RULES

PUBLICATION 103/P

GUIDELINES FOR ENERGY EFFICIENCY OF SHIPS

January
2024

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

GDAŃSK

Publication 103/P – Guidelines for energy efficiency of ships – January 2024 was approved by PRS Executive Board on 21 December 2023 and enters into force on 1 January 2024.

PRS/OP, 12/2023

CONTENTS

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.

ANNEX 5

RESOLUTION MEPC.308(73)
(adopted on 26 October 2018)

2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS

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, at its sixty-second session, 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 entered into force on 1 January 2013,

NOTING ALSO that regulation 22 (Attained Energy Efficiency Design Index (attained EEDI)) of MARPOL Annex VI, as amended, requires that the EEDI shall be calculated taking into account the guidelines developed by the Organization,

NOTING FURTHER the 2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, adopted at its sixty-third session by resolution MEPC.212(63), superseded by the 2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.245(66)), which were subsequently superseded by the 2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.308(73)),

NOTING that, at its seventy-fourth session, it adopted, by resolution MEPC.322(74), Amendments to the 2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships,

HAVING CONSIDERED, at its seventy-sixth session, proposed amendments to the 2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.308(73), as amended by resolution MEPC.322(74)),

1 ADOPTS amendments to the 2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.308(73), as amended by resolution MEPC.322(74)), as set out in the annex to the present resolution;

2 INVITES Administrations to take into account the aforementioned amendments when developing and enacting national laws which give force to, and implement provisions set forth in regulation 20 of MARPOL Annex VI, as amended;

3 REQUESTS the Parties to MARPOL Annex VI and other Member Governments to bring the amendments to the attention of shipowners, ship operators, shipbuilders, ship designers and any other interested parties;

5 *AGREES to keep these Guidelines, as amended, under review, in light of experience* gained with their implementation.

ANNEX

2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS

CONTENTS

"3 **Mandatory Reporting of Attained EEDI Values and Related Information**

3.1 In accordance with regulation 22.3 of MARPOL Annex VI, for each ship subject to regulation 24, the Administration or any organization duly authorized by it shall report the required and attained EEDI values and relevant information taking into account these Guidelines via electronic communication.

3.2 Information to be reported are as follows:

.1 applicable EEDI phase (e.g. Phase 1, Phase 2, etc.);

.2 identification number (IMO Secretariat use only);

.3 ship type;

.4 common commercial size reference* (see Note (3) in appendix 5 to

.5 these Guidelines), if available;

.6 DWT or GT (as appropriate);

.7 year of delivery;

.8 required EEDI value;

.9 attained EEDI value;

.10 dimensional parameters (length L_{pp} (m), breadth B_s (m), and draught (m));

.11 V_{ref} (knots) and P_{ME} (kW);

.12 use of innovative technologies (4th and 5th terms in the EEDI equation, if applicable);

.13 short statement* describing the principal design elements or changes employed to achieve the attained EEDI (as appropriate), if available;

.14 type of fuel used in the calculation of the attained EEDI, and for dual-fuel engines, the f_{DFgas} ratio; and
ice class designation (if applicable).

3.3 The information in paragraph 3.2 is not required to be reported for ships for which the required and attained EEDI values had been already reported to the Organization.

3.4 A standardized reporting format for Mandatory Reporting of Attained EEDI Values and Related Information is presented in appendix 5."

APPENDIX 1 A generic and simplified power plant

APPENDIX 2 (EPT-EEDI) Guidelines for the development of electric power tables for EEDI

APPENDIX 3 A generic and simplified marine power plant for a cruise passenger ship having non-conventional propulsion

APPENDIX 4 EEDI calculation examples for use of dual fuel engines

APPENDIX 5 Standard format to submit EEDI information to be included in the EEDI database

* Not subject to verification.

1 Definitions

1.1 MARPOL means the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997relating thereto, as amended.

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)

2.1 EEDI Formula

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:

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

* If part of the Normal Maximum Sea Load is provided by shaft generators, SFC_{ME} and C_{FME} may – for that part of the power – be used instead of SFC_{AE} and C_{FAE}

** In case of $P_{PTI(i)} > 0$, the average weighted value of ($SFC_{ME} \cdot C_{FME}$) and ($SFC_{AE} \cdot C_{FAE}$) to be used for calculation of P_{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.

2.2 Parameters

For the calculation of EEDI by the formula in paragraph 2.1, following parameters apply.

2.2.1 C_F ; Conversion factor between fuel consumption and CO_2 emission

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 $_{ME(i)}$ and $_{AE(i)}$ refer to the main and auxiliary engine(s) respectively. C_F corresponds to the fuel used when determining *SFC* 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:

Type of fuel	Reference	Lower calorific value (kJ/kg)	Carbon content	C_F (t-CO_2/t-Fuel)
1 Diesel/Gas Oil	ISO 8217 Grades DMX through DMB	42,700	0.8744	3.206
2 Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	41,200	0.8594	3.151
3 Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	40,200	0.8493	3.114
4 Liquefied Petroleum Gas (LPG)	Propane	46,300	0.8182	3.000
	Butane	45,700	0.8264	3.030

5 Liquefied Natural Gas (LNG)		48,000	0.7500	2.750
6 Methanol		19,900	0.3750	1.375
7 Ethanol		26,800	0.5217	1.913

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:

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

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

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;

ρ_{gas} is the density of gas fuel in kg/m^3;

ρ_{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 $f_{DFliquid}$, such as the original item of $P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$ in the EEDI calculation is to be replaced by the formula below.

$$P_{ME(i)} \cdot (f_{DFgas(i)} \cdot (C_{FME\ pilot\ fuel(i)} \cdot SFC_{ME\ pilot\ fuel(i)} + C_{FME\ gas(i)} \cdot SFC_{ME\ gas(i)}) + f_{DFliquid(i)} \cdot C_{FME\ liquid(i)} \cdot SFC_{ME\ liquid(i)})$$

2.2.2 V_{ref} ; Ship speed

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 2.2.3.1 and 2.2.3.3 (in case of passenger ships and cruise passenger ships, this condition should be summer load draught as provided in paragraph 2.2.4) at the shaft power of the engine(s) as defined in paragraph 2.2.5 and assuming the weather is calm with no wind and no waves.

2.2.3 *Capacity*

Capacity is defined as follows.

2.2.3.1 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*.

2.2.3.2 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*.

2.2.3.3 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:

$$Estimated\ \ Index\,Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{70\%\mathrm{DWT} \cdot V_{ref}}$$

.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:

Required EEDI = (1-X/100) · a · 100% deadweight $^{-c}$

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.

2.2.4 *Deadweight*

Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1,025 kg/m^3 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.

2.2.5 *P ;* Power of main and auxiliary engines

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

2.2.5.1 $P_{ME(i)}$; Power of main engines

$P_{ME(i)}$ is 75% of the rated installed power (MCR[1]) for each main engine (*i*).

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

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

Where:

$MPP_{Motor(i)}$ 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, $P_{ME(i)}$ is 83% of the rated installed power ($MCR_{SteamTurbine}$) for each steam turbine$_{(i)}$.

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

2.2.5.2 $P_{PTO(i)}$; Shaft generator

In case where shaft generator(s) are installed, $P_{PTO(i)}$ is 75% of the rated electrical output power of each shaft generator. In case that shaft generator(s) are installed to steam turbine, $P_{PTO(i)}$ 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:

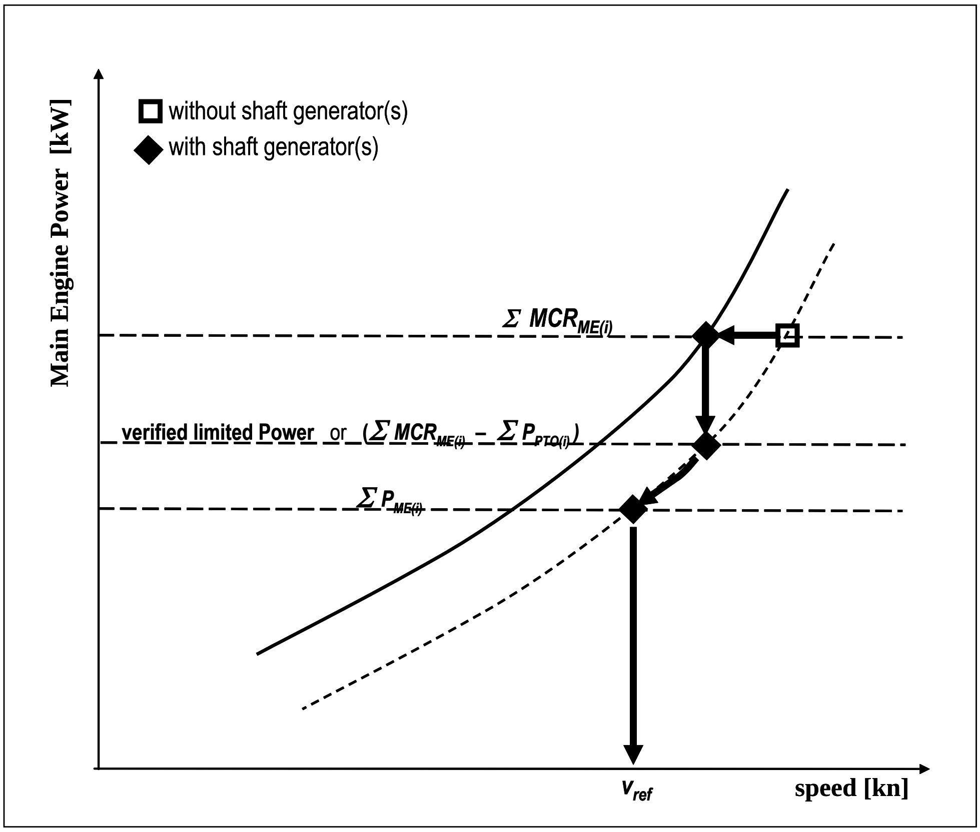
The maximum allowable deduction for the calculation of Σ $P_{ME(i)}$ is to be no more than P_{AE} as defined in paragraph 2.2.5.6. For this case, Σ $P_{ME(i)}$ is calculated as:

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

or

Option 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 Σ $P_{ME(i)}$ 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 Σ $P_{ME(i)}$:



2.2.5.3 $P_{PTI(i)}$; Shaft motor

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

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

Where:

$P_{SM,\max(i)}$ is the rated power consumption of each shaft motor

$\eta_{\overline{Gen}}$ 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:

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

$\eta_{PTI(i)}$ 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.

2.2.5.4 $P_{eff(i)}$; Innovative mechanical energy efficient technology for main engine

$P_{eff(i)}$ 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 2.2.1 and 2.2.7.

2.2.5.5 P_{AEeff} ; Innovative mechanical energy efficient technology for auxiliary engine

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

2.2.5.6 P_{AE} ; Auxiliary engine power

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 2.2.2.

2.2.5.6.1 For ships which total propulsion power ($\sum MCR_{ME(i)} + \frac{\sum P_{PTI(i)}}{0.75}$) is 10,000 kW or above, P_{AE} is defined as:

$$P_{AE\ (\Sigma MCR_{ME(i)} \geq 10{,}000kW)} = \left(0.025 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right) + 250$$

2.2.5.6.2 For ships which total propulsion power ($\sum MCR_{ME(i)} + \frac{\sum P_{PTI(i)}}{0.75}$) is below 10,000 kW, P_{AE} is defined as:

$$P_{AE\ (\Sigma MCR_{ME(i)} < 10{,}000kW)} = \left(0.05 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right)$$

2.2.5.6.3 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 2.2.5.6.3.1, 2.2.5.6.3.2 or 2.2.5.6.3.3 as below:

.1 For ships having re-liquefaction system:

$$+ CargoTankCapacity_{LNG} \times BOR \times COP_{reliquefy} \times R_{reliquefy}$$

Where:

$CargoTankCapacity_{LNG}$ is the LNG Cargo Tank Capacity in m^3.

BOR is the design rate of boil-off gas of entire ship per day, which is specified in the specification of the building contract.

$COP_{reliquefy}$ is the coefficient of design power performance for reliquefying boil-off gas per unit volume, as follows:

$$COP_{reliquefy} = \frac{425\,(kg/m^3) \times 511\,(kJ/kg)}{24\,(h) \times 3600\,(\text{sec}) \times COP_{cooling}}$$

$COP_{cooling}$ 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.

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

$$R_{reliquefy} = \frac{BOG_{reliquefy}}{BOG_{total}}$$

.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):

$$+ COP_{comp} \times \sum_{i=1}^{nME} SFC_{ME(i),gasmode} \times \frac{P_{ME(i)}}{1000}$$

Where:

COP_{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):

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

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

2.2.5.6.5 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 systems, P_{AE} may be treated as 0(zero) instead of taking into account electric load in calculating $SFC_{SteamTurbine}$.

2.2.5.7 Use of electric power table

For ship where the P_{AE} value calculated by paragraphs 2.2.5.6.1 to 2.2.5.6.3 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).

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2 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_{ME}, compared to the energy needed to compress BOG for supplying to a steam turbine.

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.

2.2.6 Consistency of parameters V_{ref}, *Capacity* and *P*

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 $MCR_{SteamTubine}$ respectively.

2.2.7 *SFC;* Certified specific fuel consumption

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

2.2.7.1 *SFC* for main and auxiliary engines

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 2.2.5.6.1 to 2.2.5.6.3 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.

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 2.2.1 of these Guidelines. The reference lower calorific value corresponding to the conversion factor of the respective fuel should be used for calculation.

2.2.7.2 *SFC* for steam turbines ($SFC_{SteamTurbine}$)

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

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

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 2.2.5.6 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°C , inlet temperature of fan 38°C, sea water temperature 24°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.

2.2.8 f_j ; Ship specific design elements

f_j is a correction factor to account for ship specific design elements:

2.2.8.1 Power correction factor for ice-classed ships

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[4].

Table 1: Correction factor for power f_j for ice-classed ships

Ship type	f_{j0}	$f_{j,min}$ depending on the ice class			
		IA Super	IA	IB	IC
Tanker	$\frac{17.444 \cdot DWT^{0.5766}}{\sum_{i=1}^{nME} MCR_{ME(i)}}$	$0.2488 \cdot DWT^{0.0903}$	$0.4541 \cdot DWT^{0.0524}$	$0.7783 \cdot DWT^{0.0145}$	$0.8741 \cdot DWT^{0.0079}$
Bulk carrier	$\frac{17.207 \cdot DWT^{0.5705}}{\sum_{i=1}^{nME} MCR_{ME(i)}}$	$0.2515 \cdot DWT^{0.0851}$	$0.3918 \cdot DWT^{0.0556}$	$0.8075 \cdot DWT^{0.0071}$	$0.8573 \cdot DWT^{0.0087}$
General cargo ship	$\frac{1.974 \cdot DWT^{0.7987}}{\sum_{i=1}^{nME} MCR_{ME(i)}}$	$0.1381 \cdot DWT^{0.1435}$	$0.1574 \cdot DWT^{0.144}$	$0.3256 \cdot DWT^{0.0922}$	$0.4966 \cdot DWT^{0.0583}$
Refrigerated cargo ship	$\frac{5.598 \cdot DWT^{0.696}}{\sum_{i=1}^{nME} MCR_{ME(i)}}$	$0.5254 \cdot DWT^{0.0357}$	$0.6325 \cdot DWT^{0.0278}$	$0.7670 \cdot DWT^{0.0159}$	$0.8918 \cdot DWT^{0.0079}$

4 HELCOM Recommendation 25/7 may be found at http://www.helcom.fi

Alternatively, if an ice-class ship is designed and constructed based on an open water ship with same shape and size of hull with EEDI certification, the power correction factor, f_j, for ice-classed ships can be calculated by using propulsion power of the new ice-class ship required by ice-class regulations, $P_{ice\ class}$, and the existing open water ship, P_{ow}, as follows:

$$f_j = \frac{P_{ow}}{P_{ice\ class}}$$

In this case, V_{ref} should be measured at the shaft power of the engine(s) installed on the existing open water ship as defined in paragraph 2.2.5.

2.2.8.2 Power correction factor for shuttle tankers with propulsion redundancy

The power correction 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.

2.2.8.3 Correction factor for ro-ro cargo and ro-ro passenger ships (f_{jRoRo})

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

$$f_{jRoRo} = \frac{1}{F_{n_L}^{\alpha} \cdot \left(\frac{L_{pp}}{B_s}\right)^{\beta} \cdot \left(\frac{B_s}{d_s}\right)^{\gamma} \cdot \left(\frac{L_{pp}}{\nabla^{1/3}}\right)^{\delta}} \quad ; \quad \text{If } f_{jRoRo} > 1 \text{ then } f_j = 1$$

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

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

and the exponents α, β, γ and δ are defined as follows:

Ship type	Exponent:			
	α	β	γ	δ
Ro-ro cargo ship	2.00	0.50	0.75	1.00
Ro-ro passenger ship	2.50	0.75	0.75	1.00

2.2.8.4 Correction factor for general cargo ships

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

$$f_j = \frac{0.174}{Fn_{\nabla}^{\ 2.3} \cdot C_b^{\ 0.3}} \quad ; \qquad \text{If } f_j > 1 \text{ then } f_j = 1$$

Where

$$Fn_{\nabla} = \frac{0.5144 \cdot V_{ref}}{\sqrt{g \cdot \nabla^{\frac{1}{3}}}} \quad ; \qquad \text{If } Fn_{\nabla} > 0.6 \text{ then } Fn_{\nabla} = 0.6$$

and

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

2.2.8.5 Correction factor for other ship types

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

2.2.9 f_w ; Factor for speed reduction at sea

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:

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

2.2.9.2 when f_w is calculated according to the subparagraph 2.2.9.2.1 or 2.2.9.2.2 below, the value for attained EEDI calculated by the formula in paragraph 2.1 using the obtained f_w should be referred to as "*attained EEDI$_{weather}$*";

2.2.9.2.1 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[4] and the method and outcome for an individual ship should be verified by the Administration or an organization recognized by the Administration; and

2.2.9.2.2 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.

2.2.9.3 f_w and *attained EEDI$_{weather}$*, 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.

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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.

2.2.10 $f_{eff(i)}$; Factor of each innovative energy efficiency technology

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

2.2.11 f_i ; Capacity factor for technical/regulatory limitation on capacity

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.

2.2.11.1 Capacity correction factor for ice-classed ships

The capacity correction factor, fi, for ice-classed ships having DWT as the measure of capacity should be calculated as follows:

$$f_i = f_{i(ice\ class)} \cdot f_{iC_b},$$

where $f_{i(ice\ class)}$ is the capacity correction factor for ice-strengthening of the ship, which can be obtained from Table 2 and f_{iC_b} is the capacity correction factor for improved ice-going capability, which should not be less than 1.0 and which should be calculated as follows:

$$f_{iC_b} = \frac{C_{b\ reference\ design}}{C_b},$$

where $C_{b\ reference\ design}$ is the average block coefficient for the ship type, which can be obtained from Table 3 for bulk carriers, tankers and general cargo ships, and C_b is the block coefficient of the ship. For ship types other than bulk carriers, tankers and general cargo ships,

$$f_{iC_b} = 1.0.$$

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

Table 2: Capacity correction factor for ice-strengthening of the hull

Ice class[7]	$f_{i(ice\ class)}$
IC	$f_{i(IC)} = 1.0041 + 58.5/DWT$
IB	$f_{i(IB)} = 1.0067 + 62.7/DWT$
IA	$f_{i(IA)} = 1.0099 + 95.1/DWT$
IA Super	$f_{i(IAS)} = 1.0151 + 228.7/DWT$

Table 3: Average block coefficients $C_{b\ reference\ design}$ for bulk carriers, tankers and general cargo ships

	Size categories				
Ship type	below 10,000 DWT	10,000 – 25,000 DWT	25,000 – 55,000 DWT	55,000 – 75,000 DWT	above 75,000 DWT
Bulk carrier	0.78	0.80	0.82	0.86	0.86
Tanker	0.78	0.78	0.80	0.83	0.83
General cargo ship	0.80				

Alternatively, the capacity correction factor for ice-strengthening of the ship ($f_{i(ice\ class)}$) can be calculated by using the formula given for the ship specific voluntary enhancement correction coefficient ($f_{i\ VSE}$) in paragraph 2.2.11.2. This formula can also be used for other ice classes than those given in Table 2.

2.2.11.2 $f_{i\ VSE}$[8] ; Ship specific voluntary structural enhancement

$f_{i\ VSE}$ for ship specific voluntary structural enhancement is expressed by the following formula:

$$f_{iVSE} = \frac{DWT_{referencedesign}}{DWT_{enhanceddesign}}$$

where:

$$DWT_{referencedesign} = \Delta_{ship} - lightweight_{referencedesign}$$

$$DWT_{enhanceddesign} = \Delta_{ship} - lightweight_{enhanceddesign}$$

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

DWT before enhancements ($DWT_{reference\ design}$) is the deadweight prior to application of the structural enhancements. DWT after enhancements ($DWT_{enhanced\ design}$) is the deadweight following the application of voluntary structural enhancement. A change of material (e.g. from

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7 For further information on approximate correspondence between ice classes, see HELCOM Recommendation 25/7, which can be found at http://www.helcom.fi

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".

aluminum alloy to steel) between reference design and enhanced design should not be allowed for the $f_{i\ VSE}$ 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.

2.2.11.3 f_{iCSR} ; Ships under the Common Structural Rules (CSR)

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_{iCSR} should apply:

$$f_{iCSR} = 1 + (0.08 \cdot LWT_{CSR} / DWT_{CSR})$$

Where DWT_{CSR} is the deadweight determined by paragraph 2.2.4 and LWT_{CSR} is the light weight of the ship.

2.2.11.4 f_i for other ship types

For other ship types, f_i should be taken as one (1.0).

2.2.12 f_c ; Cubic capacity correction factor

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.

2.2.12.1 f_c for chemical tankers

For chemical tankers, as defined in regulation 1.16.1 of MARPOL Annex II, the following cubic capacity correction factor f_c should apply:

$f_c = R^{-0.7} - 0.014$, 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 2.2.4 divided by the total cubic capacity of the cargo tanks of the ship (m^3).

2.2.12.2 f_c for gas carriers

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 2.2.4 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.

2.2.12.3 f_c for ro-ro passenger ships (f_{cRoPax})

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:

$$f_{cRoPax} = \left(\frac{(DWT/_{GT})}{0.25}\right)^{-0.8}$$

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.

2.2.12.4 f_c for bulk carriers having R of less than 0.55 ($f_{c\ bulk\ carriers\ designed\ to\ carry\ light\ cargoes}$)

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 2.2.4 divided by the total cubic capacity of the cargo holds of the ship (m^3).

2.2.13 L_{pp} ; Length between perpendiculars

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.

2.2.14 f_l ; Factor for general cargo ships equipped with cranes and cargo-related gear

f_l 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.

$$f_l = f_{cranes} \cdot f_{sideloader} \cdot f_{roro}$$

f_{cranes}	= 1	If no cranes are present.
$f_{sideloader}$	= 1	If no side loaders are present.
f_{roro}	= 1	If no ro-ro ramp is present.

Definition of f_{cranes}:

$$f_{cranes} = 1 + \frac{\sum_{n=1}^{n}\left(0.0519 \cdot SWL_n \cdot Reach_n + 32.11\right)}{Capacity}$$

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:

$$f_{sideloader} = \frac{Capacity_{No\ sideloaders}}{Capacity_{sideloaders}}$$

$$f_{RoRo} = \frac{Capacity_{No\ RoRo}}{Capacity_{RoRo}}$$

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_{ivse}.

2.2.15 d_s ; Summer load line draught

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.

2.2.16 B_s ; Breadth

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

2.2.17 ; Volumetric displacement

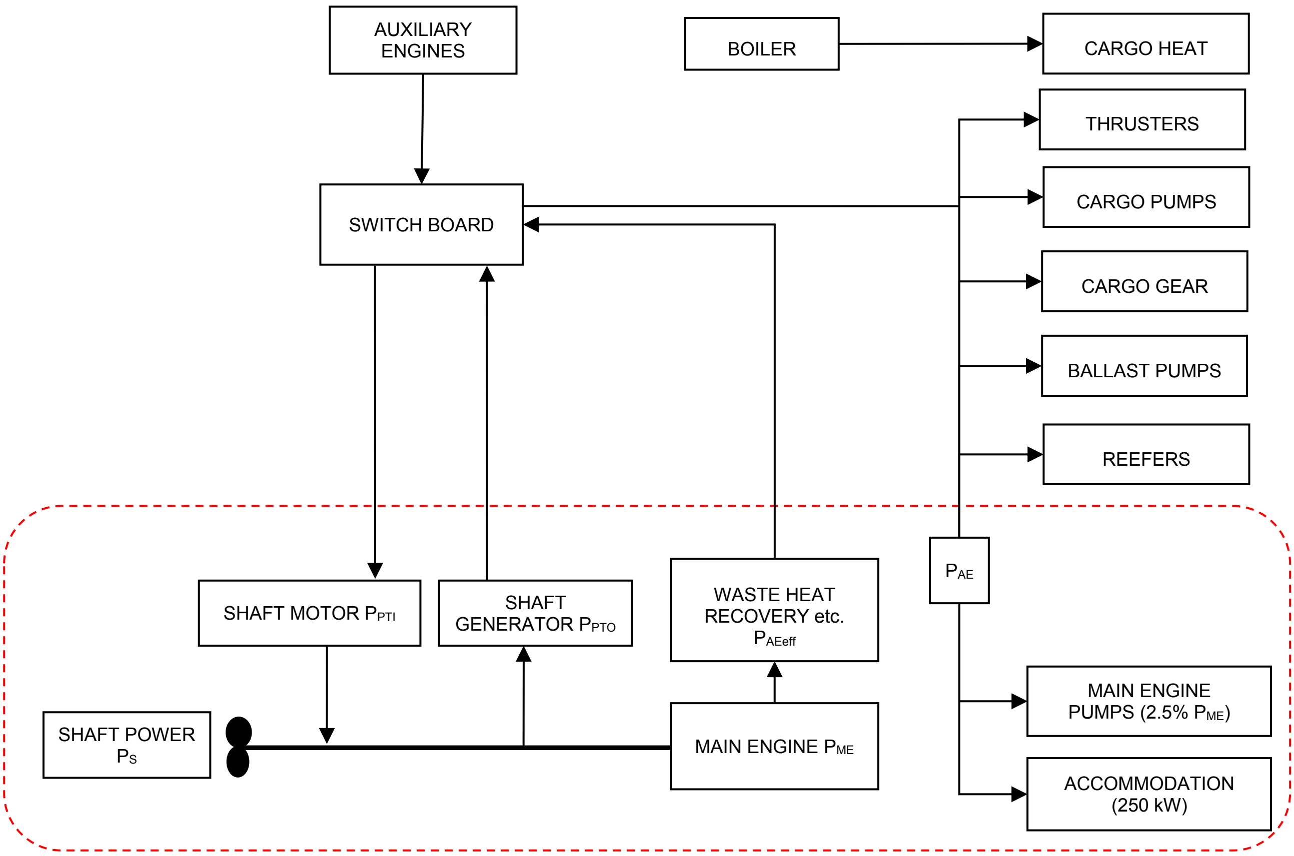
Volumetric displacement, ∇, in cubic metres (m^3), is the volume of the moulded displacement of the ship, excluding appendages, in a ship with a metal shell, and is the volume of displacement to the outer surface of the hull in a ship with a shell of any other material, both taken at the summer load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

2.2.18 g ; Gravitational acceleration

g is the gravitational acceleration, 9.81m/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 2.2.5.6 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 "*Pm*" (*kW*);
.6 Load's electric motor rated output power (*kW*);
.7 Load's electric motor efficiency "*e*" (/);
.8 Load's Rated electric power "*Pr*" (*kW*);
.9 Service factor of load "*kl*" (/);
.10 Service factor of duty "*kd*" (/);
.11 Service factor of time "*kt*" (/);
.12 Service total factor of use "*ku*" (/), where $ku=kl \cdot kd \cdot kt$;
.13 Load's necessary power "*Pload*" (*kW*), where $Pload=Pr \cdot ku$;
.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 P_{AEeff}, 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 paragraph 2.2.5.6 of the Guidelines (see rows 4 and 5 of the electric power table contained in this appendix), 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 paragraph 2.5.6 of the Guidelines (see row 5 of the electric power table contained in this appendix);

.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 (*PTI(i)*) 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 ($kl=1$, $kt=1$ and $kd=1$) 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, kd is to represent the use of spare chillers (e.g. four chillers are installed and one out four is spare then $kd=0$ for the spare chiller and $kd=1$ 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 – Galleys, 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 th 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=Pm/e (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 ½ and ½. When three compressors serves the same circuit and one runs in duty and two in stand-by, then *kd* is 1/3, 1/3 and 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=4/24.* For example, the seawater cooling pumps operate at their power all the time during the navigation at *Vref*. As a consequence *kt=1*.

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 $Pload=Pr \cdot ku$.

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.

$$PAE=\Sigma Pload(i)/(\text{average efficiency of the generator(s) weighted by power})$$

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 appendix;

.4 one Column for the group descriptions as indicated in paragraphs 4.1.1 to 4.1.12 of this appendix;

.5 one column each for items in paragraphs 4.2 to 4.14 of this appendix (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 appendix; and

.8 explanatory notes.

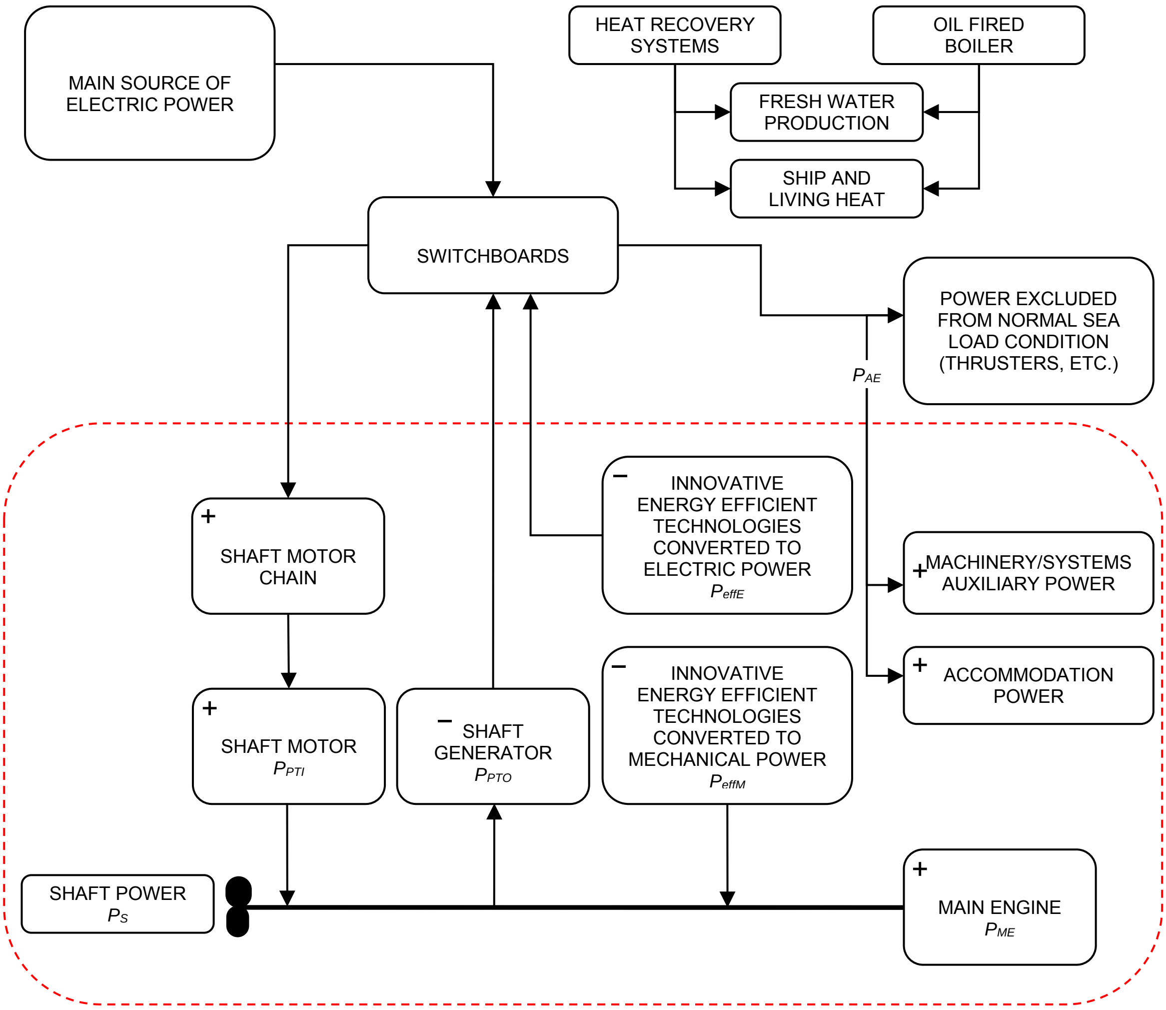
An example of an electric power table for EEDI for a cruise postal ship which transports passengers and has a car garage and reefer holds for fish trade transportation is indicated below. The data indicated and the type of ship is for reference only.

ELECTRIC POWER TABLE FOR EEDI			HULL "EXAMPLE"		PROJECT "EXAMPLE"									(NMSL=Normal Maximun Sea Load)
id	Load group	Load description	Load identification tag	Load electric circuit Identification	Load mechanical rated power *"Pm" [kW]*	Load electric motor rated output power *[kW]*	Load electric motor efficiency *"e" [/]*	Load Rated electric power *"Pr" [kW]*	service factor of load *"kl" [/]*	service factor of duty *"kd" [/]*	service factor of time *"kt" [/]*	service total factor of use *"ku" [/]*	Load necessary power *"Pload" [kW]*	Note
1	A	Hull cathodic protection Fwd	xxx	yyy	n.a.	n.a.	n.a.	5.2	1	1	1*	1	5.2	*in use 24hours/day
2	A	Hull cathodic protection mid	xxx	yyy	n.a.	n.a.	n.a.	7.0	1	1	1*	1	7	*in use 24hours/day
3	A	Hull cathodic protection aft	xxx	yyy	n.a.	n.a.	n.a.	4.8	1	1	1*	1	4.8	*in use 24hours/day
4	A	Ballast pump 3	xxx	yyy	30	36	0.92	32.6	0.9	0.5	1	0*	0	*not in use at **NMSL** see para 2.5.6 of Circ.681
5	A	Fwd Stb mooring winch motor n.1	xxx	yyy	90	150	0.92	97.8	0.8	1	0*	0*	0	*not in use at **NMSL** see para 2.5.6 of Circ.681
6	A	WTDs system main control panel	xxx	yyy	n.a.	n.a.	n.a.	0.5	1	1	1*	1	0.5	*in use 24hours/day
7	A	WTD 1, deck D frame 150	xxx	yyy	1.2	3	0.91	1.3	0.7	1	0.104*	0.0728	0.096	*180 secs to open/close x 100 opening a day
8	A	WTD 5, deck D frame 210	xxx	yyy	1.2	3	0.91	1.3	0.7	1	0.156*	0.1092	0.14	*180 secs to open/close x 150 opening a day
9	A	Stabilisers control unit	xxx	yyy	n.a.	n.a.	n.a.	0.7	1	1	1*	1	0.7	*in use 24hours/day
10	A	Stabilisers Hydraulic pack power pump 1	xxx	yyy	80	90	0.9	88.9	0.9	1	0*	0	0	*NMSL=> calm sea,=> stabiliser not in use
11	A	S-band Radar 1 controller	xxx	yyy	n.a.	n.a.	n.a.	0.4	1	1	1*	1	0.4	*in use 24hours/day
12	A	S-band Radar 1 motor	xxx	yyy	0.8	1	0.92	0.9	1	1	1*	1	0.9	*in use 24hours/day
13	A	Fire detection system bridge main unit	xxx	yyy	n.a.	n.a.	n.a.	1.5	1	1	1*	1	1.5	*in use 24hours/day
14	A	Fire detection system ECR unit	xxx	yyy	n.a.	n.a.	n.a.	0.9	1	1	1*	1	0.9	*in use 24hours/day
15	A	High pressure water fog contol unit	xxx	yyy	n.a.	n.a.	n.a.	1.2	1	1	1*	1	1.2	*in use 24hours/day
16	A	High pressure water fog engines rooms pump 1a	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0	0	*NMSL=> not emergency =>Load not in use
17	A	High pressure water fog engines rooms pump 1b	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0	0	* not emergency situations
18	B	PTi port fresh water pump 1	xxx	yyy	30	36	0.92	32.6	0.9	0.5*	1	0.45	14.7	* pump1,2 one is duty and one is stand-by
19	B	PTi port fresh water pump 2	xxx	yyy	30	36	0.92	32.6	0.9	0.5*	1	0.45	14.7	* pump1,2 one is duty and one is stand-by
20	B	Thrusters control system	xxx	yyy	n.a.	n.a.	n.a.	0.5	1	1	1*	1	0.5	in use 24hours/day (even if thruster motor isn't)
21	B	Bow thruster 1	xxx	yyy	3000	3000	0.96	3125.0	1	1	0*	0	0	*NMSL=>thrusters motor are not in use
22	B	PEM port cooling fan 1	xxx	yyy	20	25	0.93	21.5	0.9	1	n.a.	n.a	n.a.*	*this load is included in the propulsion chain data
23	C	HT circulation pump 1 DG 3	xxx	yyy	8	10	0.92	8.7	0.9	0.5*	1	0.45	3.9	* pump1,2 one is duty and one is stand-by
24	C	HT circulation pump 2 DG 3	xxx	yyy	8	10	0.92	8.7	0.9	0.5*	1	0.45	3.9	* pump1,2 one is duty and one is stand-by
25	C	DG3 combustion air fan	xxx	yyy	28	35	0.92	30.4	0.9	1	1*	0.9	27.4	*in use 24hours/day
26	C	DG3 exhaust gas boiler circulationg pump	xxx	yyy	6	8	0.93	6.5	0.8	1	1*	0.8	5.2	*in use 24hours/day
27	C	Alternator 3 external cooling fan	xxx	yyy	3	5	0.93	3.2	0.8	1	1*	0.8	2.75	*in use 24hours/day
28	C	fuel feed fwd booster pump a	xxx	yyy	7	9	0.92	7.6	0.9	0.5*	1	0.45	3.4	* pump1,2 one is duty and one is stand-by
29	C	fuel feed fwd booster pump b	xxx	yyy	7	9	0.92	7.6	0.9	0.5*	1	0.45	3.4	* pump1,2 one is duty and one is stand-by
30	D	Fwd main LT cooling pump 1	xxx	yyy	120	150	0.95	126.3	0.9	0.5*	1	0.45	56.8	* pump1,2 one is duty and one is stand-by
31	D	Fwd main LT cooling pump 2	xxx	yyy	120	150	0.95	126.3	0.9	0.5*	1	0.45	56.8	* pump1,2 one is duty and one is stand-by
32	E	FWD engine room supply fan 1	xxx	yyy	87.8	110	0.93	94.4	0.95	1	1*	0.95	89.7	*in use 24hours/day
33	E	FWD engine room exhaust fan 1	xxx	yyy	75	86	0.93	80.6	0.96	1	1*	0.96	77.4	*in use 24hours/day
34	E	purifier room supply fan 1	xxx	yyy	60	70	0.93	64.5	0.96	0.5	1*	0.48	31.0	*in use 24hours/day
35	E	purifier room supply fan 2	xxx	yyy	60	70	0.93	64.5	0.96	0.5	1*	0.48	31.0	*in use 24hours/day
36	F	HVAC chiller a	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
37	F	HVAC chiller b	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
38	F	HVAC chiller C	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
39	F	A.H.U. Ac station 5.4 supply fan	xxx	yyy	50	60	0.93	53.8	0.9	1	1*	0.9	48.4	*in use 24hours/day
40	F	A.H.U. Ac station 5.4 exhaust fan	xxx	yyy	45	55	0.93	48.4	0.9	1	1*	0.9	43.5	*in use 24hours/day
41	F	Chilled water pump a	xxx	yyy	80	90	0.93	86.0	0.88	0.5*	1	0.44	37.8	* pump1,2 one is duty and one is stand-by
42	F	Chilled water pump b	xxx	yyy	80	90	0.93	86.0	0.88	0.5*	1	0.44	37.8	* pump1,2 one is duty and one is stand-by
43	G	Italian's espresso coffee machine	xxx	yyy	n.a.	n.a.	n.a.	7.0	0.9	1	0.2*	0.18	1.3	*in use 4.8hours/day
44	G	deep freezer machine	xxx	yyy	n.a.	n.a.	n.a.	20.0	0.8	1	0.16*	0.128	3.2	*in use 4hours/day
45	G	washing machine 1	xxx	yyy	n.a.	n.a.	n.a.	8.0	0.8	1	0.33*	0.264	3.2	*in use 8hours/day
46	H	lift pax mid 4	xxx	yyy	30	40	0.93	32.3	0.5	1	0.175*	0.0875	0.9	*in use 4hours/day
47	H	vaccum collecting system 4 pump a	xxx	yyy	10	13	0.92	10.9	0.9	1	1*	0.9	8.7	*in use 24hours/day
48	H	sewage treatmet system 1 pump 1	xxx	yyy	15	17	0.93	16.1	0.9	1	1*	0.9	8.7	*in use 24hours/day
49	H	Gym running machine	xxx	yyy	n.a.	n.a.	n.a.	2.5	1	1	0.3*	0.3	0.8	*in use 7.2hours/day
50	I	Cabin's lighting MVZ3	n.a.	n.a.	n.a.	n.a.	n.a.	80*	1	1	1	1	80.0	* see explainatory note
51	I	corridors ligthing MVZ3	n.a.	n.a.	n.a.	n.a.	n.a.	10*	1	1	1	1	10.0	* see explainatory note
52	I	Cabin's sockets MVZ3	n.a.	n.a.	n.a.	n.a.	n.a.	5*	1	1	1	1	5.0	* see explainatory note
53	L	Main Theatre audio booster amplifier	xxx	yyy	n.a.	n.a.	n.a.	15.0	1	1	0.3*	0.3	4.5	*in use 7.2hours/day
54	L	Video wall atrium	xxx	yyy	n.a.	n.a.	n.a.	2.0	1	1	0.3*	0.3	0.6	*in use 7.2hours/day
55	M	Car Garage supply fan1	xxx	yyy	28	35	0.92	30.4	0.9	1	1*	0*	0	*not in use at **NMSL** see para 2.5.6 of Circ.681
56	M	Fish transportation refeer hold n.2	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0*	0	*not in use at **NMSL** see para 2.5.6 of Circ.681
57	N	Sliding glass roof	xxx	yyy	30	40	0.93	32.3	0.9	1	0.3*	0.27	0.2	*in use 7.2hours/day
												ΣPload(i)=	**3764**	

***PAE* =3764/(weighted average efficiency of generator(s)) [kW]** Group's necessary power (group A=22.9kW, B=29.8kW,C=49.9kW, D=113.7kW, E=229kW , F=3189kW, G=7.6kW, H=19kW, I=95kW, L=5.1kW, M=0kW, N=0.22kW)

APPENDIX 3

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

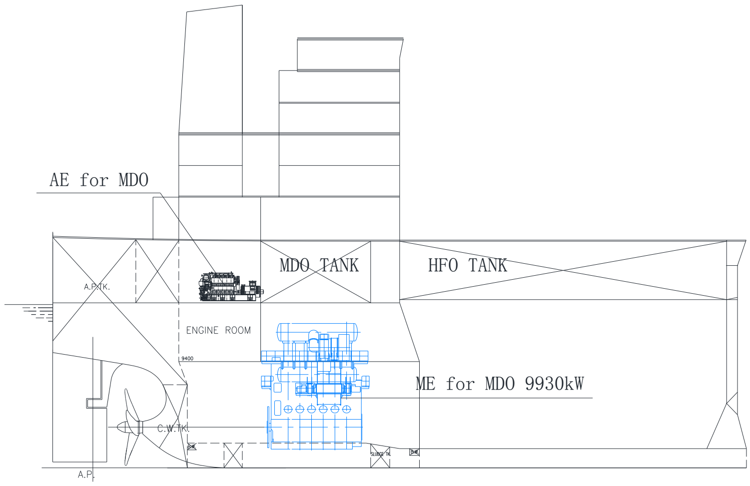


Note: Symbols for plus (+) and minus (−) indicate CO_2 contribution to EEDI formula.

