GENERATION SYSTEM (CATEGORY (C-2))

1 Summary of innovative energy efficient technology

Photovoltaic (PV) power generation system set on a ship will provide part of the electric power either for propelling the ship or for use inboard. PV power generation system consists of PV modules and other electric equipment. Figure 1 shows a schematic diagram of PV power generation system. The PV module consists of combining solar cells and there are some types of solar cell such as "Crystalline silicon terrestrial photovoltaic" and "Thin-film terrestrial photovoltaic", etc.

![Figure 1 – Schematic diagram of photovoltaic power generation system](image)

2 Method of calculation

2.1 Electric power due to photovoltaic power generation system

The auxiliary power reduction due to the PV power generation system can be calculated as follows:

\[
f_{\text{eff}} \cdot P_{AE_{\text{eff}}} = \{f_{\text{rad}} \times (1 + L_{\text{temp}} / 100) \} \times \{ P_{\text{max}} \times (1 - L_{\text{others}} / 100) \times N / \eta_{\text{GEN}} \}
\]  

(1)

2.1.1 \( f_{\text{eff}} \cdot P_{AE_{\text{eff}}} \) is the total net electric power (kW) generated by the PV power generation system.

2.1.2 Effective coefficient \( f_{\text{eff}} \) is the ratio of average PV power generation in main global shipping routes to the nominal PV power generation specified by the manufacturer. Effective coefficient can be calculated by the following formula using the solar irradiance and air temperature of main global shipping routes:

\[
f_{\text{eff}} = f_{\text{rad}} \times (1 + L_{\text{temp}} / 100)
\]  

(2)
2.1.3 $f_{rad}$ is the ratio of the average solar irradiance on main global shipping route to the nominal solar irradiance specified by the manufacturer. Nominal maximum generating power $P_{max}$ is measured under the Standard Test Condition (STC) of IEC standard\textsuperscript{6}. STC specified by manufacturer is that: Air Mass (AM) 1.5, the module’s temperature is 25°C, and the solar irradiance is 1000 W/m\textsuperscript{2}. The average solar irradiance on main global shipping route is 200 W/m\textsuperscript{2}. Therefore, $f_{rad}$ is calculated by the following formula:

$$f_{rad} = \frac{200 \text{ W/m}^2}{1000 \text{ W/m}^2} = 0.2$$ (3)

2.1.4 $L_{temp}$ is the correction factor, which is usually in minus, and derived from the temperature of PV modules, and the value is expressed in per cent. The average temperature of the modules is deemed 40°C, based on the average air temperature on main global shipping routes. Therefore, $L_{temp}$ is derived from the temperature coefficient $f_{temp}$ (percent/K) specified by the manufacturer (See IEC standard\textsuperscript{6}) as follows:

$$L_{temp} = f_{temp} \times (40°C - 25°C)$$ (4)

2.1.5 $P_{AEff}$ is the generated PV power divided by the weighted average efficiency of the generator(s) under the condition specified by the manufacturer and expressed as follows:

$$P_{AEff} = P_{max} \times (1 - L_{others}/100) \times N / \eta_{GEN},$$ (5)

where $\eta_{GEN}$ is the weighted average efficiency of the generator(s).

2.1.6 $P_{max}$ is the nominal maximum generated PV power generation of a module expressed in kilowatt, specified based on IEC Standards\textsuperscript{6}.

2.1.7 $L_{others}$ is the summation of other losses expressed by percent and includes the losses in a power conditioner, at contact, by electrical resistance, etc. Based on experiences, it is estimated that $L_{others}$ is 10 per cent (the loss in the power conditioner: 5 per cent and the sum of other losses: 5%). However, for the loss in the power conditioner, it is practical to apply the value specified based on IEC Standards\textsuperscript{7}.

2.1.8 $N$ is the numbers of modules used in a PV power generation system.

3 Method of verification

3.1 General

Verification of EEDI with innovative energy efficient technologies is conducted according to EEDI Survey Guidelines. This section provides additional requirements related to innovative technologies.

3.2 Preliminary verification at the design stage

3.2.1 In addition to paragraph 4.2.2 of EEDI Survey guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

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\textsuperscript{6} Refer to IEC 61215 “Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval” for Crystalline silicon terrestrial PV modules, and to IEC 61646 “Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval” for Thin-film terrestrial PV modules.

\textsuperscript{7} IEC 61683 “Photovoltaic systems – Power conditioners – Procedure for measuring efficiency”. 

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.1 outline of the PV power generation system;
.2 power generated by the PV power generation system; and
.3 calculated value of EEDI due to the PV power generation system.

3.2.2 In addition to paragraph 4.2.7 of the EEDI survey guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 detailed calculation process of the auxiliary power reduction by the PV power generation system; and

.2 detailed calculation process of the total net electric power \( f_{\text{eff}} \cdot P_{AE_{\text{eff}}} \) specified in paragraph 2 in this guidance.

3.3 Final verification of the attained EEDI at sea trial

The total net electric power generated by PV power generation system should be confirmed based on the EEDI Technical File. In addition to the confirmation, it should be confirmed whether the configuration of the PV power generation systems on ship is as applied, prior to the final verification.