APPENDIX 4

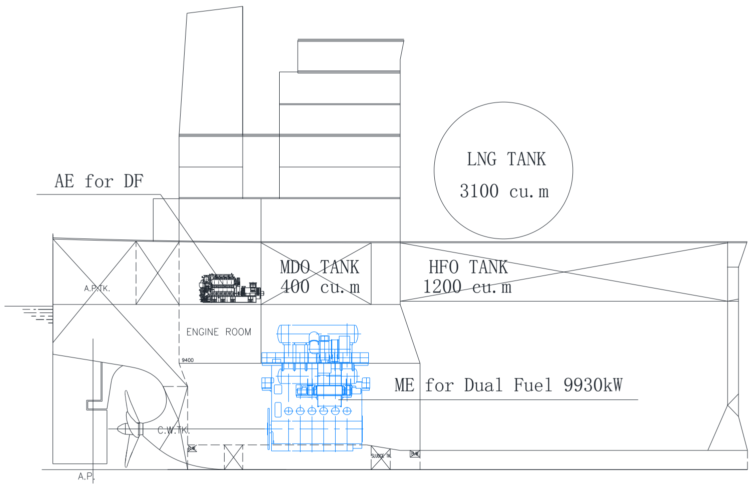
EEDI CALCULATION EXAMPLES FOR USE OF DUAL FUEL ENGINES

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



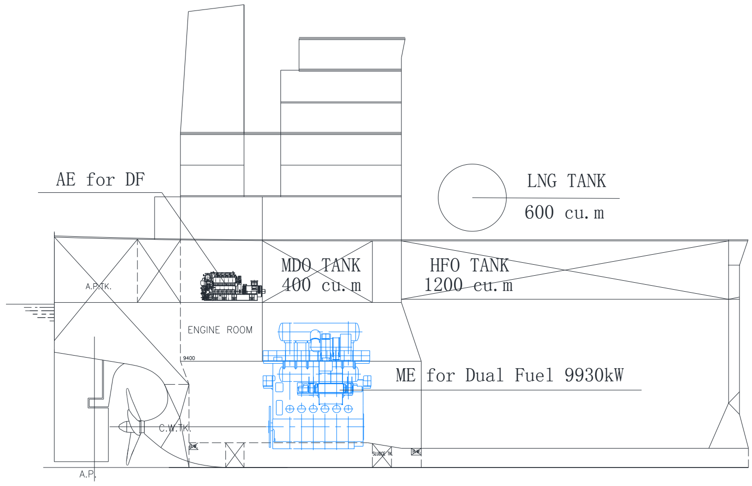
S/N	Parameter	Formula or Source	Unit	Value
1	MCR_{ME}	MCR rating of main engine	kW	9930
2	Capacity	Deadweight of the ship at summer load draft	DWT	81200
3	V_{ref}	Ships speed as defined in EEDI regulation	kn	14
4	P_{ME}	0.75 x MCR_{ME}	kW	7447.5
5	P_{AE}	0.05 x MCR_{ME}	kW	496.5
6	C_{FME}	C_F factor of Main engine using MDO	-	3.206
7	C_{FAE}	C_F factor of Auxiliary engine using MDO	-	3.206
8	SFC_{ME}	Specific fuel consumption of at P_{ME}	g/kWh	165
9	SFC_{AE}	Specific fuel consumption of at P_{AE}	g/kWh	210
10	EEDI	$((P_{ME} \times C_{F\ ME} \times SFC_{ME})+(P_{AE} \times C_{FAE} \times SFC_{AE})) / (V_{ref} \times Capacity)$	gCO_2/tnm	3.76

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:



S/N	Parameter	Formula or Source	Unit	Value
1	MCR_{ME}	MCR rating of main engine	kW	9930
2	Capacity	Deadweight of the ship at summer load draft	DWT	81200
3	V_{ref}	Ships speed as defined in EEDI regulation	kn	14
4	P_{ME}	0.75 x MCR_{ME}	kW	7447.5
5	P_{AE}	0.05 x MCR_{ME}	kW	496.5
6	$CF_{Pilotfuel}$	C_F factor of pilot fuel for dual fuel ME using MDO	-	3.206
7	$CF_{AE\ Plilotfuel}$	C_F factor of pilot fuel for Auxiliary engine using MDO	-	3.206
8	CF_{LNG}	C_F factor of dual fuel engine using LNG	-	2.75
9	$SFC_{MEPilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel ME at P_{ME}	g/kWh	6
10	$SFC_{AE\ Pilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel AE at P_{AE}	g/kWh	7
11	$SFC_{ME\ LNG}$	Specific fuel consumption of ME using LNG at P_{ME}	g/kWh	136
12	$SFC_{AE\ LNG}$	Specific fuel consumption of AE using LNG at P_{AE}	g/kWh	160
13	V_{LNG}	LNG tank capacity on board	m^3	3100
14	V_{HFO}	Heavy fuel oil tank capacity on board	m^3	1200
15	V_{MDO}	Marine diesel oil tank capacity on board	m^3	400
16	ρ_{LNG}	Density of LNG	kg/m^3	450
17	ρ_{HFO}	Density of heavy fuel oil	kg/m^3	991
18	ρ_{MDO}	Density of Marine diesel oil	kg/m^3	900
19	LCV_{LNG}	Low calorific value of LNG	kJ/kg	48000
20	LCV_{HFO}	Low calorific value of heavy fuel oil	kJ/kg	40200
21	LCV_{MDO}	Low calorific value of marine diesel oil	kJ/kg	42700
22	K_{LNG}	Filling rate of LNG tank	-	0.95
23	K_{HFO}	Filling rate of heavy fuel tank	-	0.98
24	K_{MDO}	Filling rate of marine diesel tank	-	0.98
25	f_{DFgas}	$\frac{P_{ME}+P_{AE}}{P_{ME}+P_{AE}} \times \frac{V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}{V_{HFO} \times \rho_{HFO} \times LCV_{HFO} \times K_{HFO} + V_{MDO} \times \rho_{MDO} \times LCV_{MDO} \times K_{MDO} + V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}$	-	0.5068
26	EEDI	$(P_{ME} \times (C_{F\ Pilotfuel} \times SFC_{ME\ Pilotfuel} + C_{F\ LNG} \times SFC_{ME\ LNG}) + P_{AE} \times (C_{F\ Pilotfuel} \times SFC_{AE\ Pilotfuel} + C_{F\ LNG} \times SFC_{AE\ LNG})) / (V_{ref} \times Capacity)$	gCO_2/tnm	2.78

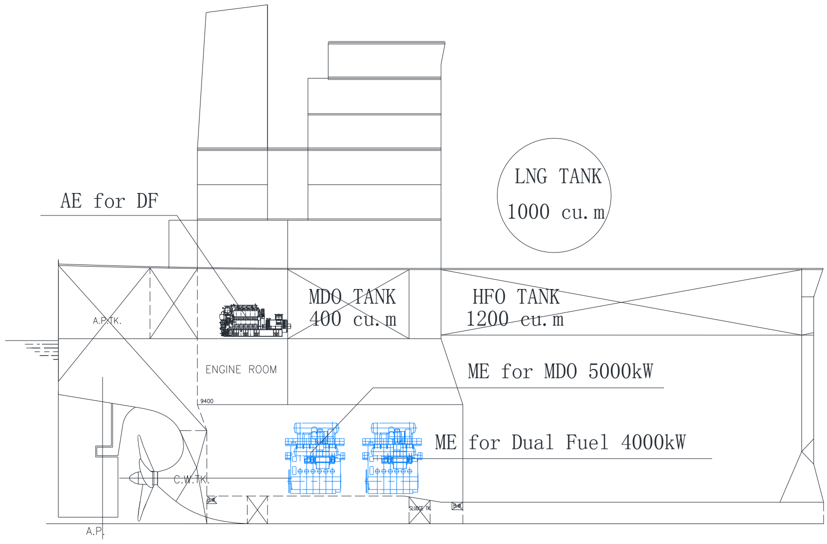
Case 3: LNG is not regarded as the "primary fuel" if dual-fuel main engine and dual-fuel auxiliary engine (LNG, pilot fuel MDO; no shaft generator) are equipped with smaller LNG tanks:



S/N	Parameter	Formula or Source	Unit	Value
1	MCR_{ME}	MCR rating of main engine	kW	9930
2	Capacity	Deadweight of the ship at summer load draft	DWT	81200
3	V_{ref}	Ships speed as defined in EEDI regulation	kn	14
4	P_{ME}	0.75 x MCR_{ME}	kW	7447.5
5	P_{AE}	0.05 x MCR_{ME}	kW	496.5
6	$C_{FPilotfuel}$	C_F factor of pilot fuel for dual fuel ME using MDO	-	3.206
7	$C_{FAE\ Plilotfuel}$	C_F factor of pilot fuel for Auxiliary engine using MDO	-	3.206
8	C_{FLNG}	C_F factor of dual fuel engine using LNG	-	2.75
9	C_{FMDO}	C_F factor of dual fuel ME/AE engine using MDO	-	3.206
10	$SFC_{MEPilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel ME at P_{ME}	g/kWh	6
11	$SFC_{AE\ Pilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel AE at P_{AE}	g/kWh	7
12	$SFC_{ME\ LNG}$	Specific fuel consumption of ME using LNG at P_{ME}	g/kWh	136
13	$SFC_{AE\ LNG}$	Specific fuel consumption of AE using LNG at P_{AE}	g/kWh	160
14	$SFC_{ME\ MDO}$	Specific fuel consumption of dual fuel ME using MDO at P_{ME}	g/kWh	165
15	$SFC_{AE\ MDO}$	Specific fuel consumption of dual fuel AE using MDO at P_{AE}	g/kWh	187
16	V_{LNG}	LNG tank capacity on board	m^3	600
17	V_{HFO}	Heavy fuel oil tank capacity on board	m^3	1800
18	V_{MDO}	Marine diesel oil tank capacity on board	m^3	400
19	ρ_{LNG}	Density of LNG	kg/m^3	450
20	ρ_{HFO}	Density of heavy fuel oil	kg/m^3	991
21	ρ_{MDO}	Density of Marine diesel oil	kg/m^3	900
22	LCV_{LNG}	Low calorific value of LNG	kJ/kg	48000
24	LCV_{HFO}	Low calorific value of heavy fuel oil	kJ/kg	40200
25	LCV_{MDO}	Low calorific value of marine diesel oil	kJ/kg	42700
26	K_{LNG}	Filling rate of LNG tank	-	0.95
27	K_{HFO}	Filling rate of heavy fuel tank	-	0.98

S/N	Parameter	Formula or Source	Unit	Value
28	K_{MDO}	Filling rate of marine diesel tank	-	0.98
29	f_{DFgas}	$\frac{P_{ME}+P_{AE}}{P_{ME}+P_{AE}} \times \frac{V_{LNG}\times\rho_{LNG}\times LCV_{LNG}\times K_{LNG}}{V_{HFO}\times\rho_{HFO}\times LCV_{HFO}\times K_{HFO}+V_{MDO}\times\rho_{MDO}\times LCV_{MDO}\times K_{MDO}+V_{LNG}\times\rho_{LNG}\times LCV_{LNG}\times K_{LNG}}$	-	0.1261
30	$f_{DFliquid}$	1- f_{DFgas}	-	0.8739
31	EEDI	$(P_{ME} \times (f_{DFgas} \times (C_{F\ Pilotfuel} \times SFC_{ME\ Pilotfuel} + C_{F\ LNG} \times SFC_{ME\ LNG}) + f_{DFliquid} \times C_{FMDO} \times SFC_{ME\ MDO}) + P_{AE} \times (f_{DFgas} \times (C_{FAE\ Pilotfuel} \times SFC_{AE\ Pilotfuel} + C_{F\ LNG} \times SFC_{AE\ LNG}) + f_{DFliquid} \times C_{FMDO} \times SFC_{AE\ MDO})) / (V_{ref} \times Capacity)$	gCO_2/tnm	3.61

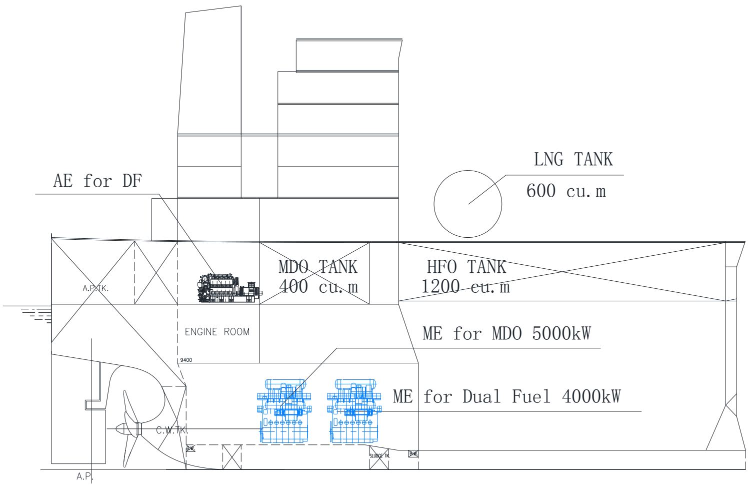
Case 4: One dual-fuel main engine (LNG, pilot fuel MDO) and one main engine (MDO) and dual-fuel auxiliary engine (LNG, pilot fuel MDO, no shaft generator) which LNG could be regarded as "primary fuel" only for the dual-fuel main engine:



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

S/N	Parameter	Formula or Source	Unit	Value
19	V_{MDO}	Marine diesel oil tank capacity on board	m^3	400
20	ρ_{LNG}	Density of LNG	kg/m^3	450
21	ρ_{HFO}	Density of heavy fuel oil	kg/m^3	991
22	ρ_{MDO}	Density of Marine diesel oil	kg/m^3	900
23	LCV_{LNG}	Low calorific value of LNG	kJ/kg	48000
24	LCV_{HFO}	Low calorific value of heavy fuel oil	kJ/kg	40200
25	LCV_{MDO}	Low calorific value of marine diesel oil	kJ/kg	42700
26	K_{LNG}	Filling rate of LNG tank	-	0.95
27	K_{HFO}	Filling rate of heavy fuel tank	-	0.98
28	K_{MDO}	Filling rate of marine diesel tank	-	0.98
29	f_{DFgas}	$\frac{P_{MEMDO}+P_{MELNG}+P_{AE}}{P_{MELNG}+P_{AE}} \times \frac{V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}{V_{HFO} \times \rho_{HFO} \times LCV_{HFO} \times K_{HFO} + V_{MDO} \times \rho_{MDO} \times LCV_{MDO} \times K_{MDO} + V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}$	-	0.5195
30	EEDI	$(P_{MELNG}$ x $(C_{F\ Pilotfuel}$ x $SFC_{ME\ Pilotfuel}$ + $C_{F\ LNG}$ x $SFC_{DF\ LNG}$) + P_{MEMDO} x $C_{F\ MDO}$ x $SFC_{ME\ MDO}$ + P_{AE} x $(C_{FAE\ Pilotfuel}$ x $SFC_{AE\ Pilotfuel}$ + $C_{F\ LNG}$ x $SFC_{AE\ LNG}$)) / (V_{ref} x *Capacity*)	gCO_2/tnm	3.28

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:



S/N	Parameter	Formula or Source	Unit	Value
1	MCR_{MEMDO}	MCR rating of main engine using only MDO	kW	5000
2	MCR_{MELNG}	MCR rating of main engine using dual fuel	kW	4000
3	Capacity	Deadweight of the ship at summer load draft	DWT	81200
4	V_{ref}	Ships speed	kn	14
5	P_{MEMDO}	0.75 x MCR_{MEMDO}	kW	3750
6	P_{MELNG}	0.75 x MCR_{MELNG}	kW	3000
7	P_{AE}	0.05 x (MCR_{MEMDO} + MCR_{MELNG})	kW	450
8	$C_{FPilotfuel}$	C_F factor of pilot fuel for dual fuel ME using MDO	-	3.206
9	$C_{FAE\ Plilotfuel}$	C_F factor of pilot fuel for Auxiliary engine using MDO	-	3.206
10	C_{FLNG}	C_F factor of dual fuel engine using LNG	-	2.75
11	C_{FMDO}	C_F factor of dual fuel ME/AE engine using MDO	-	2.75
12	$SFC_{MEPilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel ME at P_{ME}	g/kWh	6

S/N	Parameter	Formula or Source	Unit	Value
13	$SFC_{AE\ Pilotfuel}$	Specific fuel consumption of pilot fuel for dual fuel AE at P_{AE}	g/kWh	7
14	$SFC_{DF\ LNG}$	Specific fuel consumption of dual fuel ME using LNG at P_{ME}	g/kWh	158
15	$SFC_{AE\ LNG}$	Specific fuel consumption of AE using LNG at P_{AE}	g/kWh	160
16	$SFC_{DF\ MDO}$	Specific fuel consumption of dual fuel ME using MDO at P_{ME}	g/kWh	185
17	$SFC_{ME\ MDO}$	Specific fuel consumption of single fuel ME at P_{ME}	g/kWh	180
18	$SFC_{AE\ MDO}$	Specific fuel consumption of AE using MDO at P_{AE}	g/kWh	187
19	V_{LNG}	LNG tank capacity on board	m^3	600
20	V_{HFO}	Heavy fuel oil tank capacity on board	m^3	1200
21	V_{MDO}	Marine diesel oil tank capacity on board	m^3	400
22	ρ_{LNG}	Density of LNG	kg/m^3	450
23	ρ_{HFO}	Density of heavy fuel oil	kg/m^3	991
24	ρ_{MDO}	Density of Marine diesel oil	kg/m^3	900
25	LCV_{LNG}	Low calorific value of LNG	kJ/kg	48000
26	LCV_{HFO}	Low calorific value of heavy fuel oil	kJ/kg	40200
27	LCV_{MDO}	Low calorific value of marine diesel oil	kJ/kg	42700
28	K_{LNG}	Filling rate of LNG tank	-	0.95
29	K_{HFO}	Filling rate of heavy fuel tank	-	0.98
30	K_{MDO}	Filling rate of marine diesel tank	-	0.98
31	f_{DFgas}	$\frac{P_{MEMDO}+P_{MELNG}+P_{AE}}{P_{MELNG}+P_{AE}} \times \frac{V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}{V_{HFO} \times \rho_{HFO} \times LCV_{HFO} \times K_{HFO} + V_{MDO} \times \rho_{MDO} \times LCV_{MDO} \times K_{MDO} + V_{LNG} \times \rho_{LNG} \times LCV_{LNG} \times K_{LNG}}$	-	0.3462
32	$f_{DFliquid}$	1- f_{DFgas}	-	0.6538
33	EEDI	(P_{MELNG} x (f_{DFgas} x ($C_{F\ Pilotfuel}$ x $SFC_{ME\ Pilotfuel}$ + $C_{F\ LNG}$ x $SFC_{DF\ LNG}$) + $f_{DFliquid}$ x C_{FMDO} x $SFC_{DF\ MDO}$))+ P_{MEMDO} x $C_{F\ MDO}$ x $SFC_{ME\ MDO}$ + P_{AE} x (f_{DFgas} x ($C_{FAE\ Pilotfuel}$ x $SFC_{AE\ Pilotfuel}$ + $C_{F\ LNG}$ x $SFC_{AE\ LNG}$) + $f_{DFliquid}$ x C_{FMDO} x $SFC_{AE\ MDO}$)) / (V_{ref} x *Capacity*)	gCO_2/tnm	3.54

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ANNEX 16

RESOLUTION MEPC.322(74)
(adopted on 17 May 2019)

AMENDMENTS TO THE 2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS (RESOLUTION MEPC.308(73))

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, at its sixty-second session, 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 entered into force on 1 January 2013,

NOTING ALSO that regulation 20 (Attained Energy Efficiency Design Index (attained EEDI)) of MARPOL Annex VI, as amended, requires that the EEDI shall be calculated taking into account the guidelines developed by the Organization,

NOTING FURTHER the *2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, adopted at its sixty-third session by resolution MEPC.212(63), and the amendments thereto, adopted at its sixty-fourth session by resolution MEPC.224(64),

NOTING FURTHER that, at its sixty-sixth session, it adopted, by resolution MEPC.245(66), *2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, and, at its sixty-eighth session, by resolution MEPC.263(68), MEPC.281(70), amendments thereto,

NOTING FURTHER that, at its seventy-three, it adopted, by resolution MEPC.308(73), *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*,

RECOGNIZING that the amendments to MARPOL Annex VI require relevant guidelines for the smooth and uniform implementation of the regulations,

HAVING CONSIDERED, at its seventy-fourth session, proposed amendments to the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, as amended

1 ADOPTS amendments to the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, as amended*, as set out in the annex to the present resolution;

2 INVITES Administrations to take the aforementioned amendments into account when developing and enacting national laws which give force to and implement provisions set forth in regulation 20 of MARPOL Annex VI, as amended;

3 REQUESTS the Parties to MARPOL Annex VI and other Member Governments to bring the amendments to the attention of shipowners, ship operators, shipbuilders, ship designers and any other interested parties;

4 AGREES to keep these Guidelines, as amended, under review, in the light of experience gained with their implementation.

ANNEX

AMENDMENTS TO THE 2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS (RESOLUTION MEPC.308(73))

1 The following text is added after 2.2.18 in the table of "CONTENTS":

"2.2.19 f_m ; Factor for ice-classed ships having IA Super and IA"

2 The EEDI Formula in section 2.1 is replaced with the following:

"2.1 EEDI Formula

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:

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

"

3 A new section 2.2.19 is added after the existing section 2.2.18 as follows:

"2.2.19 f_m ; Factor for ice-classed ships having IA Super and IA

For ice-classed ships having IA Super or IA, the following factor, f_m, should apply:

$$f_m = 1.05$$

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

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* HELCOM Recommendation 25/7 may be found at http://www.helcom.fi

"APPENDIX 5

STANDARD FORMAT TO SUBMIT EEDI INFORMATION TO BE INCLUDED IN THE EEDI DATABASE

IMO Number (1)	Type of ship (2)	Common commercial size (3)	Capacity (4)		Dimensional parameters			Year of delivery	Applicable phase	Required EEDI	Attained EEDI	Vref (knot) (9)	P_{ME} (kW) (10)	Type of fuel (11)	f_{DF} gas (12)	Ice class (13)	EEDI 4th term (Installation of innovative electrical technology)		EEDI 5th term (Installation of innovative mechanical technology)		Short statement as appropriate describing the principal design elements or changes employed to achieve the attained EEDI (15)
			DWT	GT (5)	Lpp (m) (6)	Bs (m) (7)	Draught (m) (8)										Yes/ No	Name, outline and means/ ways of performance of technology (14)	Yes/ No	Name, outline and means/ ways of performance of technology (14)	

Note:

(1) IMO number to be submitted for Secretariat use only.

(2) As defined in regulation 2 of MARPOL Annex VI.

(3) Common commercial size reference (TEU for containership, CEU (RT43) for ro-ro cargo ship (vehicle carrier), cubic meter for gas carrier and LNG carrier), if available, should be provided.

(4) The exact DWT or GT, as appropriate, should be provided. The Secretariat should round the DWT or GT data up to the nearest 500 when these data are subsequently provided to MEPC. (For containerships, 100% DWT should be provided while 70% of DWT should be used when calculating the EEDI value).

(5) GT should be provided for a cruise passenger ship having non-conventional propulsion as defined in regulations 2.2.11and 2.2.19, respectively, of MARPOL Annex VI. Both DWT and GT should be provided for a ro-ro cargo ship (vehicle carrier) as defined in regulation 2.2.27 of MARPOL Annex VI.

(6) As defined in paragraph 2.2.13 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended). The exact Lpp should be provided. The Secretariat will round the Lpp data up to the nearest 10 when these data are subsequently provided to MEPC.

(7) As defined in paragraph 2.2.16 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended). The exact Bs should be provided. The Secretariat will round the Bs data up to the nearest 1 when these data are subsequently provided to MEPC.

(8) As defined in paragraph 2.2.15 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended). The exact draught should be provided. The Secretariat will round the draught data up to the nearest 1 when these data are subsequently provided to MEPC.

(9) As defined in paragraph 2.2.2 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended). The exact Vref should be provided. The Secretariat will round the Vref data up to the nearest 0.5 when these data are subsequently provided to MEPC.

(10) As defined in paragraph 2.2.5.1 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended). The exact P_{ME} should be provided. The Secretariat will round the PME data up to the nearest 100 when these data are subsequently provided to MEPC.

(11) As defined in paragraph 2.2.1 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended) or other (to be stated). In case of a ship equipped with a dual-fuel engine, type of "primary fuel" should be provided.

(12) As defined in paragraph 2.2.1 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308 (73), as amended), if applicable.

(13) Ice class, which was used to calculate correction factors for ice-classed ships as defined in paragraphs 2.2.8.1 and 2.2.11.1 of the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73), as amended), if applicable, should be provided.

(14) In the case that the innovative energy efficiency technologies are already included in the *2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI* (MEPC.1/Circ.815), the name of technology should be identified. Otherwise, name, outline and means/ways of performance of the technology should be identified.

(15) To assist the IMO in assessing relevant design trends, provide a short statement as appropriate, describing the principal design elements or changes employed to achieve the attained EEDI.

"

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ANNEX 12

RESOLUTION MEPC.350(78)
(adopted on 10 June 2022)

2022 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI)

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,

NOTING that the Committee adopted, at its seventy-sixth session, by resolution MEPC.328(76), the *2021 Revised MARPOL Annex VI*, which will enter into force on 1 November 2022,

NOTING IN PARTICULAR that the *2021 Revised MARPOL Annex VI* (MARPOL Annex VI) contains amendments concerning mandatory goal-based technical and operational measures to reduce carbon intensity of international shipping,

NOTING FURTHER that regulation 23 of MARPOL Annex VI requires that the attained Energy Efficiency Existing Ship Index (EEXI) shall be calculated taking into account the guidelines developed by the Organization,

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

NOTING that, at its seventy-sixth session, the Committee adopted, by resolution MEPC.333(76), the *2021 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI),*

HAVING CONSIDERED, at its seventy-eighth session, the draft *2022 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI),*

1 ADOPTS the *2022 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI),* as set out in the annex to the present resolution;

2 INVITES Administrations to take the annexed Guidelines into account when developing and enacting national laws which give force to and implement requirements set forth in regulation 23 of MARPOL Annex VI;

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

4 AGREES to keep the Guidelines under review in light of experience gained with their implementation, also taking into consideration that in accordance with regulation 25.3 of

MARPOL Annex VI a review of the technical measure to reduce carbon intensity of international shipping shall be completed by 1 January 2026;

5 REVOKES the *2021 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI)* adopted by resolution MEPC.333(76).

ANNEX

2022 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI)

CONTENTS

1 Definitions

1.1 *MARPOL* means the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997 relating thereto, as amended.

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

2 Energy Efficiency Existing Ship Index (EEXI)

2.1 EEXI formula

The attained Energy Efficiency Existing Ship Index (EEXI) is a measure of ship's energy efficiency (g/t*nm) and calculated by the following formula:

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

* If part of the Normal Maximum Sea Load is provided by shaft generators, SFC_{ME} and C_{FME} may – for that part of the power – be used instead of SFC_{AE} and C_{FAE}

** In case of $P_{PTI(i)} > 0$, the average weighted value of ($SFC_{ME} \cdot C_{FME}$) and ($SFC_{AE} \cdot C_{FAE}$) to be used for calculation of P_{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.

Ships falling into the scope of EEDI requirement can use their attained EEDI calculated in accordance with the *2018 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.308(73), as amended, the "EEDI Calculation Guidelines" hereafter) as the attained EEXI if the value of the attained EEDI is equal to or less than that of the required EEXI.

2.2 Parameters

For calculation of the attained EEXI by the formula in paragraph 2.1, parameters under the EEDI Calculation Guidelines apply, unless expressly provided otherwise. In referring to the aforementioned guidelines, the terminology "EEDI" should be read as "EEXI".

2.2.1 $P_{ME(i)}$; Power of main engines

In cases where overridable Shaft / Engine Power Limitation is installed in accordance with the *2021 Guidelines on the shaft / engine power limit to comply with the EEXI requirements and use of a power reserve* (resolution MEPC.335(76)), $P_{ME(i)}$ is 83% of the limited installed power (MCR_{lim}) or 75% of the original installed power (*MCR*), whichever is lower, for each main engine *(i)*. In cases where the overridable Shaft / Engine Power Limitation and shaft generator(s) are installed, in referring to paragraph 2.2.5.2 (option 1) of the EEDI Calculation Guidelines, "MCR_{ME}" should be read as "MCR_{lim}".

For LNG carriers having steam turbine or diesel electric propulsion, $P_{ME(i)}$ is 83% of the limited installed power (MCR_{lim}, MPP_{lim}), divided by the electrical efficiency in case of diesel electric propulsion system, for each main engine *(i)*. For LNG carriers, the power from combustion of the excessive natural boil-off gas in the engines or boilers to avoid releasing to the atmosphere or unnecessary thermal oxidation should be deducted from $P_{ME(i)}$ with the approval of the verifier.

2.2.2 $P_{AE(i)}$; Power of auxiliary engines

2.2.2.1 $P_{AE(i)}$ is calculated in accordance with paragraph 2.2.5.6 of the EEDI Calculation Guidelines.

2.2.2.2 For ships where power of auxiliary engines (P_{AE}) value calculated by paragraphs 2.2.5.6.1 to 2.2.5.6.3 of the EEDI Calculation Guidelines is significantly different from the total power used at normal seagoing, e.g. in cases of passenger ships, 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, divided by the average efficiency of the generator(s) weighted by power (see appendix 2 of the EEDI Calculation Guidelines).

2.2.2.3 In cases where the electric power table is not available, the P_{AE} value may be approximated either by:

.1 annual average figure of P_{AE} at sea from onboard monitoring obtained prior to the EEXI certification;

.2 for cruise passenger ships, approximated value of power of auxiliary engines ($P_{AE,app}$), as defined below:

$$P_{AE,app} = 0.1193 \times GT + 1814.4 \quad \text{[kW]}$$

.3 for ro-ro passenger ships, approximated value of power of auxiliary engines ($P_{AE,app}$), as defined below:

$$P_{AE,app} = 0.866 \times GT^{0.732} \quad \text{[kW]}$$

2.2.3 V_{ref} ; Ship speed

2.2.3.1 For ships falling into the scope of the EEDI requirement, the ship speed V_{ref} should be obtained from an approved speed-power curve as defined in the *2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)*, as amended (resolution MEPC.254(67), as amended).

2.2.3.2 For ships not falling into the scope of the EEDI requirement, the ship speed V_{ref} should be obtained from an estimated speed-power curve as defined in the *2022 Guidelines on survey and certification of the attained EEXI* (resolution MEPC.351(78)).

2.2.3.3 For ships not falling into the scope of the EEDI requirement but whose sea trial results, which may have been calibrated by the tank test, under the EEDI draught and the sea condition as specified in paragraph 2.2.2 of the EEDI Calculation Guidelines are included in the sea trial report, the ship speed V_{ref} may be obtained from the sea trial report:

$$V_{ref} = V_{S,EEDI} \times \left[\frac{P_{ME}}{P_{S,EEDI}}\right]^{\frac{1}{3}} \quad \text{[knot]}$$

where,

$V_{S,EEDI,}$ is the sea trial service speed under the EEDI draught; and

$P_{S,EEDI}$ is power of the main engine corresponding to $V_{S,EEDI}$.

2.2.3.4 For containerships, bulk carriers or tankers not falling into the scope of the EEDI requirement but whose sea trial results, which may have been calibrated by the tank test, under the design load draught and sea condition as specified in paragraph 2.2.2 of the EEDI Calculation Guidelines are included in the sea trial report, the ship speed V_{ref} may be obtained from the sea trial report:

$$V_{ref} = k^{\frac{1}{3}} \times \left(\frac{DWT_{S,service}}{Capacity}\right)^{\frac{2}{9}} \times V_{S,service} \times \left[\frac{P_{ME}}{P_{S,service}}\right]^{\frac{1}{3}} \quad \text{[knot]}$$

where,

$V_{S,service}$ is the sea trial service speed under the design load draught;

$DWT_{S,service}$ is the deadweight under the design load draught;

$P_{S,service}$ is the power of the main engine corresponding to $V_{S,service}$;

k is the scale coefficient, which should be:

.1 0.95 for containerships with 120,000 DWT or less;

.2 0.93 for containerships with more than 120,000 DWT;

.3 0.97 for bulk carrier with 200,000 DWT or less;

.4 1.00 for bulk carrier with more than 200,000 DWT;

.5 0.97 for tanker with 100,000 DWT or less; and

.6 1.00 for tanker with more than 100,000 DWT.

2.2.3.5 In cases where the speed-power curve is not available or the sea trial report does not contain the EEDI or design load draught condition, the ship speed V_{ref} can be obtained from the in-service performance measurement method conducted and verified in accordance with the methods and procedures as specified in the *Guidance on methods, procedures and verification of in-service performance measurements* (MEPC.1/Circ.901).

2.2.3.6 In cases where the speed-power curve is not available or the sea trial report does not contain the EEDI or design load draught condition, the ship speed V_{ref} can be approximated by $V_{ref,app}$ to be obtained from statistical mean of distribution of ship speed and engine power, as defined below:

$$V_{ref,app} = (V_{ref,avg} - m_V) \times \left[\frac{\sum P_{ME}}{0.75 \times MCR_{avg}}\right]^{\frac{1}{3}} \quad \text{[knot]}$$

For LNG carriers having diesel electric propulsion system and cruise passenger ships having non-conventional propulsion,

$$V_{ref,app} = (V_{ref,avg} - m_V) \times \left[\frac{\sum MPP_{Motor}}{MPP_{avg}}\right]^{\frac{1}{3}} \quad \text{[knot]}$$

where,
V_{ref}

$_{,avg}$ is a statistical mean of distribution of ship speed in given ship type and ship size, to be calculated as follows:

$$V_{ref,avg} = A \times B^C$$

where

A, B and C are the parameters given in the appendix;

m_V is a performance margin of a ship, which should be 5% of $V_{ref,avg}$ or one knot, whichever is lower; and

MCR_{avg} is a statistical mean of distribution of MCRs for main engines and MPP_{avg} is a statistical mean of distribution of MPPs for motors in given ship type and ship size, to be calculated as follows:

$$MCR_{avg} or\ MPP_{avg} = D \times E^F$$

where

D, E and F are the parameters given in the appendix;

In cases where the overridable Shaft / Engine Power Limitation is installed, the ship speed V_{ref} approximated by $V_{ref,app}$ should be calculated as follows:

$$V_{ref,app} = (V_{ref,avg} - m_V) \times \left[\frac{\sum P_{ME}}{0.75 \times MCR_{avg}}\right]^{\frac{1}{3}} \quad \text{[knot]}$$

For LNG carriers having diesel electric propulsion system and cruise passenger ship having non-conventional propulsion, the ship speed V_{ref} approximated by $V_{ref,app}$ should be calculated as follows:

$$V_{ref,app} = \left(V_{ref,avg} - m_V\right) \times \left[\frac{\sum MPP_{lim}}{MPP_{avg}}\right]^{\frac{1}{3}}$$

2.2.3.7 Notwithstanding the above, in cases where the energy-saving device* is installed, the effect of the device may be reflected in the ship speed V_{ref} with the approval of the verifier, based on the following methods in accordance with defined quality and technical standards:

.1 sea trials after installation of the device; and/or

.2 in-service performance measurement method; and/or

.3 dedicated model tests; and/or

* Devices that shift the power curve, which results in the change of P_P and V_{ref}, as specified in MEPC.1/Circ.896 on *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI*.

.4 numerical calculations.

2.2.4 *SFC*; Certified specific fuel consumption

In cases where overridable Shaft / Engine Power Limitation is installed, the *SFC* corresponding to the P_{ME} should be interpolated by using *SFC*s listed in an applicable test report included in an approved NO_x Technical File of the main engine as defined in paragraph 1.3.15 of the NO_x Technical Code.

Notwithstanding the above, the *SFC* specified by the manufacturer or confirmed by the verifier may be used.

For those engines which do not have a test report included in the NO_X Technical File and which do not have the *SFC* specified by the manufacturer or confirmed by the verifier, the *SFC* can be approximated by SFC_{app} defined as follows:

$$SFC_{ME,app} = 190\ [g/kWh]$$

$$SFC_{AE,app} = 215\ [g/kWh]$$

2.2.5 C_F ; Conversion factor between fuel consumption and CO_2 emission

For those engines which do not have a test report included in the NO_x Technical File and which do not have the *SFC* specified by the manufacturer, the C_F corresponding to SFC_{app} should be defined as follows:

$C_F = 3.114\ [t \cdot CO_2/t \cdot Fuel]$ for diesel ships (incl. HFO use in practice)

Otherwise, paragraph 2.2.1 of the EEDI Calculation Guidelines applies.

2.2.6 Correction factor for ro-ro cargo and ro-ro passenger ships (f_{jRoRo})

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

$$f_{jRoRo} = \frac{1}{F_{n_L}^{\alpha} \cdot \left(\frac{L_{pp}}{B_S}\right)^{\beta} \cdot \left(\frac{B_S}{d_S}\right)^{\gamma} \cdot \left(\frac{L_{pp}}{\nabla^{1/3}}\right)^{\delta}}$$; if $f_{jRoRo} > 1$ then $f_j = 1$

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

$$F_{n_L} = \frac{0.5144 \cdot V_{ref,F}}{\sqrt{L_{pp} \cdot g}}$$

where $V_{ref,F}$ is the ship design speed corresponding to 75% of MCR_{ME}.:

and the exponents α, β, γ and δ are defined as follows:

Ship type	Exponent:			
	α	β	γ	δ
Ro-ro cargo ship	2.00	0.50	0.75	1.00
Ro-ro passenger ship	2.50	0.75	0.75	1.00

2.2.7 Cubic capacity correction factor for ro-ro cargo ships (vehicle carrier) ($f_{cVEHICLE}$)

For ro-ro cargo ships (vehicle carrier) having a DWT/GT ratio of less than 0.35, the following cubic capacity correction factor, $f_{cVEHICLE}$, should apply:

$$f_{cVEHICLE} = \left(\frac{\left(DWT/_{GT}\right)}{0.35}\right)^{-0,8}$$

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.

APPENDIX

Parameters to calculate $V_{ref,avg}$

Ship type	A	B	C
Bulk carrier	10.6585	DWT of the ship	0.02706
Gas carrier	7.4462	DWT of the ship	0.07604
Tanker	8.1358	DWT of the ship	0.05383
Containership	3.2395	DWT of the ship where DWT ≤ 80,000 80,000 where DWT > 80,000	0.18294
General cargo ship	2.4538	DWT of the ship	0.18832
Refrigerated cargo carrier	1.0600	DWT of the ship	0.31518
Combination carrier	8.1391	DWT of the ship	0.05378
LNG carrier	11.0536	DWT of the ship	0.05030
Ro-ro cargo ship (vehicle carrier)	16.6773	DWT of the ship	0.01802
Ro-ro cargo ship	8.0793	DWT of the ship	0.09123
Ro-ro passenger ship	4.1140	DWT of the ship	0.19863
Cruise passenger ship having non-conventional propulsion	5.1240	GT of the ship	0.12714

Parameters to calculate MCR_{avg} or MPP_{avg} (= D x E^F)

Ship type	D	E	F
Bulk carrier	23.7510	DWT of the ship	0.54087
Gas carrier	21.4704	DWT of the ship	0.59522
Tanker	22.8415	DWT of the ship	0.55826
Containership	0.5042	DWT of the ship where DWT ≤ 95,000 95,000 where DWT > 95,000	1.03046
General cargo ship	0.8816	DWT of the ship	0.92050
Refrigerated cargo carrier	0.0272	DWT of the ship	1.38634
Combination carrier	22.8536	DWT of the ship	0.55820
LNG carrier	20.7096	DWT of the ship	0.63477
Ro-ro cargo ship (vehicle carrier)	262.7693	DWT of the ship	0.39973
Ro-ro cargo ship	37.7708	DWT of the ship	0.63450
Ro-ro passenger ship	9.1338	DWT of the ship	0.91116
Cruise passenger ship having non-conventional propulsion	1.3550	GT of the ship	0.88664

Calculation of parameters to calculate $V_{ref,avg}$ and MCR_{avg}

Data sources

1 IHS Fairplay (IHSF) database with the following conditions are used.

Ship type	Ship size	Delivered period	Type of propulsion systems	Population
Bulk carrier	≥ 10,000 DWT	From 1 January 1999 to 1 January 2009	Conventional	2,433
Gas carrier	≥ 2,000 DWT		Conventional	292
Tanker	≥ 4,000 DWT		Conventional	3,345
Containership	≥ 10,000 DWT		Conventional	2,185
General cargo ship	≥ 3,000 DWT		Conventional	1,673
Refrigerated cargo carrier	≥ 3,000 DWT		Conventional	53
Combination carrier	≥ 4,000 DWT		Conventional	3,351
LNG carrier	≥ 10,000 DWT		Conventional, Non-conventional	185
Ro-ro cargo ship (vehicle carrier)	≥ 10,000 DWT		Conventional	301
Ro-ro cargo ship	≥ 1,000 DWT	From 1 January 1998 to 31 December 2010	Conventional	188
Ro-ro passenger ship	≥ 250 DWT		Conventional	350
Cruise passenger ship having non-conventional propulsion	≥ 25,000 GT	From 1 January 1999 to 1 January 2009	Non-conventional	93

2 Data sets with blank/zero "Service speed", "Capacity" and/or Total kW of M/E" are removed.

3 Ship type is in accordance with table 1 and table 2 of resolution MEPC.231(65) on *2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI)*. However, "Gas carrier" does not include "LNG carrier". Parameters for "LNG carrier" are given separately.

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ANNEX 13

RESOLUTION MEPC.351(78)
(adopted on 10 June 2022)

2022 GUIDELINES ON SURVEY AND CERTIFICATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI)

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,

NOTING that the Committee adopted, at its seventy-sixth session, by resolution MEPC.328(76), the *2021 Revised MARPOL Annex VI*, which will enter into force on 1 November 2022,

NOTING IN PARTICULAR that the *2021 Revised MARPOL Annex VI* (MARPOL Annex VI) contains amendments concerning mandatory goal-based technical and operational measures to reduce carbon intensity of international shipping,

NOTING FURTHER that regulation 5.4 (Surveys) of MARPOL Annex VI requires that ships to which chapter 4 applies shall also be subject to survey and certification taking into account guidelines developed by the Organization,

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

NOTING that, at its seventy-sixth session, the Committee adopted, by resolution MEPC.334(76), the *2021 Guidelines on survey and certification of the attained Energy Efficiency Existing Ship Index (EEXI),*

HAVING CONSIDERED, at its seventy-eighth session, draft amendments to the *2021 Guidelines on survey and certification of the attained Energy Efficiency Existing Ship Index (EEXI),*

1 ADOPTS the *2022 Guidelines on survey and certification of the attained Energy Efficiency Existing Ship Index (EEXI),* as set out in the annex to the present resolution;

2 INVITES Administrations to take the annexed Guidelines into account when developing and enacting national laws which give force to and implement requirements set forth in regulation 5 of MARPOL Annex VI;

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

4 AGREES to keep the Guidelines under review in light of experience gained with their implementation, also taking into consideration that in accordance with regulation 25.3 of MARPOL Annex VI a review of the technical measure to reduce carbon intensity of international shipping shall be completed by 1 January 2026;

5 REVOKES the *2021 Guidelines on survey and certification of the attained Energy Efficiency Existing Ship Index (EEXI),* adopted by resolution MEPC.334(76).

ANNEX

2022 GUIDELINES ON SURVEY AND CERTIFICATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI)

Table of contents

1 GENERAL

The purpose of these Guidelines is to assist verifiers of the Energy Efficiency Existing Ship Index (EEXI) of ships in conducting the survey and certification of the EEXI, 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 EEXI.

2 DEFINITIONS[1]

2.1 *Verifier* means an Administration, or organization duly authorized by it, which conducts the survey and certification of the EEXI 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), or as a replacement for model tests provided that the methodology and numerical model used have been validated/calibrated against parent hull sea trials and/or model tests, with the approval of the verifier.

2.4 *MARPOL* means the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997 relating thereto, as amended.

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

3 APPLICATION

These Guidelines should be applied to ships for which an application for a survey for verification of the ship's EEXI 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 EEXI should be calculated in accordance with regulation 23 of MARPOL Annex VI and the *2022 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI)* (resolution MEPC.350(78)) (EEXI Calculation Guidelines).

4.1.2 The *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI* (MEPC.1/Circ.896) should be applied for calculation of the attained EEXI, if applicable.

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[1] Other terms used in these Guidelines have the same meaning as those defined in the *2018 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.308(73), as amended) and the *2022 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI)* (resolution MEPC.350(78)).

4.1.3 The information used in the verification process may contain confidential information of submitters, including shipyards, 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.

4.2 Verification of the attained EEXI

4.2.1 For verification of the attained EEXI, an application for a survey and an EEXI Technical File containing the necessary information for the verification and other relevant background documents should be submitted to a verifier, unless the attained EEDI of the ship satisfies the required EEXI.

4.2.2 The EEXI Technical File should be written at least in English. The EEXI Technical File should include, but not be limited to:

.1 deadweight (DWT) or gross tonnage (GT) for ro-ro passenger ship and cruise passenger ship having non-conventional propulsion;

.2 the rated installed power (*MCR*) of the main and auxiliary engines;

.3 the limited installed power (MCR_{lim}) in cases where the overridable Shaft/Engine Power Limitation system is installed;

.4 the ship speed (V_{ref});

.5 the approximate ship speed ($V_{ref,app}$) for pre-EEDI ships in cases where the speed-power curve is not available, as specified in paragraph 2.2.3.5 of the EEXI Calculation Guidelines;

.6 an approved speed-power curve under the EEDI condition as specified in paragraph 2.2 of the EEDI Calculation Guidelines, which is described in the EEDI Technical File, in cases where regulation 22 of MARPOL Annex VI (Attained EEDI) is applied;

.7 an estimated speed-power curve under the EEDI condition, or under a different load draught to be calibrated to the EEDI condition, obtained from tank test and/or numerical calculations, if available;

.8 estimation process and methodology of the power curves, as necessary, including documentation on consistency with the defined quality standards (e.g. ITTC 7.5-03-01-02 and ITTC 7.5-03-01-04 in their latest revisions) and the verification of the numerical set-up with parent hull or the reference set of comparable ships in case of using numerical calculations;

.9 a sea trial report including sea trial results, which may have been calibrated by the tank test, under the sea condition as specified in paragraph 2.2.2 of the EEDI Calculation Guidelines, if available;

.10 an in-service performance measurement report, where applicable, as specified in paragraphs 2.2.3.5 and 2.2.3.7.2 of the EEXI Calculation Guidelines;

.11 calculation process of $V_{ref,app}$ for pre-EEDI ships in cases where the speed-power curve is not available, as specified in paragraph 2.2.3.6 of the EEXI Calculation Guidelines;

.12 type of fuel;

.13 the specific fuel consumption (*SFC*) of the main and auxiliary engines, as specified in paragraph 2.2.4 of the EEXI Calculation Guidelines;

.14 the electric power table[2] for certain ship types, as necessary, as defined in the EEDI Calculation Guidelines;

.15 the documented record of annual average figure of the auxiliary engine load at sea obtained prior to the date of application for a survey for verification of the ship's EEXI, as specified in paragraph 2.2.2.3 of the EEXI Calculation Guidelines, if applicable;

.16 calculation process of $P_{AE,app}$, as specified in paragraph 2.2.2.3 of the EEXI Calculation Guidelines, if applicable;

.17 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;

.18 description of energy-saving equipment, if available;

.19 calculated value of the attained EEXI, 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 EEXI; and

.20 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 2.2.5.6.3 of the EEDI Calculation Guidelines;

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

.4 shaft power of the propeller shaft after transmission gear at the de-rated output of motor ($MPP_{Motor,lim}$) in cases where the overridable Shaft / Engine Power Limitation is installed;

.5 maximum continuous rated power ($MCR_{SteamTurbine}$) for steam turbine;

.6 limited maximum continuous rated power ($MCR_{SteamTurbine,lim}$) for steam turbine in cases where the overridable Shaft / Engine Power Limitation is installed; and

[2] Electric power tables should be validated separately, taking into account the guidelines set out in appendix 2 of the *2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)* (resolution MEPC.254(67), as amended by resolutions MEPC.261(68) and MEPC.309(73)); consolidated text: MEPC.1/Circ.855/Rev.2, as may be further amended).

.7 $SFC_{SteamTurbine}$ for steam turbine, as specified in paragraph 2.2.7.2 of the EEDI Calculation Guidelines. If the calculation is not available from the manufacturer, $SFC_{SteamTurbine}$ may be calculated by the submitter.

A sample of an EEXI Technical File is provided in the appendix.

4.2.3 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, 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.

4.2.4 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 criteria specified in paragraph 4.2.3 of the *2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)*, as amended,[3] as a basis for the guidance of the Administration.

4.2.5 Notwithstanding paragraphs 4.2.3 and 4.2.4, in cases where overridable Shaft/Engine Power Limitation is installed, or in cases where engines do not have a test report included in the NO_x Technical File, *SFC* should be calculated in accordance with paragraph 2.2.4 of the EEXI Calculation Guidelines. For this purpose, actual performance records of the engine may be used if satisfactory and acceptable to the verifier.

4.2.6 The verifier may request further information from the submitter, as specified in paragraph 4.2.7 of the EEDI Survey and Certification Guidelines, in addition to that contained in the EEXI Technical File, as necessary, to examine the calculation process of the attained EEXI.

4.2.7 In cases where the sea trial report as specified in paragraph 4.2.2.9 is submitted, the verifier should request further information from the submitter to confirm that:

.1 the sea trial was conducted in accordance with the conditions specified in paragraphs 4.3.3, 4.3.4 and 4.3.7 of the EEDI Survey and Certification Guidelines, as applicable;

.2 sea conditions were measured in accordance with ISO 15016:2002 or the equivalent if satisfactory and acceptable to the verifier;

.3 ship speed was measured in accordance with ISO 15016:2002 or the equivalent if satisfactory and acceptable to the verifier; and

.4 the measured ship speed was calibrated, if necessary, by taking into account the effects of wind, tide, waves, shallow water and displacement in accordance with ISO 15016:2002 or the equivalent which may be acceptable provided that the concept of the method is transparent for the verifier and publicly available/accessible.

4.2.8 In cases where the in-service performance measurement report as specified in paragraph 4.2.2.10 is submitted, the verifier should confirm that the in-service performance measurement was conducted and verified in accordance with the methods and procedures as specified in the *Guidance on methods, procedures and verification of in-service performance measurements* (MEPC.1/Circ.901).

[3] Resolution MEPC.254(67), as amended.

4.2.9 The estimated speed-power curve obtained from the tank test and/or numerical calculations and/or the sea trial results calibrated by the tank test should be reviewed on the basis of the relevant documents in accordance with the EEDI Survey and Certification Guidelines, the defined quality standards (e.g. ITTC 7.5-03-01-02 and ITTC 7.5-03-01-04 in their latest revisions) and the verification of the numerical set-up with parent hull or the reference set of comparable ships.

4.2.10 In cases where the overridable Shaft/Engine Power Limitation system is installed, the verifier should confirm that the system is appropriately installed and sealed in accordance with the *2021 Guidelines on the Shaft/Engine Power Limitation system to comply with the EEXI requirements and use of a power reserve* (resolution MEPC.335(76)) and that a verified Onboard Management Manual (OMM) for overridable Shaft/Engine Power Limitation is on board the ship.

4.3 Verification of the attained EEXI in case of major conversion

4.3.1 In cases of a major conversion of a ship taking place at or after the completion date of the survey for EEXI verification specified in regulation 5.4.7 of MARPOL Annex VI, the shipowner should submit to a verifier an application for a general or partial survey with the EEXI Technical File duly revised, based on the conversion made and other relevant background documents.

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

.1 details of the conversion;

.2 EEXI parameters changed after the conversion and the technical justifications for each respective parameter;

.3 reasons for other changes made in the EEXI Technical File, if any; and

.4 calculated value of the attained EEXI 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 EEXI after the conversion.

4.3.3 The verifier should review the revised EEXI Technical File and other documents submitted and verify the calculation process of the attained EEXI to ensure that it is technically sound and reasonable and follows regulation 23 of MARPOL Annex VI and the EEXI Calculation Guidelines.

4.3.4 For verification of the attained EEXI after the major conversion, speed trials of the ship may be conducted, as necessary.

APPENDIX

SAMPLE OF EEXI TECHNICAL FILE

1 Data

1.1 General information

Shipowner	XXX Shipping Line
Shipbuilder	XXX Shipbuilding Company
Hull no.	12345
IMO no.	94112XX
Ship type	Bulk carrier

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

Manufacturer	XXX Industries
Type	6J70A
Maximum continuous rating (MCR_{ME})	15,000 kW x 80 rpm
Limited maximum continuous rating with the Engine Power Limitation installed ($MCR_{ME,lim}$)	9,940 kW x 70 rpm
SFC at 75% of MCR_{ME} or 83% of $MCR_{ME,lim}$	166.5 g/kWh
Number of sets	1
Fuel type	Diesel Oil

1.4 Auxiliary engine

Manufacturer	XXX Industries
Type	5J-200
Maximum continuous rating (MCR_{AE})	600 kW x 900 rpm
SFC at 50% MCR_{AE}	220.0 g/kWh
Number of sets	3
Fuel type	Diesel Oil

1.5 Ship speed

Ship speed (V_{ref}) (with the Engine Power Limitation installed)	13.20 knots

2 Power curve

(Example 1; case of the EEDI ship)
An approved speed-power curve contained in the EEDI Technical File is shown in figure 2.1.

(Example 2; case of the pre-EEDI ship)
An estimated speed-power curve obtained from the tank test and/or numerical calculations, if available, is also shown in figure 2.1.

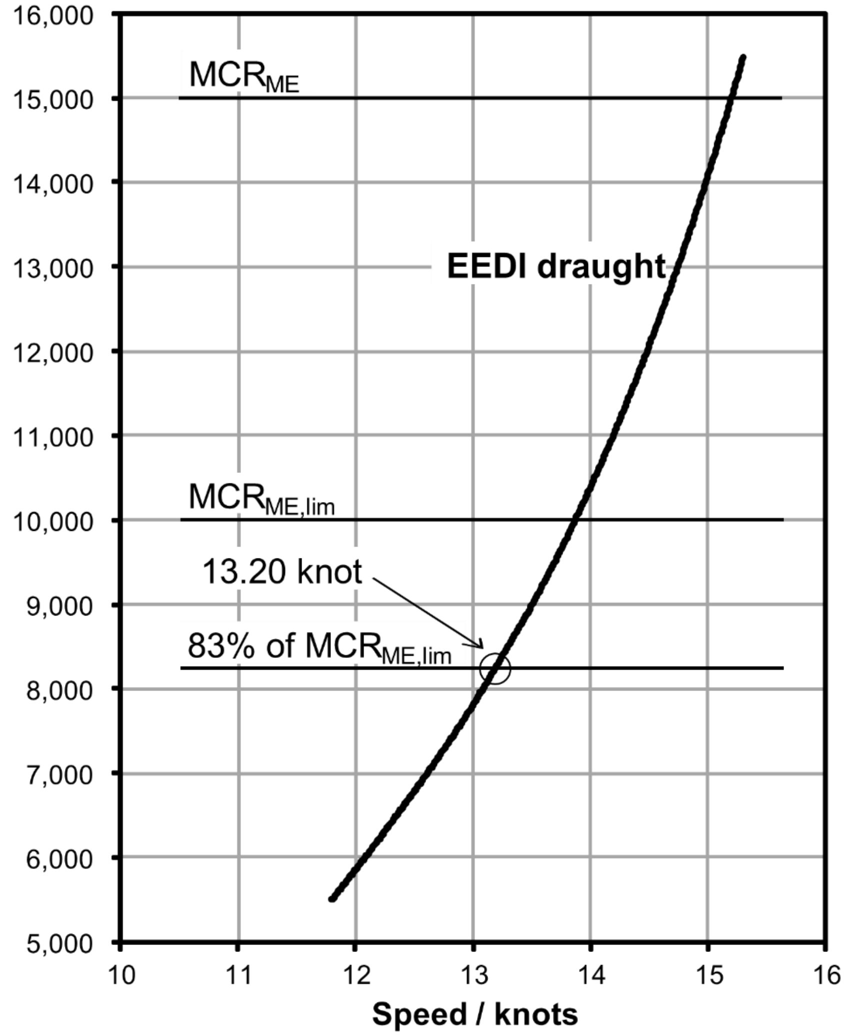


Figure 2.1: Power curve

(Example 3; case of the pre-EEDI ship with sea trial result calibrated to a different load draught)
An estimated speed-power curve under a ballast draught calibrated to the design load draught, obtained from the tank test and/or numerical calculations, if available, is shown in figure 2.2.

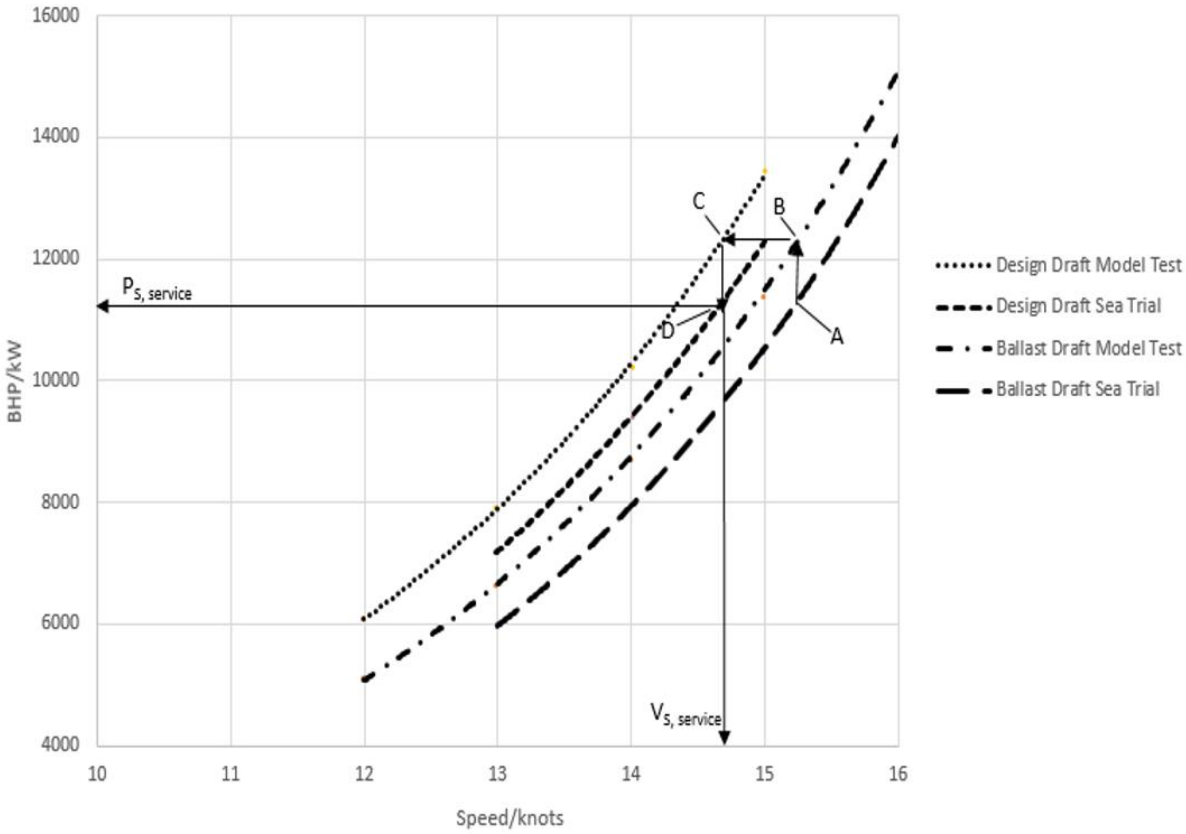


Figure 2.2: Power curve

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

Type	Fixed pitch propeller
Diameter	7.0 m
Number of blades	4
Number of sets	1

3.2 Electric power supply system

3.2.1 Auxiliary engines
Refer to paragraph 1.4 of this appendix.

3.2.2 Main generators

Manufacturer	XXX Electric
Rated output	560 kW (700 kVA) x 900 rpm
Voltage	AC 450 V
Number of sets	3

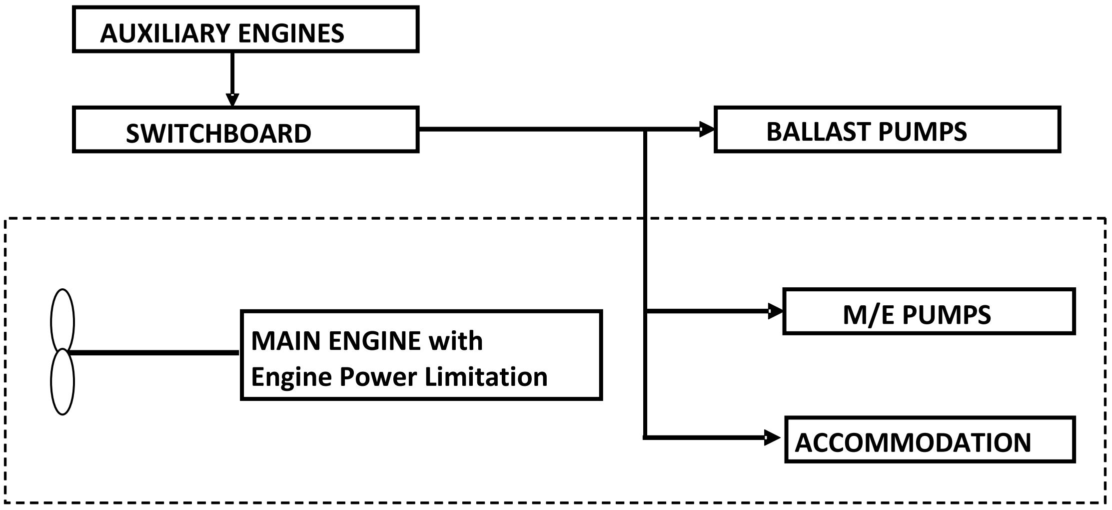


Figure 3.1: Schematic figure of propulsion and electric power supply system

4 Estimation process of speed-power curve

(Example: case of pre-EEDI ship)
Speed-power curve is estimated based on model test results and/or numerical calculations, if available. The flow of the estimation processes is shown below.

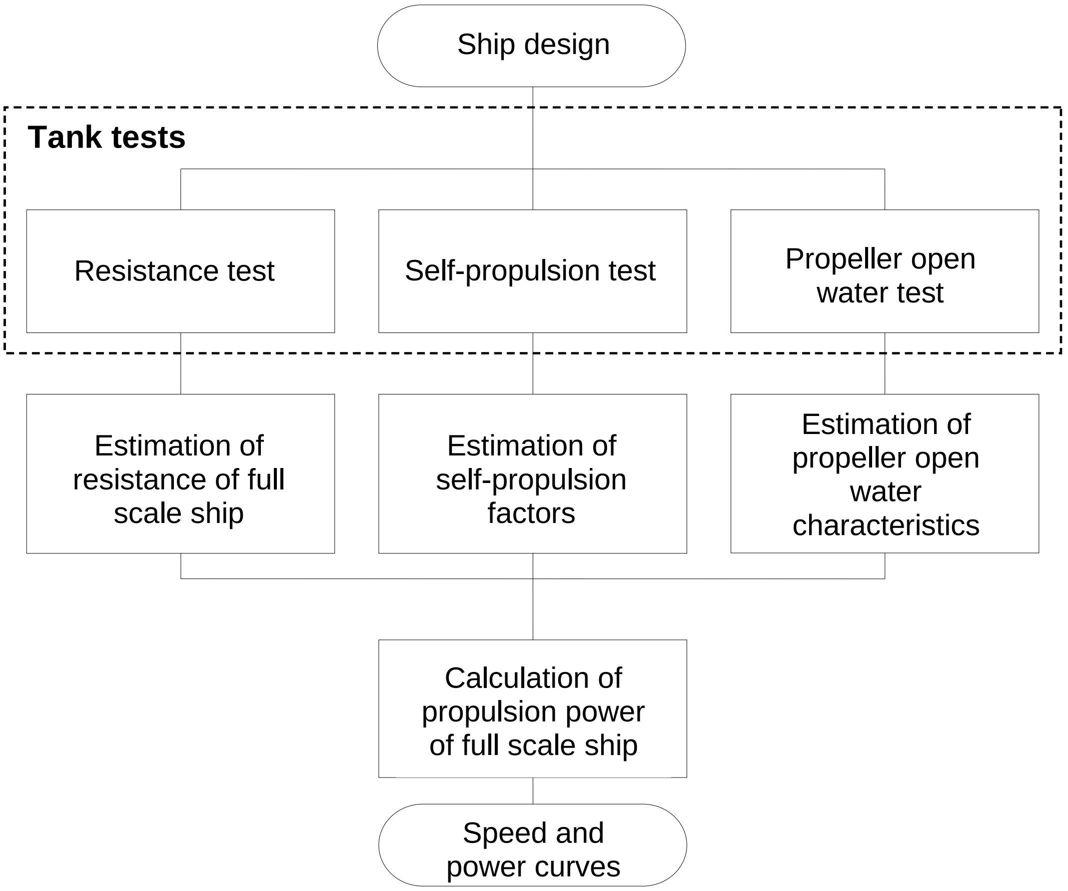


Figure 4: Flow chart of process for estimating speed-power curve from tank tests

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 EEXI calculation formula

N/A

5.2 Other energy-saving equipment

(Example)

5.2.1 Rudder fins

5.2.2 Rudder bulb
……
(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 EEXI

6.1 Basic data

Type of ship	Capacity DWT	Speed V_{ref} (knots)
Bulk carrier	150,000	13.20

6.2 Main engine

MCR_{ME} (kW)	$MCR_{ME,lim}$ (kW)	P_{ME} (kW)	Type of fuel	C_{FME}	SFC_{ME} (g/kWh)
15,000	9,940	8,250	Diesel oil	3.206	166.5

6.3 Auxiliary engines

P_{AE} (kW)	Type of fuel	C_{FAE}	SFC_{AE} (g/kWh)
625	Diesel oil	3.206	220.0

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 EEXI

$$EEXI = \frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

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

$$- \frac{\left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

$$= \frac{1 \times (8250 \times 3.206 \times 166.5) + (625 \times 3.206 \times 220.0) + 0 - 0}{1 \times 1 \times 1 \times 150000 \times 1 \times 13.20 \times 1}$$

$$= 2.45\ (g - CO_2/ton \cdot mile)$$

attained EEXI: 2.45 g-CO_2/ton mile

***

No. 173 (Nov 2022)

Guidelines on Numerical Calculations for the purpose of deriving the V_{ref} in the framework of the EEXI Regulation

1. Background

IMO resolutions MEPC.350(78) and MEPC. 351(78) considers Numerical Calculations as an acceptable way to derive the reference speed (V_{ref}) in the EEXI regulation framework. These guidelines have been developed to provide a methodology for deriving V_{ref} using numerical calculations.

2. Applicability

Numerical calculations methodology presented in these guidelines involves three (3) steps (which are detailed in section 5):

Step 1: Demonstration of qualification

Step 2: Validation/Calibration

Step 3: Calculation

This methodology can be applied to the following scenarios:

- In cases where a new speed power curve should be derived at the EEDI/EEXI draft in cases where the vessel has not been subjected to modifications.
- In case where the vessel has been subjected to modifications, the methodologies described here-after can still be used where the step 2 is computed with the original hull and the step 3 is performed on the modified hull.

3. Supporting Documentation/Guidelines

The following supporting guidelines are to be followed and referred to when performing Numerical Calculation. Whenever possible, these should be followed and applied. Deviations may be accepted as indicated in this document or as approved by verifier.

- ITTC 7.5-03-01-02, Rev.02, 2021
- ITTC 7.5-03-01-04, Rev.00, 1999[1]
- ITTC 7.5-03-03-01, Rev.00, 2014

4. Definitions

Numerical Calculations are understood as being computer aided calculations in which the Navier-Stokes equations are resolved by means of a Computational Fluid Dynamics (CFD) solvers/software, which requires to implement at least Reynolds-Averaged Navier-Stokes equations as governing equations with the consideration of viscosity and in presence of free-surface.

ITTC website suggests that these guidelines have been deleted. They are however kept as they are referenced in the MEPC. 351(78).

Parent hull is defined as the original hull of the vessel that will be submitted to CFD calculations. Noting that appendages could be modified without changing the main hull (i.e. parent hull) shape.

Similar ship is a vessel with the similar[2] hull form, same number of shafts/propellers, within a threshold of 5% difference in terms of *Lpp*, *Cb*, displacement at Maximum Summer Load Draft, with similar bow shape (bulbous/straight bow, integrated bulbous bow, etc) and similar stern hull shape and arrangement with appendages.

Set of comparable ships are those with the similar[2] hull form, with the same number of shafts/propellers and with similar bow shape (bulbous bow, integrated bulbous bow, straight bow) and stern shape.

Calibration factor is defined as the ratio between the sea trial power and/or model tests and the numerical calculation found power. The calibration factor can be found as an average of the power settings evaluated in Sea Trials and/or models test and by numerical calculation. The calibration factor can also be computed and applied at each power setting, if preferred.

5. Numerical Calculations Methodology

As per Resolution MEPC.334(76), numerical calculation can be used as a complement to model tests or as a replacement of the latter. It is nonetheless stated that the methodology and numerical model used need to be validated/calibrated against parent hull sea trials and/or model tests, with the approval of the verifier. The methodology to be applied is as follows.

Step 1: Demonstration of qualifications

It should be demonstrated by the provider their ability to carry out CFD predictions. The companies may refer to the demonstration process as outlined in the ITTC 7.5-03-01-02, Rev.02, 2021 (referenced in MPEC. 351(78)), or an alternative methodology provided which is approved by the verifier. This demonstration should be performed against a reference “set of comparable ships” (see definition in section 4). Public domain hull forms and validation tests may be used, such as KCS, KVLCC1, KVLCC2, JBC, DTC, etc.

Step 2: Validation/Calibration

In case model test or sea trials are available, the numerical models used are to be calibrated against the parent hull.

By calibration one understands as the procedure of finding the ratio between the target values (sea trials or model tests) and the achieved values. One understands that it is not possible or not pertinent to fully replicate the model test and/or sea trials. In that case, the results achieved by means of numerical calculations can be calibrated against the model test or sea trials results.

The calibration should be conducted after the results from the CFD calculations have been completely post-processed. If the simulations are performed in model scale, the scaling should be performed following the ITTC 78 procedures (or deviations of it, following the

[2] Similar should be regarded same ship type. In some cases, e.g. RO-RO Cargo Carrier, RO-RO Passenger Carrier and RO-RO Cargo Carrier (Vehicle) may be considered as having similar hull form, although having different ship type. The same would apply to the cases of change of ship type, where preference would be to refer to the original ship type for the definition of similar.

No. 173 (cont)

principles as outlined in PR38 Rev.3) and the final values are to account for roughness and appendages, where applicable.

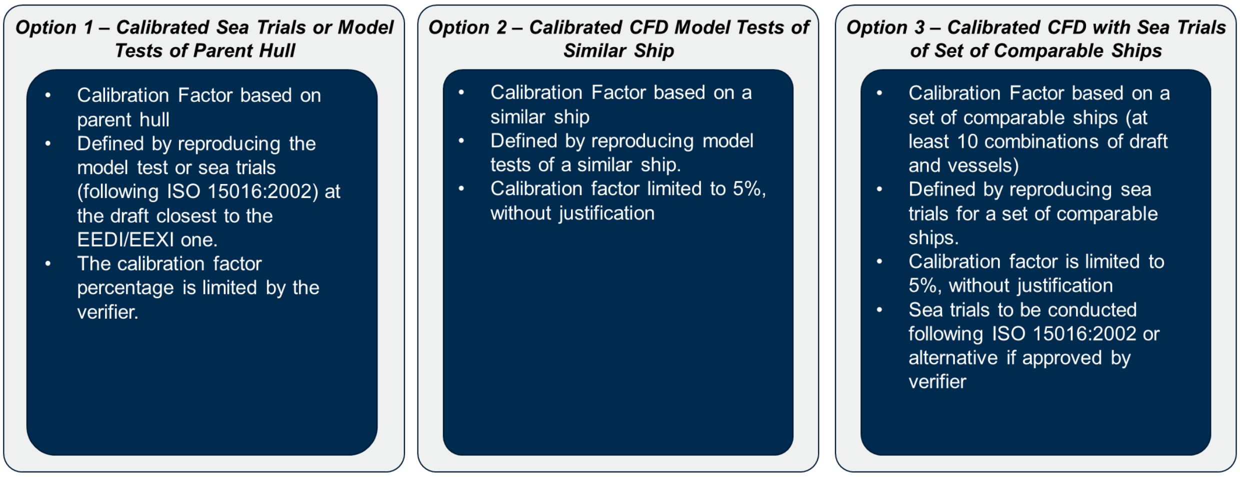
In case model tests and/or sea trials are not available, or if the CFD provider does not use them for justifiable reasons, the calibration needs to be conducted against a similar ship or a set of comparable ships (see definition in 4). The validation can be demonstrated both in model and full scale.

It is noted that the paragraph 2.3 of Resolution MEPC. 351(78) refers to both words validation and calibration of the numerical models. Further in the same resolution, reference is mainly given to “calibration”. For the purposes of these guidelines, it is understood that the word validation and calibration are intended to have similar meaning. As further outlined in these guidelines, IACS has taken the position to apply strict limits to the calibration factor which fall under acceptable thresholds applied by the industry to validate numerical models.

Step 3: Calculation

The calculation of the new reference speed or speed power curve is performed for the target ship. The same numerical calculation procedure as in step 2 should be used. Additionally, the results are to be corrected to model test or sea trial conditions using a calibration factor obtained from step 2.

Based on the above steps 2 and 3, the options are summarized in the chart below and detailed in the following sections.



5.1 Option 1: Calibrated CFD with sea trials or model tests of parent hull

In this case, the baseline for comparison would be the availability of previous sea trials or model tests for the vessel in a draft different than the one required for the EEXI or in a different configuration. In such scenario, firstly a simulation would be performed at full or model scale and at the same draft and configuration as the one in the sea trials or model tests. The draft closest to the EEXI draft should be selected. Sea trial results that have been scaled from ballast draft to laden draft based on model test results can be used. Sea trials are to be performed following ISO15016:2002, or the equivalent if satisfactory and acceptable to the verifier.

The CFD results are then post-processed to account for details not included directly in the simulations (e.g. appendages, hull roughness, windage) to arrive at the CFD predicted power.

No. 173 (cont)

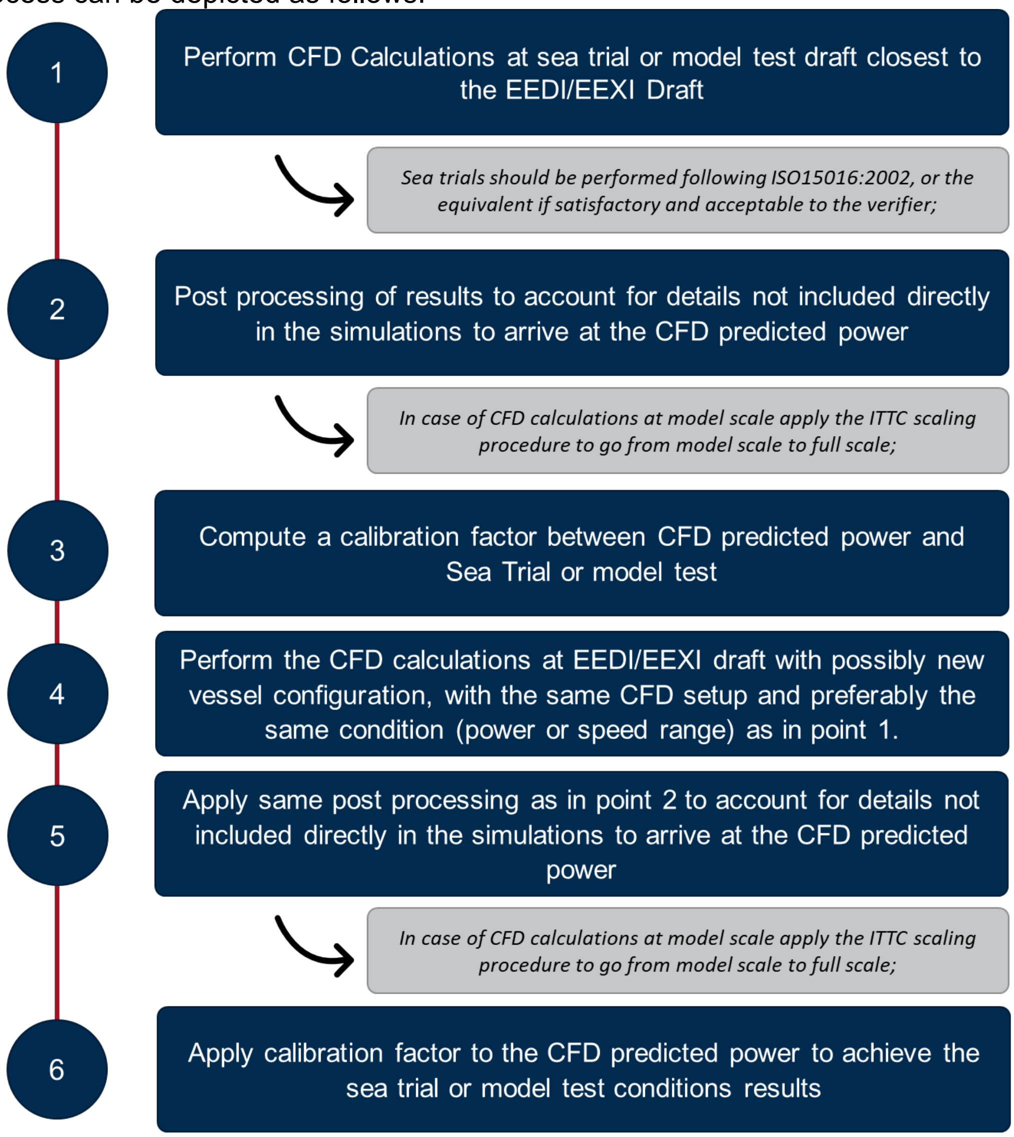
In case of model scale simulations, the results need to be extrapolated to full scale following ITTC 78 (or deviations of it, following the principles as outlined in PR38 Rev. 3). As far as possible the conditions as in the model test are to be followed (Ca, ITTC procedure, how appendages have been accounted for, etc).

A calibration factor would then be computed by comparing the CFD predicted power to the Sea Trials or model tests.

Then, a new CFD simulation would be performed at the EEXI draft and possibly new configuration (e.g. bulbous bow retrofit, new propeller, etc), the same post-processing would be applied, and the correction factor computed previously can be applied to the CFD predicted power obtained for the EEXI draft to achieve the EEXI Draft Sea Trials Conditions Speed vs Power Curve.

This general principle is to follow the same reasoning that is currently applied to correct model tests to the sea trial conditions, using as reference the calibration factor which is a ratio between the sea trial and model test results at the sea trial draft.

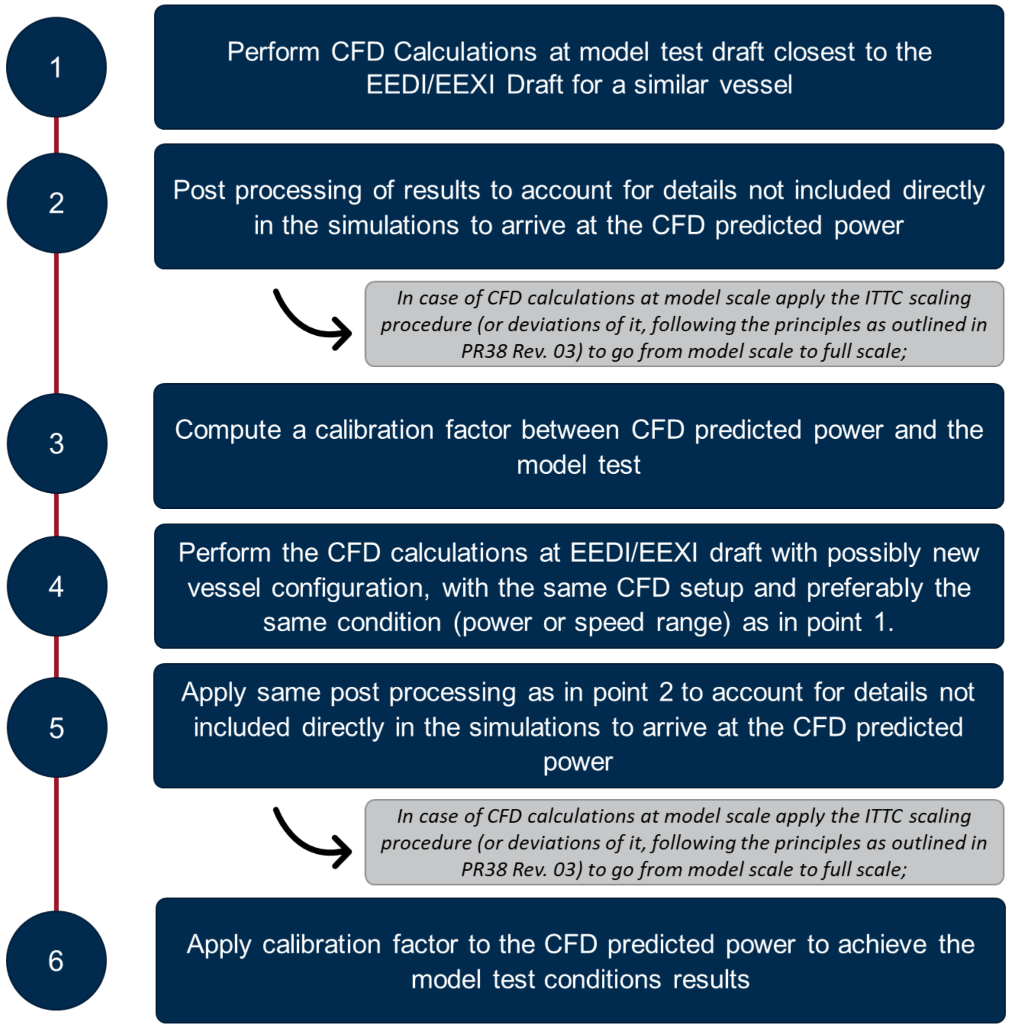
The process can be depicted as follows:



No. 173 (cont)

5.2 Option 2: Calibrated CFD with model test of similar ship

In this case, the procedure is similar to that for option 1 with the exception that the calibration is conducted based on model tests performed following the applicable ITTC procedures. If the achieved calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the verifier without further technical justification. However, if the calibration is lower than 0.95 or higher than 1.05, a technical explanation should be provided, documented and approved by the verifier. The definition of calibration factor can be found in Section 4.



5.3 Option 3 – Calibrated CFD with sea trials of a set of comparable ships

In this case, the procedure is the same as that for option 1 with the exception that the calibration is conducted based on sea trials of a set of comparable ships. Sea trial results that have been scaled from ballast draft to laden draft based on model test results CANNOT be used. Sea trials are to be performed as per ISO15016:2002, or the equivalent if satisfactory and acceptable to the verifier. Sea trials in ballast and laden condition should be included in the assessment.

As a minimum, at least 10 combinations of vessels and drafts need to be included when deriving a unique calibration factor. Such unique calibration factor should be derived from the individual calibration factors calculated for every ship in the database following the definition in section 4 and the methodology should be approved by the verifier. The individual

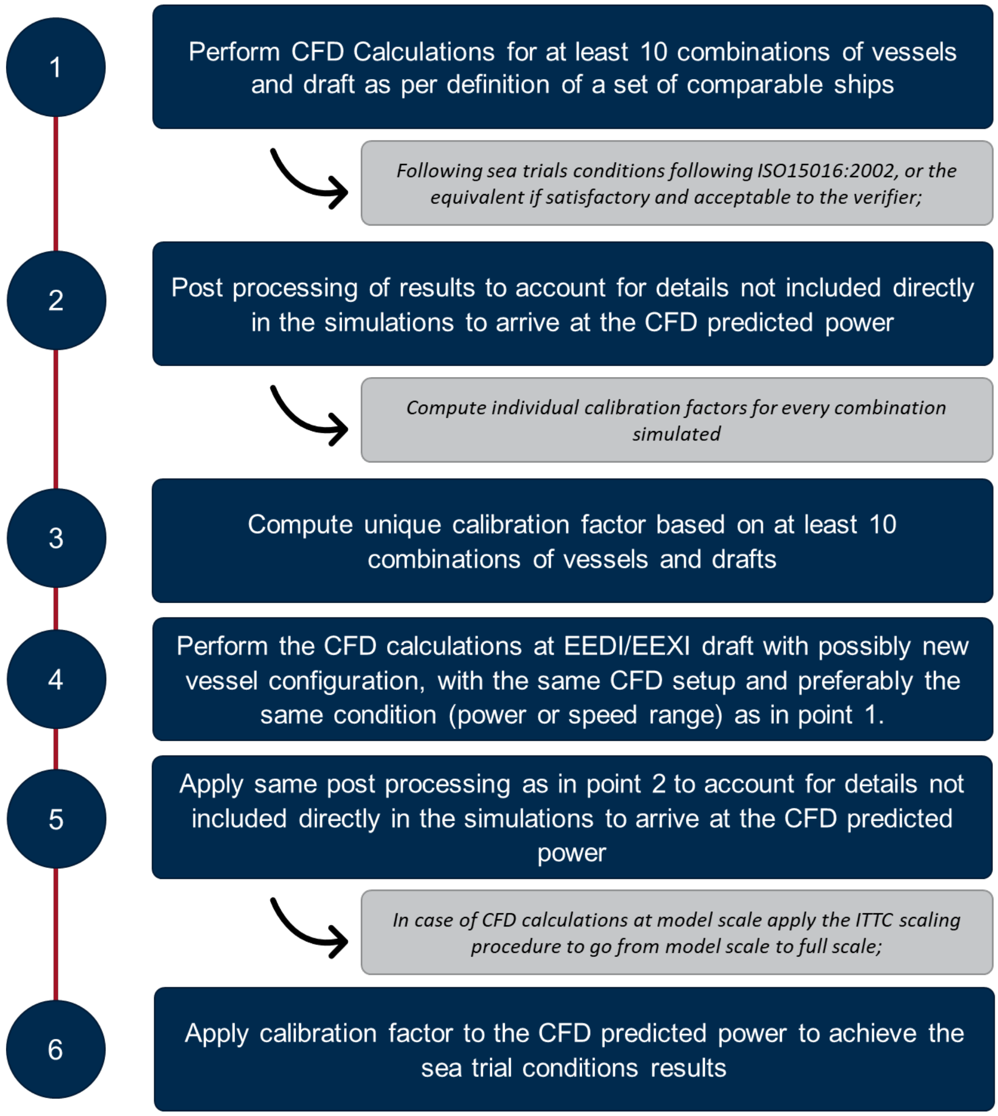
No. 173 (cont)

calibration factors are limited to be between 0.90 and 1.10. If the individual calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the verifier without further technical justification. However, if the calibration lies between 0.90 and 1.1, a technical explanation should be provided, documented, and approved by the verifier.

The *Lpp*, displacement and *Cb* (both at EEXI/EEDI draft) of the target vessel should not lie below or above the values from the dataset of vessels used to derive the calibration factor. The calibration factor should only be interpolated and not extrapolated, for the referenced particular. In addition, the calibration factor should be achieved on the basis of a regression curve or surface and should not be a simple average of the 10 combinations of vessels and drafts.

In either case the verifier is to verify the accuracy and representativeness of the dataset used to derive the calibration factor, i.e., that these are evenly spread across the range of *Lpp*, displacement and *Cb*. It is also to be verified that at least 2 vessels of the database are between 0.85 and 1.15 *Lpp* of the target ship.

With option 3, the provider is exempted from demonstrating qualifications as per section 7.2. All the simulations contained in the database are to be done following at best the requirements outlined in these guidelines in section 6. The verifier may require access to the details of the calculations included in the database to derive the calibration factor.



No. 173 (cont)

6 Technical Aspects

Technical aspects to be applied to the simulations are detailed in this section. These aspects are to be covered in the numerical calculations to be reviewed by the verifier.

6.1 Scale

Technically, simulations can be performed both at model and full scale. The following preference should be given to each of the options listed in section 5. For option 1, preference is given to model-scale simulations if calibrating against model tests and full-scale simulations may be accepted if approved by verifier. For the other options, both scales may be used. The validation/calibration and calculation need to be conducted at the same scale.

6.2 Numerical Modelling

Information on the required numerical modelling is provided in the following table.

Table 1 – Details on the required numerical modelling level.

Item	Value
Geometry	Fully appended, if not possible then appendages not accounted for should be corrected using other methods (empirical methods, etc). If not feasible, then this should be included in the calibration/correlation factor.
Degrees of freedom	Model should at least be free in heave and pitch.
Propeller modelling	As a minimum requirement, actuator Disk. Note that for Energy Efficiency Technologies, other requirements are set in section 8.
Turbulence model	Industry is commonly using k-w SST or RSM as standard model for marine applications. This should be the preferred model but alternative ones (at least two equations models) may be accepted upon demonstrated validation against a “set of comparable ships”.
Time discretization	Simulations should be resolved in the time domain or in a quasi-steady approach.
Post-processing	It needs to be demonstrated that enough time steps are accounted for in the averaging of final results so to smooth potential oscillations in the results.
Roughness	Roughness should not be taken into account directly in the numerical simulations, but in post-processing of the results following the ITTC procedure. If roughness is included in the numerical simulations, detailed validation should be demonstrated by the company providing the numerical calculation. This validation should be demonstrated for a “set of comparable ships”.
Turbulence intensity	It should not exceed 10%. In case a higher value is used, this should be documented and the reason for such to be justified and validated against a “set of comparable ships”.
Y+ values	ITTC 7.5-03-02-03 to be followed

7. Reporting Requirements

The sections below detail the level of requirements that may be included in a Numerical Analysis report to be used as supporting documentation for the development of the EEXI Technical File. For reference, an example of template report is provided in Appendix 1.

7.1 Introduction & Objectives

This section may introduce the work being performed and state the objectives of the simulations. It should be detailed if the simulations are to be performed by calibrations against model test or sea trials of parent hull or reference ships.

7.2 Qualifications

Reference is made to the ITTC 7.5-03-01-02 Quality Assurance in Ship CFD Applications, Section 5. Companies that wish to demonstrate their ability to carry out CFD predictions may refer to the demonstration process as outlined in the reference guidelines. This should be taken as part of the Quality Assurance procedures to be demonstrated by the company carrying out the CFD analysis.

This demonstration may include the ship types under consideration, referring to the definition of “set of comparable ships” as per section 4. It remains at the discretion of the verifier to assess if the documentation provided is sufficient to ensure the ability of the company to deliver the numerical calculations.

7.3 Description of supporting documentation

A section should be included in report referencing the supporting documentation used by the company delivering the numerical analysis. As example, the following could be included:

- Model test report
- Sea trial report
- Hull drawings
- General arrangement
- Propeller drawings

This should be included in the appendices, if possible and considered necessary by the verifier.

7.4 Vessel Description

A section detailing the particulars of the vessel under consideration should be included in the report. It should account for at least the following:

- Ship name
- IMO Number and/or Hull Number
- Vessel type
- Design draft
- Lightweight and displacement
- EEXI draft

No. 173 (cont)

- Main Engine Power (SMCR, NCR)
- Length between perpendiculars (LPP)
- Beam molded (B)
- Depth (D)
- Propeller data:
  - Diameter
  - Number of blades
  - Rotation direction
  - Expanded area ratio
  - Main dimensions of the hub
  - Chord length, maximum thickness, and pitch ratio at a reference radius (usually 0.7 R), if available.
  - ESD type, if applied

7.5 CFD Software

A section containing a description of the CFD software used and the version of the same. This can be part of the Qualifications step as detailed in section 7.2.

7.6 CFD Model Geometry and Mesh

A section detailing the geometry model should be included in the report. Any simplifications and omissions should be documented and its impacts on the results to be clearly identified together with remediation actions (if necessary).

A table comparing the hydrostatic values and coefficients between the model used in the numerical calculation and those from the model tests or the actual hull as built. The following parameters are to be compared:

- LOA & LPP
- Molded beam (B)
- Depth (D)
- Displacement at the different drafts under consideration in the study
- Wetted Surface including rudder and with the bare hull
- LCB in % of LPP
- VCB from Baseline

It is of the verifiers responsibility to agree that the vessel being used in the numerical model faithfully represents the actual hull under consideration. To support such, different views of the model geometry are to be provided. Verifier may request comparative views between construction, lines plan and the 3D CFD model.

A convergence study should be provided justifying the use of the mesh refinement chosen by the supplier. This can be replaced by a convergence study performed on a different vessel if approved by the verifier. Such convergence curve should contain at least 3 discrete mesh sizes.

In addition, the report should include the following information:

- Grid sizes and description of the mesh main sizes (boundary layer, cell sizes, etc). These are to be provided for the different refinement zones of the domain and at every direction (x,y,z), if they differ.

- Different views of the mesh covering different aspects:
  - Boundary layer mesh for different parts of the hull if they differ
  - Close up views of the mesh around key parts of the hull: bow, aft, transom and appendages.

7.7 CFD Set-up

A section containing the details of the CFD set-up used in the calculations. The following should be included:

- CFD software and version being used
- CFD equations being solved
- Simulation type, steady vs unsteady
- Turbulence model being used and justification for its choice
- Numerical solution schemes used: for example, second-order upwind and iteration stop criteria
- Fluid domain dimensions
- Boundary conditions applied on all the surfaces of the fluid domain
- Description of the coordinates system and model origin
- Degrees of freedom used in the model
- Description on the propeller modelling: full propeller, RANS-BEM, actuator disk, etc.
- Convergence criteria used to assess if the calculations have converged
- Description of the initial conditions used

7.8 Validation Assessment

A validation assessment procedure may be performed by the provider. This is to demonstrate that the values obtained are within reasonable and expected values. The goal is not to strictly validate the absolute values contained in the results but rather to validate that the final values and flow pattern obtained agree with physical reality.

This should be performed with a qualitative assessment of the results and by demonstration using as supporting documentation quantitative reference values of the results obtained. This can be done by using a subset of the results (graphically and numerically) and justifying how they can be considered "as-expected".

7.9 Post-processing and Results

The report should contain an explanation on the post-processing procedure (if averaged, last value, etc) used. Also, the description of the methodology by which the final self-propulsion point was found (if propeller open water CFD simulations were used, in which case the details of these are also required).

In addition, the results obtained for all the conditions under which the hull under question was assessed: drafts and speeds. The following should be included in the report:

- One figure showing an example of one of the simulations showing the residuals. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.

- One figure showing an example of a convergence plot of the total resistance, viscous resistance, pressure resistance, propeller thrust. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.

- The following views of the flow are required with colour code as a minimum:
  - Global view of the wave pattern with wave height
  - Zoom view of the wave pattern at the bow and stern regions
  - Views of the y+ values for the hull and appendages
  - Views of the pressure coefficient for the hull and appendages
  - In case propeller is fully modelled or in case an EET is considered, cross section views of flow past the propeller and EET device (normalized velocity and pressure at different cross sections)

- Summary of values obtained from simulations
  - Ship resistance (total, viscous and pressure resistances)
  - Thrust deduction factor (1+t)
  - Wake deduction factor (1+w)
  - Propeller Thrust
  - Propeller Torque
  - Propeller efficiency
  - Rotation Rate
  - Delivered Power

8. Consideration of Energy Efficiency Technologies

Energy Efficiency Technologies (EET) as per MEPC.1/Circ.896 may also be included in the simulations. To that extent, it is understood that the following technologies are not covered by these guidelines:

1. Air Lubrication (EET-B)

2. Hull painting and coatings (EET-A)

In the future, these guidelines may be revisited to include for the above.

For the others, it is suggested that the methodology to follow, as much as possible, the same principles as described previously in these guidelines.

The procedure suggested to be applied relies on finding the improvements in power due to the addition of the EET and applying these as a correction factor on previously already obtained speed power curves (from sea trials, model test or other CFD calculations). These power improvements are to be calculated by comparing the results from two simulations, with and without EET, as follows:

1. Perform two simulations, with and without presence of EET.

2. Compute the gains delivered by the EET by comparing the power difference from the simulation with EET with the one without EET.

No. 173
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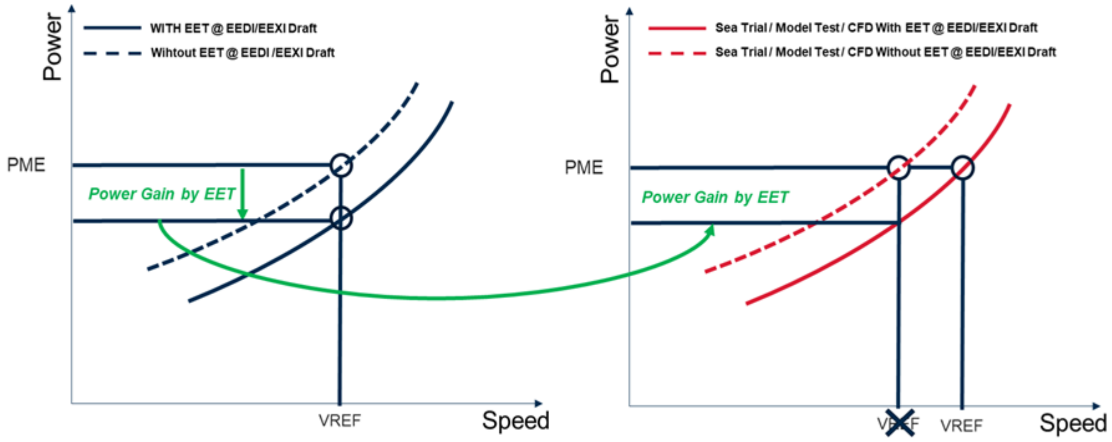
3. Apply the gains on top of the final Speed Power Curve as derived following options in section 5, or as previously available from existing sea trials and/or model tests.



The following aspects are required to be verified and/or improved in the simulations when considering energy saving devices before or after the propeller:

1. That the same definition of numerical calculation is applied as in section 3

   - Free-surface: the free-surface may not be modelled, if considered acceptable to the verifier. It should be demonstrated by evidence that removing the free-surface does not affect the results. Such evidence should include previous validation cases for a "set of comparable ships" performed by the CFD provider.

   - Hull Geometry: the hull geometry should be fully modelled in the Numerical Simulation following the consideration in section 6 with the following notes:

     - Only a section of the hull may be modelled. In such case, the boundary conditions are to be set in a way that these represent the flow pattern induced by the part of the hull not represented in the simulation. It should be demonstrated by evidence that removing part of the hull does not affect the results. Such evidence may include previous validation cases performed by the CFD provider against a "set of comparable ships".

     - In case it is demonstrated by sufficient evidence that the same results, in terms of comparative gains, are obtained for a "similar ship", then the hull form for a similar ship may be used as a replacement.

2. That the qualifications as per section 7.2 are demonstrated, in this case for cases where an Energy Efficiency Technology was considered.

3. That the simulations are performed with the propeller fully modelled, i.e., that its actual surfaces are present in the simulation and are not simplified by means of an actuator disk or another numerical artifice. Lower order models, such as BEM, may be accepted provided that such methodology validation is duly demonstrated.

4. That the propeller RPM without EET is compared to the expected values as in model test or sea trials. The differences are expected to be within reasonable thresholds, to be defined and agreed with the verifier.

No. 173 (cont)

5. In absence of the geometry of the propeller for the target hull, a replacement propeller may be rebuilt based on the data at disposal. The target should be to achieve a geometry as close as possible to the actual propeller. The provider is expected to demonstrate accuracy of the propeller geometry used by the following means:

   - If the Kt Kq curves of the target propeller are available, the report should show that the replacement propeller provides values no more than 3% different from the target values in the relevant propeller range[3] (comparison on the basis Kt, 10Kq and η_O)

   - If the Kt Kq curves are not available, the provider may use as reference an equivalent curve (e.g. Wageningen Series) obtained based on the data at disposal. The report should show that the replacement propeller provides values no more than 3% different from the equivalent ones in the relevant operating range[3] (comparison on the basis Kt, 10Kq and η_O)

   - The final geometry has the same features (diameter, number of blades, hub diameter, etc) as those that are available to the provider. A table should be provided comparing the features of the replacement and target propeller as per table below:

	Replacement Propeller	Target Propeller
Diameter		
Number of blades		
Rotation Direction		
Expanded Area Ratio		
Hub diameter		
Chord Length		
Max. thickness		
Pitch Ratio at 0.7R		

6. That the mesh used in numerical model has its convergence demonstrated with the inclusion of the propeller or the alternative model as per point 3.

[3] By relevant operating range, it is meant the advance coefficient in which the propeller is expected to operate when installed on the vessel and for the EEXI condition of relevance for the analysis. The validation should cover the range of advance coefficients close to the relevant operating points.

9. Propeller Open Water Simulations

As per MEPC. 351(78), numerical simulations can be used with a view to complementing or replacing the use of model tests for propeller open water calculations. In such a way, this section pertains to discussing the level of requirement to be demonstrated when Numerical Calculations are used for these purposes and the following points are observed:

1. That the same definition of numerical calculation is applied as in section 3.

2. Fluid domain and boundary conditions are to be set in a way that these do not influence the results obtained. This should be documented in the report to be issued by the provider.

3. Definitions and requirements in section 6 are followed with the following deviations being accepted:

   - As a minimum requirement, propeller should be modelled using BEM models and Actuator Disk/Force models are not accepted.

4. In replacement to the qualifications as set in section 7.6, the report may include a validation report for the proposed methodology on an equivalently similar propeller (i.e. Wageningen B series). The differences between the numerical and expected results should be within 3% in the relevant propeller operating range[3] (comparison on the basis Kt, 10Kq and η_O).

[3] By relevant operating range, it is meant the advance coefficient in which the propeller is expected to operate when installed on the vessel and for the EEXI condition of relevance for the analysis. The validation should cover the range of advance coefficients close to the relevant operating points.

No. 173 (cont)

Appendix 1 – Example of Template Report

INTRODUCTION

This report contains the description of the CFD modelling used to derive the EEDI/EEXI reference speed (*Vref*) for the VESSEL (NAME). The procedure used in this report follows the IACS Guidelines and the most updated ITTC guidelines on the topic of Numerical Modelling. Deviations of these have been properly documented in this report and justification is provided.

The final Reference Speed (*Vref*) is computed for the EEDI/EEXI draft as per MEPC. 350(78) following the calibration performed against the available model tests and/or sea trials. The following sections detail the methodology, parameters, post-processing and final results obtained.

QUALIFICATIONS

Following ITTC 7.5-03-01-02, evidence on the ability of the consultants delivering this report is provided hereafter.

General Qualifications

COMPANY (NAME) has been involved in multiple R&D, JIP and JDPs projects covering the topics of ship resistance and propulsive performance for the past XX years. Examples of projects are listed below:

Project #	Year	Description
1	2013	
2	2014	
3	2015	
4	2016	
5	2016	
…	…	

COMPANY (NAME) has participated in the following benchmarking/validation exercises in which is has obtained the accuracy by employing its standard modelling procedures:

Project #	Year	Ship type	Scale
1	2013	*Tanker 59kDWT*	*Full Scale*
2	2014		
3	2015		
4	2016		
5	2016		
…	…		

No. 173 (cont)

Case Specific Qualifications

COMPANY (NAME) has carried out a number of projects in which ship performance was evaluated by means of Numerical Calculations for ships falling within the category of “set of comparable ships” as per IACS Guidelines.

Project #	Year	Scale
1	2013	
2	2014	
3	2015	
4	2016	
5	2016	
…	…	

SUPPORTING DOCUMENTATION

The following list of supporting documentation was used in connection to these calculations and are provided in the Annex of this report.

Document Number and/or Name	Description

CFD SOFTWARE DESCRIPTION

Short Description of the CFD software used in the simulations, account for the software and version being used alongside a general description of the same.

VESSEL DESCRIPTION

The vessel characteristics are found below:

Vessel Name	
IMO Number	
Vessel Type	
MCR x RPM	
DWT	
LWT	

No. 173 (cont)

Design Draft	
EEXI/EEDI Draft	
LPP	
Beam molded (B)	
Depth (D)	

The propeller characteristics are found below:

Diameter	
Number of blades	
Rotation Direction	
Expanded Area Ratio	
Hub diameter	
Chord Length	
Max. thickness	
Pitch Ratio at 0.7R	

CFD MODEL GEOMETRY

In here the model used in the CFD calculations is presented. It is expected that a comparison between the actual hull as built is compared to the model used in the calculations. This can be done by comparing the hydrostatics between the hull as built and the one used in the CFD calculations. This should be done for the hull and appendages included in the modelling.

In case geometry simplifications have been implement or parts of the vessel have not been accounted for in the CFD model, this must be noted and detailed in this section. Example for different views to be provided are presented below.

Figure 1 – Example of different views of a geometry used in CFD calculation.

The fluid domain size is also to be detailed here and different views describing the main dimensions should be provided.

NUMERICAL MODEL SET-UP DESCRIPTION

In this section, the numerical model should be detailed. This should account for the following information:

- CFD equations being solved
- Simulation type, steady vs unsteady
- Turbulence model being used and justification for its choice
- Numerical solution schemes used: for example, second-order upwind and iteration stop criteria
- Boundary conditions applied on all the surfaces of the fluid domain
- Description of the coordinates system and model origin
- Degrees of freedom used in the model
- Description on the propeller modelling: full propeller, actuator disk, etc.
- Description of the initial conditions used

An image should be provided to detail the boundary conditions used in the CFD calculation.

The meshing strategy should be detailed. General description of the size of the cell size, type of grids being utilized, boundary layer refinement, etc, should be provided. Different views of the different refinement zones are also to be provided.

The post-processing methodology is also to be detailed here: how open water propeller data is used, if more than two simulations are performed (resistance and self-propulsion), etc. The reasoning used to achieve the self-propulsion point should be detailed.

RESULTS

In addition, the results obtained for all the conditions under which the hull under question was assessed: drafts and speeds. The following should be included in the report:

- One figure showing an example of one of the simulations showing the residuals. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc;

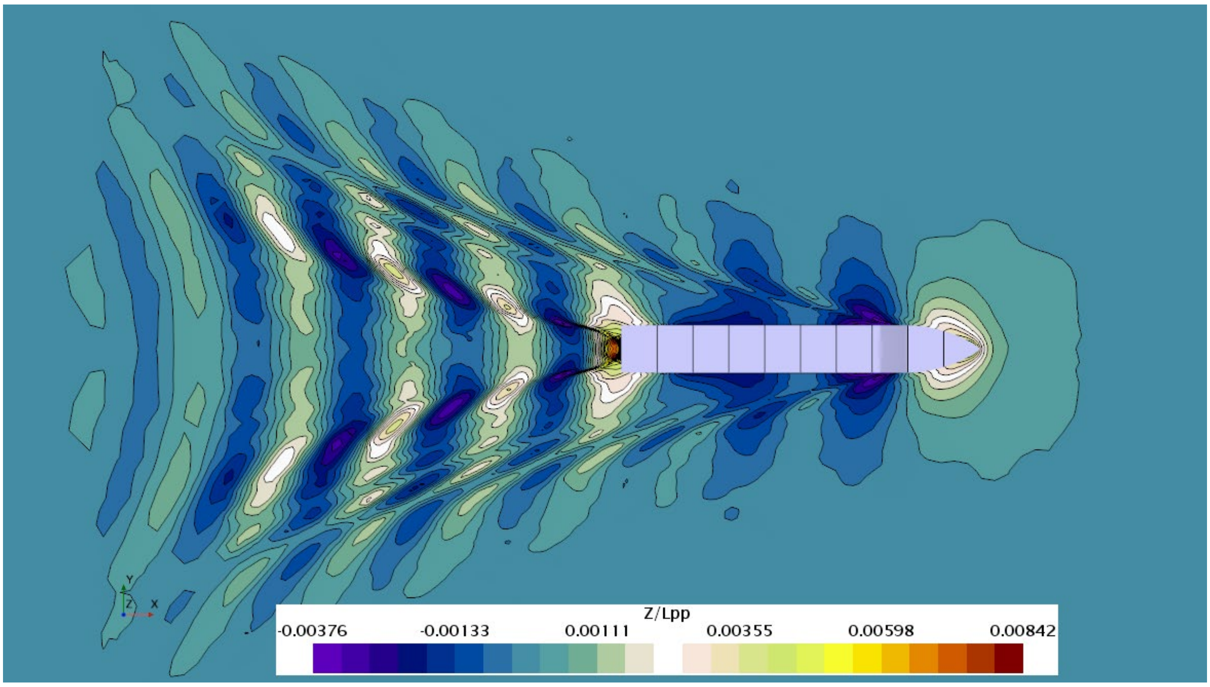
- One figure showing an example of a convergence plot of the total resistance, viscous resistance, pressure resistance, propeller thrust. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc;

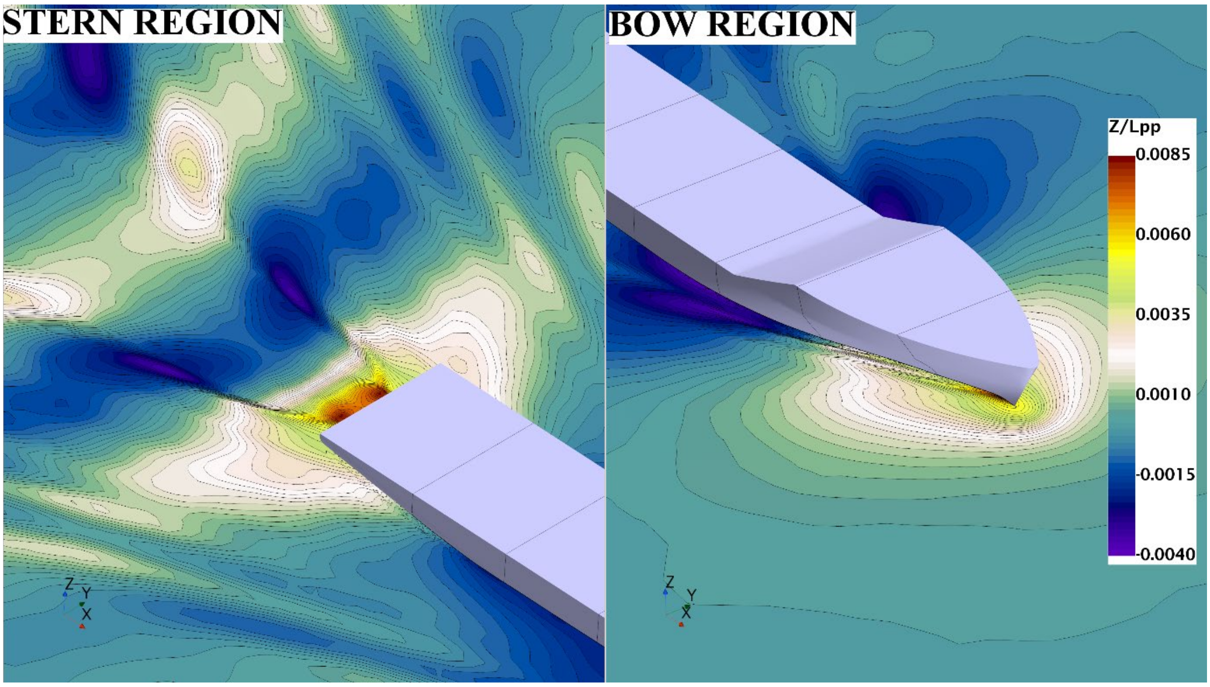
- The following views of the flow are required with colour code as a minimum:
  - Global view of the wave pattern with wave height
  - Zoom view of the wave pattern at the bow and stern regions
  - Views of the y+ values for the hull and appendages
  - Views of the pressure coefficient for the hull and appendages
  - In case propeller is fully modelled or in case an EET is considered, cross section views of flow past the propeller and EET device (normalized velocity and pressure at different cross sections)

No. 173 (cont)

Different examples on the views/results expected are shown below:

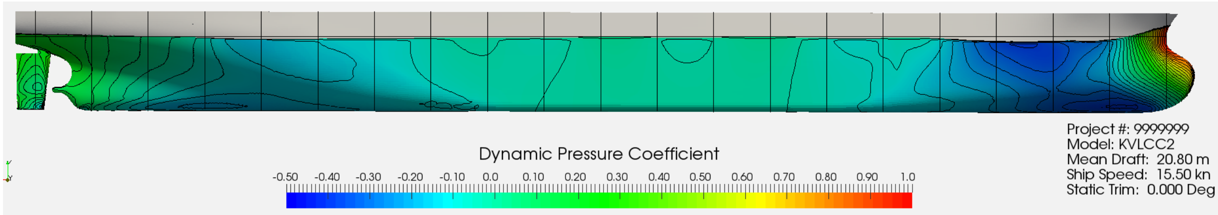
Wave pattern:

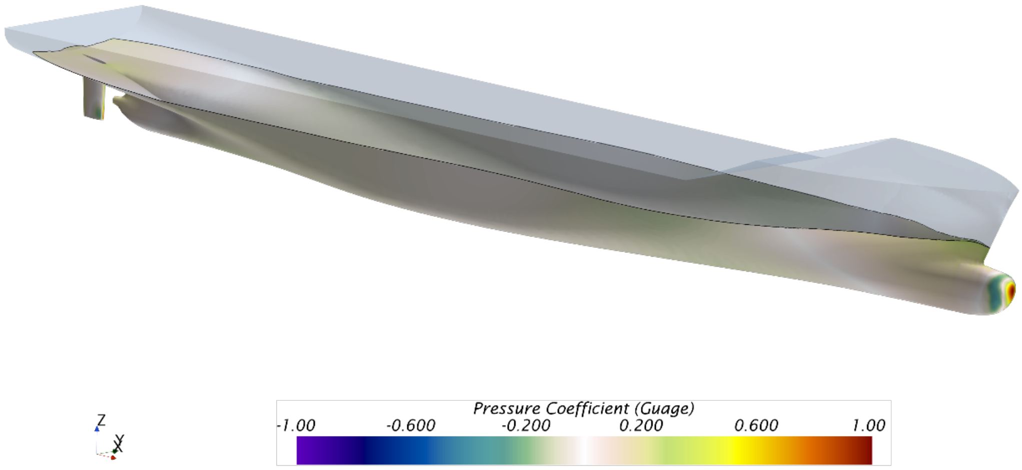




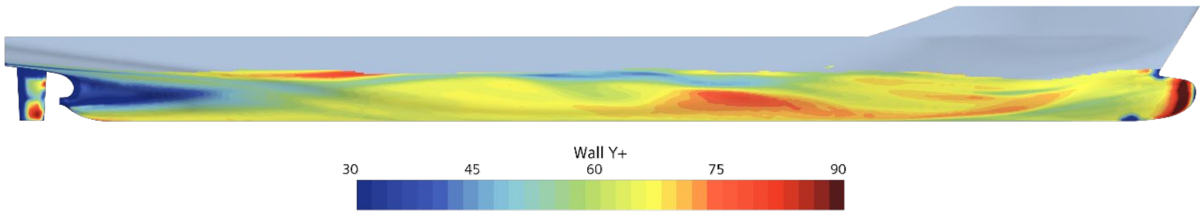
No. 173 (cont)

Dynamic Pressure field:

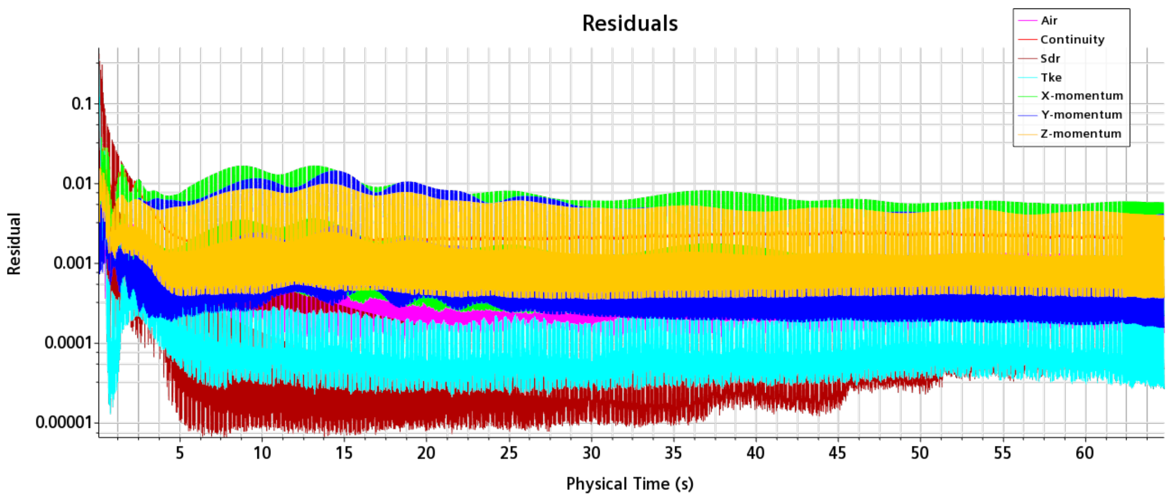




Y+ Values

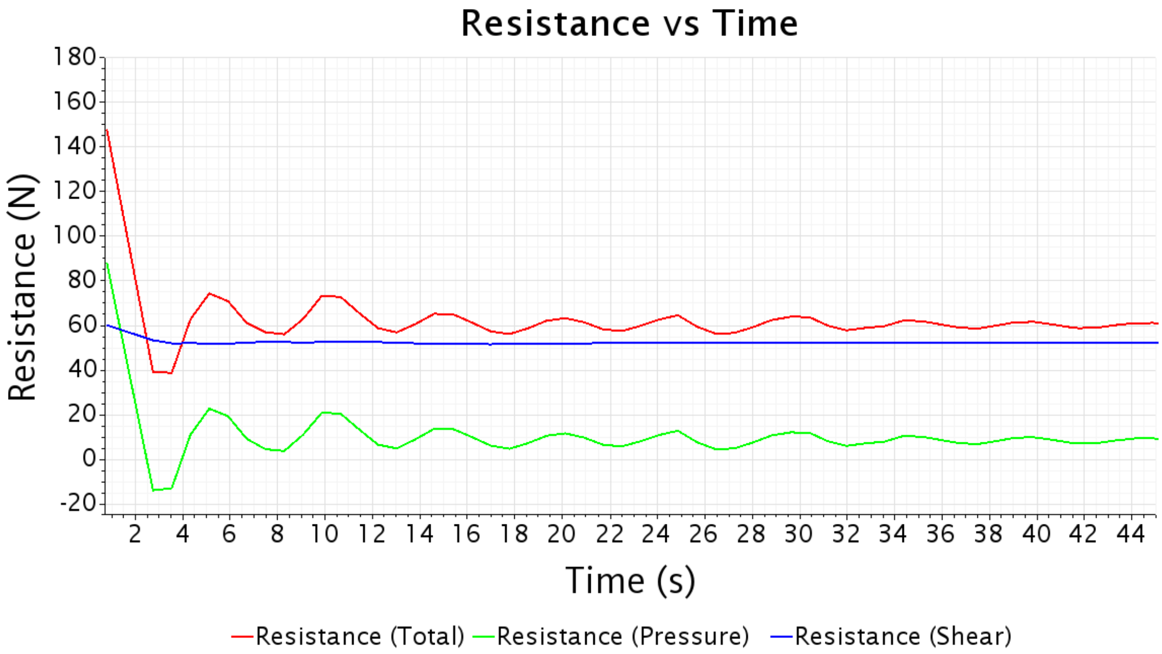


Convergence Plot of Numerical Residuals



No. 173
(cont)

Convergence Plot of main Efforts



Summary of values obtained from simulations in a tabular format for all the drafts and speeds/power setting simulated:

- Ship resistance (total, viscous and pressure resistances)
- Thrust deduction factor (1+t)
- Wake deduction factor (1+w)
- Propeller Thrust
- Propeller Torque
- Propeller efficiency
- Rotation Rate
- Delivered Power

VALIDATION ASSESSMENT

A validation assessment procedure may be presented. This is to demonstrate that the values obtained are within reasonable and expected values. This can be done by using a subset of the results (graphically and numerically) and justifying how they can be considered “as-expected”.

End of Document

ANNEX 8

RESOLUTION MEPC.346(78)
(adopted on 10 June 2022)

2022 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,

NOTING that the Committee, at its seventy-sixth session, adopted, by resolution MEPC.328(76), the 2021 revised MARPOL Annex VI, which will enter into force on 1 November 2022,

NOTING IN PARTICULAR that the 2021 revised MARPOL Annex VI (MARPOL Annex VI) contains amendments concerning mandatory goal-based technical and operational measures to reduce the carbon intensity of international shipping,

NOTING FURTHER that regulation 26 of MARPOL Annex VI requires each ship to keep on board a Ship Energy Efficiency Management Plan (SEEMP), to be developed and reviewed, taking into account the guidelines adopted by the Organization,

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

NOTING that the Committee, at its seventieth session, adopted, by resolution MEPC.282(70), the *2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)*,

HAVING CONSIDERED, at its seventy-eighth session, the draft *2022 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)*,

1 ADOPTS the *2022 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)*, as set out in the annex to the present resolution;

2 INVITES Administrations to take the annexed Guidelines into account when developing and enacting national laws which give force to and implement requirements set forth in regulation 26 of MARPOL Annex VI;

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

4 AGREES to keep the Guidelines under review in light of experience gained with their implementation, also taking into consideration that in accordance with regulations 25.3 and 28.11 of MARPOL Annex VI a review of the technical and operational measures to reduce the carbon intensity of international shipping shall be completed by 1 January 2026;

5 REVOKES the *2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)* adopted by resolution MEPC.282(70).

2022 GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

CONTENTS

APPENDIX 3 – STANDARDIZED DATA REPORTING FORMAT FOR THE DATA COLLECTION SYSTEM AND OPERATIONAL CARBON INTENSITY TO THE ADMINISTRATION

APPENDIX 4 – STANDARDIZED DATA REPORTING FORMAT FOR THE PARAMETERS TO CALCULATE THE TRIAL CARBON INTENSITY INDICATORS ON A VOLUNTARY BASIS

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 26 of MARPOL Annex VI.

1.2 Taken together, the aims of the SEEMP should assist the international shipping sector to achieve the goal of Chapter 4 of MARPOL Annex VI set out in regulation 20, which is reducing the carbon intensity of international shipping. The aims of the SEEMP are threefold:

1.2.1 To encourage companies to incorporate actions to improve the energy efficiency and carbon intensity of their ships and ship management practices.

1.2.2 To specify the methodology the ship should use to collect the data required by regulation 27.1 of MARPOL Annex VI and the processes that should be used to report the data to the ship's Administration or any organization duly authorized by it.

1.2.3 To specify the methodology the ship should use to calculate the attained annual operational carbon intensity indicator (CII) as required by regulation 28.1 of MARPOL Annex VI and the processes that should be used to report the data to the ship's Administration or any organization duly authorized by it.

1.3 There are three parts to a SEEMP:

1.3.1 Guidance for Part I of the SEEMP required by regulation 26.1 of MARPOL Annex VI, is addressed in sections 3, 4, and 5 of these Guidelines. The purpose of this part is to provide an approach to monitor ship and fleet efficiency performance over time and describe ways to improve the ship's energy efficiency performance and carbon intensity. Part I of the SEEMP applies to any ship of 400 GT and above.

1.3.2 Guidance for part II of the SEEMP required by regulation 26.2 of MARPOL Annex VI, is addressed in sections 6, 7, and 8 of these Guidelines. The purpose of this part is to provide a description of the methodologies that should be used to collect the data required pursuant to regulation 27 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. Part II of the SEEMP applies to any ship of 5,000 GT and above.

1.3.3 Guidance for part III of the SEEMP required by regulations 26.3 and 28.8 of MARPOL Annex VI is addressed in sections 9, 10, 11, 12, 13, 14 and 15 of these Guidelines. The purpose of this part is to provide:

.1 a description of the methodology that should be used to calculate the ship's attained annual operational CII required by regulation 28 of MARPOL Annex VI;

.2 the processes that should be used to report this value to the ship's Administration or any organization duly authorized by it;

.3 the required annual operational CII for the next three years;

.4 an implementation plan documenting how the required annual operational CII should be achieved during the next three years;

.5 a procedure for self-evaluation and improvement; and

.6 for ships rated as D for three consecutive years or rated as E, a plan of corrective actions to achieve the required annual operational CII.

1.3.4 Part III of the SEEMP applies to any ship of 5,000 GT and above which falls into one or more of the categories in regulations 2.2.5, 2.2.7, 2.2.9, 2.2.11, 2.2.14 to 2.2.16, 2.2.22, and 2.2.26 to 2.2.29 of MARPOL Annex VI.

1.3.5 Sample forms of the various sections of the SEEMP are presented in appendices 1, 2, and 2*bis* for illustrative purposes. A standardized data-reporting format for the data collection system and operational carbon intensity is presented in appendix 3. A standardized data reporting format for the trial carbon intensity indicators on voluntary basis is presented in appendix 4.

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.

2.4 "Carbon Intensity Indicator" means a performance indicator by which it is possible to measure the carbon intensity of the ship, as defined in the guidelines developed by the Organization,[1] taking into account data listed for reporting in appendix IX to MARPOL Annex VI.

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

3 GENERAL

3.1 Regulation 26.1 of MARPOL Annex VI requires each ship of 400 gross tonnage and above, subject to chapter 4 to keep on board a ship-specific Ship Energy Efficiency Management Plan (SEEMP).

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 and reduce the carbon intensity 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 ships 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.

1 Refer to the *2021 Guidelines on operational carbon intensity indicators and the calculation methods (CII guidelines, G1)* (Resolution MEPC.336(76)) and the *2022 Guidelines on correction factors and voyage adjustments for CII calculations (G5)* (Resolution MEPC.XXX(78)).

3.4 In addition, many companies already develop, implement and maintain a safety management system. In such case, part I of SEEMP may form part of the ship's safety management system.

3.5 This section provides guidance for the development of part I of SEEMP that should be adjusted to the characteristics and needs of individual companies and ships. Part I of the SEEMP is intended to be a management tool to assist a company in managing the ongoing environmental performance of its ships and, as such, it is recommended that a company develop procedures for implementing the plan in a manner which limits any onboard 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 the energy efficiency and reduce carbon intensity of a ship 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 and reduce its carbon intensity. 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 energy efficiency and carbon intensity reduction 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 a voyage and the need to avoid high risk areas may also be important parameters as well as 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 carbon intensity and the expected improvement of ship energy efficiency and reduction of carbon intensity. 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 energy efficiency and reduce carbon intensity (e.g. speed optimization, confirming berth availability and arrival time with port of destination, weather routeing, hull maintenance, retrofitting of energy efficiency devices, and use of alternative fuels), the best package of measures for a ship to improve energy efficiency and reduce carbon intensity depends to a great extent upon ship type, cargoes, routes and other factors that 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 the planning 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 and carbon intensity reducing measures that already have been undertaken, and should determine how effective these measures are in terms of improving energy efficiency and reducing carbon intensity. Part I also should identify what measures can be adopted to further improve the energy efficiency and reduce the carbon intensity 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 in 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 onboard administrative burden.

Company-specific measures

4.1.5 The improvement of energy efficiency and reduction of carbon intensity 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, fuel suppliers, 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 services. The better the coordination among such stakeholders, 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 should also establish an energy efficiency and carbon intensity management plan to improve the performance of 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.

.1 For ships also subject to regulation 28 of MARPOL Annex VI, the goal setting should be consistent with the continuous CII improvements set out by that regulation, and should include the relevant information (see paragraph 9.7). These ships are also encouraged to consider setting ship-specific goals in addition to the applicable CII requirements that strive for additional energy efficiency improvements and carbon intensity reductions.

.2 For ships or companies not subject to regulation 28, there are no requirements to define a goal and to communicate it to the public, or to be a subject to external inspection, surveys, or audits with respect to the SEEMP. Nevertheless, a meaningful goal should be defined to serve as a signal on a company's commitment to improve the energy efficiency and carbon intensity of the ship. The goal can be set using different indicators, including the annual fuel consumption, Annual Efficiency Ratio (AER), cgDIST, Energy

Efficiency Operational Indicator (EEOI) or other carbon intensity indicators (CIIs).[2] In all cases, 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 energy efficiency and carbon intensity measures to be implemented, it is essential to establish a system for their implementation. This is done by developing the procedures for energy management, defining tasks associated with those procedures, and assigning those tasks to responsible personnel. The implementation system should include procedures to ensure execution of measures and specify defined levels of authority and lines of communication. Also, it should include procedures for internal audits and management review, where relevant. In sum, part I of the SEEMP should describe how each measure should be implemented and who the responsible person or persons are. The implementation period (start and end dates) of each selected measure should be indicated. The development of such an implementation 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, the reason or reasons should be recorded for internal use. It is recommended that events and operational conditions outside the control of the ship's crew (for example, waiting for berths, extended port dwell times, operation in severe adverse weather) which may affect the ships rating be documented.

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. In many cases, the monitoring tool should target the goal indicator set out in paragraph 4.1.7 (e.g. AER, cgDIST, EEOI, or other CIIs as agreed by the Organization). If a quantitative goal is not defined for a ship, a quantitative performance indicator developed by the Organization (e.g. AER, EEOI, CII) or another internationally established tool should be selected. A ship subject to regulation 28 is likely to use the CII as its monitoring tool.

4.3.2 If used, these CIIs should be calculated in accordance with the guidelines developed by the Organization,[3] adjusted, as necessary, to a specific ship and trade.

4.3.3 Ships subject to regulation 28 may use other measurement tools in addition to the CII, if convenient and/or beneficial for a ship or a company. In the case where other monitoring

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[2] Refer to the *2022 Guidelines on operational carbon intensity indicators and the calculation methods (CII guidelines, G1)* (Resolution MEPC.352(78)) and the *2022 Interim guidelines on correction factors and voyage adjustments for CII calculations (G5)* (Resolution MEPC.355(78)).

[3] Refer to the *Guidelines for voluntary use of the ship energy efficiency operational indicator (EEOI)* (MEPC.1/Circ.684) and the *2022 Guidelines on operational carbon intensity indicators and the calculation methods (CII guidelines, G1)* (Resolution MEPC.352(78)) and the *2022 Interim guidelines on correction factors and voyage adjustments for CII calculations (G5)* (Resolution MEPC.355(78)).

tools are used, the reason for the use of the tool and the method of monitoring should be clarified at the planning stage.

4.3.4 It is highly advised to conduct monitoring at regular intervals for checking consistency of data and verification assistance. The ship's fuel oil consumption should be monitored using daily reporting, such as noon reports, or higher frequency data.

Establishment of monitoring system

4.3.5 It should be noted that whatever measurement tools are used, continuous and consistent and reliable data collection is the foundation of monitoring. To allow for meaningful and consistent monitoring, a 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.

4.3.6 It should be noted that, in order to avoid unnecessary administrative burdens on ships' staff, monitoring should be carried out as much as possible by shore staff when the data can be automatically transferred, utilizing data obtained from existing required records such as the official and engineering logbooks and oil record books. Additional data could be obtained as appropriate.

Search and rescue

4.3.7 When a ship diverts from its scheduled passage to engage in search and rescue operations, and for which emissions are excluded pursuant to regulation 3, it is recommended that data obtained during such operations is not used in ship energy efficiency monitoring, and that such data should 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:

.1 evaluate the effectiveness of the planned measures and their implementation;

.2 deepen the understanding of the overall characteristics of the ship's operation such as what types of measures can or cannot function effectively, and how and/or why;

.3 comprehend the trend of the efficiency improvement of that ship; and

.4 develop the improved management plan for the next cycle through identification of further opportunities for improving energy efficiency and reducing carbon intensity.

4.4.3 For this process, procedures for self-evaluation of the ship energy efficiency management plan should be developed. Furthermore, self-evaluation should be implemented periodically by using data collected through monitoring. In addition, it is recommended that time be invested in identifying the cause and effect of the performance during the evaluated period so lessons learned can be taken into account when revising and improving the next stage of the ship's energy efficiency management plan.

5 GUIDANCE ON BEST PRACTICES FOR FUEL-EFFICIENT OPERATION OF SHIPS

5.1 The search for energy efficiency and carbon intensity improvement across the entire transport chain takes responsibility beyond what can be delivered by the company 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, fuel suppliers, ports and vessel traffic management services, etc. for the specific voyage. All parties involved 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 software tools are available to assist in voyage planning.

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.

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 ship 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. For LNG carriers speed optimization means, quite often, a higher speed at the start of laden passages to control tanks pressure and at the end of ballast passages to use the operational LNG quantity needed for cargo tank cooling in propulsion instead of wasting in GCU or condenser steam dump. Charterers are generally aware of the improved efficiency of this speed pattern.

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 ships 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. The use of automated engine management systems to control speed rather than relying on human intervention may be beneficial.

5.2.11 When optimizing shaft power, due attention should be given to overall power system efficiency. For example, in some cases reducing load or shaft speed below the minimum necessary to operate energy recovery systems and shaft generators may increase overall emissions.

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 improved energy 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. during 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 the company'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 systems use thermal heat losses from the exhaust gas for either electricity generation, heating or additional propulsion with a shaft power take in.

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 or terminal operators and optimum solutions matched to ship and port or terminal requirements should be explored. However, in cases where ships use their own cargo handling equipment (e.g. cargo cranes, self-unloading booms, cargo pumps (tankers)), procedures should be in place to efficiently utilize the energy produced from any additional generators required to operate the equipment.

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 CO_2 reduction method, but availability will often determine the applicability.

5.9 Other measures

5.9.1 Development of computer software for the calculation of current 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 solar (or photovoltaic) cell technology, have improved enormously in recent years and should be considered for onboard 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. Various systems are available for retrofit, including Flettner rotors, wing sails and aerofoil kites.

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 as applied to part I of the SEEMP are potentially cost-effective in case of high oil prices. The financial feasibility of a specific energy efficiency enhancement can be evaluated by various means. One way would be to estimate the return on investment (ROI) time. However, while measures with lower ROI may have the lowest cost, this does not guarantee the best results in energy efficiency performance improvement. 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, certain types of 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. Air draft limitations may also affect the feasibility of wind assistance technology and certain other emission reduction measures. 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 energy efficiency benefits by adopting the same measures or combination of measures as other ships that operate in different areas. 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 also 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.

5.10.5 Environmental conditions and the nature of cargo carried also varies between regions. For example, some routes may carry greater volumes of goods requiring careful temperature conditioning, or some transit regions may be subject to frequent severe adverse weather conditions. This may lead to an increase of emissions of ships serving those routes and regions.

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

6 GENERAL

6.1 Regulation 26.2 of MARPOL Annex VI specifies that, "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 27.1 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 under way and other data required by regulation 27 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 covered ship's SEEMP complies with regulation 26.2 of MARPOL Annex VI prior to collecting any data.

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

Fuel oil[4] 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 under way 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:

4 Regulation 2.1.14 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."

.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;

.2 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;

.3 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;

.4 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;

.5 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

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

.2 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:

.1 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;

.2 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;

.3 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;

.4 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

.5 calibration of the flow meters should be specified. Calibration and maintenance records should be available on board;

.3 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;

.4 method using LNG cargo tank monitoring on board:

LNG ships use the Custody Transfer Monitoring System (CTMS) to monitor/record the cargo volumes inside the tanks. When calculating the consumption:

.1 the LNG liquid volume consumed is converted to mass using the methane density of 422 kg/m³. This is because LNG is transported at methane boiling point, while other heavier hydrocarbons have a higher boiling point and remain at liquid state; and

.2 nitrogen mass content is subtracted for each laden voyage from LNG consumption as it does not contribute to CO_2 emissions;

.5 method using cargo tank monitoring on board for ships using cargo other than LNG as a fuel:

.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 to the cargo used as a fuel. The method for tank readings should be specified in the SEEMP Data Collection Plan; and

.2 the tank readings will normally occur daily when the ship is at sea and each time the ship is loading or discharging cargo; and 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, nitrogen content for LNG, if applied, should be documented.[5]

Conversion factor CF

7.3 If fuel oils are used that do not fall into one of the categories as described in the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73)), as amended, and have no CF-factor assigned (e.g. some "hybrid fuel oils"), the fuel oil supplier should provide a CF-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 logbook in accordance with SOLAS regulation V/28.1;[6]

.2 the distance travelled while the ship is under way under its own propulsion should be included in 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 under way

7.5 Appendix IX of MARPOL Annex VI specifies that hours under way should be submitted to the Administration. Hours under way should be an aggregated duration while the ship is under way 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 safety management system. Additional measures to be considered could include:

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

.2 the procedure to address data gaps if monitoring data is missing, for example, flow meter malfunctions.

A standardized data reporting format

7.7 Regulation 27.3 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

5 For example, ISO 8217 provides a method for liquid fuel.

6 Distance travelled measured using satellite data is distance travelled over the ground.

Organization. The collected data should be reported to the Administration in the standardized format shown in appendix 3.

8 DIRECT CO_2 EMISSIONS MEASUREMENT

8.1 Direct CO_2 emission measurement is not required by regulation 27 of MARPOL Annex VI.

8.2 Direct CO_2 emissions measurement, if used, should be carried out as follows:

.1 this method is based on the determination of CO_2 emission flows in exhaust gas stacks by multiplying the CO_2 concentration of the exhaust gas with the exhaust gas flow. In case of the absence or/and breakdown of direct CO_2 emissions measurement equipment, manual tank readings will be conducted instead;

.2 the direct CO_2 emissions measurement equipment applied to monitoring is located so as to measure all CO_2 emissions from the ship. The locations of all equipment applied are described in the monitoring plan; and

.3 calibration of the CO_2 emissions measurement equipment should be specified. Calibration and maintenance records should be available on board.

PART III OF THE SEEMP: SHIP OPERATIONAL CARBON INTENSITY PLAN

9 GENERAL

9.1 Regulation 26.3.1 of MARPOL Annex VI specifies that, for certain categories of ships of 5,000 GT and above, on or before 1 January 2023, the SEEMP shall include:

.1 a description of the methodology that will be used to calculate the ship's attained annual operational CII required by regulation 28 of MARPOL Annex VI and the processes that will be used to report this value to the ship's Administration;

.2 the required annual operational CIIs, as specified in regulation 28 of MARPOL Annex VI, for the next three years;

.3 an implementation plan documenting how the required annual operational CIIs will be achieved during the next three years; and

.4 a procedure for self-evaluation and improvement.

9.2 Sections 9 to 15 of these Guidelines provide guidance for ships to which regulation 26.3 of MARPOL Annex VI applies for the following purposes:

.1 to assist them in developing part III of the ship's SEEMP, including guidance on developing a ship-specific method to collect necessary data;

.2 to describe the methodology that will be used to calculate the ship's attained annual operational CII value and report this to the ship's Administration;

.3 to determine the ship's required annual operational CII for the next three years;

.4 to develop and apply an implementation plan documenting how the required annual operational CIIs will be achieved during the next three years;

.5 to define a procedure for self-evaluation and improvement; and

.6 to develop corrective actions, as applicable.

9.3 The required annual operational CII is to be calculated in accordance with regulation 28 and taking into account the guidelines developed by the Organization.[7]

9.4 In addition, pursuant to regulation 28 of MARPOL Annex VI, part III of the SEEMP is further to include calculation methodologies and a plan of corrective actions for ships that are rated D for three consecutive years or rated as E.

9.5 The ship's attained annual operational carbon intensity is to be calculated taking into account the guidelines developed by the Organization.[8]

9.6 Ships of 5,000 gross tonnage and above that are subject to regulations 26.3 and 28 of MARPOL Annex VI are strongly encouraged to review part I of their SEEMP to revise it as needed to reflect the actions taken to achieve the ship's CII requirements.

9.7 The goal setting, as referred to in paragraph 4.1.7 in part I, should be consistent with the requirements of regulation 28 of MARPOL Annex VI and should include the ship's required annual operational CII for the next three years following the updating of the SEEMP.

9.8 In addition, while ships subject to regulation 28 of MARPOL Annex VI may relay on the CII requirements when defining goals under part I of the SEEMP, they are encouraged to consider setting additional ship-specific goals that go beyond the applicable CII requirements and strive for energy efficiency improvements and carbon intensity reductions beyond such requirements.

9.9 Ships subject to regulation 28 of MARPOL Annex VI may consider voluntarily using one or more of the trial CIIs (EEPI, cbDIST, clDIST or EEOI), where applicable, for the purpose of providing supporting data for decision-making to support the review clause set out in regulation 28.11 of MARPOL Annex VI. A standardized data reporting format for the parameters to calculate the trial carbon intensity indicators on a voluntary basis is presented in appendix 4. A description of the methodology that should be used to calculate the trial CII should be included in the SEEMP.

9.10 Part III of the ship's SEEMP should be updated in case of voluntary modifications or necessary corrective actions are involved (every three years).

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7 Refer to the *2022 Guidelines on the reference lines for use with operational carbon intensity indicators (CII reference lines guidelines, G2)* (Resolution MEPC.353(78) and the *2021 Guidelines on the operational carbon intensity reduction factors relative to reference lines (CII reduction factors guidelines, G3)* (Resolution MEPC.338(76).

8 Refer to the *2022 Guidelines on operational carbon intensity indicators and calculation methods (CII Guidelines, G1)* (Resolution MEPC.352(78)) and the *2022 Interim guidelines on correction factors and voyage adjustments for CII calculations (G5)* (Resolution MEPC.355(78)).

10 ATTAINED ANNUAL OPERATIONAL CII CALCULATION METHODOLOGY; DATA COLLECTION PLAN AND DATA QUALITY

10.1 Taking into account the guidelines developed by the Organization,[9] part III of the SEEMP provides detailed information on how the ship's attained annual operational CII should be calculated. Regulation 28 of MARPOL Annex VI states that the attained annual operational CII shall be calculated, using the data collected in accordance with regulation 27 (Fuel Oil Data Collection System).

10.2 In describing the calculation methodology, part III of the SEEMP should include a detailed description of the data required for the calculation of the attained annual operational CII. The data collection should follow the relevant methodology and requirements on the Fuel Oil Data Collection System pursuant to regulation 27 of MARPOL Annex VI (see part II of these Guidelines).

10.3 In case of transfer of the ship from one company to another according to regulation 27.5 or 27.6 of MARPOL Annex VI, all relevant data necessary for the calculation of the attained annual operational CII should be submitted by the former company to the receiving company within one month after the date of transfer. The data should have been verified by the Administration or any organization duly authorized by it according to regulation 6.7 of MARPOL Annex VI before they are transferred to the receiving company. The format of the transfer should be consistent with appendix 3 and such that the receiving company can use it in the calculations of the attained annual operational CII for the whole year in which the transfer takes place.

10.4 In case the former company does not transfer the required data, the Administration may make relevant data submitted to the IMO Fuel Oil Consumption Database available to the receiving company. In case of a transfer of both company and Administration concurrently, the incoming Administration may make a request to the Organization for access to the data according to regulation 27.11. If no such data is available, the attained annual operational CII can be calculated and verified using the available data covering a period of the preceding calendar year as long as practically possible.

10.5 In case of transfer of a ship from one Administration to another according to regulation 27.4 of MARPOL Annex VI the data needed for calculating the annual attained CII is already in the possession of the relevant company and no further exchange of data is needed.

11 REQUIRED ANNUAL OPERATIONAL CII FOR NEXT THREE YEARS

11.1 Part III of the SEEMP describes the required annual operational CII values for the ship for each of the next three years, calculated in accordance with regulation 28 of MARPOL Annex VI and taking into account the guidelines developed by the Organization,[10] as the basis for those calculations.

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[9] Refer to the *2022 Guidelines on operational carbon intensity indicators and calculation methods (CII Guidelines, G1)* (Resolution MEPC.352(78)) and the *2022 Interim guidelines on correction factors and voyage adjustments for CII calculations (G5)* (Resolution MEPC.355(78)).

[10] Refer to the *2022 Guidelines on the reference lines for use with operational carbon intensity indicators (CII reference lines guidelines, G2)* (Resolution MEPC.353(78)) and the *2021 Guidelines on the operational carbon intensity reduction factors relative to reference lines (CII reduction factors guidelines, G3)* (Resolution MEPC.338(76)).

12 THREE-YEAR IMPLEMENTATION PLAN

12.1 The three-year implementation plan describes the measures the ship plans to take to continue to achieve the required annual operational CII over the next three-year period. These may include, but are not limited to, measures as outlined in section 5 of these Guidelines.

12.2 The three-year implementation plan is ship-specific.

12.3 The three-year implementation plan should be SMART (Specific, Measurable, Achievable, Realistic, and Time-bound) to the extent envisaged and feasible. It should include:

.1 a list of measures that improve the energy efficiency and reduce the carbon intensity of the ship, with time and method of implementation necessary for achieving the required operational CII;

.2 a description of how, when the listed measures are implemented, the required operational CII will be achieved, taking into consideration the combined effect of the measures on operational carbon intensity;

.3 the company personnel responsible for the three-year implementation plan, and for monitoring and recording performance throughout the year for the reviewing of the effectiveness of the three-year implementation plan; and

.4 identification of possible impediments to the effectiveness of the measures for improving the energy efficiency and reducing the carbon intensity of the ship, including possible contingency measures put in place to overcome these impediments.

12.4 The three-year implementation plan should be monitored and adjusted when necessary, and the data to be monitored, identified.

13 PROCESS FOR SELF-EVALUATION AND IMPROVEMENT (IN ADDITION TO SECTION 4.4. OF THESE GUIDELINES)

13.1 The purpose of self-evaluation is to evaluate the effectiveness of the planned measures and their implementation, to deepen the understanding of the overall characteristics of the ship's operation, such as what types of measures can function effectively, and how or why, to comprehend the trend of the efficiency improvement of that ship, to understand trends in the ship's utilization in terms of cargo carried and areas of operation, and to develop an improved action plan for the next cycle. This evaluation should produce meaningful feedback based on experience in the previous period, to enhance performance in the next period.

13.2 Procedures for self-evaluation of the ship's energy usage and carbon intensity should be developed and included in this section of the SEEMP. Self-evaluation should be carried out periodically based on data collected through monitoring. It is recommended that the cause and effect of the ship's performance in the evaluated period be identified in order to identify measures for improving performance during the next period.

13.3 The process of self-evaluation and improvement could consist of the following elements:

.1 regular internal shipboard and company audits to verify implementation and the effectiveness of the system;

.2 improvement, i.e. implementing preventive or modifying measures (responsible personnel within the company should evaluate such audit reports and implement corrective actions including preventive or modifying measures); and

.3 periodical review of the SEEMP and associated documents, to update the SEEMP in a manner which minimizes any administrative and unnecessary burdens on company's personnel and ship's staff.

13.4 The content of the self-evaluation and improvement could include the following elements:

.1 criteria for evaluation, including elements to evaluate, such as quality of monitoring, record-keeping, effectiveness of implemented measures (including cause and effect) and achievement of the goal;

.2 the evaluation of the effectiveness of the different measures taken, in terms of energy efficiency and carbon intensity;

.3 which measures contribute the most and how much, which measures do not contribute and are therefore not efficient, which ship and/or company-specific elements adversely affect the CII and how these could be improved;

.4 timeline for starting the review process ahead of the end of the compliance period and for implementation of new measures in the subsequent year;

.5 measures identified to address deficiencies and discrepancies including correction of data gaps and system weaknesses, new measures to improve implementation (e.g. training) as well as new carbon intensity improvement measures as needed;

.6 where relevant, actions that will be taken to bring the ship into better CII ratings including estimated quantification of the additional expected reduction in carbon intensity;

.7 where applicable, if a plan of corrective actions is required, the plan should include items listed under 15.4.5 to bring the ship out of inferior performance; and

.8 where relevant, identification of critical factors that contributed to missing the CII target.

14 REVIEW AND UPDATE OF PART III OF THE SEEMP

14.1 Regulation 26.1 of MARPOL Annex VI provides: "Each ship shall keep on board a ship-specific Ship Energy Efficiency Management Plan (SEEMP). This may form part of the ship's safety management system. The SEEMP shall be developed and reviewed, taking into account guidelines adopted by the Organization". Regulation 26.3.2 of MARPOL Annex VI provides: "For ships rated as D for three consecutive years or rated as E, in accordance with regulation 28 of this Annex, the SEEMP shall be reviewed in accordance with regulation 28.8 of this Annex to include a plan of corrective actions to achieve the required annual operational CII".

14.2 The company should ensure that the SEEMP is reviewed and updated when necessary, as per paragraph 9.10.

14.3 The SEEMP should include a log for when it has been reviewed and updated and identify which parts have been changed.

15 PLAN OF CORRECTIVE ACTIONS

15.1 A plan of corrective actions is not required to be included in the SEEMP unless a ship has been rated D for three consecutive years or E for one year.

15.2 For a ship that is required to develop a plan of corrective actions in accordance with regulation 28.7 of MARPOL Annex VI, a revised SEEMP including the corrective actions for CII reduction shall be submitted to the Administration or any organization duly authorized by it for verification in accordance regulation 28.8 of MARPOL Annex VI. The revised SEEMP should be submitted together with, but in no case later than one month after reporting the attained annual operational CII in accordance with regulation 28.2.

15.3 Regulation 28.9 of MARPOL Annex VI further provides that "A ship rated as D for three consecutive years or rated as E shall duly undertake the planned corrective actions in accordance with the revised SEEMP."

15.4 **Developing the plan of corrective actions**

15.4.1 The purpose of the plan of corrective actions is to set out what actions a ship that was rated D for three consecutive years or E for one year should take to achieve at least a C rating for the calendar year following the adoption of the plan of corrective actions and ultimately the required annual operational CII.

15.4.2 The plan of corrective actions is ship-specific.

15.4.3 Many of the approaches described in section 5 of these guidelines or any other suitable measure may be applied to a ship to improve its fuel efficiency and thus its CII rating.

15.4.4 The plan for corrective action should describe the actions that the ship plans to take, the timeline in which those actions will be applied, and the expected impact their application will have on the ship's CII rating. It should be demonstrated how the corrective actions will contribute to achieving the required annual operational CII, so as to ascertain the effectiveness of the corrective actions. Experience gained from previously taken corrective actions and their degree of effectiveness should be taken into account when selecting the proper corrective actions.

15.4.5 The plan of corrective actions should be SMART (Specific, Measurable, Achievable, Realistic, and Time-bound). It should include:

.1 an analysis of the cause of the inferior CII rating;

.2 an analysis of the performance of implemented measures;

.3 a list of additional measures and revised measures to be added to the implementation plan with time and method of implementation necessary for achieving the required operational CII;

.4 designation of a company person to be responsible for the added and revised measures in the implementation plan, monitoring and recording performance throughout and reviewing of the effectiveness of the corrective actions; and

.5 identification of possible impediments to the effectiveness of the measures for improving the energy efficiency and reducing the carbon intensity of the ship, including possible additional contingency measures put in place to overcome and how these impediments will be overcome.

15.4.6 The implementation of the plan of corrective actions should be monitored and adjusted when necessary. Additional measures should be taken to strengthen corrective actions in case of insufficient intermediate results.

15.4.7 The company should ensure that it is in a position to perform the actions set out in the plan of corrective actions and confirm that it is able to do so when submitting its updated SEEMP.

APPENDIX 1

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

Name of ship:		Gross tonnage:	
Ship type:		Capacity:	
IMO number:			

Date of development:		Developed by:	
Implementation period:	From: Until:	Implemented by:	
Planned date of next evaluation:			

Review and update log

Date/timeline	**Updated parts**	**Developed by**	**Implemented by**

1 MEASURES

Energy efficiency measures	**Implementation** (including the starting date)	**Responsible personnel**

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 Review and update log

Date/timeline	Updated parts	Developed by	Implemented by

2 Ship particulars

Name of ship	
IMO number	
Company	
Flag	
Year of delivery	
Ship type	
Gross tonnage	
NT	
DWT	
Attained EEDI (if applicable)	
Attained EEXI (if applicable)	
Ice class	

3 Record of revision of Fuel Oil Consumption Data Collection Plan

Date of revision	Revised provision

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

	Engines or other fuel oil consumers	Power	Fuel oil types
1	Type/model of main engine	(kW)	
2	Type/model of auxiliary engine	(kW)	
3	Boiler	(…)	
4	Inert gas generator	(…)	

5 Emission factor

C_F is a non-dimensional conversion factor between fuel oil consumption and CO_2 emission in the *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73)), 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.

Fuel oil type	C_F (t-CO_2 / t-Fuel)
Diesel/Gas oil (e.g. ISO 8217 grades DMX through DMB)	3.206
Light fuel oil (LFO) (e.g. ISO 8217 grades RMA through RMD)	3.151
Heavy fuel oil (HFO) (e.g. ISO 8217 grades RME through RMK)	3.114
Liquefied petroleum gas (LPG) (Propane)	3.000
Liquefied petroleum gas (LPG) (Butane)	3.030
Liquefied natural gas (LNG)	2.750
Methanol	1.375
Ethanol	1.913
Other (………)	

6 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.

Method	Description

7 Method to measure distance travelled

Description

8 Method to measure hours under way

Description

9 Processes that will be used to report the data to the Administration

Description

10 Data quality

Description

APPENDIX 2*bis*

SAMPLE FORM OF SHIP OPERATIONAL CARBON INTENSITY PLAN (PART III OF THE SEEMP)

1 Review and update log

Date/timeline	Updated parts	Developed by	Implemented by
<1st time>			
<2nd time>			
Etc.			

2 Required CII over the next three years, attained CII and rating over three consecutive years

Name of the ship		IMO number		
Company		Year of delivery		
Flag		Ship type		
Gross tonnage		DWT		
Applicable CII		☐AER ; ☐cgDIST		
Year	Required annual operational CII	Attained annual operational CII (before any correction)	Attained annual operational CII	Operational carbon intensity rating (A, B, C, D or E):
<year -1>				
<year -2>				
<year -3>				

	Required annual operational CII
<year>:	
<year + 1>	
<year + 2>	

3 Calculation methodology of the ship's attained annual CII, including required data and how to obtain these data as far as not addressed in part II

Description

4 Three-year implementation plan

Description

Company personnel to be responsible for the three-year implementation plan, monitoring and recording performance

List of measures to be considered and implemented

Measure	Impact on CII	Time and method of implementation and responsible personnel	Impediments and contingency measures
		Milestone / Due / Responsible	Impediment / Contingencies
		Milestone / Due / Responsible	Impediment / Contingencies
		Milestone / Due / Responsible	Impediment / Contingencies
		Milestone / Due / Responsible	Impediments / Contingencies

Calculation showing the combined effect of the measures and that the required operational CII will be achieved

Year	Required annual operational CII	Targeted operational annual CII	Targeted rating
<year>:			
<year + 1>			
<year + 2>			

5 Self-evaluation and improvement

Description

6 Plan of corrective actions (if applicable)

Analysis of causes for inferior CII rating

Cause	Analysis of effect	Actions

Analysis of measures in the implementation plan

Measure	Analysis of effect	Actions

List of additional measures and revised measures to be added to the implementation plan

Measure	Impact on CII	Time and method of implementation and responsible personnel			Impediments and contingency measures	
		Milestone	Due	Responsible	Impediments	Contingencies

APPENDIX 3

STANDARDIZED DATA REPORTING FORMAT FOR THE DATA COLLECTION SYSTEM AND OPERATIONAL CARBON INTENSITY TO THE ADMINISTRATION

Name of the ship		IMO number	
Company		Year of delivery	
Flag		Ship type	
Gross tonnage		DWT	
Applicable CII		☐AER ; ☐cgDIST	
Operational carbon intensity rating		□A ; □B ; □C ; □D ; □E	
CII for trial purpose (none, one or more on voluntary basis)		□EEPI ; □cbDIST ; □clDIST ; □EEOI	

Attained annual operational CII before any correction (AER in g CO_2/dwt.nm or cgDIST in g CO_2/gt.nm)	
Attained annual operational CII (AER in g CO_2/dwt.nm or cgDIST in g CO_2/gt.nm)	
End date for annual CII (dd/mm/yy)*	
Start date for annual CII (dd/mm/yy)*	
Attained EEDI (if applicable)	
Attained EEXI (if applicable)	
EEPI (gCO_2/dwt.nm)	
cbDIST (gCO_2/berth.nm)	
clDIST (gCO_2/m.nm)	
EEOI (gCO_2/t.nm or others)	
……	
……	
IMO number	
End date for DCS (dd/mm/yy)	
Start date for DCS (dd/mm/yy)	

APPENDIX 4

STANDARDIZED DATA REPORTING FORMAT FOR THE PARAMETERS TO CALCULATE THE TRIAL CARBON INTENSITY INDICATORS ON VOLUNTARY BASIS*

Attained annual EEOI	
Metric of Cargo Mass Carried or Work Done in EEOI calculation (gCO_2/t.nm or others)*****	
Transport work*****	
Attained annual EEPI (gCO_2/dwt.nm)	
Laden distance travelled (n.m)	
Attained annual clDIST (gCO_2/m.nm) ****	
Length of lanes (metre) ****	
Attained annual cbDIST(gCO_2/berth.nm) ***	
Available lower berths***	
End date for trial CII (dd/mm/yy)**	
Start date for trial CII (dd/mm/yy)**	
IMO number**	
End date for DCS (dd/mm/yy)**	
Start date for DCS (dd/mm/yy)**	

* For reporting a trial CII, the data should be reported as applicable taking into account the information already provided in appendix 3.

** Consistent with appendix 3.

*** Only applicable to cruise passenger ships.

**** Only applicable to ro-ro ships.

***** As defined in section 3 of *Guidelines for voluntary use of the ship energy efficiency operational indicator (EEOI)* circulated by MEPC.1/Circ.684. The distance travelled shall be determined from berth of the port of departure to berth of the port of arrival and shall be expressed in nautical miles.

***

No. 175
(Apr 2023)

SEEMP/CII Implementation Guidelines

Introduction

These guidelines have been developed to provide further guidance on implementation of

1. 2022 Guidelines for the development of a Ship Energy Efficiency Plan (SEEMP) - Resolution MEPC.346 (78), hereafter referred as “SEEMP Guidelines”

2. Guidelines for the verification and company audits by the Administration of Part III of the Ship Energy Efficiency Plan (SEEMP) – Resolution MEPC.347 (78), hereafter referred as “SEEMP Verification Guidelines”.

3. 2022 Guidelines on Operational Carbon Intensity Indicators and the Calculation Methods (CII Guidelines, G1) – Resolution MEPC.352 (78).

4. 2022 Guidelines on the Reference Lines for Use with Operational Carbon Intensity Indicators (CII Reference Lines Guidelines, G2) – Resolution MEPC.353 (78).

5. 2021 Guidelines on the Operational Carbon Intensity Reduction Factors relative to Reference Lines (CII Reduction Factors Guidelines, G3) - Resolution MEPC.338 (76).

6. 2022 Guidelines on the Operational Carbon Intensity Rating of Ships (CII Rating Guidelines, G4) – Resolution MEPC.354 (78).

7. 2022 Interim Guidelines on Correction Factors and Voyage Adjustments for CII Calculations (CII Guidelines, G5) - Resolution MEPC.355 (78).

The document may be updated whenever new issues are brought to the attention of IACS.

1 Objective

These guidelines aim to address issues in relation to SEEMP/CII verification and provide guidance for supporting the implementation of IMO SEEMP/CII as per reg. 26 and 28 of MARPOL Annex VI. In the context of SEEMP, the emphasis is on implementation of SEEMP Part III, specifically, as per reg. 26.3.

2 Inter-relation between various Parts of SEEMP

The inter-relation between the various parts of SEEMP is shown in figure 2.1.

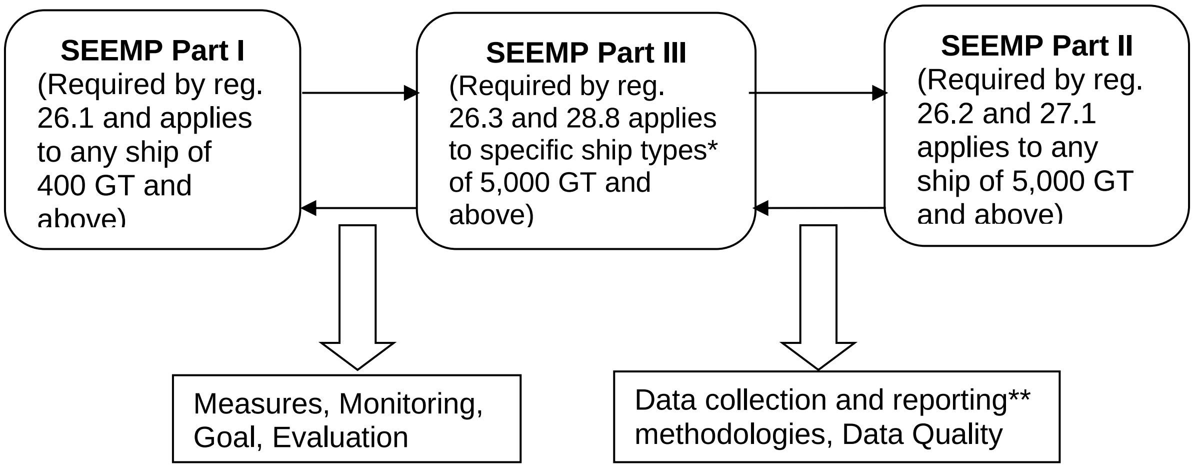

Figure 2.1 Inter-relation between various parts of SEEMP

Note: *Bulk Carrier, Combination carrier, Containership, Cruise passenger ship, Gas carrier, General cargo ship, LNG carrier, Refrigerated cargo carrier, Ro-ro cargo ship, Ro-ro cargo ship (vehicle carrier), Ro-ro passenger ship, Tanker. As per MARPOL Regulation 19.3, Regulation 28 shall not apply to category A ships as defined in the Polar Code. Therefore, unless advised otherwise by Flag Administration, Regulation 26.3 is not considered applicable to Category A ships as defined in the Polar Code. **The data reporting for vessels that operate in international waters only during a limited period of the year and the rest of the year operate in national waters (that may be or not the same Flag they fly) is subject to the respective Administration's requirements.

2.1 SEEMP Part I provides a generic approach to monitor ship and fleet efficiency performance over time and describes various energy efficiency measures to improve the ship's energy efficiency performance and reduce carbon intensity.

2.2 SEEMP Part II provides a description of the methodologies that will be used to collect data on fuel oil consumption (method of fuel collection, fuel type and quantity), distance travelled and hours underway.

2.3 SEEMP Part III provides an implementation plan on how the attained annual operational CII will be maintained less than or equal to the required annual operational CII for the next three years. It also describes the required data for the calculation of CII and methodologies to obtain relevant data if not addressed in SEEMP Part II.

2.4 The calculation of the attained CII is based on the verified fuel oil consumption data collected by implementation of methodologies described in SEEMP Part II and if relevant, adjusted as per interim guidelines on correction factors and voyage adjustments for CII calculations (G5 guidelines, resolution MEPC.355(78)).

2.5 For those ships where SEEMP Part III is applicable, following sections of SEEMP Part I should be revised by the Company as needed to reflect the actions taken in SEEMP Part III to maintain consistency with the requirements of regulation 28 of MARPOL Annex VI.

- Measures (consistent with list of measures considered and implemented in three-year implementation plan)
- Monitoring (consistent with data required for calculation methodology of attained annual operational CII, milestones described in three-year implementation plan)

- Goal (consistent with the required annual operational CII)

- Evaluation (consistent with the self-evaluation and improvement described in three-year implementation plan)

3 Data transfer in case of change of company and/or Administration

Partial year data transfer

3.1 In case of transfer of the ship from one company to another (irrespective of change in Administration), the former company should get the partial data (for the operated period) verified by the relevant Administration or any organization duly authorized by it and transfer the verified data with the supporting documents to the receiving company within one month after the date of transfer (day of completion of the change or as close as practical thereto report). In this regard, any company which intends to transfer the ship to another company should make early arrangements so that the verification of the data is completed within one month after the date of transfer. Companies are therefore advised to establish procedure(s) in their management system which ensures that the data is submitted for verification and transferred to the new company within one month after the date of transfer. In case of change of company and the Administration, the receiving company should obtain the data verified by the losing Administration or any organization duly authorize by it for the partial period of the calendar year when the transfer takes place. Receiving Administration will use the verified partial data to verify the calculation of the attained annual operational CII for the whole year. The receiving company should review the previously verified SEEMP Part III and may update as necessary in-line with company's practices before submitting it to the Administration/RO for verification.

3.2 In any case if no such verified or non-verified partial data is available from the former company, the receiving company can calculate the Attained annual operational CII using the available data (engine room log, noon reports, bunker delivery notes, AIS data, etc.) covering a period as long as practically possible.

Whole calendar year data transfer

3.3 In case the former company does not transfer the verified data (when available) for the whole calendar year when the transfer takes place in early months of the next calendar year, the receiving company should request the losing as well as gaining Administration to make relevant data (submitted to the IMO Fuel Oil Consumption Database) available to them for calculating the Attained annual CII.

3.4 In case the former company does not transfer the non-verified data for the whole calendar year when the transfer takes place in early months of the next calendar year, the receiving company can calculate the Attained annual operational CII using the available data (engine room log, noon reports, bunker delivery notes, AIS data, etc.) covering a period of the preceding calendar year as long as practically possible.

No. 175 (cont)

4 CII reduction factors

4.1 Resolution MEPC.338(76) provides reduction factors to calculate required annual operational CII value up to year 2026 only. For the SEEMP Part III which will be developed in 2025 year (as a part of mandatorily update after every three years) to include implementation plan for next three years (2026-2028), it is expected that the CII reduction factors for 2027 and 2028 years will be available by the end of 2025.

In case CII reduction factors are not available for the complete 3-year period at the time of developing the SEEMP III the required annual operational CII can be left blank for the year(s) where the reduction factor is not available (e.g. 2027 for a 2025 to 2027 plan), However the SEEMP Part III should be updated later with the required annual operational CII when those CII reduction factors are determined.

4.2 Taking into account, future progressive increase in reduction factors for required annual CII, a company may set a voluntary target annual CII that is different from the IMO requirement (required annual CII) but must be more stringent than the latter (required annual CII). However, when a vessel achieves IMO required annual CII and could not achieve the voluntary target, such non-achievement should not be considered as company audit finding.

Any such case may be analysed by the company, with the aim to identify the reasons for non-achieving a set voluntary target annual CII, and the results of the analysis may be used by the company in case of any future setting of annual CII.

5 Self-evaluation and improvement

5.1 The purpose of self-evaluation is to evaluate the effectiveness of the measures aimed to achieve required annual operational CII at the planned milestone. In this process, a CII investigation study can be undertaken by the company. Instead of simplistic annual average speed or annual single speed-power curve, the vessel performance model could combine operational data, draughts, speeds, encountered weather (i.e. combined AIS and Hindcast MetOcean data) with vessel's technical data. The CII investigation study when evaluating the performance should include the results of the measures which are described in the three-year implementation plan of SEEMP Part III.

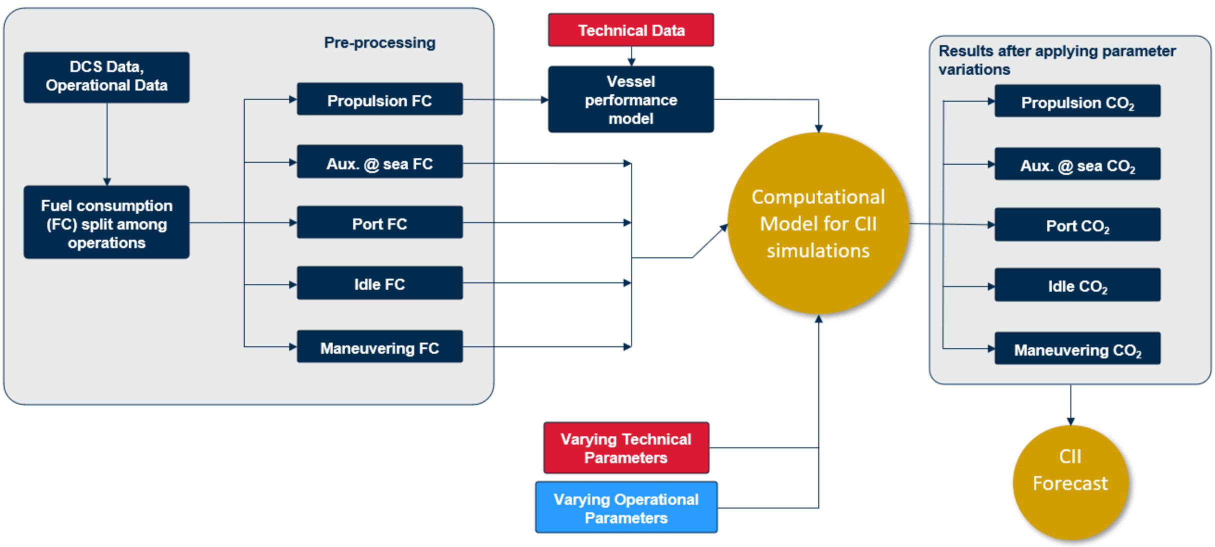

Figure 5.1 Sample CII investigation study methodology

No.
175
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5.2 Alternative procedures can also be described and implemented to demonstrate impact of adopted energy efficiency measures through the self-evaluation and improvement process. In a simpler way, based on the studies performed for which the data/claim is available in published form, approximate reduction potential of the energy efficiency measure can be used directly from such studies. The calculation of the forecasted operational CII should still consider the vessel' technical characteristics and operational profile as far are practicable. For example, for an energy efficiency measure whose published studies show that 5% reduction in fuel consumption can be achieved, the potential reduction may be converted to attained CII by assuming that the distance travelled remains same for the whole year service.

5.3 The effect of the adopted energy efficiency measures should be measurable and provide data to perform self-evaluation. Documentation relevant to self-evaluation and improvement should be maintained. In case, the self-evaluation concludes that a certain energy efficiency measure is not effective towards achieving required CII, additional measures should be identified or existing measures should be amended for improvement by performing root cause and effect analysis. In such a case, SEEMP Part III needs to be revised as part of improvement process and re-verification should be followed.

5.4 The monitoring frequency of the CII performance should be decided based on the best compromise to ensure sufficient precision and reduce the work burden. This frequency and the triggers for action, dependent on the deviation from the target CII, should be identified. For instance, a company may decide that if the CII is greater than the target by x%, then the monitoring frequency may be increased. Whilst if the CII is greater than the target by y%, then concerned higher authority/management level at shore to be informed, an investigation to commence, etc.

No. 175 (cont)

6 Corrective actions plan (CAP)

6.1 MEPC.346(78) para 15.4.1 reads as *the purpose of the plan of corrective actions is to set out what actions a ship that was rated D for three consecutive years or E for one year should take to achieve the required annual operational CII*.

In case a ship requires to develop a CAP, a revised SEEMP Part III including the corrective actions for CII reduction should be submitted to the Administration or any organization duly authorized by it for verification under the requirement of additional verification (regulation 6.8 of MARPOL Annex VI) as described in section 7.3 of this guidelines. Figure 6.1 illustrates the process of SEEMP Part III and Corrective Actions Plan (CAP).

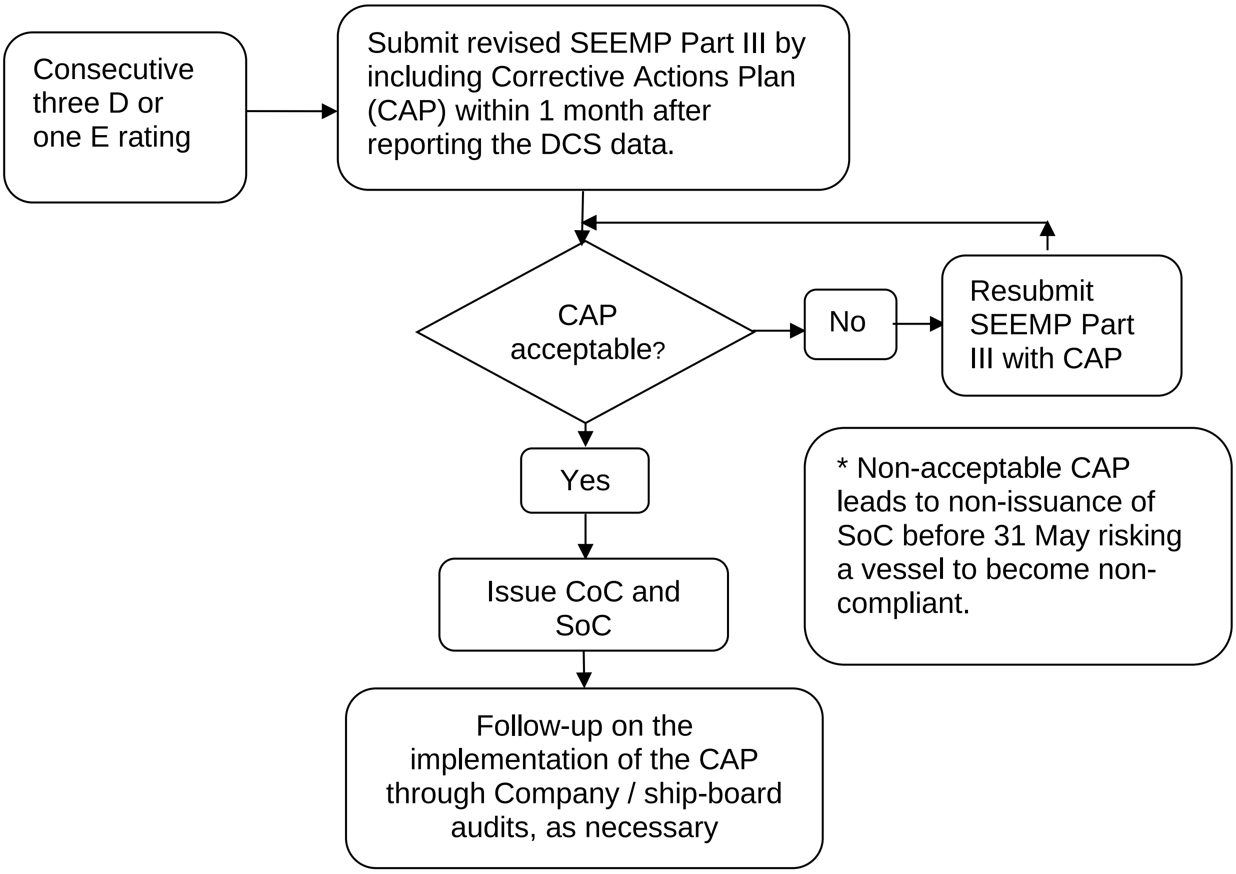

Figure 6.1 Corrective Actions Plan process flow

6.2 In accordance with MEPC.1/Circ.795 (UI 20), *in case an inferior rating* 'E' or third time 'D' consecutively *is given for data collected in calendar year 'YYYY'* (e.g. 2023), *the revised SEEMP including the plan of corrective actions should be verified in year 'YYYY+1'* (i.e 2024), *and it should be developed to achieve the required annual operational CII for data collected in the calendar year 'YYYY+2'* (i.e. 2025).

Upon identification of need of CAP and its acceptance (within revised SEEMP Part III) by end of May YYYY+1, a vessel will get approximately 19 months (from June YYYY+1 to end of YYYY+2) of time to achieve the required annual operational CII. However, the required annual operational CII also becomes more stringent after 19 months. Therefore, CAP should be developed appropriately to achieve the required annual operational CII.

No. 175 (cont)

In case the CAP is made in the last year of the three-year period, the CAP should be included in the SEEMP III for the next three-year period and the additional or revised measures should be integrated with the other planned measures.

It is recommended to establish intermediate milestones to be achieved with timelines followed by self-evaluation and analysis of the attained CII trend and if the trend is not indicating improvement in attained CII values, the implementation of corrective actions plan should be strengthened.

6.3 The revised SEEMP Part III should be submitted together with, but in no case later than one month after reporting the attained annual operational CII that is along with the annual fuel oil consumption data to be reported as per Appendix 3 of SEEMP guidelines (resolution MEPC.346(78)). Company is advised to be pro-active into assessing if a vessel's attained annual operational CII would be less than the required annual operational CII and if a Corrective Actions Plan is needed in the coming reporting period.

6.4 In case of repeated E rating or more than three consecutive D rating, a new corrective actions plan should be created to ensure that the vessel achieves the required rating. The new corrective actions plan may be developed based on the previous version or may be entirely new.

An analysis of the cause of the inferior rating should be undertaken to ensure that any ineffective part of the previous corrective actions plan is replaced or improved in the new plan.

6.5 The preparation of corrective actions plan should start with investigation of the inferior CII rating and determination of the root cause considering all the aspects of ship operations where fuel is consumed. Analysis of effect of each cause on the CII rating should be performed and followed with the necessary corrective actions in order to avoid recurrence of the cause. Also, analysis of already implemented measures as per the implementation plan should be performed to know which measures are contributing to the inferior CII rating. Results of the self-evaluation can also be used as the basis for the analysis, for example referring to a CII investigation study or alternative procedures in section 5 of these guidelines.

6.6 The CAP should include a root cause analysis, the self-evaluation described in the SEEMP Part III and any other relevant investigation, to determine the cause of the inferior CII. Corrective actions to improve the CII rating should be devised, ensuring that these actions are achievable, measurable and time bound. Objective supporting documentation for each measure needs to be maintained and produced during the company audit.

6.7 Within three-years plan (eg. 2023-2025), if a vessel achieves the required CII value for the data collection year YYYY+1 (e.g. 2024 data verified in 2025) by effective implementation of the Corrective Actions Plan that was developed in the year YYYY+1 (i.e. 2024), the CAP may be retained as a part of SEEMP Part III until end of the year YYYY+2 (i.e. 2025). The SEEMP Part III may be reviewed in view of considering measures of CAP for their inclusion in its next three-year implementation plan and CAP may be removed.

7 SEEMP verification and documentation

In general, the aim of SEEMP Part III verification is to ensure that the SEEMP Part III complies with regulation 26.3.1 of MARPOL Annex VI in accordance with regulation 5.4.6 (initial verification and periodical verification) and in accordance with regulation 6.8 (additional verification for corrective actions plan).

SEEMP Part III verification (initial, periodical, and additional) should be based on documentary evidence.

Despite of the supporting documentation as required in sections 7.1 to 7.3 of these Guidelines for the verification of SEEMP Part III, in order to ensure that the individual energy efficiency measure or their combination included in the implementation plan are adequate to achieve the required annual CII, it is recommended to submit following minimum documentation along with SEEMP Part III.

a) Copy of latest SEEMP Part I kept on-board (if referred to in the SEEMP Part III)

b) Copy of latest verified SEEMP Part II kept on-board

   Note: SEEMP Part II does not need to be revised and verified against the 2022 Guidelines for the development of SEEMP (MEPC.346(78)), unless the company resubmits this plan due to a change of flag, change of company or change of data collection methodology for fuel, distance and hours underway.

7.1 Initial verification

Initial verification should be performed to verify that SEEMP Part III of all vessels which are in service on 1 January 2023 complies with regulation 26.3.1 of MARPOL Annex VI and on satisfactory assessment of the SEEMP Part III, the Administration, or any organization duly authorized by it, issues the Confirmation of Compliance which is to be retained on board the vessel.

For vessels which are delivered after 1 January 2023, the initial verification should be performed, and Confirmation of Compliance should be issued and kept on board the vessel.

Verification could consist, but not be limited to, the following elements:

1. verification of the method of calculations of the attained CII complying with G1 guidelines (resolution MEPC.352(78) and G5 guidelines on correction factors and voyage adjustments for CII calculations MEPC.355 (78)) including the methodologies to collect data relevant to above calculations;

   Note: The vessel's actual capacity (DWT or GT) should be used for the calculation of attained annual operational CII value irrespective of application of voyage adjustments and correction factors.

2. verification of required CII complying with G2 and G3 guidelines (resolution MEPC.353(78) and 338(76));

   Note: The vessel's actual capacity (DWT or GT) or the threshold Capacity (as applicable) given in Table 1 of G2 guidelines (resolution MEPC.353(78)) should be used for the calculation of required annual operational CII value.

No. 175 (cont)

3. verification of the description of the method to report ship data to the Administration complies with Appendix 3 of SEEMP guidelines (resolution MEPC.346(78));

4. verify that the implementation plan is prepared in line with the format provided in Appendix 2bis of MEPC.346(78);

5. assess the effectiveness (of the combination) of measures, so that when implemented the ship will with reasonable assurance achieve the required annual operational CII, including the goal as set in accordance with paragraph 4.1.7 and 9.7 of the SEEMP Guidelines;

6. verify that self-evaluation is planned to improve the implementation actions if necessary;

7. identification of impediments during the course of implementation plan execution and remedial actions;

8. robustness of the three-year implementation plan through imparting adequate training to the responsible personnel, implementing data collection-communication-storage system, changes in company's internal documentation, procedures and audit system for shore and on-board operations relevant to the implementation plan, etc.;

Supporting documentation to be submitted: Company should submit following documentation along with its completely filled SEEMP Part III and any other supporting documents as requested by the Administration, or any organization duly authorized by it.

a) Verified SEEMP Part II on methodologies on the Fuel Oil Data Collection System pursuant to regulation 27 of MARPOL Annex VI (to verify that the data and relevant data collection process used for the calculation of ship's attained annual operational CII are in line with this methodology).

7.2 Periodical verification

After the initial verification done before 01 January 2023, vessels' SEEMP Part III should be revised for the following cases. The revised SEEMP shall be verified the Administration, or any organization duly authorized by it, to ensure the SEEMP complies with regulation 26.3.1 of MARPOL Annex VI and Confirmation of Compliance be re-issued. Administrative changes not subject to regulation 26.3.1 and changes other than the following cases may be done without verification. In any case, the original timeline (i.e. the start and end years) of the Three-year implementation plan will remain.

Case 1: Change of company and/or Administration after initial verification

A new SEEMP III will be required in this case as stated in MEPC.1/Circ.795/Rev.7 (UI 19.2).

In the case of change of Administration (and no change of company) and SEEMP Part III being remain same for the vessel, the periodical verification could consist of verifying following elements:

1. the attribute 'Flag' to verify gaining Administration
2. year of the transfer is the first year of the three-year implementation plan
3. in case, the vessel was assigned CII rating in previous year(s), verify that CII values and rating

No. 175 (cont)

In the case of change of company (irrespective of change of Administration), the periodical verification could consist of the verification elements as described in section 7.1 of these Guidelines. Additional elements of verification could consist, but not be limited to:

1. Verification of name of gaining company and/or Administration
2. Verify year of the transfer is the first year of the three-year implementation plan
3. company obtained relevant verified (partial) data (with supporting documents) from the former company necessary for the calculation of the attained annual operational CII
4. in case, the vessel was assigned CII rating in previous year(s), verify that CII values and rating.

Supporting documentation (in addition to those described in section 7.1 of these Guidelines) to be submitted:

a) Document of Compliance (DOC) issued to the company
b) Vessel's Safety Management Certificate (SMC) certificate
c) Vessel's Certificate of Classification
d) Previously verified SEEMP Part III and Confirmation of Compliance certificate
e) documentation showing verification of partial data received from former company
f) Statement of Compliance certificates for last three years

Case 2: Addition and/or deletion of energy efficiency measure(s) impacting CII calculation in implementation plan as a result of the self-evaluation and improvement, change in methodology to calculate CII values

Verification could consist, but not be limited to, the following elements:

1. verification of the method of calculations of the attained CII complying with G1 guidelines (resolution MEPC.352(78) and G5 guidelines on correction factors and voyage adjustments for CII calculations MEPC.355 (78)) including the methodologies to collect data relevant to above calculations

2. assess the effectiveness (of the combination) of measures, so that when implemented the ship will with reasonable assurance achieve the required annual operational CII, including the goal as set in accordance with paragraph 4.1.7 and 9.7 of the SEEMP Guidelines;

3. verify that self-evaluation is planned to improve the implementation actions if necessary

4. identification of impediments during the course of implementation plan execution and remedial actions;

5. robustness of the three-year implementation plan through imparting adequate training to the responsible personnel, implementing data collection-communication-storage system, changes in company's internal documentation, procedures and audit system for shore and on-board operations relevant to the implementation plan, etc.

Supporting documentation to be submitted:

a) Records of self-assessment and decisions made which resulted in modification to the original energy efficiency measures, adoption of additional corrections factors or change in calculation methodology etc.;

b) Verified SEEMP Part II on methodologies on the Fuel Oil Data Collection System pursuant to regulation 27 of MARPOL Annex VI (to verify that the data and relevant data collection process used for the calculation of ship's attained annual operational CII are in line with this methodology).

Case 3: Major conversion (change in dimensions, carrying capacity or engine power, ship type) done after initial verification as an action on adopted energy efficiency measures or on deterioration of CII rating

Verification could consist, but not be limited to:

1. verification of elements of major conversion (dimensions, carrying capacity or engine power, ship type)

2. date of major conversion to ensure conversion is done after initial verification

3. verification of the method of calculations of the attained CII (before and after conversion) complying with G1 guidelines (resolution MEPC.352(78), G5 guidelines on correction factors and voyage adjustments for cii CII calculations MEPC.355 (78)) including the methodologies to collect data relevant to above calculations and para 5.4, 5.5 of resolution MEPC.348(78)

4. verification of the method of calculation of required CII complying with G2 and G3 guidelines (resolution MEPC.353(78) and 338(76)) and para 5.4, 5.5 of resolution MEPC.348(78)

5. assess the effectiveness (of the combination) of measures, so that when implemented the ship will with reasonable assurance achieve the required annual operational CII, including the goal as set in accordance with paragraph 4.1.7 and 9.7 of the SEEMP Guidelines

6. verify that self-evaluation is planned to improve the implementation actions if necessary

7. identification of impediments during the course of implementation plan execution and remedial actions

8. robustness of the three-year implementation plan through imparting adequate training to the responsible personnel, implementing data collection-communication-storage system, changes in company’s internal documentation, procedures and audit system for shore and on-board operations relevant to the implementation plan, etc.

Supporting documentation to be submitted: Same as those described in section 7.1 of these Guidelines.

Case 4: Every three years after initial verification

A SEEMP Part III should be revised (before the end of the last year in the Three-year implementation plan) and re-verified every three years (e.g. for a ship delivered prior to 1January 2023, before 2026 for 2026-2028 period, before 2029 for 2029-2031 period)

In such as case, section 7.1 of these Guidelines to be referred for verification activities and supporting documentation. Additionally, section 2 of the revised SEEMP Part III is to be verified to ensure that CII values and rating of the previous three years are described.

Supporting documentation (in addition to those described in section 7.1 of these Guidelines) to be submitted:

a) Previously verified SEEMP Part III and Confirmation of Compliance certificate
b) Statement of Compliance certificates for last three years

7.3 Additional verification

Starting with the first CII verification in 2024, if a ship is rated as D for three consecutive years or E for one year, SEEMP Part III should be reviewed and updated by inclusion of corrective actions plan. The plan of corrective actions shall list additional measures and revised measures to be added to the three-year implementation plan necessary for achieving the required CII. The updated SEEMP Part III shall be submitted for re-verification to ensure that a plan of corrective actions has been established in accordance with regulations 28.7 and 28.8 and re-issuance of the Confirmation of Compliance. An example is given in Table 7.1 explaining the additional verification case.

Table 7.1 Example of additional verification in case of three consecutive D or E rating for ships delivered before 1 January 2023

Verification Year	2023	2024	2025	2026	2027	2028
Data year	-	2023	2024	2025	2026	2027
Case 1 - CII rating	-	**E**	C(*)	C	B	C
Case 2 - CII rating	-	C	D	**E**	C(*)	C
Case 3 - CII rating	-	**D**	**D**	**D**	C(*)	C
Remarks	Initial SEEMP without corrective actions plan.	For case 1: SEEMP to be revised by including corrective actions plan to achieve the required annual operational CII for data collected in the calendar year 2025 and to be submitted for verification (additional verification).		For cases 2 and 3: SEEMP to be revised by including corrective actions plan to achieve the required annual operational CII for data collected in the calendar year 2027 and submitted for verification (additional verification).		
	By the end of 2025 updated SEEMP should be prepared and submitted for verification under periodical verification.			By the end of 2028 updated SEEMP should be prepared and submitted for verification under periodical verification.		

Note: (*) - C rating and above should remain the objective for each ship for which an inferior rating is given for data collected in calendar year YYYY. But taking into account the

No. 175 (cont)

provisions of paragraph 15.4.1 of Res. MEPC.346(78), and MEPC.1/Circ.795 (UI 20) on a case-by-case basis, a lower rating may be accepted provided a route plan is established in the SEEMP, taking into account the provisions in paragraph 6.2 of these guidelines, to achieve the required annual operational CII for data collected in calendar year YYYY+2.

Similarly, if the ship is rated as D in years 2024, 2025 and 2026 for data of 2023, 2024 and 2025 respectively, the SEEMP Part III should be updated in 2026 by including corrective actions plan to be implemented in 2026 and 2027 and submitted for re-verification and re-issuance of the Confirmation of Compliance.

On satisfactory verification of the plan of corrective actions included in the revised SEEMP Part III i.e. re-issuance of the Confirmation of Compliance, the Administration/RO can issue the Statement of Compliance.

Additional verification could consist (in addition to those described in section 7.1 of these Guidelines), but not be limited to, the following elements:

1. verify that the corrective actions plan is necessary for the subject vessel.

2. verification of corrective actions plan that it has been developed in the format prescribed by Appendix 2bis of the SEEMP Guidelines.

3. verification of the planned timelines for application of actions described in corrective actions plan.

4. assess the effectiveness (of the combination) of corrective actions (measures), so that when implemented the ship will with reasonable assurance achieve the required annual operational CII.

5. verify that company is able to perform the actions set out in the plan of corrective actions.

Supporting documentation to be submitted:

a) previously verified SEEMP Part III and Confirmation of Compliance certificate.

b) Statement of Compliance certificates for last three years.

c) documentation in support of analysis of the cause for the inferior CII rating.

d) documentation in support of analysis of the performance of measures in the previous implementation plan.

e) documentation in support of additional and revised measures added to the implementation plan.

f) possible impediments to the effectiveness of the additional measures and relevant contingency measures put in place to overcome these impediments.

No. 175 (cont)

8. Audits

8.1 Company audits

MARPOL Annex VI Regulation 26.3.3 requires that the SEEMP is subject to company audits for ships required to comply with MARPOL Annex VI Reg 28. According to MEPC.347(78), external company audits should be carried out periodically.

The aim of an audit is to verify that the effectiveness of the system and that the SEEMP is implemented by the Company and onboard its fleet. To minimize the administrative burden to the companies, to the ships and to the Administration/RO the Company audit for SEEMP may be combined with ISM audits.

SEEMP audit and ISM audit are two distinct activities and date of conducting both audits may differ. General purpose of the SEEMP audits is to verify the implementation aspects, e.g. that the implementation plan is followed. SEEMP audit and ISM audit may be carried out during the same visit, as combined audit, by suitably qualified persons for each activity. However, when these two audits are carried out by two different ROs, at different dates, Company should be able to make available reports of previous audits.

A Company audit for implementation aspects of the SEEMP can be carried out based on documentary evidence which was sent to RO or Administration.

Company audits neither substitute nor duplicate the verification of the SEEMP leading to issuance of Confirmation of Compliance, or the verification of operational carbon intensity leading to issuance of Statement of Compliance.

Though the company audits are mandatory to conduct, the periodicity of company audit with mandatory nature is not specified in MARPOL Annex VI regulation 26.3.3. A Company may be audited every three years.

The purpose of the audit is to

1. verify that the SEEMP for which the Confirmation of Compliance has previously been issued complies with regulation 26.3.1 and, in the case of non-compliance, require remedial action.
   Guidance note: The SEEMP has already been verified for compliance. Consequently, the purpose of the audit is to verify that the personnel identified in the SEEMP are aware of their roles, responsibilities and duties, has received training as appropriate, and are receiving necessary support and resources to fulfill their role.

2. confirm that the each sampled ship is being operated in accordance with SEEMP part III, regardless of its rating.
   Guidance note: Whilst the Auditor is not expected to carry out calculations, the Auditor should request objective evidence that each measure or its contingency, has been implemented by the due date, as per SEEMP implementation plan.
   Verify that the implementation of the measures are progressing according to plan.
   Verify that the contribution of each measure to CII impact is being evaluated.
   Verify that the CII is being monitored.
   Verify other procedures associated with the SEEMP Part III.

3. verify the progress made in the (corrective) actions to be taken in the execution of the three-year implementation plan and the plan of corrective actions.
   Guidance note: This is applicable for vessels are rated D three consecutive years or rated E for one year. Verify the plan of corrective actions as per section .2 above.

4. verify self-assessment and improvement of actions taken; and
   Guidance note: Verify that this is carried out according to the plan, and the effectiveness of the process.

5. verify the assignment of responsibilities related to the implementation and monitoring of measures.
   Guidance note: Verify that this is carried out according to the plan, and the effectiveness of the process. Interview the responsible personnel. Check familiarity with plan and procedures, training level and availability of resources.

On fleet level, the company's policy and approach for implementation, monitoring, self-assessment, improvement and corrective actions should be focus for the audit, while SEEMP implementation for individual vessels should be assessed on a sampling basis.

8.2 Shipboard audit

SEEMP shipboard audit may be combined with ISM audit. Periodical shipboard audit is not required, unless the Administration decides otherwise if the company audit is concluded as non-satisfactory.

8.3 Audit execution and reporting

The audit shall be carried out in accordance with documented procedures. The audit result and any non-compliance identified at the audit shall be documented and brought to the attention of the Company. The verification audits may be carried out in accordance with guidelines on implementation of the ISM Code by Administrations, referred to in Chapter 15 of the ISM Code.

8.4 Qualifications of auditors

Persons performing SEEMP Company audits should have auditing experience (if audit is combined with the ISM audits).
Each RO shall define and document its requirements for qualification of personnel conducting company and shipboard audits.

No. 175 (cont)

9 LNG Carriers

9.1 Nitrogen (N_2) content correction

Boil-off-Gas (BoG) means vapour which results from evaporation of LNG in the cargo tanks. After cargo loading, heel and cargo gets mixed and there is no distinction being made between with respect to source of BoG. Practically, when BoG is used as fuel, it comes from both the heel and the cargo.

When calculating the fuel consumption for LNG ships, nitrogen mass content should be subtracted for each laden voyage from LNG consumption as it does not contribute to CO_2 emissions. To determine the quantity of nitrogen, certificates (e.g. Custody Transfer Management System (CTMS)), issued from terminals during loading and unloading of LNG certifying its quantity and quality information containing the composition of LNG components (including nitrogen) are to be used. Where such corrections are applied, the certificates of quantity and quality should be submitted for verification of annual fuel oil consumption and subsequent verification of CII.

In case, vessel is installed with gas chromatograph that can monitor real time nitrogen content in the gas flow to the engines, such reports should be submitted for verification of nitrogen subtraction from LNG. The volume will then be converted to mass by multiplication with the density.

CTMS based example for determining Nitrogen content in LNG for correction:

		LNG received		**LNG discharged**	
LNG Component	**Molecular Weight (Mi)**	**Molar Fraction (Xi)**	**Molecular Mass (Mi × Xi/100)**	**Molar Fraction (Xi)**	**Molecular Mass (Mi × Xi/100)**
Methane (CH_4)	16.042	94.95	15.232	96.52	15.484
Ethane (C_2H_6)	30.069	4.56	1.371	3.12	0.938
Propane (C_3H_8)	44.096	0.30	0.132	0.30	0.132
i-Butane (i-C_4H_{10})	58.122	0.04	0.023	0.02	0.012
N-Butane (n-C_4H_{10})	58.122	0.04	0.023	0.02	0.012
i-Pentane (i-C_5H_{12})	72.149	0.00	0.000	0.00	0.000
n-Pentane (n-C_5H_{12})	72.149	0.00	0.000	0.00	0.000
Hexane Plus (C_6H_{14})	86.175	0.00	0.000	0.00	0.000
Nitrogen (N_2)	28.013	0.11	0.031	0.02	0.006
Oxygen (O_2)	31.999	0.00	0.000	0.00	0.000
Carbon Dioxide (CO_2)	44.010	0.00	0.000	0.00	0.000
Total		100.00	16.812	100.00	16.584
Density (t/m^3)*		0.436		0.432	
Cargo loaded/discharged (m^3)		169603		166500	
Cargo loaded/discharged (t)		73946.91		71928.00	
LNG consumed during the voyage (t)		2018.91			
N_2 mass (t)		(169603×0.436×0.031) /16.812 = 136.35		(166500×0.432×0.006) / 16.584 = 26.02	
N_2 content (t) correction		110.33			

*When actual density value is not available, 0.422 t/m^3 may be used.

9.2 Gas Combustion Unit (GCU) consumption

Boil-off-Gas (BoG) burnt in GCU on-board, as a secondary means of controlling the tank pressure, is considered as fuel and shall be reported as part of the IMO DCS reporting. Measurement of BoG burnt in GCU can be performed by following ways:

- use the Custody Transfer Monitoring System (CTMS);

- Gas flow meters; although these are common only installed on the newer built ships. If gas is measured in volume, then it should be converted to mass using appropriate density, pressure and temperature corrections.

9.3 Gas Carriers built with the purposes of carrying LNG and having their IEEC changed from Gas Carriers to LNG Carriers

SEEMP Part III and CII requirements are applied based on the definitions in Regulation 2 of MARPOL Annex VI and separate definitions and ship categories for gas carriers (regulation 2.26) and LNG carriers (regulation 2.38) are defined.

For the purposes of compliance with SEEMP Part III and CII, an LNG carrier will be an LNG carrier regardless of when ship has been delivered and the ship type applied when her SEEMP Part III and CII was verified.
Gas Carriers built with the purposes of carrying LNG and their IEEC is changed from Gas carrier to LNG carrier are expected to comply with the requirement of SEEMP and CII applicable to LNG Carrier.

These Gas Carriers would need to achieve the required annual CII for LNG carriers. In addition, correction factors for cargo cooling and reliquification plant will also apply.

10 Case of change in DWT and/or GT

MEPC.348(78) states that permanent changes to vessel's deadweight (DWT) and/or gross tonnage (GT) can be undertaken as a measure within SEEMP Part III or a corrective actions plan to improve the ship's operational carbon intensity performance. Such changes undertaken after to initial verification of SEEMP Part III should only be considered as a measure to improve the ship's operational carbon intensity performance.

- all future required annual operational CII should be calculated and verified using the original DWT or GT value before DWT or GT conversion; and

- the attained annual operational CII which is to be used to assess compliance should be calculated and verified using the new DWT or GT value after conversion. Except for the year of conversion where the attained CII should be calculated and verified based on the average DWT or GT value weighted on distance travelled before and after conversion.

In case of DWT and/or GT change, SEEMP Part III to be revised and submitted for verification.

In case of a ship which permanently changes its deadweight and where the change is not so substantial as to qualify as a major conversion and which are not identified as a CII reducing measure in the SEEMP III or the CAP, both the attained and required CII should be calculated and verified using the new DWT or GT after conversion. Except for the year of conversion where the attained and required CII should be calculated and verified based on the average DWT or GT value weighted on distance travelled before and after conversion

In case of a ship undergone major conversion, including extensive changes of carrying capacity and/or ship type during the year, defined by regulation 2.2.17 and regarded by the Administration as a newly constructed ship as per regulation 5.4.3, the required and attained annual operational CII should be calculated and verified as per a newly constructed ship for the period after conversion. For the year when the major conversion is made, the data for partial year before conversion should still be reported for verification but will not be included in the calculation and verification of the attained annual operational CII. In case where the major conversion occurs at the end of the year, such conversions can be considered as non-substantial conversion for the year of conversion for calculating the required and attained annual operational CII values.

11 Definitions for voyage adjustments

Fuel consumption and distance travelled for a defined period of voyages (partial or whole voyage) may be exempted from consideration in the calculation of the annual operational attained CII subject to certain threshold conditions being met. These conditions are specified in regulation 3.1 of MARPOL Annex VI (endangering safe navigation of a ship - safety of a ship or saving life at sea, damage to a ship or its equipment) and sailing in ice conditions (ice classed ships sailing in a sea area within the ice edge). Only the parts of the voyage directly related to securing the safety of a ship or saving life at sea can be exempted. This does not include for example running at higher speed to catch up after delays, even if that delay was caused by such causes; or sailing to a yard for repair.

The fuel consumption and the distance travelled for the voyage adjustment the following should be noted:

- The fuel oil consumption for voyage periods should include all the fuel oil consumed on board (main engine(s), auxiliary engine(s), boiler(s), inert gas generator, etc).

- All fuel types consumed onboard.

- Regardless of whether a ship is under way or not.

Voyages subject to voyage adjustment (usually involving the safety of the ship) may include (however respective Flag Administration's instructions needs to be followed on case-by-case basis):

- When a vessel encounters imminent safety concerns during its voyage, including (example situations):

    - saving life at sea, i.e., search and rescue operations, evacuation.

    - navigation hazards such as icebergs.

    - areas that have been designated on an ad-hoc period due to prevailing navigational hazards.

    - piracy risk or other areas restricted for navigation due to war risk

The use of each correction factor of voyage adjustments should be evidenced by presenting relevant data/parameter/information (voyage period, date and time, ship position, distance travelled, starting and leaving a particular area, equipment starting and stopping data, etc.) and recorded in the Ship Log Book, Engine Log Book or Noon Report and copy of such official documentation shall be submitted to the RO/Administration at the time of verification in the data reporting format. Flag Administration's advice may be considered on case-by-case basis.

11.1 Ice-edge

MEPC.355(78), section 2.7 defined ice edge as "*Ice edge is defined by paragraph 4.4. of the WMO Sea-Ice Nomenclature, March 2014 as the demarcation at any given time between the open sea and sea ice of any kind, whether fast or drifting*."

The ice edge moves very rapidly with wind, current and influenced by ice melt or freezing, it is challenging to determine exact details on the ice edge as required for the exemptions.

When voyages are excluded from CII calculation, the verification should primarily be based on ice charts or log-book extracts, possibly be supported by statements by Master and/or ice navigator/pilot i.e. documented support for the voyage exclusion when the vessel enters the ice edge and finish when leaves the ice edge.

Where such voyages are to be excluded from the CII calculation, the fuel oil consumed and the distance travelled during this period is to be measured and documented in the Ship's log book along with data entries for the voyage period with date, time and position of the ship when this started to apply (entering the ice edge) and ceased to apply (leaving the ice edge). Justification for adjustment to primarily be based on ice charts or log-book extracts, possibly be supported by statements by Master and/or ice navigator/pilot. i.e. documented support for the voyage exclusion when the vessel enters the ice edge and finish when leaves the ice edge. This shall be submitted to the RO/ Administration at the time of verification.

11.2 Piracy

When voyages are excluded from CII calculation, reports submitted by the ship to its Flag Administration/ Port States would be considered to verify acts of piracy and armed robbery against ships, with log-book extracts as supporting documentation.

Additional information regarding acts of piracy and armed robbery against ships which is publicly available (subject to registration) in IMO's Piracy and Armed Robbery module within the Organization's Global Integrated Shipping Information System (GISIS) may be considered as reference documentation.

11.3 Safe / Unsafe navigation

When voyages are excluded from CII calculation, reports submitted by the ship to its Flag Administration/ Port States would be considered to verify ship's making unsafe navigation, with log-book extracts as supporting documentation.

For weather related unsafe navigation where vessel is seaworthy, i.e. without any known damage nor critical equipment failures, the vessel's operational safety envelope, vessel's maximum and minimum speeds at different drafts in different weather conditions, for manoeuvring, crew sickness, equipment failure, may be considered as supporting documentation for verifying the voyage adjustment.

11.4 Damage to a ship or its equipment

Regarding the damage to ship's equipment as per regulation 3.1.2, any CO_2 emissions as a result of ship or equipment damage may not be that likely. As such damage to critical equipment or ship may not qualify under reg. 3.1.2 unless the damage itself increases the CO_2 intensity for the given period and that all reasonable precautions have been taken after the damage to prevent or minimizing the emissions. This can for example be that the engine for dual fuel system is damaged and incapable of running on e.g. LNG and have to run on diesel with higher emission as a result. CO_2 emissions during an accidental oil spill may not be excluded, although if the ship participates in a clean-up effort, this part can be deducted.

The higher fuel consumption and corresponding increase in CO2 emissions as a result of damage to a ship or it's equipment (provided that the intent of MARPOL Annex VI, Regulation 3.1.2.1 has been met) can be excluded from the CII calculation. The Company should record such instances in the Ship log book, Engine log book or noon report together with details of the increase consumption and how it has been ascertained, for reporting to the RO/ Administration.

12 AF_{Tanker} for corrections to shuttle tankers or STS voyages on tankers

12.1 Tankers engaged in Ship-to-Ship (STS) operation when operating in accordance with regulation 41.2 of MARPOL Annex I may apply the correction factor $AF_{Tanker,STS}$ to all fuel consumption relating to STS voyages only for tankers carrying oil.

Correction includes for activities such as cargo oil transfer (loading or discharge) at offshore location, voyage, cargo discharge in port and waiting periods at anchor or drifting (idle time; either drifting or at anchor) during which the ship reports being part of an STS operation and voyage. The STS operation includes fuel consumption in port where the transferred cargo is discharged after such a voyage.

To qualify for using $AF_{Tanker,STS}$ a voyage (between cargo loading and cargo discharging locations, or between cargo discharging and cargo loading locations) shall be max 600nm and limited to 72 hours.
In the case of a voyage with multiple STS operations, any leg between two STS operations shall be max to 600nm and limited to 72 hours for the voyage to qualify for the correction factor $AF_{Tanker,STS}$.

The aforementioned time limit of 72 hours refers to the time corresponding to when the ship is moving (i.e. under propulsion) only, and excludes the idle time corresponding to stationary conditions such as at anchor, discharge, loading and drifting.

The Ship is to record the fuel consumption for the above operation in the Ship Log book or voyage reports or noon reports, including proof from the vessel that it has been engaged STS operation e.g. cargo manifest oil is being carried as cargo, and submit to the RO/Administration for verification.

Tankers which are involved in cargo oil transfer from a vessel's cargo tank to another vessel's cargo tank are qualified. Bunker operations, which involves oil transfer from a vessel's cargo tank to another vessel's bunker tank, are not qualified for STS correction. Various scenarios of voyages qualified for STS correction are shown in Figure 12.1.

Where $AF_{Tanker,STS}$ is applied, $FC_{electrical}$, FC_{boiler} and FC_{others} should not be used.

12.2 Tankers (shuttle tankers) equipped with dynamic positioning and specialized cargo handling equipment making it capable of loading crude oil at offshore installations may apply the correction factor $AF_{Tanker,Shuttle}$ to total fuel consumption.

The Ship is to record the fuel consumption for the above operation in the Ship Log book or voyage reports or noon reports, and submit to the RO/ Administration for verification.

Where $AF_{Tanker,Shuttle}$ is applied, $FC_{electrical}$, FC_{boiler}, FC_{others} and $AF_{Tanker,STS}$ should not be used.

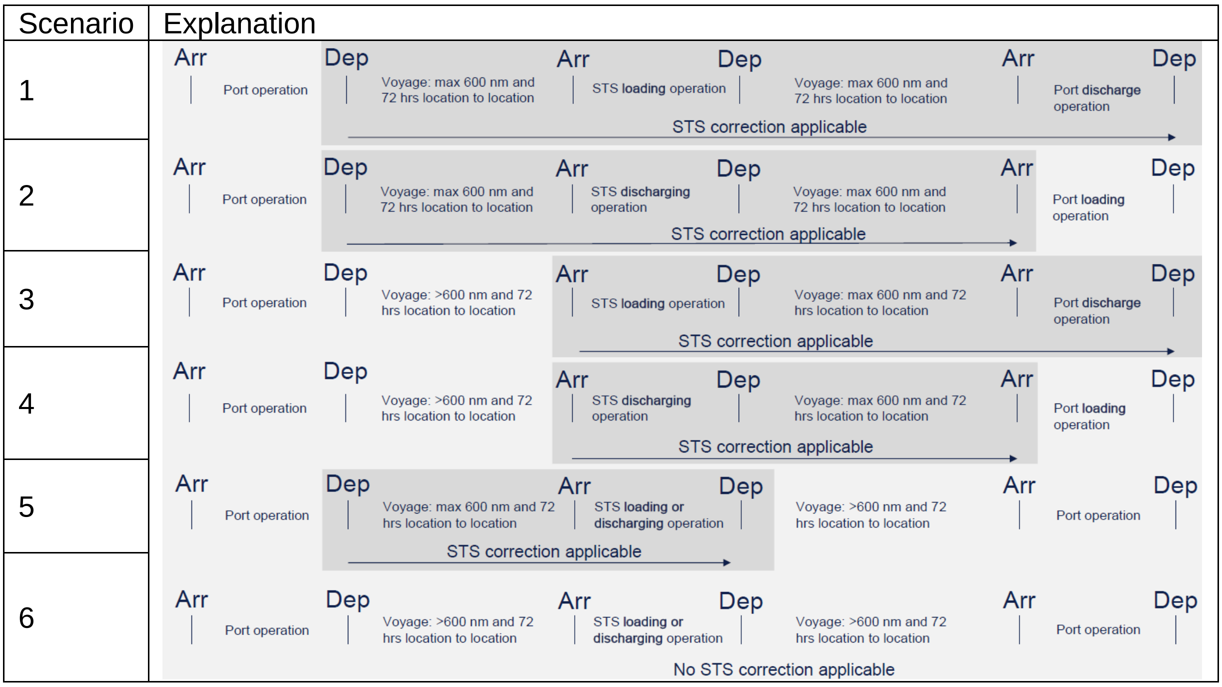

Figure 12.1 Different scenarios of STS correction

13 $FC_{electrical,j}$ for corrections relating to electrical power

The parameter $FC_{electrical,j}$ is the mass (in grams) of fuel type , consumed for production of electrical power during the calendar year which may be deducted from the calculation of the attained CII for the following purposes:

1. Electrical consumption (kWh) of refrigerated containers (on all ships where they are carried, including intermodal refrigerated containers fitted on trucks/trailers)). $FC_{electrical\_reefer,j}$ represents the estimated fuel consumption attributed in-use refrigerated containers carried using the calculation methodology specified in part A of appendix 1 of the G5 guidelines.

   The primary method to monitor reefer electrical consumption (kWh) is by kWh meter. The Ship is to record the kWh meter readings for the entire calendar year with supporting evidence in the ship's log book or noon reports etc, and submit to the RO/ Administration for verification.

   If this is not available, then a default consumption of 2.75 kW/h per reefer multiplied with number of reefer containers as recorded in the BAPLIE (BayPlan Including Empties) file when in Port and at Sea is to be used as specified in part A of appendix 1 of the G5 guidelines (resolution MEPC.355(78)).

   The number of reefer containers is to be the actual number of in-use reefer containers, regardless the size of the containers as recorded in the BAPLIE file and this is to be submitted to the RO/Administration for verification, when this correction factor is applied.

2. Electrical consumption (kWh) of cargo cooling/reliquification systems on gas carriers and LNG Carriers measured by kWh meter. $FC_{electrical\_cooling,j}$ represents the estimated fuel consumption attributed to cooling of gas cargoes using the calculation methodology specified in part A of appendix 1 of the G5 guidelines.

No. 175 (cont)

The Ship is to record the kWh meter readings of the electrical equipment used for cargo cooling and reliquefication for the entire calendar year with supporting evidence in the ship's log book or noon reports etc, and submit to the RO/ Administration for verification.

3. Electrical consumption (kWh) of directly or indirectly electrically powered cargo discharge pumps on tankers.

   $FC_{electrical\_discahrge,j}$ represents the estimated fuel consumption attributed to the use cargo discharge pumps during cargo operation regardless of operation, for example recirculation, internal transfer tank cleaning operations.

   Indirectly electrically powered cargo discharge pumps may be hydraulically operated pumps using an electric motor driven hydraulic power pack (HPP).

   The electrical consumption related to other hydraulic consumers on the same system such as mooring winches, windlass and ballast pumps is considered either insignificant or related to use of cargo discharge pumps and therefore the total electrical consumption by the HPP may be used for calculating the $FC_{electrical\_discahrge,j}$. $FC_{electrical,j}$ can also be applied to directly or indirectly electrically powered pumps operated for heating purposes.

   The Ship is to record the kWh meter readings from these devices installed to electrically powered cargo discharge pumps or the HPP electric motors when in operation during the entire calendar year with supporting evidence in the ship's log book or noon reports etc, and submit to the RO/ Administration for verification.

With reference to Res. MEPC.355(78) Appendix 1 Part A, it is intended that SFOC is the power-weighted average among SFOCs of the respective engines used to provide the electrical power, as indicated in the EEDI or EEXI Technical file and obtained as specified in MEPC.364(79) para 2.2.7, independently of the actual engine load in the condition relevant to the correction factor applied.

Possible alternatives to monitoring of Electrical consumption (kWh) using the kWh meter counters are as follows provided the same is approved by the Administration before such data is collected, is based on the configurations on board the ship and provides an accuracy equivalent to the installation of kWh meter counters:

1. Derivation of fuel consumption:
   Based on the ship specific fuel oil piping system configuration, the ship is to document the procedure in the SEEMP III on how the fuel consumption to the engine (s) can be ascertained specific to cargo operations alone, and submit to the Administration/RO for their approval. This should include information on the data that will need to be captured and recorded by the ship staff in the ship log-book or noon reports and be made available during the verification process, to ascertain the fuel consumption

2. For kWh from auto-logged data (automatically logged data during) or recorded data, it can be determined by the following three-phase power consumption calculation formula considering voltage, current and power factor:

   $$W = \sqrt{3} \times V \times I \times \mathrm{pf} \times \mathrm{H} \times 0.001$$

   where:

   W represents the power in kWh.

No. 175 (cont)

V represents the voltage in volts and may be measured from the main switchboard in engine control room.

I represents the current in amps and may be measured from group starter panel.

P_f represents the power factor and may take account for the difference between the real power which performs useful work and the apparent power which is supplied to the circuit. The typical power factors are as follows:

Device	Power Factor
Lamp, fluorescent uncompensated	0.5
Lamp, fluorescent compensated	0.93
Lamp, incandescent	1
Motor, induction 100% load	0.85
Motor, induction 50% load	0.73
Motor, induction 0% load	0.17
Motor, synchronous	0.9
Oven, resistive heating element	1
Oven, induction compensated	0.85
Pure resistive load	1

Source : https://www.engineeringtoolbox.com/three-phase-electrical-d_888.html

H represents the running hours of the equipment or system in hours and may be measured by running hour meter. The running hours after each cargo operations are to be recorded in the ship's log book or noon reports and should be submitted to the Administration/RO for verification.

V, I, P_f may be measured at regular interval (e.g. 4 hours) and recorded in the ship's log book or noon reports and should be submitted to the Administration/RO for verification.

Alternatives to monitoring of kWh such as derivation of fuel consumption or kWh from auto-logged data are subject to approval by the Administration/RO.

The method should have been stated in the SEEMP Part III and may include software updates to control and monitoring systems to calculate of specific fuel consumption for given consumers.

14 $FC_{boiler,j}$ for corrections relating to boiler fuel consumption

The parameter is the mass (in grams) of fuel oil type, consumed by the oil fired boiler during the calendar year which may be deducted from the calculation of the attained CII, for the purposes of cargo heating and cargo discharge on tankers for the period that the cargo heating or steam driven cargo pumps are in operation. Some amount of fuel consumed by the boiler during cargo heating or discharge operations may be attributed to other purposes, e.g. calorifiers. It is not necessary to split these out from reporting. Fuel consumption for boiler should be measured by flow meters installed on the fuel supply line. Alternatively, where tank sounding method is adopted, the Company is to detail the procedure on how the fuel oil consumption for the Boiler alone is being ascertained for deductions.

The Ship is to record the fuel consumption for the above operation in the Ship Log book or voyage reports or noon reports, and submit to the RO/ Administration for verification. Boiler consumption should not include consumption during voyage adjustment periods.

No. 175 (cont)

15 $FC_{others,j}$ for corrections relating to other fuel consumption devices

The parameter is the mass (in grams) of fuel oil type, consumed by standalone engine driven cargo pumps (e.g. hydraulic pumps/power packs) during discharge operations on tankers which may be deducted from the calculation of the attained CII. It should be measured by accepted means, e.g. tank soundings, flow meters. This may include hydraulic deep-well pumps using a hydraulic power pack (HPP) driven by a standalone engine.

Consumption by Inert gas generators on tankers (including flue gas and N_2 generators) should not be considered for any corrections.

For tankers with discharge pumps powered by their own engine, the amount of fuel used for the period that the discharge pumps are in operation should be measured by flow meters installed on the fuel supply line. Alternatively, where tank sounding method is adopted, the Company is to detail the procedure on how the fuel oil consumption for the engine driven cargo pumps alone is being ascertained for deductions.

For vessels with hydraulic deep-well pumps using an standalone engine driven HPP, the fuel oil consumption related to other hydraulic consumers on the same system such as mooring winches, windlass and ballast pumps is considered either insignificant or related to use of cargo discharge pumps and therefore the total fuel oil consumption by the HPP may be used for calculating $FC_{others,j}$.

The Ship is to record the fuel consumption for the above operation in the Ship Log book or voyage reports or noon reports, and submit to the RO/ Administration for verification.
All consumption related to the operation of discharge pumps on tankers is subject for correction, including electrical consumption and fuel oil consumption for boilers and other standalone engines.

16 $FC_{electrical\_cooling,j}$ for corrections relating to cargo cooling fuel oil consumption on LNG carrier having steam turbine

SFOC for $FC_{electrical\_cooling,j}$ is the specific fuel consumption in g/kWh associated with the relevant source of electrical power as per the EEDI/EEXI Technical File or NOx Technical File. In the case of ships without a Technical File, a default value of 175 g/kWh for 2 stroke engines and 200 g/kWh for 4 stroke engines may be applied.

In case of LNG carrier having steam turbine which could not distinguish its engine type, the total fuel consumption per hour of its boiler after converted in g/kWh may be applied.

17 EEDI and EEXI correction factors

EEDI and EEXI correction factors may be applied, provided they are included in the ship's EEDI Technical File or EEXI Technical File. These includes:

f_i capacity correction factor for ice-classed ships as specified in paragraph 2.2.11.1 of the *2022 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.364(79))

f_m factor for ice-classed ships having IA Super and IA as specified in paragraph 2.2.19 of the *2022 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.364(79))

No. 175 (cont)

f_c cubic capacity correction factors for chemical tankers as specified in paragraph 2.2.12.1 of the *2022 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.364(79))

$f_{i,VSE}$ correction factor for ship-specific voluntary structural enhancement as specified in paragraph 2.2.11.2 of the *2022 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC. 364(79)), to be applied only to self-unloading bulk carriers

These factors, if applied, are to be described in SEEMP Part III. If EEDI or EEXI correction factors are not applied, these factors should be taken as one (1.0).

18 Use of fuel oil types not listed in resolution MEPC.364(79) and their carbon conversion factors

The conversion factor for the type of the fuel oil not covered by resolution MEPC.364(79), as may be further amended, should be obtained from the fuel oil supplier supported by documentary evidence.
Company needs to submit the methodology for sampling, methods of analysis, and a description of the laboratories used (with confirmed ISO 17025 accreditation where relevant), the conversion factor or the carbon content, on which it is based for the fuel in question.

It is intended that a biofuel is a type of fuel oil not covered by resolution MEPC.364(79), and the relevant conversion factor should be obtained from the biofuel oil supplier supported by documentary evidence such as statement declaring carbon conversion factor or methodology for sampling, methods of analysis, test reports issued by the accredited laboratory.

Relevant Flag Administration's instructions on use of biofuel should be followed.

19 Use of multiple types of fuels and correction factor

In case of different fuel types are used on-board, mass of consumed fuel of each type should accounted while determining the correction factors. Relevant records are to be submitted in the case of use of different fuel types. Mass quantities of consumed fuel of each accounted in correction factor should correspond with the reported quantity in IMO DCS in that year.

End of Document

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MEPC.1/Circ.855/Rev.2
14 January 2019

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) AND RESOLUTION MEPC.309(73))

1 The Marine Environment Protection Committee, at its seventy-third session (22 to 26 October 2018), adopted, by resolution MEPC.309(73), amendments to the *2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)* (resolution MEPC.254(67), as amended by resolution MEPC.261(68)). A revised consolidated text of the Guidelines, as requested by the Committee (MEPC 73/19, paragraph 5.87), is set out in the annex.

2 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.

3 This circular revokes MEPC.1/Circ.855/Rev.1.

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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) AND RESOLUTION MEPC.309(73))

Table of contents

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[1]

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 *2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.308(73)) (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.

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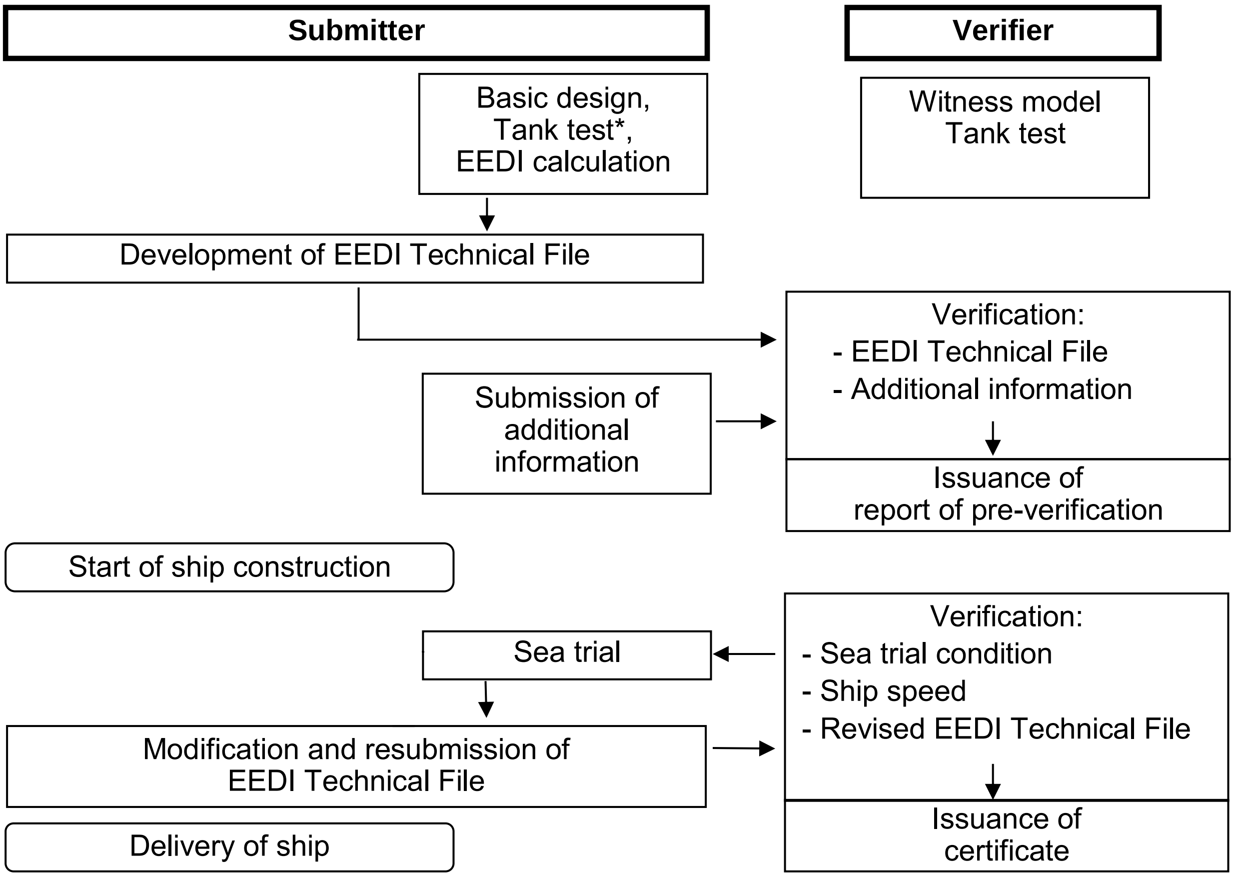
[1] Other terms used in these guidelines have the same meaning as those defined in the *2018 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.308(73)).



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

Figure 1: Basic flow of survey and certification process

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 2.2.2 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[2] for certain ship types, as necessary, as defined in the EEDI Calculation Guidelines;

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

.2 power curve(s) (kW – knot) estimated at design stage under the condition as specified in paragraph 2.2.2 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 2.2.5.6.3 of the EEDI Calculation Guidelines;

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

.4 maximum continuous rated power ($MCR_{SteamTurbine}$) for steam turbine; and

.5 $SFC_{SteamTurbine}$ for steam turbine, as specified in paragraph 2.2.7.2 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:

$$\frac{V_{gas} \times \rho_{gas} \times LCV_{gas} \times K_{gas}}{\left(\sum_{i=1}^{nLiquid} V_{liquid(i)} \times \rho_{liquid(i)} \times LCV_{liquid(i)} \times K_{liquid(i)}\right) + V_{gas} \times \rho_{gas} \times LCV_{gas} \times K_{gas}} \geq 50\%$$

whereby:

V_{gas} is the total net tank volume of gas fuel on board in m^3;

V_{liquid} is the total net tank volume of every liquid fuel on board in m^3;

ρ_{gas} is the density of gas fuel in kg/m^3;

ρ_{liquid} is the density of every 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.

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

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

* 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_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_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_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_X Technical File is broad and specification of engines belonging to the same group/family may vary; and
>
> .2 the rate of NO_X emission of the parent engine is the highest in the group/family – i.e. CO_2 emission, which is in the trade-off relationship with NO_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 2.2.2 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 2.2.2 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 2.2.2 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 NO_X 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 ship speed; and

.5 shaft power and RPM.

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 2017 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 2017 or ISO 15016:2015, and at more than two points of which range includes the power of the main engine as specified in paragraph 2.2.5 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 2017 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 2.2.2 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 2.2.5 of the EEDI Calculation Guidelines; and

.2 for ships for which sea trial cannot be conducted under the condition as specified in paragraph 2.2.2 of the EEDI Calculation Guidelines: if the measured ship speed at the power of the main engine as specified in paragraph 2.2.5 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 2.2.2 of the EEDI Calculation Guidelines by an appropriate correction method that is agreed by the verifier.

.3 An example of the scheme of conversion from trial condition to EEDI condition at EEDI power is given as follows:

V_{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 α_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 α_P is V_{ref}.

$$\alpha_P = \frac{P_{Trial,P}}{P_{Trial,S}}$$

where:

$P_{Trial,P}$: power at trial condition predicted by the tank tests

$P_{Trial,S}$: power at trial condition obtained by the S/P trials

α_p: power ratio

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

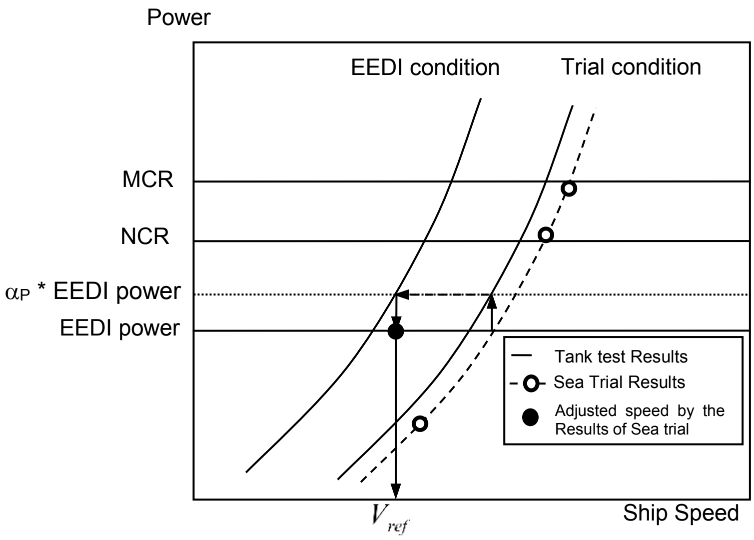


Figure 2: An example of scheme of conversion from trial condition to EEDI condition at EEDI power

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 2.2.2 of the EEDI Calculation Guidelines), the finally determined deadweight/gross tonnage, η 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

Shipbuilder	JAPAN Shipbuilding Company
Hull no.	12345
IMO no.	94111XX
Ship type	Bulk carrier

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

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

1.4 Auxiliary engine

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

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.

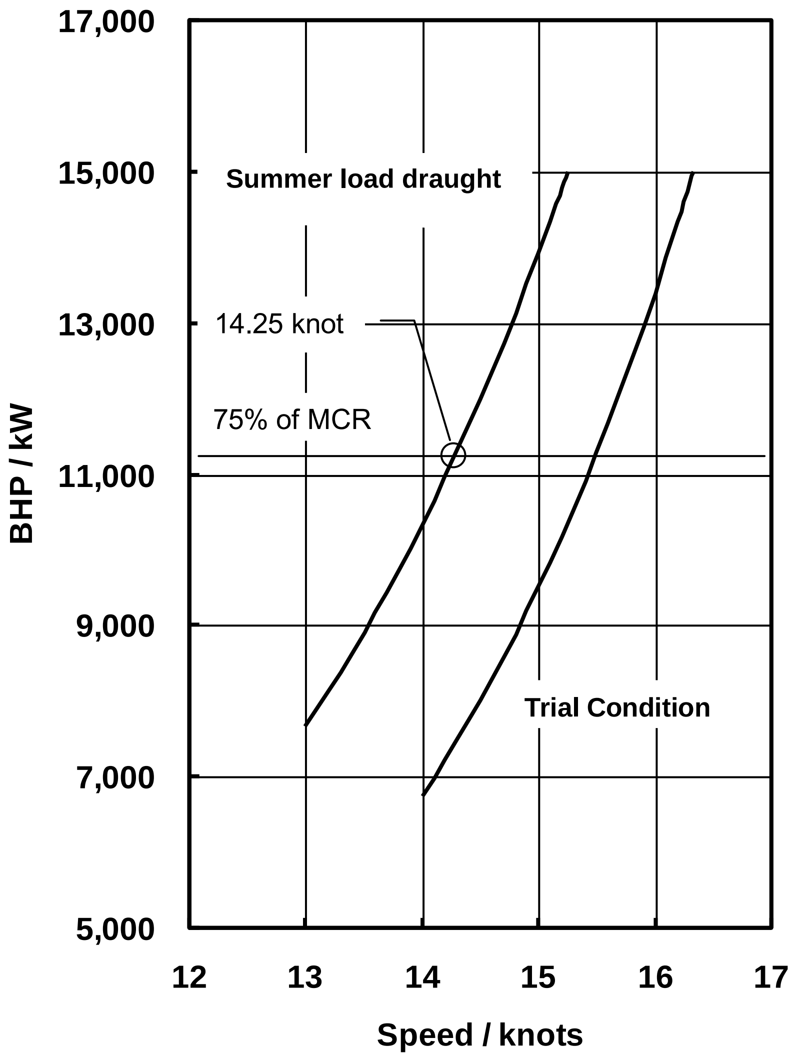


Figure 2.1: Power curves

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

Type	Fixed pitch propeller
Diameter	7.0 m
Number of blades	4
Number of sets	1

3.2 Electric power supply system

3.2.1 Auxiliary engines
Refer to paragraph 1.4 of this appendix.

3.2.2 Main generators

Manufacturer	JAPAN Electric
Rated output	560 kW (700 kVA) x 900 rpm
Voltage	AC 450 V
Number of sets	3

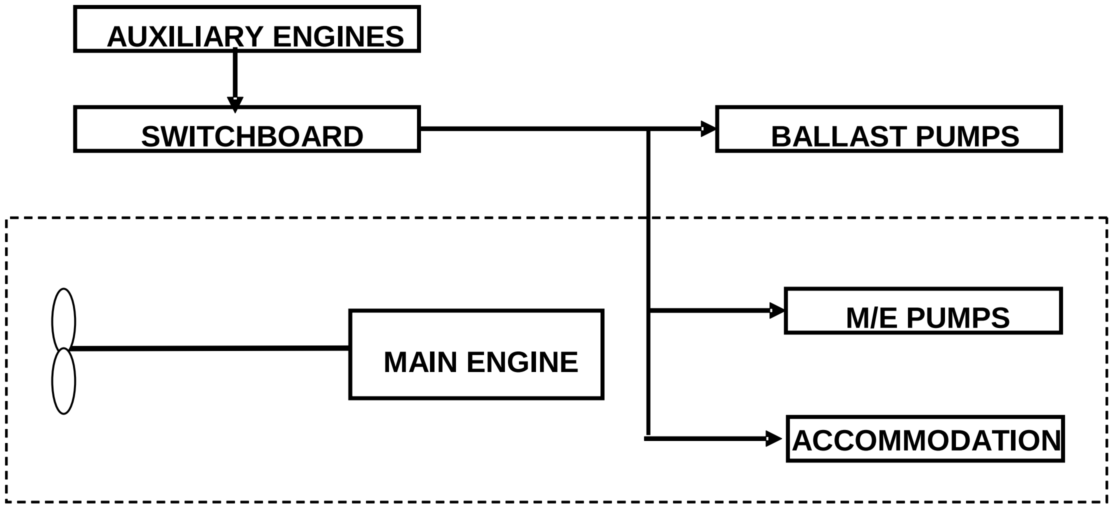


Figure 3.1: Schematic figure of propulsion and electric power supply system

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.

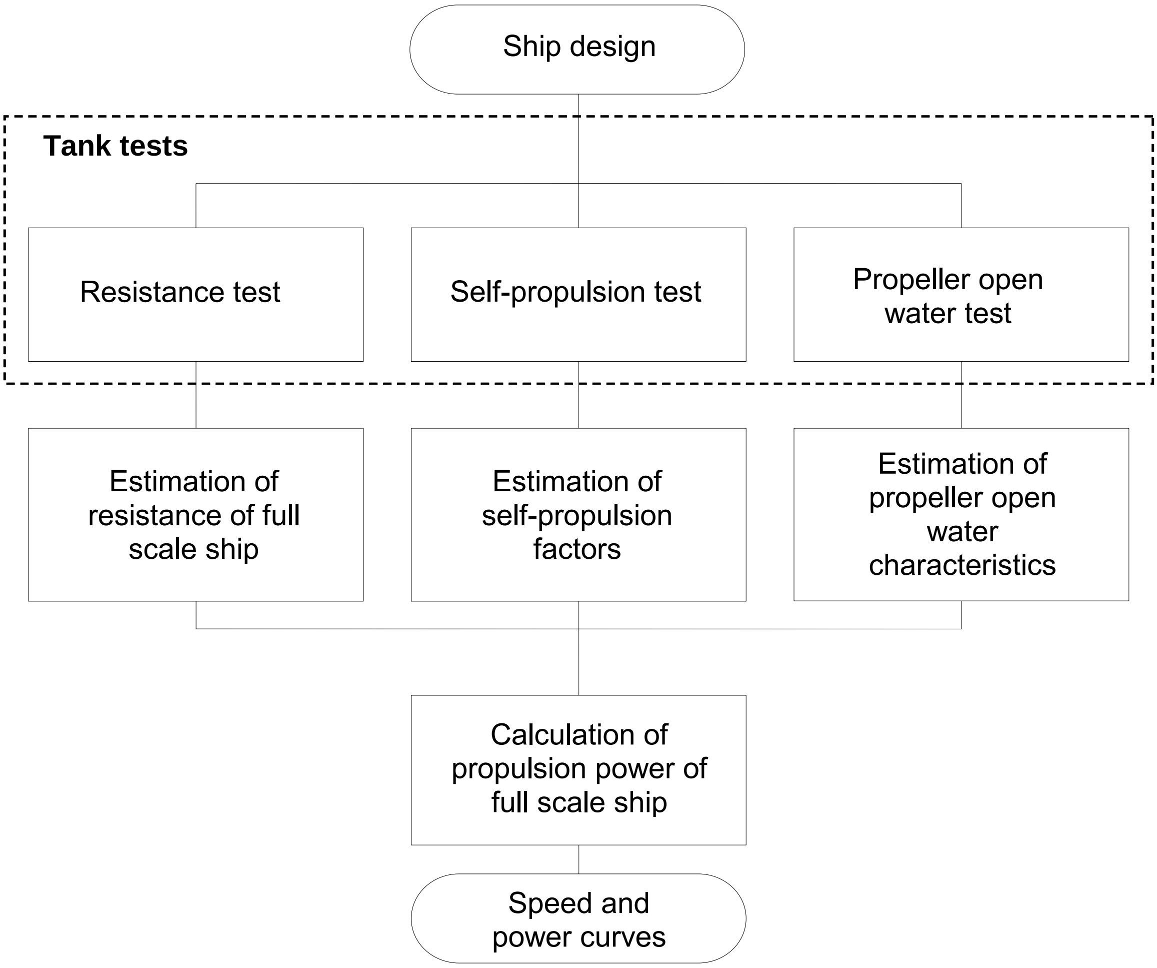


Figure 4.1: Flow-chart of process for estimating power curves

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

Type of ship	Capacity DWT	Speed V_{ref} (knots)
Bulk Carrier	150,000	14.25

6.2 Main engine

MCR_{ME} (kW)	Shaft gen.	P_{ME} (kW)	Type of fuel	C_{FME}	SFC_{ME} (g/kWh)
15,000	N/A	11,250	Diesel Oil	3.206	165.0

6.3 Auxiliary engines

P_{AE} (kW)	Type of fuel	C_{FAE}	SFC_{AE} (g/kWh)
625	Diesel Oil	3.206	220.0

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

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

$$= \frac{1 \times (11250 \times 3.206 \times 165.0) + (625 \times 3.206 \times 220.0) + 0 - 0}{1 \cdot 1 \cdot 150000 \cdot 1 \cdot 14.25}$$

$$= 2.99 \quad (g - CO_2/ton \cdot mile)$$

attained EEDI: 2.99 g-CO_2/ton mile

7 Calculated value of attained $EEDI_{weather}$

7.1 Representative sea conditions

	Mean wind speed	Mean wind direction	Significant wave height	Mean wave period	Mean wave direction
BF6	12.6 (m/s)	0 (deg.)*	3.0 (m)	6.7 (s)	0 (deg.)*

* 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 2.2.5.7 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 2.2.5.6 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 2.2.5.7 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; and

.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.

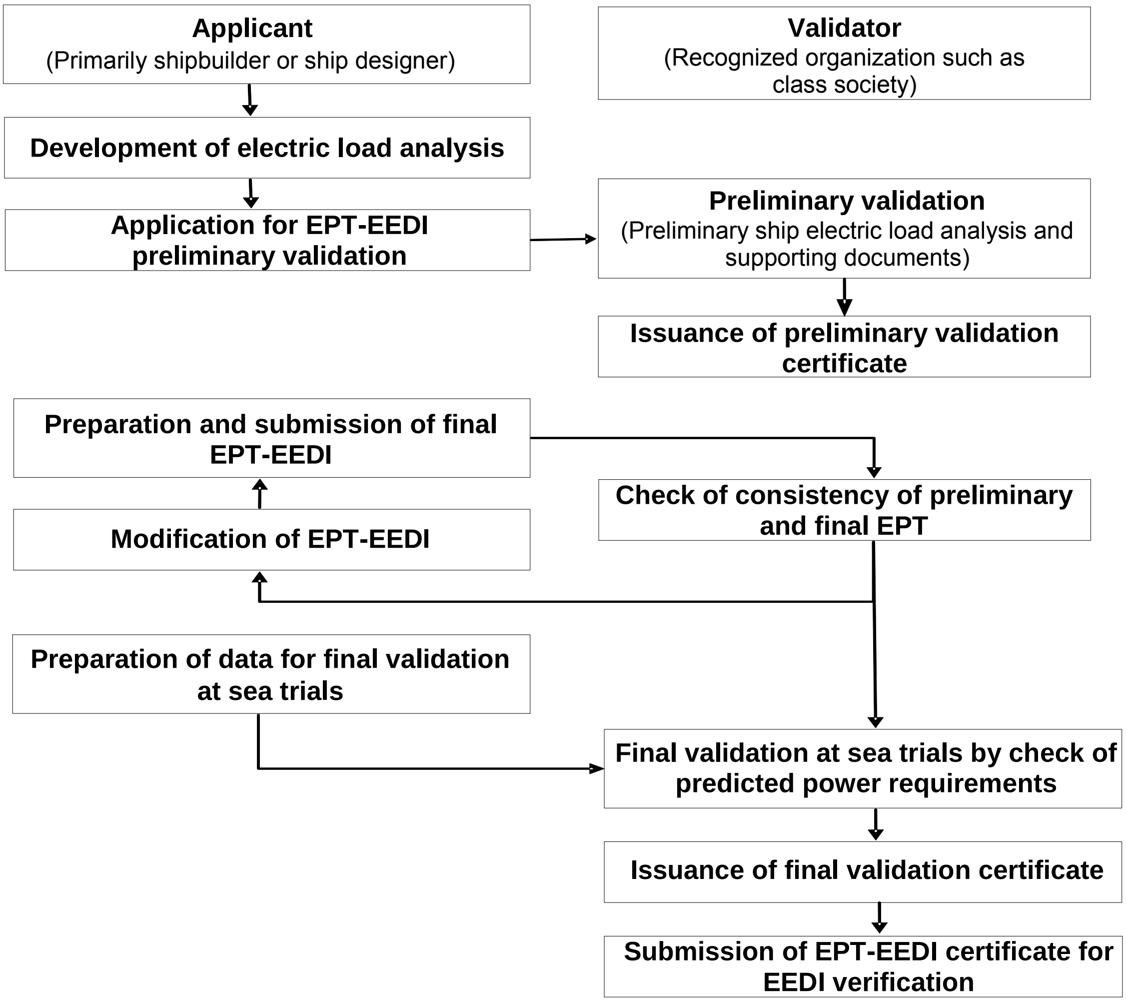


Figure 6.1: Basic flow of EPT-EEDI validation process

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:
Name:_____________________________
Address:___________________________
____

Validation stage:
☐ Preliminary validation
☐ Final validation

Summary results of EPT-EEDI

Load group	Seagoing condition EEDI Calculation guidelines		Remarks
	Continuous load (kW)	Intermittent load (kW)	
Ship service and engine-room loads			
Accommodation and cargo loads			
Total installed load			
Diversity factor			
Normal seagoing load			
Weighted average efficiency of generators			
P_{AE}			

Supporting documents

Title	ID or remarks

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. REVOKES 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.

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

1 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.

2 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.

3 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

4 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.

5 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.

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

7 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

8 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.

9 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.

10 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 $MCR_{ME(i)}$.

11 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.

12 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

13 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. $C_{F,ME} = C_{F,AE} = CF = 3.1144$ g CO_2/g fuel;

.2 the specific fuel consumption for all ship types is constant for all main engines, i.e. $SFC_{ME} = 190$ 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. $SFC_{AE} = 215$ 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:

$$P_{AE} = 0.866 \cdot GT^{0.732}$$

.7 no correction factors are used except for f_{jRoRo} and f_{cRoPax}; 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. $P_{AEeff} = 0$, $P_{PTI} = 0$, $P_{eff} = 0$.

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:

$$Estimated\ \ Index\ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$$

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:

$$Estimated\ \ Index\ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{70\%\mathrm{DWT} \cdot V_{ref}}$$

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

$$Estimated\,Index\,Value = f_{roroV} \cdot 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{nME} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$$

Where:

$$f_{roroV} = \frac{-15571 \cdot F_n^2 + 5538.4 \cdot F_n - 132.67}{287}$$

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

$$Estimated\,Index\,Value = \frac{3.1144 \cdot (f_{jRoRo} \cdot 190 \cdot \sum_{i=1}^{nME} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$$

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

$$Estimated\,Index\,Value = \frac{3.1144 \cdot (\mathrm{f_{jRoRo}} \cdot 190 \cdot \sum_{i=1}^{nME} P_{MEi} + 215 \cdot P_{AE}}{f_{cRoPax} \cdot Capacity \cdot V_{ref}}$$

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_{cRoPax}, 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

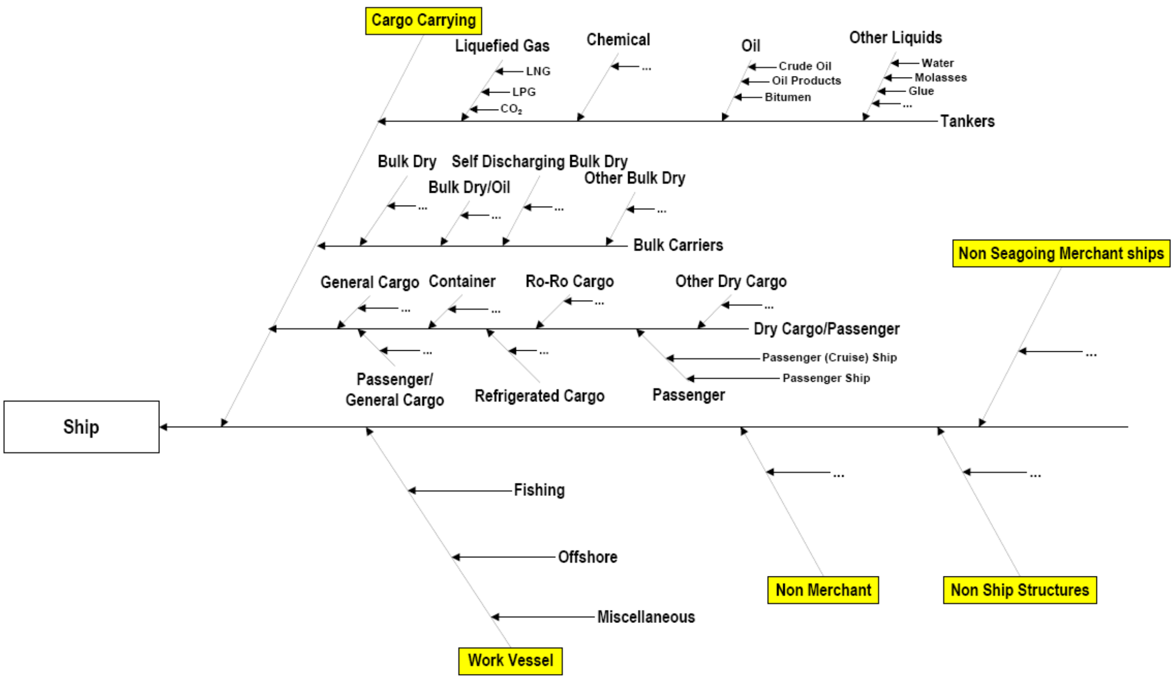
For the purpose of the EEDI, only group "A cargo carrying" needs to be considered. A graphical representation of this is given below.

.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

.1 Bulk carrier	Bulk dry	A21A2BC	Bulk carrier	A single deck cargo vessel with an arrangement of topside ballast tanks for the carriage of bulk dry cargo of a homogeneous nature.
	Bulk dry	A21B2BO	Ore carrier	A single deck cargo ship fitted with two longitudinal bulkheads. Ore is carried in the centreline holds only.
	Self-discharging bulk dry	A23A2BD	Bulk cargo carrier, self-discharging	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.
	Other dry bulk	A24A2BT	Cement carrier	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.
		A24B2BW	Wood chips carrier, self-unloading	A single deck cargo vessel with high freeboard for the carriage of wood chips. May be self-discharging.
		A24C2BU	Urea carrier	A single deck cargo vessel for the carriage of urea in bulk. May be self-discharging.
		A24D2BA	Aggregates carrier	A single deck cargo vessel for the carriage of aggregates in bulk. Also known as a sand carrier. May be self-discharging.
		A24E2BL	Limestone carrier	A single deck cargo vessel for the carriage of limestone in bulk. There are no weather deck hatches. May be self-discharging.
.2 Gas carrier	Liquefied gas	A11A2TN	LNG tanker	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.
		A11B2TG	LPG tanker	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 ("semi-pressurized") to achieve liquefaction.
		A11C2LC	CO_2 tanker	A tanker for the bulk carriage of liquefied carbon dioxide.
		A11A2TQ	CNG tanker	A tanker for the bulk carriage of compressed natural gas. Cargo remains in gaseous state but is highly compressed.

.3 Tanker	Chemical	A12A2LP	Molten sulphur tanker	A tanker for the bulk carriage of molten sulphur in insulated tanks at a high temperature.
		A12A2TC	Chemical tanker	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.
		A12B2TR	Chemical/ products tanker	A chemical tanker additionally capable of the carriage of clean petroleum products.
		A12C2LW	Wine tanker	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.
		A12D2LV	Vegetable oil tanker	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.
		A12E2LE	Edible oil tanker	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.
		A12F2LB	Beer tanker	A tanker for the bulk carriage of beer.
		A12G2LT	Latex tanker	A tanker for the bulk carriage of latex.
		A12H2LJ	Fruit juice tanker	A tanker for the bulk carriage of fruit juice concentrate in insulated tanks.
	Oil	A13A2TV	Crude oil tanker	A tanker for the bulk carriage of crude oil.
		A13A2TW	Crude/oil products tanker	A tanker for the bulk carriage of crude oil but also for carriage of refined oil products.
		A13B2TP	Products tanker	A tanker for the bulk carriage of refined petroleum products, either clean or dirty.
		A13B2TU	Tanker (unspecified)	A tanker whose cargo is unspecified.
		A13C2LA	Asphalt/ Bitumen tanker	A tanker for the bulk carriage of asphalt/bitumen at temperatures between 150 and 200 deg C.
		A13E2LD	Coal/oil mixture tanker	A tanker for the bulk carriage of a cargo of coal and oil mixed as a liquid and maintained at high temperatures.
	Other liquids	A14A2LO	Water tanker	A tanker for the bulk carriage of water.
		A14F2LM	Molasses tanker	A tanker for the bulk carriage of molasses.
		A14G2LG	Glue tanker	A tanker for the bulk carriage of glue.
		A14H2LH	Alcohol tanker	A tanker for the bulk carriage of alcohol.
		A14N2LL	Caprolactam tanker	A tanker for the bulk carriage of caprolactam, a chemical used in the plastics industry for the production of polyamides.
	Chemical	A12A2TL	Parcels tanker	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.

.4 Containership	Container	A33A2CC	Containership (fully cellular)	A single deck cargo vessel with boxed holds fitted with fixed cellular guides for the carriage of containers.
.5 General cargo ship	General cargo	A31A2GX	General cargo ship	A single or multi-deck cargo vessel for the carriage of various types of dry cargo. Single deck vessels will typically have box-shaped holds. Cargo is loaded and unloaded through weather deck hatches.
	Other dry cargo	A38H2GU	Pulp carrier	A vessel designed for carrying paper pulp.
.6 Refrigerated cargo carrier	Refrigerated cargo	A34A2GR	Refrigerated cargo ship	A multi-deck cargo ship for the carriage of refrigerated cargo at various temperatures.
.7 Combination carrier	Bulk dry/oil	A22A2BB	Bulk/oil carrier (OBO)	A bulk carrier arranged for the alternative (but not simultaneous) carriage of crude oil.
	Bulk dry/oil	A22B2BR	Ore/oil carrier	An ore carrier arranged for the alternative (but not simultaneous) carriage of crude oil.
	Bulk dry/oil	A22A2BP	Ore/bulk/ products carrier	A bulk carrier arranged for the alternative (but not simultaneous) carriage of oil products.

Table 2: Ship types from IHSF not included in the calculation of reference lines for use with the EEDI

.1 Bulk carrier	Bulk dry	A21A2BG	Bulk carrier, laker only	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.
	Bulk dry	A21A2BV	Bulk carrier (with vehicle decks)	A bulk carrier with movable decks for the additional carriage of new vehicles.
	Bulk dry/oil	A22A2BB	Bulk/oil carrier (OBO)	A bulk carrier arranged for the alternative (but not simultaneous) carriage of crude oil.
	Bulk dry/oil	A22B2BR	Ore/oil carrier	An ore carrier arranged for the alternative (but not simultaneous) carriage of crude oil.
	Bulk dry/oil	A22A2BP	Ore/bulk/products carrier	A bulk carrier arranged for the alternative (but not simultaneous) carriage of oil products.
	Self-discharging bulk dry	A23A2BK	Bulk cargo carrier, self-discharging, laker	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.
	Other bulk dry	A24H2BZ	Powder carrier	A single deck cargo vessel for the carriage of fine powders such as fly ash. There are no weather deck hatches.
	Other bulk dry	A24G2BS	Refined sugar carrier	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).
.2 Gas carrier	Liquefied gas	A11B2TH	LPG/chemical tanker	An LPG tanker additionally capable of the carriage of chemical products as defined in the International Bulk Chemical Code.
.3 Tanker	Oil	A13A2TS	Shuttle tanker	A tanker for the bulk carriage of crude oil specifically for operation between offshore terminals and refineries. Is typically fitted with bow loading facilities.
.4 Containership	Container	A33B2CP	Passenger/ containership	A containership with accommodation for the carriage of more than 12 passengers.

.5 General cargo ship	General cargo	A31A2GO	Open hatch cargo ship	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.
	General cargo	A31A2GS	General cargo/tanker (container/oil/bulk – COB ship)	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.
	General cargo	A31A2GT	General cargo/tanker	A general cargo ship fitted with tanks for the additional carriage of liquid cargo.
	General cargo	A31C2GD	Deck cargo ship	A vessel arranged for carrying unitized cargo on deck only. Access may be by use of a ro-ro ramp.
	Passenger/general cargo	A32A2GF	General cargo/ passenger ship	A general cargo ship with accommodation for the carriage of more than 12 passengers.
	Other dry cargo	A38A2GL	Livestock carrier	A cargo vessel arranged for the carriage of livestock.
	Other dry cargo	A38B2GB	Barge carrier	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).
	Other dry cargo	A38C3GH	Heavy load carrier, semi-submersible	A heavy load carrier which is semi-submersible for the float on loading/unloading of the cargoes.
	Other dry cargo	A38C3GY	Yacht carrier, semi-submersible	A semi-submersible heavy load carrier specifically arranged for the carriage of yachts.
	Other dry cargo	A38D2GN	Nuclear fuel carrier	A cargo vessel arranged to carry nuclear fuel in flasks.
	Other dry cargo	A38D2GZ	Nuclear fuel carrier (with ro-ro facility)	A nuclear fuel carrier which is loaded and unloaded by way of a ro-ro ramp.
	Other dry cargo	A38B3GB	Barge carrier, semi-submersible	A barge carrier which is semi-submersible for the float on loading/unloading of the barges.
	Other dry cargo	A38C2GH	Heavy load carrier	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.

* * *

Appendix 2

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

	Direct Drive Diesel	Dual Fuel Diesel – Electronic (DFDE)	Steam Turbine
Margins	$Engine : 10\%$ $Sea : 20\%$	$Engine : -$ $Sea : 20\%$	$Engine : -$ $Sea : 20\%$
Design Margin	$M\arg in = \frac{0.9}{1.2}$ $M\arg in = 75\%$	$M\arg in = \frac{1}{1.2}$ $M\arg in = 83\%$	$M\arg in = \frac{1}{1.2}$ $M\arg in = 83\%$
P_{ME} Formula[1]	$P_{ME(i)} = 0.75 \cdot (MCR_{ME(i)} - P_{PTO(i)})$	$P_{ME(i)} = 0.83 \cdot \frac{MPP_{(i)}}{\eta_{Electrical(i)}}$	$P_{ME(i)} = 0.83 \cdot (MCR_{ME(i)} - P_{PTO(i)})$
SFC_{ME} in g/kWh (Fuel)	$190\ (HFO)$	$175\ (FBO)$	$285\ (FBO)$
P_{AE} Formula[2]	$P_{AE} = 0.025 \cdot \sum_{i=1}^{nME} MCR_{ME(i)} + 250 + Capacity \cdot BOR \cdot 15$	$P_{AE} = (0.025 + 0.02) \cdot \sum_{i=1}^{nME} P_{ME(i)} + 250$	$P_{AE} = 0$
Index Formulae	$3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{nME} P_{ME(i)} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$	$2.75 \cdot \frac{175 \cdot \sum_{i=1}^{nME} P_{ME(i)} + 175 \cdot P_{AE}}{Capacity \cdot V_{ref}}$	$2.75 \cdot \frac{285 \cdot \sum_{i=1}^{nME} P_{ME(i)}}{Capacity \cdot V_{ref}}$

NOTES:

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

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MEPC.1/Circ.850/Rev.3
7 July 2021

GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS

1 The Marine Environment Protection Committee (the Committee), at its seventy-sixth session (10 to 17 June 2021), approved amendments to the 2013 *Interim Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions* (MEPC.1/Circ.850/Rev.2) including the change of title to *Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions*.

2 The *Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions* are set out in the annex.

3 The Committee also agreed to keep the Guidelines under review and invited Member States and international organizations to report on the experiences gained in the implementation of the Guidelines to a future session of the Committee.

4 Member Governments are invited to bring the annexed *Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions* to the attention of Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

5 This circular revokes MEPC.1/Circ.850/Rev.2.

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ANNEX

GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS

0 Purpose

The purpose of these Guidelines is to assist Administrations and recognized organizations in verifying that ships, complying with Energy Efficiency Design Index (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:

Significant wave height h_s, m	Peak wave period T_P, s	Mean wind speed V_w, m/s
6.0	7.0 to 15.0	22.6

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 as the following threshold value of ship size:

Ship length, m	Significant wave height h_s, m	Peak wave period T_P, s	Mean wind speed V_w, m/s
Less than 200	4.5	7.0 to 15.0	19.0
200 ≤ L_{pp} ≤ 250	Parameters linearly interpolated depending on ship's length		
More than 250	Refer to paragraph 1.1		

2 Applicability*

2.1 These Guidelines should be applied in the case of all new ships of types as listed in table 1 of appendix 1 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.

2.4 These Guidelines are applied in maximum summer load condition.

* These guidelines are applied to ships required to comply with regulations on energy efficiency for ships according to regulation 24 of MARPOL Annex VI (i.e. for those ship types as in table 1 of appendix 1 with the 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 minimum power 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 the manoeuvrability in adverse conditions.

4.2 The minimum power lines for the different types of ships are provided in appendix 1.

5 Assessment level 2 – minimum power assessment

5.1 The methodology for the minimum power assessment is provided in appendix 2.

5.2 If the ship under consideration fulfils the requirements as defined in the minimum power assessment, the ship should be considered to have sufficient power to maintain the 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 1

THE METHODOLOGY FOR THE MINIMUM POWER LINES ASSESSMENT

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 1: Parameters a and b for determination of the minimum power line values for the different ship types

Ship type	a	b
Bulk carrier which DWT is less than 145,000	0.0763	3374.3
Bulk carrier which DWT is 145,000 and over	0.0490	7329.0
Tanker	0.0652	5960.2
Combination Carrier	see tanker above	

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.

APPENDIX 2

THE METHODOLOGY FOR THE MINIMUM POWER ASSESSMENT

1 Minimum Power Assessment is based on the solution of a one degree-of-freedom manoeuvring equation in longitudinal direction to demonstrate that the ship can move with the speed of 2.0 knots through water in wind and wave directions from head to 30 degrees off-bow for a situation of weather vaning. The assessment consists of the following steps:

.1 calculate the maximum total resistance in the longitudinal ship direction over wind and wave directions from head to 30 degrees off-bow;

.2 calculate corresponding required brake power and rotation speed of the installed engine, considering the resistance and propulsion characteristics of the ship including appendages; and

.3 check whether the required brake power does not exceed the maximum available brake power of the installed engine, defined according to the engine manufacturer data at the actual rotation speed of the installed engine.

2 The maximum total resistance is defined as sum of the resistance in calm-water at the 2.0 knots forward speed U and the maximum added resistance in seaway X_a over wind and wave directions from head to 30 degrees off-bow.

Requirement

3 To satisfy the requirements of Minimum Power Assessment, the required brake power P_B^{req} in the adverse conditions at the forward speed 2.0 knots through water should not exceed the available brake power of the installed engine P_B^{av} in the same conditions:

$$P_B^{req} \leq P_B^{av}$$

4 The required brake power P_B^{req} is calculated as

$$P_B^{req} = \frac{2\pi n_P Q}{\eta_s \eta_g \eta_R}$$

where

n_P (1/s)	is the propeller rotation rate in the specified adverse conditions and the specified forward speed;
Q (N·m)	is the corresponding propeller torque;
η_s	is the mechanical transmission efficiency of the propeller shaft, approved for the EEDI verification;
η_g	is the gear efficiency, approved for the EEDI verification; and
η_R	is the relative rotative efficiency.

5 The available brake power P_B^{av} in the adverse conditions at the forward speed is defined as the maximum engine output at the actual rotation speed, taking into account maximum torque limit, surge/air limit and all other relevant limits in accordance with the engine manufacturer's data.

Definition of propulsion point

6 The propeller rotation rate n_P and the corresponding propeller advance ratio J in the adverse conditions at the forward speed are defined from the propeller open-water characteristics by solving the following equation:

$$\frac{K_T}{J^2} = \frac{T}{\rho u_a^2 D_P^2}$$

where

K_T	is the thrust coefficient of the propeller, defined from the propeller open-water characteristics;
T (N)	is the required propeller thrust;
ρ (kg/m^3)	is the sea water density, ρ = 1025 kg/m^3;
u_a (m/s)	is the propeller advance speed; and
D_P (m)	is the propeller diameter.

7 The corresponding torque of the propeller is calculated as

$$Q = K_Q \rho n_P^2 D_P^5$$

where

K_Q	is the torque coefficient of the propeller, defined from the propeller open-water characteristics.

8 The propeller advance speed u_a is calculated as

$$u_a = U(1 - w)$$

where

U (m/s)	is the forward speed 2.0 knots through water; and
W	is the wake fraction.

Definition of required propeller thrust

9 The required propeller thrust T is defined from the equation

$$T = \frac{X_s + X_a}{1 - t}$$

where

X_s (N)	is the resistance in calm-water at the forward speed including resistance due to appendages;
X_a (N)	is the maximum added resistance in seaway X_a; and
t	is the thrust deduction factor taking into account suction force on the ship hull due to propeller thrust.

Definition of calm water characteristics

10 The calm-water characteristics used for the assessment, such as calm-water resistance, self-propulsion factors and propeller open-water characteristics, are defined by the methods approved for EEDI verification, including:

.1 the calm-water resistance X_s, defined from the following equation:

$$X_s = (1 + k)C_F \frac{1}{2} \rho S U^2$$

where k is the form factor, C_F is the frictional resistance coefficient, ρ is sea water density, ρ = 1025 kg/m^3, S is the wetted surface area of the hull and the appendages and U is the forward speed;

.2 the thrust deduction factor t and wake fraction w at the forward speed and relative rotative efficiency η_R. Default conservative estimate may also be used for thrust deduction factor and wave fraction; t=0.1 and w=0.15 respectively; and

.3 the propeller open-water characteristics $K_T(J)$ and $K_Q(J)$.

Definition of added resistance

11 The maximum added resistance in seaway X_a is defined as sum of maximum added resistance due to wind X_w, maximum added resistance due to waves X_d and maximum added rudder resistance due to manoeuvring in seaway X_r over wind and wave directions from head to 30 degrees off-bow.

Definition of wind resistance

12 The maximum added resistance due to wind X_w is calculated as

$$X_w = 0.5 X'_w(\varepsilon) \rho_a v_{wr}^2 A_F$$

where

$X'_w(\varepsilon)$	is the non-dimensional aerodynamic resistance coefficient;
ε (degree)	is the apparent wind angle;
ρ_a (kg/m^3)	is the air density, $\rho_a = 1.2$ kg/m^3;
v_{wr} (m/s)	is the relative wind speed, $v_{wr} = U + v_w \cos\mu$;
v_w (m/s)	is the absolute wind speed, defined by the adverse conditions in paragraph 1 of these guidelines; and
A_F (m^2)	is the frontal windage area of the hull and superstructure.

13 The maximum added resistance due to wind X_w is defined as maximum over wind directions from head $\varepsilon = 0$ to 30 degrees off-bow $\varepsilon = 30$.

14 The non-dimensional aerodynamic resistance coefficient X'_w is defined from wind tunnel tests or equivalent methods verified by the Administrations or the Recognized Organizations. Alternatively, it can be assumed with $X'_w = 1.1$, as the maximum over wind directions from head to 30 degrees off-bow. If deck cranes are installed in the ship and the lateral projected area of the deck cranes is equal to or exceeds 10% of the total lateral

projected area above the waterline of the ship, $X'_w = 1.4$ should be assumed instead of $X'_w = 1.1$.

Definition of added resistance due to waves

15 The maximum added resistance due to waves X_d is defined in accordance with either

.1 expression

$$X_d = 1336(5.3 + U)\left(\frac{B \cdot d}{L_{PP}}\right)^{0.75} \cdot h_s^2$$

where

L_{PP} (m)	is the length of the ship between perpendiculars;
B	is the breadth of the ship;
d	is the draft at the specified condition of loading; and
h_s (m)	is the significant wave height, defined according to paragraph 1 of these guidelines.

This expression defines the maximum added resistance over wave directions from head to 30 degrees off-bow.

.2 or spectral method

$$X_d = 2\int_0^{\infty}\int_0^{2\pi}\frac{X_d(U,\mu',\omega')}{A^2}S_{\varsigma\varsigma}(\omega')D(\mu-\mu')\,d\omega'\,d\mu'$$

where

$\frac{X_d}{A^2}$ (N/m^2)	is the quadratic transfer function of the added resistance in regular waves and A is the wave amplitude;
$S_{\varsigma\varsigma}(\omega')$	is the seaway spectrum specified as JONSWAP spectrum with the peak parameter 3.3;
$D(\mu-\mu')$	is the spreading function of wave energy with respect to mean wave direction specified as cos^2-directional spreading;
ω' (rad/s)	is the wave frequency of component;
μ (rad)	is the encountered angle between ship and wave; and
μ' (rad)	is the direction of the wave component.

16 The maximum added resistance due to waves X_d is defined as maximum over wave directions from head $\mu = 0$ to 30 degrees off-bow $\mu = 30$. The range of peak wave periods T_P applied in the assessment is from $3.6\sqrt{h_s}$ to the greater one of $5.0\sqrt{h_s}$ or 12.0 seconds, with the step of peak wave period not exceeding 0.5 seconds.

17 The added resistance in short-crested irregular head waves may be regarded as the maximum added resistance over wave directions from head to 30 degrees off-bow, because in short-crested waves, the maximum added resistance over wave directions from head waves to 30 degrees off-bow occurs in head waves.

18 The spreading function $D(\mu-\mu')$ is defined as cos^2-directional spreading. Alternatively, long-crested seaway may be assumed with $D(\mu-\mu') = 1$; in this case, the

maximum added resistance due to waves X_d can be determined by multiplying the added resistance in long-crested irregular head waves by the correction factor 1.3, to consider that maximum of the added resistance in long-crested waves does not always correspond to head wave direction.

19 The quadratic transfer functions of added resistance in regular waves $\frac{X_d}{A^2}$ are defined from seakeeping tests or equivalent methods verified by the Administrations or the Recognized Organizations. Alternatively, the semi-empirical method specified in appendix of this document can be used.

Definition of added rudder resistance due to manoeuvring in seaway

20 The maximum additional rudder resistance due to manoeuvring in seaway X_r may be calculated for practicality in a simplified way as

$X_r = 0.03 \cdot T_{er}$, where T_{er} is the propeller thrust excluding X_r from T.

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APPENDIX TO APPENDIX 2

SEMI-EMPIRICAL METHOD FOR QUADRATIC TRANSFER FUNCTIONS OF ADDED RESISTANCE IN REGULAR WAVES

The method for the calculation of the quadratic transfer functions of added resistance give in this appendix can be applied to wave directions from head to beam. Therefore, this method can be used for obtaining the added resistance in short-crested irregular waves of the head mean wave direction.

The quadratic transfer functions of added resistance in regular head to beam waves $\mathrm{X}'_{\mathrm{d}} = \frac{\mathrm{X}_{\mathrm{d}}}{\mathrm{A}^2}$, N/m^2, can be calculated as a sum

$$\mathrm{X}'_{\mathrm{d}} = \mathrm{X}'_{\mathrm{dM}} + \mathrm{X}'_{\mathrm{dR}}$$

of $\mathrm{X}'_{\mathrm{dM}}$, the component of added resistance due to motion (radiation) effect, and $\mathrm{X}'_{\mathrm{dR}}$, the component of added resistance due to reflection (diffraction) effect in regular waves.

The expression of X'_{dM} is given as follows:

$$\mathrm{X}'_{\mathrm{dM}} = 4\rho g \frac{B^2}{L_{pp}} a_1 a_2 \overline{\omega}^{b_1} e^{\frac{b_1}{d_1}(1-\overline{\omega}^{d_1})}$$

where

$$\overline{\omega} = \begin{cases} 2.142\sqrt[3]{k_{yy}}\sqrt{\frac{L_{pp}}{\lambda}}\left[1 - \frac{0.111}{C_B}\left(\ln\frac{B}{d} - \ln 2.75\right)\right]\frac{(2-\cos\beta)}{3}(Fr + 0.62) & \text{for } Fr < 0.1 \\ 2.142\sqrt[3]{k_{yy}}\sqrt{\frac{L_{pp}}{\lambda}}\left[1 - \frac{0.111}{C_B}\left(\ln\frac{B}{d} - \ln 2.75\right)\right]\frac{(2-\cos\beta)}{3}Fr^{0.143} & \text{for } Fr \geq 0.1 \end{cases}$$

$$a_1 = 60.3 C_B^{1.34}\left(4\mathrm{k}_{\mathrm{yy}}\right)^2\left(\frac{0.87}{C_{\mathrm{B}}}\right)^{-(1+\mathrm{Fr})\cos\beta}\left(\ln\frac{\mathrm{B}}{\mathrm{d}}\right)^{-1}\frac{(1-2\cos\beta)}{3} \quad \text{for } \frac{\pi}{2} \leq \beta \leq \pi$$

$$a_2 = \begin{cases} 0.0072 + 0.1676Fr & \text{for } Fr < 0.12 \\ Fr^{1.5}exp(-3.5Fr) & \text{for } Fr \geq 0.12 \end{cases}$$

for $C_B > 0.75$

$$\mathrm{b}_1 = \begin{cases} 11.0 & \text{for } \overline{\omega} < 1 \\ -8.5 & \text{elsewhere} \end{cases}$$

$$\mathrm{d}_1 = \begin{cases} 566\left(\frac{\mathrm{L}_{\mathrm{PP}}}{\mathrm{B}}\right)^{-2.66} & \text{for } \overline{\omega} < 1 \\ -566\left(\frac{\mathrm{L}_{\mathrm{PP}}}{\mathrm{B}}\right)^{-2.66} \times 6 & \text{elsewhere} \end{cases}$$

for $C_B \leq 0.75$

$$\mathrm{b}_1 = \begin{cases} 11.0 & \text{for } \overline{\omega} < 1 \\ -8.5 & \text{elsewhere} \end{cases}$$

$$\mathrm{d}_1 = \begin{cases} 14.0 & \text{for } \overline{\omega} < 1 \\ -566\left(\frac{\mathrm{L}_{\mathrm{PP}}}{\mathrm{B}}\right)^{-2.66} \times 6 & \text{elsewhere} \end{cases}$$

where

$\beta = \pi - \mu$	is the wave direction, $\beta=\pi$ means head seas;
λ (m)	is the length of the incident wave;
B (m)	is the beam of the ship;
d (m)	is the draft of the ship; and
k_{yy}	is the non-dimensional radius of gyration of pitch.

The expression of X'_{dR} is given as follows:

$$X'_{dR} = \sum_{i=1}^{4} {X'_{dR}}^{i}$$

where

${X'_{dR}}^{i}$ is the added resistance due to reflection/diffraction effect of the S_i waterline segment, as shown in Figure 1.

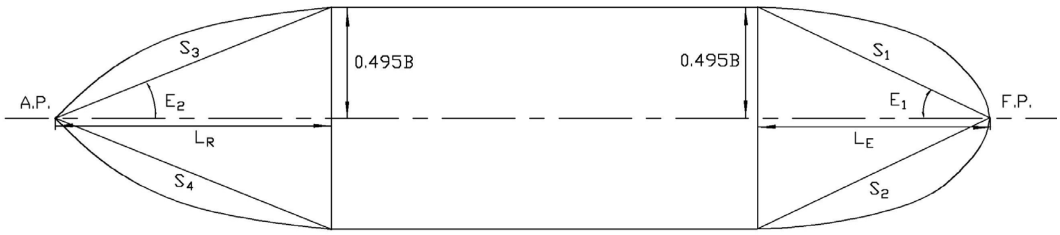

Figure 1: Sketch of the waterline profile of a ship and related definitions

when $E_1 \leq \beta \leq \pi$

$${X'_{dR}}^{1} = \frac{2.25}{4}\rho g B \alpha_{d^*}\left\{\sin^2(E_1-\beta) + \frac{2\omega_0 U}{g}\left[\cos E_1 \cos(E_1-\beta) - \cos\beta\right]\right\}\left(\frac{0.87}{C_B}\right)^{(1+4\sqrt{Fr})f(\beta)}$$

when $\pi\text{-}E_1 \leq \beta \leq \pi$

$${X'_{dR}}^{2} = \frac{2.25}{4}\rho g B \alpha_{d^*}\left\{\sin^2(E_1+\beta) + \frac{2\omega_0 U}{g}\left[\cos E_1 \cos(E_1+\beta) - \cos\beta\right]\right\}\left(\frac{0.87}{C_B}\right)^{(1+4\sqrt{Fr})f(\beta)}$$

when $0 \leq \beta \leq \pi\text{-}E_2$

$${X'_{dR}}^{3} = -\frac{2.25}{4}\rho g B \alpha_{d^*}\left\{\sin^2(E_2+\beta) + \frac{2\omega_0 U}{g}\left[\cos E_2 \cos(E_2+\beta) - \cos\beta\right]\right\}$$

when $0 \leq \beta \leq E_2$

$${X'_{dR}}^{4} = -\frac{2.25}{4}\rho g B \alpha_{d^*}\left\{\sin^2(E_2-\beta) + \frac{2\omega_0 U}{g}\left[\cos E_2 \cos(E_2-\beta) - \cos\beta\right]\right\}$$

where

ω_0 is the frequency of the incident wave;

α_{d^*} is the draft coefficient, calculated as

$$\alpha_{d^*} = \begin{cases} 0 & \text{for } \frac{\lambda}{L_{pp}} > 2.5 \\ 1 - \exp\left[-4\pi\left(\frac{d^*}{\lambda} - \frac{d^*}{2.5L_{pp}}\right)\right] & \text{for } \frac{\lambda}{L_{pp}} \leq 2.5 \end{cases}$$

where for S_1 and S_2 segments

$$d^* = d$$

and for S_3 and S_4 segments

$$d^* = \begin{cases} \dfrac{d\left(4+\sqrt{|\cos\beta|}\right)}{5} & \text{for } C_B \le 0.75 \\ \dfrac{d\left(2+\sqrt{|\cos\beta|}\right)}{3} & \text{for } C_B > 0.75 \end{cases}$$

$$f(\beta) = \begin{cases} -\cos\beta & \text{for } \pi - \mathrm{E}_1 \le \beta \le \pi \\ 0 & \text{for } \beta < \pi - \mathrm{E}_1 \end{cases}$$

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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

$$\textit{Reference line value} = 170.84 \cdot b^{-0.214}$$

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. $C_{F,ME} = C_{F,AE} = C_F = 3.1144$ g CO_2/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.

.2 $P_{ME(i)}$ 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).

.3 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}=215g/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.

.4 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.

.5 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.

.6 $P_{PTI(i)}$ 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.

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

$$Estimated\ Index\ Value = \frac{3.1144 \cdot 190 \cdot \sum_{i=1}^{nME} P_{ME(i)} + C_{F,AE} \cdot SFC_{AE} \cdot \left(P_{AE} + \sum_{i=1}^{nPTI} P_{PTI(i)}\right)}{Gross\ tonnage \cdot V_{ref}}$$

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2022 INDUSTRY GUIDELINES FOR CALCULATION AND VERIFICATION OF THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)

TABLE OF CONTENTS

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 latest IMO Resolutions with respect to following Guidelines:

- 2022 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships adopted by Resolution MEPC.364(79) as amended referred to as the "IMO Calculation Guidelines" in the present document.

- 2022 Guidelines on the Survey and Certification of the Energy Efficiency Design Index (EEDI) adopted by Resolution MEPC.365(79) as amended referred to as the "IMO Verification Guidelines" in the present document.

- Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions MEPC.1/Circ.850/Rev.3 as amended.

- 2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI, MEPC.1/Circ.896 .

- 2012 interim Guidelines for the calculation of the coefficient f_w for decrease in ship speed in a representative sea condition for trial use, MEPC.1/Circ.796.

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 2.2.18 of MARPOL Annex VI of 400 gross tonnage and above of the ship types to which Regulation 22 of MARPOL Annex VI is applicable and defined under regulations of MARPOL Annex VI.

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 category A ships as defined in the Polar Code

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:

$$EEDI = \frac{CO_2 emission}{Transport\ work}$$

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 in 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:

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

With the following notes:

The global fi factor may also be written:

$$f_i = \left(\prod_{i=1}^{m} f_i\right)$$

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 $P_{AE} \cdot C_{FAE} \cdot SFC_{AE}$ may be replaced by:

$$\left(P_{AE} - 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)}\right) \cdot C_{FAE} \cdot SFC_{AE} + 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$$

with the condition $0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} \leq P_{AE}$.

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

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 compliance with Regulations 22, 24 of 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 the NOx Technical Code 2008.

The fuel used when determining corrected SFC corresponds to the value of the CF conversion factor, according to the table provided under paragraph "CF ; Conversion factor between fuel consumption and CO2 emission" of the IMO Calculation Guidelines.

SFC is the corrected specific fuel consumption, measured in g/kWh, of the engines or steam turbines as defined under paragraph "SFC, Certified specific fuel consumption" of the IMO Calculation guidelines.

- In case SFC is corrected to ISO standard reference conditions with standard LCV of LFO (41,200 kJ/kg), SFC and the conversion factor, Cf (3.151), are to correspond to LFO;
- In case SFC is corrected to ISO standard reference conditions with standard LCV of MDO (42,700kJ/kg), SFC and the conversion factor, Cf (3.206), are to correspond to MDO.

For main engines certified to the E2 or E3 test cycles of the NOx Technical Code 2008, the engine Specific Fuel Consumption (SFCME(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.

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 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 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 passenger and cruise passenger ships and of the deadweight for other types of ships as indicated the IMO Calculation Guidelines.

For the computation of the deadweight according to 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.

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).

The total propulsion power is conventionally taken as follows:

$$\sum_{i=1}^{nME} P_{ME(i)} + \sum_{i=1}^{nPTI} (P_{PTI(i)} \cdot \eta_{PTI(i)}) \cdot \eta_{\overline{Gen}}$$

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)

If shaft motors are installed (PTI), then in principle 75% of the shaft motor propulsion power is accounted for in the EEDI calculation. Detailed explanation about this is given in section 6.

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.

1 under "PAE ; Auxiliary engine power" of the IMO Calculation Guidelines.

For Passenger ships, Ro-Ro Passenger Ships and Cruise Passenger Ships, 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 (EPT), divided by the average efficiency of the generator(s) weighted by power.

As an option for other vessel types, if the difference between P_{AE} value calculated by paragraphs "PAE ; Auxiliary engine power" of IMO Calculation Guidelines and P_{AE} based on EPT, leads to a variation of the computed EEDI value exceeding 1%, the value for auxiliary power could be taken from the EPT.

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 paragraphs "$P_{PTO(i)}$; Shaft generator" and "$P_{PTI(i)}$; Shaft Motor" of IMO Calculation Guidelines, content of this section applies to ships other than LNG carriers having diesel-electric propulsion system.

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 other 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} 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 "Option 2 of $P_{PTO(i)}$; Shaft generator" 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 “PAE ; Auxiliary engine power” of the IMO Calculation Guidelines. Then the main engine power P_{ME} is:

$$P_{PTO(i)} = 0.75 \times MCR_{PTO(i)}$$

$$\sum_{i=1}^{nME} P_{ME(i)} = 0.75 \times \sum MCR_{ME(i)} - 0.75 \times \sum P_{PTO(i)} \qquad with \sum P_{PTO(i)} \leq \frac{P_{AE}}{0.75}$$

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 to be used in the EEDI calculation must NOT be greater than the auxiliary power calculated in accordance to Para. “PAE ; Auxiliary engine power” of 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.

$$P_{ME(i)} = 0.75 \times P_{shaft,limit}$$

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 ΣP_{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) $\eta_{\overline{Ge}}$ is taken into account for EEDI calculation[3].

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

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

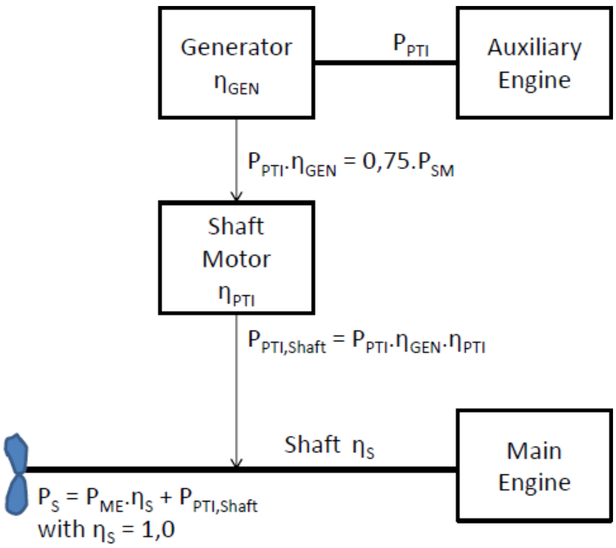

Figure 1.1: flow of power in a generic shaft motor installation

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.

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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.

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

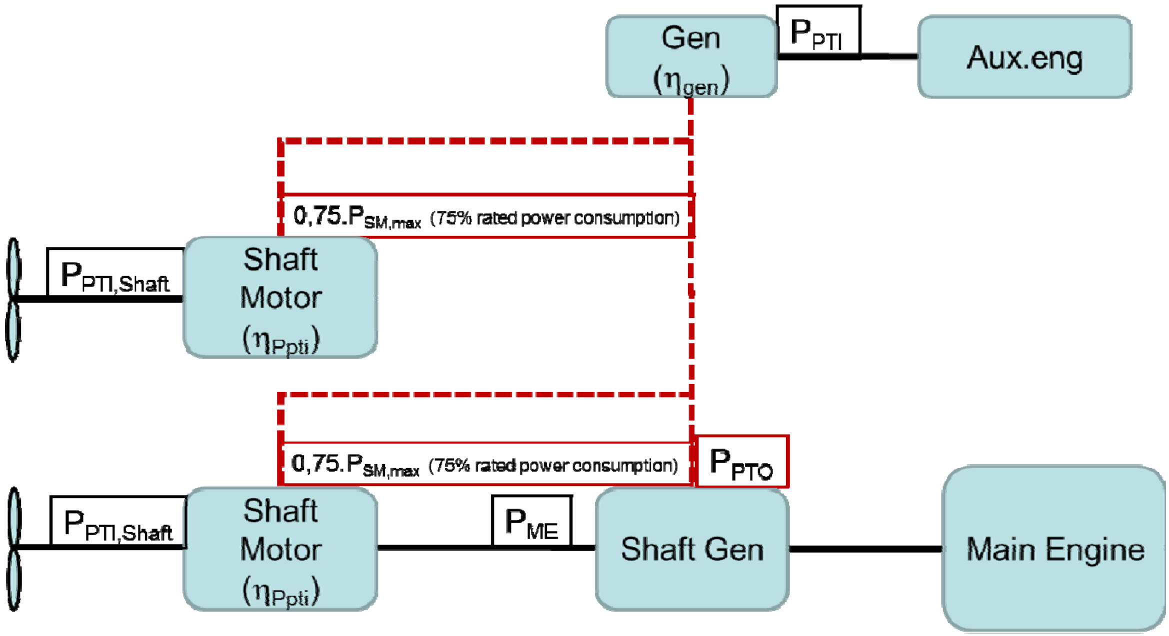


Figure 1.2: Typical arrangement of propulsion and electric power system

6.5 Calculation examples

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

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

6.5.1 One main engine, no shaft generator

$MCR_{ME} = 20{,}000 kW$
$P_{ME} = 0.75 \times MCR_{ME} = 0.75 \times 20{,}000 kW =$
$15{,}000 kW$ $P_{AE} = (0.025 \times 20{,}000) + 250 kW =$
$750 kW$

$EEDI = ((15{,}000 \times 3.206 \times 190) + (750 \times 3.206 \times 215))/(20 \times 20{,}000)$
$= 24.1\ g\ CO_2 / t\ nm$

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

$MCR_{PTO} = 500kW$
$P_{PTO} = 500kW \times 0.75 = 375kW$
$MCR_{ME} = 20{,}000kW$

$P_{ME} = 0.75 \times MCR_{ME} - 0.75 \times P_{PTO} = 0.75 \times 20{,}000kW - 0.75 \times 375kW = 14{,}719kW$

$P_{AE} = (0.025 \times MCR_{ME}) + 250kW = 750kW$
$V_{ref} = 19.89kn$: The speed at P_{ME} determined from the power curve
$EEDI = (P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME}) + ((P_{AE} - 0.75 \times P_{PTO}) \times C_{F,AE} \times SFC_{AE}) / (DWT \times V_{ref})$

$= 23.8\ g\ CO_2 / t\ nm \approx$

6.5.3 One main engine, 0.75 x P_{PTO}=P_{AE}, option 1

$MCR_{PTO} = 1{,}333kW$
$P_{PTO} = 1{,}333kW \times 0.75 = 1{,}000kW$
$MCR_{ME} = 20{,}000kW$

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

$P_{AE} = (0.025 \times MCR_{ME}) + 250kW = 750kW$
$v_{ref} = 19.71kn$: The speed at P_{ME} determined from the power curve

$EEDI = (P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME}) / (DWT \times V_{ref})$

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

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

$MCR_{PTO} = 2{,}000kW$
$0.75 \times P_{PTO} = 0.75 \times 2{,}000kW \times 0.75 = 1{,}125kW > P_{AE} \Rightarrow P_{PTO} = P_{AE} / 0.75 = 1{,}000kW$
$MCR_{ME} = 20{,}000kW$

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

$P_{AE} = (0.025 \times MCR_{ME}) + 250kW = 750kW$
$V_{ref} = 19.71kn$: The speed at P_{ME} determined from the power curve

$EEDI = (P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME}) / (DWT \times V_{ref})$

$= 23.2\ g\ CO_2 / tnm \approx 4\%$

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

$MCR_{PTO} = 2{,}000kW$
$MCR_{ME} = 20{,}000kW$
$P_{Shaft,limit} = 18{,}000kW$
$P_{ME} = (0.75 \times P_{Shaft,limit})$=0.75×(18,000 kW)=13.500kW
$P_{AE} = (0.025 \times MCR_{ME}) + 250kW = 750kW$
$V_{ref} = 19.41kn$: The speed at P_{ME} determined from the power curve

$EEDI = (P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME}) / (DWT \times V_{ref})$

=22.4 g CO2 / t nm ≈ 7%

6.5.6 One main engine, one shaft motor

$MCR_{ME} = 18{,}000kW$

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

$P_{AE} = \left\{0.025 \times \left(MCR_{ME} + \frac{P_{PTI}}{0.75}\right)\right\} + 250kW = \left\{0.025 \times \left(18000 + \frac{1612.9}{0.75}\right)\right\} + 250kW = 754kW$

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

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

$\eta_{PTI} = 0.97$

$\eta_{Gen} = 0.93$

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

$14{,}955kW$ $v_{ref} = 20kn$

$EEDI = (P_{ME} \times C_{F,ME} \times SFC_{ME}) + (P_{AE} \times C_{F,AE} \times SFC_{AE}) + (P_{PTI} \times C_{F,AE} \times SFC_{AE}) / (DWT \times V_{ref})$

$= 24.6\ g\ CO_2 / t\ nm \approx -2\%$

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 $EEDI_{weather}$" in order to clearly distinguish it from the attained EEDI under regulations 22 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, as amended.

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 power correction factor is indicated in the IMO Calculation Guidelines[4].

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 correction factor f_{jRoRo} is to be computed according to the IMO calculation Guidelines.

For general cargo ships, the correction factor f_j is to be computed according to 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 and Correction Factor f_m for ice-classed ships having IA Super or IA

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 capacity correction factor is indicated in the IMO Calculation Guidelines.[4]

For a ship with voluntary structural enhancement, the f_{iVSE} ship specific voluntary structural enhancement factor is to be computed according to 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_{iCSR} factor is to be computed according to the IMO Calculation Guidelines.

f_i capacity factors can be cumulated (multiplied), but the reference design for calculation of f_{iVSE} is to comply with the ice notation and/or Common Structural Rules as the case may be.

For ice-classed ships having IA Super or IA, the factor, f_m = 1.05 should apply according to 2.2.19 of the IMO Calculation Guidelines.

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 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 the IMO Calculation Guidelines. This factor is not to be applied to LNG carriers defined in regulation 2.2.16 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_{cRoPax} is to be computed according to the IMO Calculation Guidelines.

For bulk carriers having R of less than 0.55 (e.g. wood chip carriers), the cubic capacity correction factor, fc bulk carriers designed to carry light cargoes, = R-0.15 should apply according to the IMO Calculation Guidelines. where, R is the capacity ratio of the deadweight of the ship (tonnes) divided by the total cubic capacity of the cargo tanks of the ship (m3)

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 the IMO Calculation Guidelines.

11 Innovative energy efficient technologies

Innovative energy efficient technologies are to be taken into account according to the 2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI, MEPC.1/Circ.896.

[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 fi and fj factors may be accepted for ice-classed ships outside this scope of application (e.g. very large ships or POLAR CLASS)

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: MCR_{PTO} (kW) = KVA_{PTO} * 0.8 where 0.8 is the conventional power factor.

Table 1: input parameters for calculation of EEDI

Symbol	Name	Usage	Source	Scope
	Service notation	Capacity, f_i, f_j and f_c factors		For the ship
	Class notations	fj for shuttle tanker, f_{iCSR}	Classification file	
	Ice notation	fi, fj for ice class		
Lpp	Length between perpendiculars (m)	fi, fj for ice class, f_{jRoRo}, f_j for general cargo ships		
B_S	Breadth (m)	f_{jRoRo}, f_j for general cargo ships		
d_S	Summer load line draught (m)	f_{jRoRo}, f_j for general cargo ships		
∇	Volumetric displacement	f_{jRoRo}, f_j for general cargo ships		
Δ	Displacement @ summer load draught (t)	deadweight, f_{iVSE}, f_{cRoPax}, f_l for general cargo ships, f_c for bulk carriers	final stability file	
LWT	Ligthweight (t)	deadweight, f_{iVSE}, f_{iCSR}, f_{cRoPax} f_l for general cargo ships	Sheets of Submitter calculation for $lightweight_{referencedesign}$ lightweight check report	
GT	Gross tonnage	Capacity, f_{cRoPax}		
P_{AE}	Auxiliary engine power (kW)	EEDI	Note: Computed from engines & PTIs powers or electric power table	
V_{ref}	Reference speed (knot)	EEDI, f_{jRoRo}, f_j for general cargo ships	Sea trial report	
Cube	Total cubic capacity of the cargo tanks (m3)	f_c for chemical tankers and gas carriers	Tonnage file	
Vgas(or liquid)	Tank volume for fuels (m3)	f_{DFgas}, $f_{DFliquid}$ availability ratios	Capacity plan	
SWL	Safe working load of the crane (t)	f_l for general cargo ships		
Reach	Reach of the crane (m)	f_l for general cargo ships		

Symbol	Name	Usage	Source	Scope
MCR	Rated installed power (kW)	P_{ME}	EIAPP certificate or nameplate (if less than 130 kW)	Per engine (nME + nGEN)
MCR_{lim}	Limited rated output power after PTO in (kW)	P_{ME} with PTO option 2	Verification file	
MPP_{Motor}	Rated output of motor (kW)	P_{ME} for LNG carriers having diesel electric propulsion system	Certificate of the product	
η	Electrical efficiency	P_{ME} for LNG carriers having diesel electric propulsion system		
$MCR_{SteamTurbine}$	Rated installed power (kW)	P_{ME} for LNG carriers having steam turbine propulsion system	Certificate of the product	
	Fuel grade	C_F, SFC	NOX Technical File of the parent engine	
SFC	Corrected specific fuel consumption (g/kWh)	EEDI	NOx Technical File of the parent engine	
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)
η_{PTI}	efficiency	power		
η_{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 according to the IMO verification Guidelines. 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.

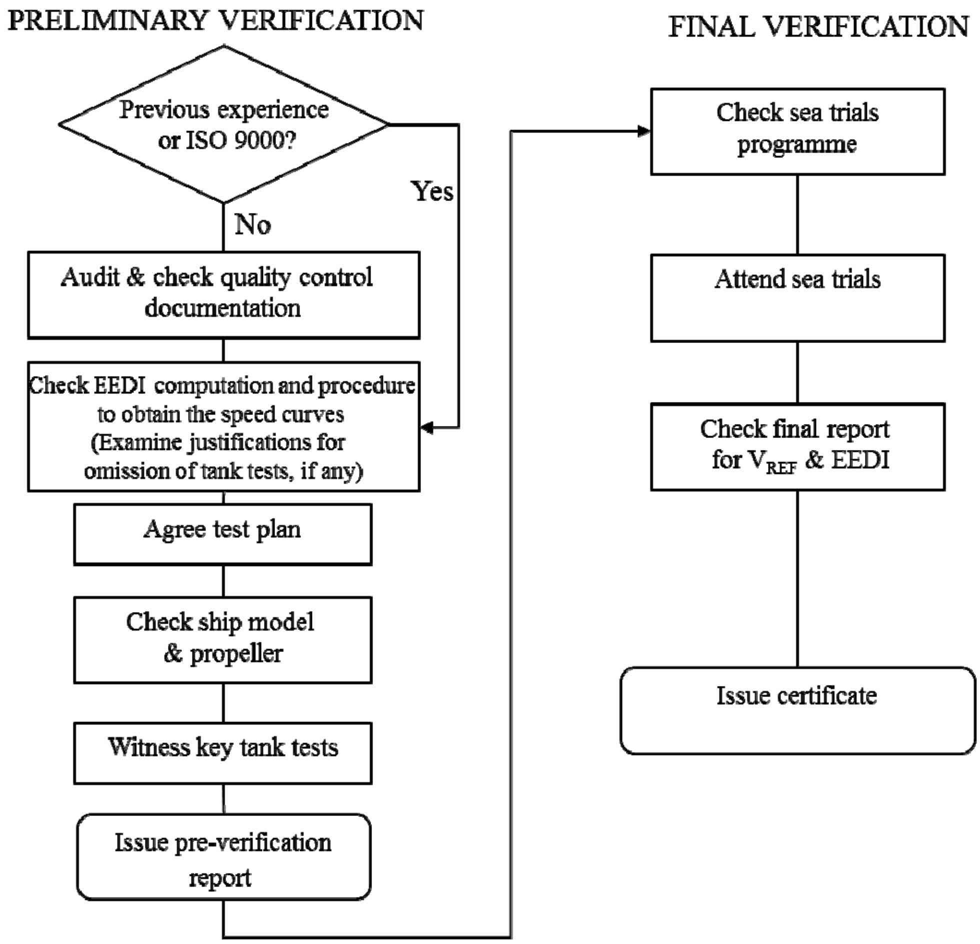


Figure 2: Flow of survey and certification process by verifier

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/documents are to be submitted by the submitter to the verifier at the design stage. Reference is to be made also to Appendix 1, Appendix 3 and Appendix 4

Table 2: documents to be submitted at the design stage

EEDI Technical File	EEDI Technical File as defined in the IMO Verification Guidelines. See example of the EEDI Technical File in Appendix 1 of IMO Verification Guidelines.
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 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

Programme of sea trials	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.
Sea trials report	Report of sea trials with detailed computation of the corrections allowing determination of the reference speed V_{ref}
Final stability file	Final stability file including lightweight of the ship and displacement table based on the results of the inclining test or the lightweight check
Final power curves	Final power curve in the EEDI condition showing the speed adjustment methodology
Revised EEDI Technical File	Including identification of the parameters differing from the calculation performed at the initial verification stage
Ship lines	Lines of actual ship

Concerning confidential information of submitters that may be contained in the above mentioned documents, reference is to be made to IMO Verification Guidelines,

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. ΔC_{FC} and Δw_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.

Possible omission of towing tank tests is addressed in 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:

$$C_{TS} = \frac{S_S + S_{BK}}{S_S} \cdot [(1+k) \cdot C_{FS} + \Delta C_F + C_A] + C_R + C_{AAS} + C_{AppS}$$

The way of calculating the form factor k, the roughness allowance ΔC_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 (ΔC_{FC} - Δw_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 Cp and ΔC_{FC} between the EEDI condition (∇_{full}) and sea trial condition if different from EEDI condition (∇) 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.

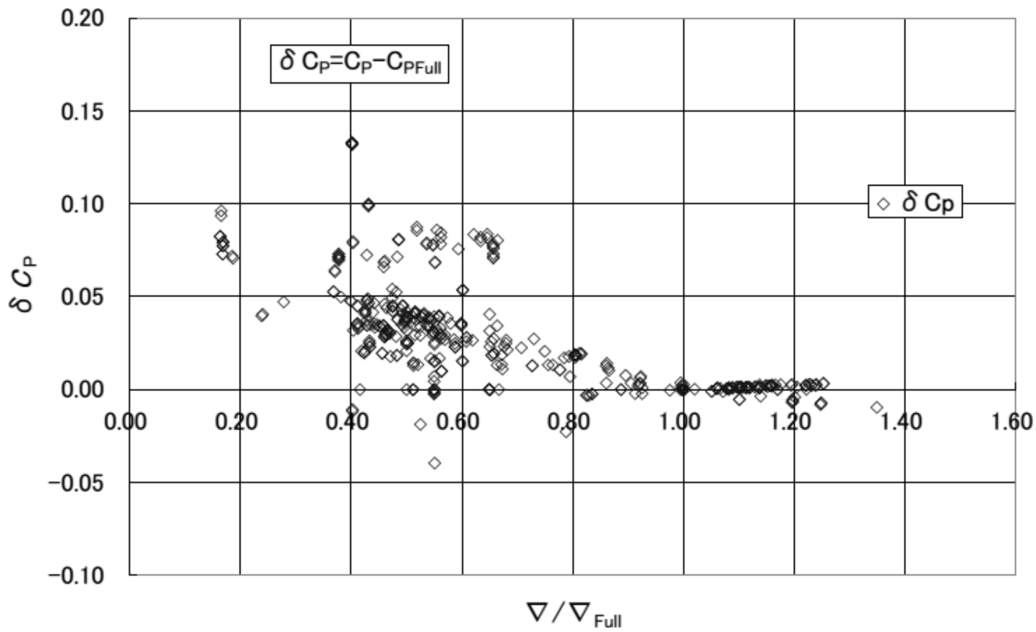


Figure 3.1: Variation of C_P- C_{PFull} as a function of the displacement ratio

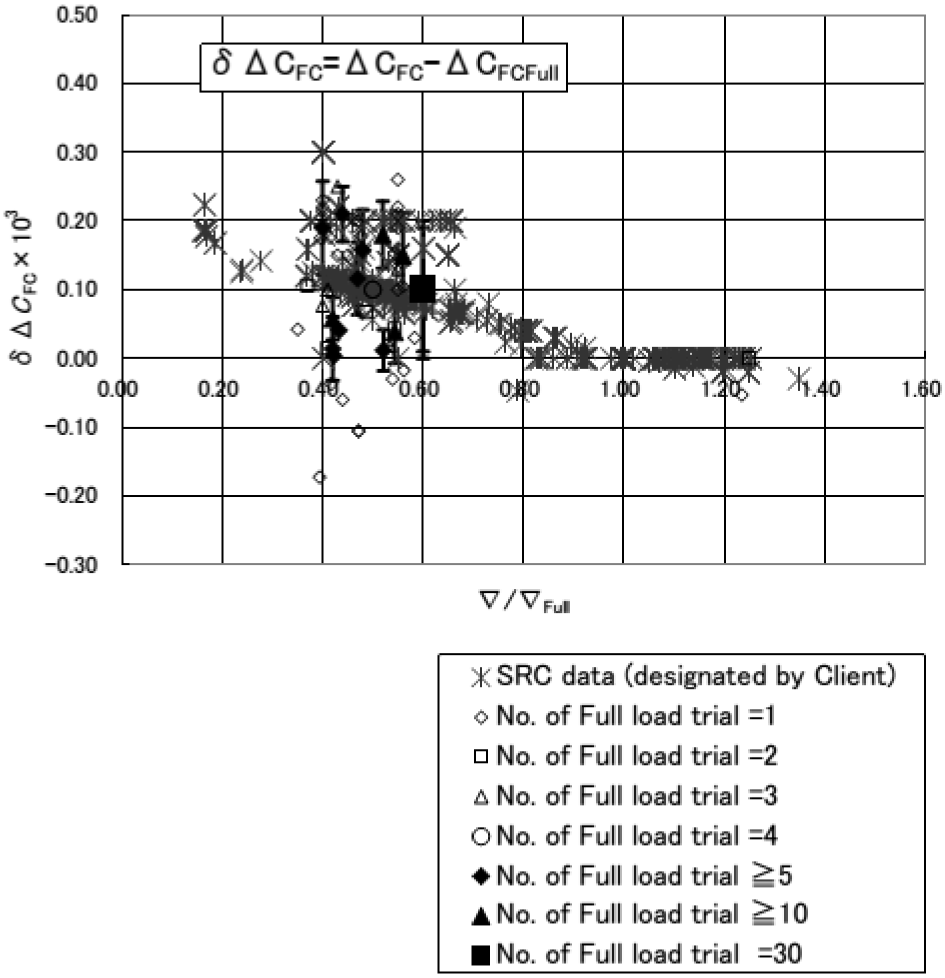


Figure 3.2: Variation of ΔC_{FC} as a function of the displacement ratio

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

- 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 2017 or ISO 15016:2015.

Table 4 lists data which are to be measured and recorded during sea trials:

Table 4: Measured data during sea trials

Symbol	Name	Measurement	Remark
	Time and duration of sea trial		
	Draft marks readings		
	Air and sea temperature		
	Main engine setting	Machinery log	
Ψ_0	Course direction (rad)	Compass	
V_G	Speed over ground (m/s)	GPS	
n	Propeller rpm (rpm)	Tachometer	
P_S	Power measured (kW)	Torsion meter or strain gauges (for torque measurement) or any alternative method that offer an equivalent level of precision and accuracy of power measurement	
V_{WR}	Relative wind velocity (m/s)	Wind indicator	
Ψ_{WR}	Relative wind direction (rad)	See above	
T_m	Mean wave period (seas and swell) (s)	Visual observation by multiple observers supplemented by hindcast data or wave measuring devices (wave buoy, wave radar, etc.)	
$H_{1/3}$	Significant wave height (seas and swell) (m)	See above	
χ	Incident angle of waves (seas and swell) (rad)	See above	
δ_R	Rudder angle (rad)	Rudder	
β	Drift angle (rad)	GPS	

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_{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 introduction section of ISO 15016:2015. 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_{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

Reference is to be made to para 4.3.13 and para 4.3.14 of the IMO Verification 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 2.2.17 and interpretations in MEPC.1/Circ.795/ Rev6 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

Ref.	Function	Survey method	Reference document	Documentation available to verifier	Remarks
01	EEDI Technical File	Review	IMO Verification Guidelines This document	Documents in table 2	
02	Limitation of power	Review	IMO Calculation Guidelines	Verification file of limitation technical means	Only If means of limitation are fitted
03	Electric Power Table	Review	Appendix 2 to IMO Calculation Guidelines Appendix 2 to IMO Verification Guidelines	EPT EPT-EEDI form	As described under paragraph 5.2 of this industry guideline.
04	Calibration of towing tank test measuring equipment	Review & witness	Appendix 3	Calibration reports	Check at random that measuring devices are well identified and that calibration reports are currently valid
05	Model tests – ship model	Review & witness	Appendix 4	Ship lines plan & offsets table Ship model report	Checks described in Appendix 4.1
06	Model tests – propeller model	Review & witness	Appendix 4	Propeller model report	Checks described in Appendix 4.2
07	Model tests – Resistance test, Propulsion test, Propeller open water test	Review & witness	Appendix 4	Towing tank tests report	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.

Ref.	Function	Survey method	Reference document	Documentation available to verifier	Remarks
08	Model-ship extrapolation and correlation	Review	ITTC 7.5-02-03-01.4 1978 ITTC performance prediction method (rev.04 of 2017 or subsequent revision) Appendix 4 This document 15.7	Documents in table 2	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 (ΔC_{FC} - Δw_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
09	Numerical calculations replacing towing tank tests	Review	ITTC 7.5-03-01-04 (latest revision) or equivalent	Report of calculations	For justification of calculations replacing model tests refer to 15.3.
10	Electrical machinery survey prior to sea trials	Witness	Appendix 2 to IMO Verification Guidelines		Only if P_{AE} is computed from EPT
11	Programme of sea trials	Review	IMO Verification Guidelines	Programme of sea trials	Check minimum number of measurement points (3) Check the EEDI condition in EPT (if P_{AE} is computed from EPT)
12	Sea trials	Witness	ISO 15016:2015 or ITTC 7.5-04-01-01.1 (latest revision)		Check: • Propulsion power, particulars of the engines • Draught and trim • Sea conditions • Ship speed • Shaft power & 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)

Ref.	Function	Survey method	Reference document	Documentation available to verifier	Remarks
13	Sea trials – corrections calculation	Review	ISO 15016:2015 or ITTC Recommended Procedure 7.5-04-01-01.1(latest revision)	Sea trials report	Check that the displacement and trim of the ship in sea trial condition has been obtained with sufficient accuracy Check compliance with ISO 15016:2015 or ITTC Recommended Procedure 7.5-04-01-01.1(latest revision)
14	Sea trials – adjustment from trial condition to EEDI condition	Review	This document 16.2	Power curves after sea trial	Check that the power curve estimated for EEDI condition is obtained by power adjustment
15	EEDI Technical File – revised after sea trials	Review	IMO Verification Guidelines	Revised EEDI Technical File	Check that the file has been updated according to sea trials results

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*

Revision list

B	01/05/2014	Final stage: sections 1 to 16	XYZ	YYY	ZZZ
A	01/01/2013	Design stage: sections 1 to 13	XXX	YYY	ZZZ
REV.	**ISSUE DATE**	**DESCRIPTION**	**DRAWN**	**CHECKED**	**APPROVED**

1 General

This calculation of the Energy Efficiency Design Index (EEDI) is based on:

- All adopted MEPC resolutions regarding amendments to Chapter 4 of MARPOL Annex VI prior to the date of revision of this guideline
- Resolution MEPC.364 (79) 2022 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, as amended.

Calculations are being dealt with according to the Industry Guidelines on calculation and verification of EEDI, 2020 issue.

2 Data

2.1 Main parameters

Parameter	Value	Reference
Owner	OWNER	
Builder	YARD	
Hull No.	12346	
IMO No.	94111XX	
Ship's type	Bulk carrier	
Ship classification notations	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	
HULL PARTICULARS		
Length overall	191.0 m	
Length between perpendiculars	185.0 m	
Breadth, moulded	32.25 m	
Depth, moulded	17.9 m	
Summer load line draught, moulded	12.70 m	
Deadweight at summer load line draught	55000 DWT	
Lightweight	11590 tons	
Owner's voluntary structural enhancements	No	
MAIN ENGINE		
Type & manufacturer	BUILDER 6SRT60ME	
Specified Maximum Continuous Rating (SMCR)	9200 kW x 105 rpm	
SFC at 75% SMCR	171 g/kWh	See paragraph 10.1
Number of set	1	
Fuel type	Diesel/Gas oil	
AUXILIARY ENGINES		

Parameter	Value	Reference
Type & manufacturer	BUILDER 5X28	
Specified Maximum Continuous Rating (SMCR)	650 kW x 700 rpm	
SFC at 50% SMCR	205 g/kWh	See paragraph 10.2
SFC at 75% SMCR (In case PAE is estimated by the electric power table (EPT) for the reason that PAE computed using the formula in the IMO Calculation Guidelines is significantly different from the total power used at normal seagoing)	199 g/kWh	See paragraph 10.2
Number of set	3	
Fuel type	Diesel/Gas oil	
OVERVIEW OF PROPULSION SYSTEM AND ELECTRICITY SUPPLY SYSTEM		See section 4
SHAFT GENERATORS		
Type & manufacturer	None	
Rated electrical output power		
Number of set	0	
SHAFT MOTORS		
Type & manufacturer	None	
Rated power consumption		
Efficiency		
Number of set	0	
MAIN GENERATORS		
Type & manufacturer	BUILDER AC120	
Rated output	605 kWe	
Efficiency	0.93	
Number of set	3	
PROPULSION SHAFT		
Propeller diameter	5.9 m	
Propeller number of blades	4	
Voluntarily limited shaft propulsion power	No	
Number of set	1	
ENERGY SAVING EQUIPMENT		See section 9
Description of energy saving equipment	Propeller boss cap fins	
Power reduction or power output	None	

2.2 Preliminary verification of attained EEDI

Parameter	Value	Reference
TOWING TANK TEST ORGANIZATION		
Identification of organization	TEST corp.	See section 6.
ISO Certification or previous experience?	Previous experience	

TOWING TANK TESTS		
Exemption of towing tank tests	No	
Process and methodology of estimation of the power curves		See section 7
Ship model information		See subparagraph 7.2.1
Propeller model information		See subparagraph 7.2.2
EEDI & sea trial loading conditions	EEDI: mean draft: 12.7 m Trim 0 Sea trial (ballast): mean draft: 5.8 m Trim 2.6 m by stern	
Propeller open water diagram (model, ship)		See paragraph 7.4
Experience based parameters		See paragraph 7.3
Power curves at full scale		See section 3
Ship Reference speed	14.25 knots	
ELECTRIC POWER TABLE (as necessary, as defined in IMO Calculation Guidelines)	As described under paragraph 5.2 of this industry guideline.	See section 5
CALCULATION OF ATTAINED EEDI	5.06	See section 11
CALCULATION OF REQUIRED EEDI	5.27	See section 12
CALCULATION OF ATTAINED $EEDI_{weather}$	Not calculated	See section 13

2.3 Final verification of attained EEDI

Parameter	Value	Reference
SEA TRIAL LOADING CONDITION		
POWER CURVES		See section 3
Sea trial report with corrections		See section 15
Ship Reference speed	14.65 knots	
FINAL DEADWEIGHT		See section 14
Displacement	66171 tons	
Lightweight	11621 tons	
Deadweight	54550 DWT	
FINAL ATTAINED EEDI	4.96	See section 16

3 Power curves

The power curves estimated at the design stage and modified after the sea trials are given in Figure 3.1.

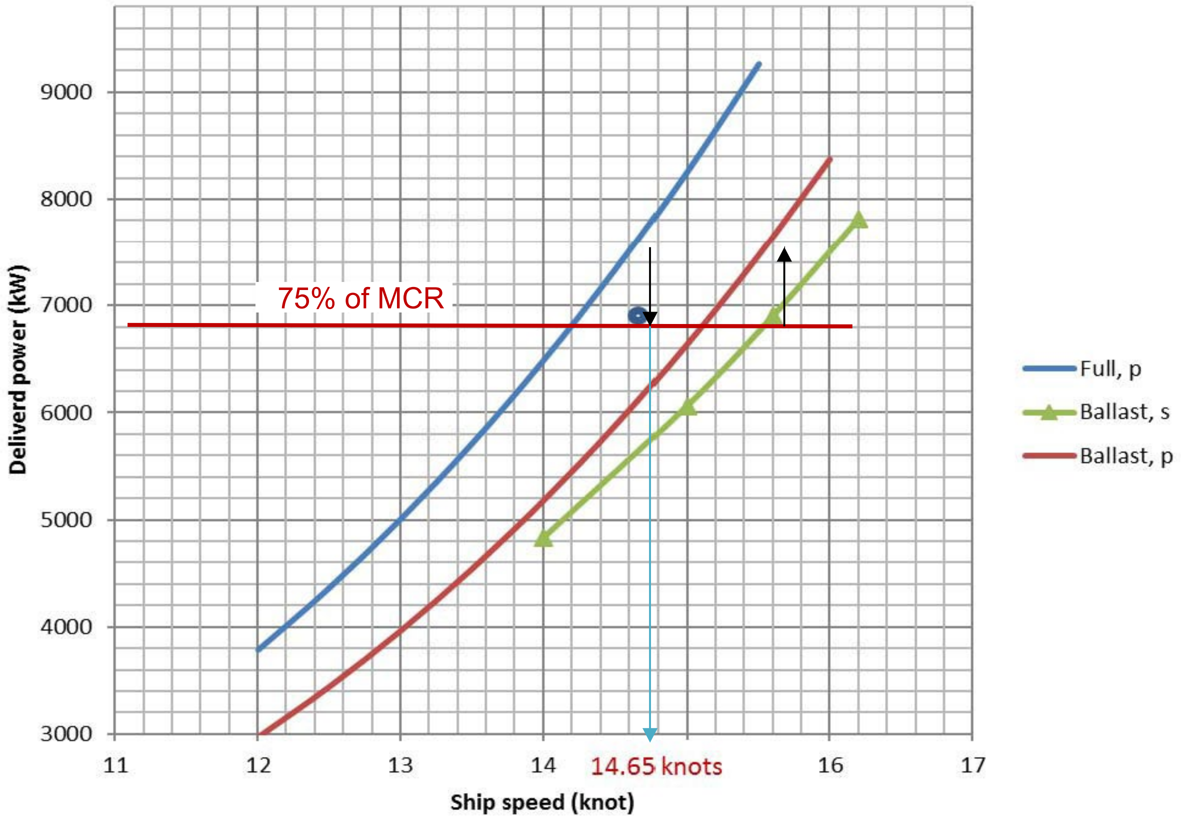


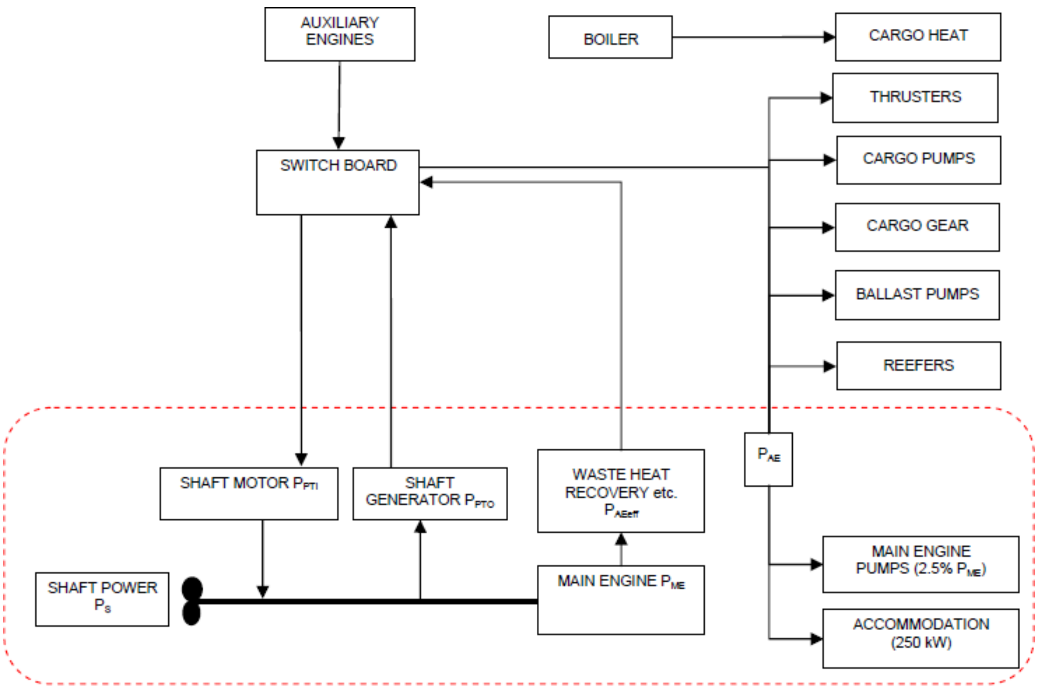
Figure 3.1: Power curves

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.

Figure 4.1 scheme of the propulsion and power generation systems



5 Electric power table

The electric power for the calculation of EEDI is provided in table 5.1.

Table 5.1: Electric power table for calculation of P_{AE}

Id	Grou p	Description	Mech. Power "Pm"	El. Motor output	Efficien. "e"	Rated el. Power "Pr"	load facto r "kl"	duty facto r "kd"	time facto r "kt"	use facto r "ku"	Necessary power "Pload"
1	A	STEERING GEAR	N.A.	N.A.	N.A.	45,0	0,9	1	0,3	0,27	12.2
2	A	HULL CATHODIC PROTECTION	N.A.	N.A.	N.A.	10	1	1	1	1,00	10,0
3	A	CRANE	N.A.	N.A.	N.A.	10,00	0,2	1	1	0,20	2,0
4	A	COMPASS	N.A.	N.A.	N.A.	0,5	1	1	1	1,00	0,5
5	A	RADAR NO.1	N.A.	N.A.	N.A.	1,3	1	0,5	1	0,50	0,7
6	A	RADAR NO.2	N.A.	N.A.	N.A.	1,3	1	0,5	1	0,50	0,7
7	A	NAVIGATION EQUIPMENT	N.A.	N.A.	N.A.	5,0	1	1	1	1,00	5,0
8	A	INTERNAL COMM. EQUIPMENT	N.A.	N.A.	N.A.	2,5	1	1	0,1	0,10	0,2
9	A	RADIO EQUIPMENT	N.A.	N.A.	N.A.	3,5	1	1	0,1	0,10	0,4
10	A	MOORING EQ.	N.A.	N.A.	N.A.	7,0	1	1	0,1	0,10	0,7
11	B	MAIN COOLING SEA WATER PUMP NO.1	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0
12	B	MAIN COOLING SEA WATER PUMP NO.2	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0
13	B	MAIN COOLING SEA WATER PUMP NO.3	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0
14	B	LT COOLING FW PUMP NO.1	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0
15	B	LT COOLING FW PUMP NO.2	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0
16	B	LT COOLING FW PUMP NO.3	28,0	30	0,925	30,3	0,9	0,66	1	0,59	18,0

Id	Grou p	Description	Mech. Power "Pm"	El. Motor output	Efficie n. "e"	Rated el. Power "Pr"	load facto r "kl"	duty factor "kd"	time facto r "kt"	use facto r "ku"	Neces sa ry power "Ploa d"
17	B	M/E COOLING WATER PUMP NO.1	13,0	15	0,9	14,4	1	0,5	1	0,50	7,2
18	B	M/E COOLING WATER PUMP NO.2	13,0	15	0,9	14,4	1	0,5	1	0,50	7,2
19	C	MAIN LUB. OIL PUMP NO.1	55,0	90	0,94	58,5	0,9	0,5	1	0,45	26,3
20	C	MAIN LUB. OIL PUMP NO.2	55,0	90	0,94	58,5	0,9	0,5	1	0,45	26,3
21	C	H.F.O. TRANSFER PUMP	6,0	7,5	0,88	6,8	1	1	0,1	0,10	0,7
22	C	D.O. TRANSFER PUMP	6,0	7,5	0,88	6,8	1	1	0,1	0,10	0,7
23	C	L.O. TRANSFER PUMP	1,4	2,5	0,8	1,8	1	1	0,1	0,10	0,2
24	C	TECHNICAL FRESH WATER PUMP NO.1	2,5	3,5	0,85	2,9	1	0,5	0,1	0,05	0,1
25	C	TECHNICAL FRESH WATER PUMP NO.2	2,5	3,5	0,85	2,9	1	0,5	0,1	0,05	0,1
26	C	E/R SUPPLY FAN NO.1	14,0	20	0,9	15,5	0,9	1	1	0,90	14,0
27	C	E/R SUPPLY FAN NO.2	14,0	20	0,9	15,5	0,9	1	1	0,90	14,0
28	C	E/R SUPPLY FAN NO.3	14,0	20	0,9	15,5	0,9	1	1	0,90	14,0
29	C	E/R SUPPLY FAN NO.4	14,0	20	0,9	15,5	0,9	1	1	0,90	14,0
30	C	PURIFIER ROOM EXH.VENTILATOR	2,5	3	0,82	3,0	0,9	1	1	0,90	2,7
31	C	PUMP HFO SUPPLY UNIT NO.1	2,1	3	0,8	2,6	0,9	0,5	1	0,45	1,2
32	C	PUMP HFO SUPPLY UNIT NO.2	2,1	3	0,8	2,6	0,9	0,5	1	0,45	1,2
33	C	CIRC. PUMP FOR HFO SUPPLY UNIT NO.1	2,8	3,5	0,84	3,3	0,9	0,5	1	0,45	1,5
34	C	CIRC. PUMP FOR HFO SUPPLY UNIT NO.2	2,8	3,5	0,84	3,3	0,9	0,5	1	0,45	1,5
35	C	H.F.O. SEPARATOR NO.1	N.A.	N.A.	N.A.	6,5	0,9	0,5	0,9	0,41	2,6
36	C	H.F.O. SEPARATOR NO.2	N.A.	N.A.	N.A.	6,5	0,9	0,5	0,9	0,41	2,6
37	C	MAIN AIR COMPRESSER NO.1	N.A.	N.A.	N.A.	43,0	1	0,5	0,1	0,05	2,2
38	C	MAIN AIR COMPRESSER NO.2	N.A.	N.A.	N.A.	43,0	1	0,5	0,1	0,05	2,2
39	C	SERVICE AIR COMPRESSER	N.A.	N.A.	N.A.	22,0	1	1	0,1	0,10	2,2
40	C	VENT. AIR SUPPLY	N.A.	N.A.	N.A.	1,0	1	1	0,5	0,50	0,1
41	C	BILGE WATER SEPARATOR	N.A.	N.A.	N.A.	1,5	1	1	0,1	0,10	0,2
42	C	M/E L.O. SEPARATOR	N.A.	N.A.	N.A.	6,5	0,9	1	0,2	0,18	1,2
43	C	G/E L.O. SEPARATOR	N.A.	N.A.	N.A.	6,5	0,9	1	0,2	0,18	1,2
44	D	HYDROPHORE PUMP NO.1	2,8	4	0,84	3,3	1	0,5	0,1	0,05	0,2
45	D	HYDROPHORE PUMP NO.2	2,8	4	0,84	3,3	1	0,5	0,1	0,05	0,2

Id	Grou p	Description	Mech. Power "Pm"	El. Motor output	Efficien. "e"	Rated el. Power "Pr"	load factor "kl"	duty factor "kd"	time factor "kt"	use factor "ku"	Necessa ry power "Pload"
46	D	HOT WATER CIRCULATING PUMP NO.1	0,5	1,0	0,8	0,8	1	0,5	0,2	0,10	0,1
47	D	HOT WATER CIRCULATING PUMP NO.2	0,5	1,0	0,8	0,8	1	0,5	0,2	0,10	0,1
48	E	E/R WORKSHOP WELDING SPACE EXH.	0,5	0,8	0,8	0,6	0,9	1	1	0,90	0,6
49	F	ECR COOLER UNIT	N.A.	N.A.	N.A.	4,2	1	1	0,5	0,50	2,1
50	F	FAN FOR AIR CONDITIONING PLANT	N.A.	N.A.	N.A.	8,0	0,9	1	0,5	0,45	3,6
51	F	COMP. AIR CONDITIONING PLANT NO.1	N.A.	N.A.	N.A.	10,0	0,9	1	0,5	0,45	4,5
52	F	COMP. AIR CONDITIONING PLANT NO.2	N.A.	N.A.	N.A.	10,0	0,9	1	0,5	0,45	4,5
53	F	COMP. AIR CONDITIONING PLANT NO.3	N.A.	N.A.	N.A.	10,0	0,9	1	0,5	0,45	4,5
54	F	COMP. AIR CONDITIONING PLANT NO.4	N.A.	N.A.	N.A.	10,0	0,9	1	0,5	0,45	4,5

Id	Group	Description	Mech. Power "Pm"	El. Motor output	Efficien. "e"	Rated el. Power "Pr"	load factor "kl"	duty factor "kd"	time factor "kt"	use factor "ku"	Necessary power "Pload"
55	G	FAN FOR GALLEY AIR COND. PLANT	N.A.	N.A.	N.A.	1,5	0,9	1	0,5	0,45	0,7
56	G	COMP. FOR GALLEY AIR COND. PLANT	N.A.	N.A.	N.A.	3,5	0,9	1	0,5	0,45	1,6
57	G	REF. COMPRESSOR NO.1	N.A.	N.A.	N.A.	4,0	1	0,5	0,1	0,05	0,2
58	G	REF. COMPRESSOR NO.2	N.A.	N.A.	N.A.	4,0	1	0,5	0,1	0,05	0,2
59	G	GALLEY EQUIPMENT	N.A.	N.A.	N.A.	80,0	0,5	1	0,1	0,05	4,0
60	H	VAC. COLLECTION SYSTEM	2,4	3,0	0,8	3,0	1	1	1	1,00	3,0
61	H	GALLEY EXH.	1,2	1,5	0,8	1,5	1	1	1	1,00	1,5
62	H	LAUNDRY EXH.	0,1	0,15	0,8	0,1	1	1	1	1,00	0,1
63	H	SEWAGE TREATMENT	N.A.	N.A.	N.A.	4,5	1	1	0,1	0,10	0,5
64	H	SEWAGE DISCHARGE	3	7,5	0,88	3,4	0,9	1	0,1	0,09	0,3
65	I	ACCOMMODATION LIGHTING	N.A.	N.A.	N.A.	16,0	1	1	0,5	0,5	8,0
66	I	E/R LIGHTING	N.A.	N.A.	N.A.	18,0	1	1	1	1,00	18,0
67	I	NAVIGATION LIGHTING	N.A.	N.A.	N.A.	0,9	1	0,5	1	0,50	0,4
68	I	BACK. NAV. LIGHTING	N.A.	N.A.	N.A.	0,9	1	0,5	1	0,50	0,4
								TOTAL POWER			**354,0**
P_{AE} = Total Power / (average efficiency of generators) = 354/0.93 = 381 kW											

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

	Manufacturer	Model	Series	Lab. Id.	status
Propeller dynamometer	B&N	6001	300	125-2	Calibrated 01/01/2011
…					

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 2017), with prediction of the full scale rpm and delivered power by use of the C_P – C_N 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:

$$P_D = C_p \cdot P_{DS}$$

$$n_T = C_N \cdot n_S$$

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:

$$C_{TS} = \frac{S_S + S_{BK}}{S_S} \cdot [(1+k) \cdot C_{FS} + \Delta C_F] + C_R + C_{AAS} + C_{AppS}$$

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 7.5-02-02-01

C_{FS}: ship frictional resistance coefficient (computed according to ITTC 1957 formula)

ΔC_F: roughness allowance, computed according to Bowden-Davison formula. Here ΔC_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

ρ_A and ρ_S are the air density and water density, respectively

A_{VS} is the projected wind area, here 820 m^2

C_{AAS} = 7.9.10^{-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 7.1: results of trial prediction in EEDI condition

Model reference: SX100 - model scale: 40					
Loading condition: EEDI loading condition (12.70 m draft)					
Resistance test: R001		Propulsion test: P001		Model propeller: Prop01	
Ship speed V (knot)	Wake factor w_{TM}-w_{TS}	Propeller thrust T_S (kN)	Propeller torque Q_S (kNm)	rpm on ship n_S	Delivered Power P_D (kW)
12	0.098	522	467	78	3781
12.5	0.093	578	514	82	4362

13	0.089	638	563	86	5004
13.5	0.081	701	615	90	5710
14	0.079	768	669	93	6486
14.5	0.086	838	727	97	7333
15	0.091	912	786	101	8257
15.5	0.099	990	849	105	9261
Experience-based factor C_P: 1.01					
Experience based factor C_N: 1.02					

Table 7.2: results of trial prediction in sea trial condition

Model reference: SX100 - model scale: 40					
Loading condition: Sea trial condition (5.80 m draft)					
Resistance test: R002		Propulsion test: POO2		Model propeller: Prop01	
Ship speed V (knot)	Wake factor w_{TM}-w_{TS}	Propeller thrust T_S (kN)	Propeller torque Q_S (kNm)	rpm on ship n_S	Delivered Power P_D (kW)
12	0,079	406	379	72	2974
12,5	0,081	451	418	76	3445
13	0,083	500	459	79	3968
13,5	0,085	551	503	83	4545
14	0,087	606	549	87	5181
14,5	0,088	664	597	90	5878
15	0,091	725	648	94	6641
15,5	0,089	790	701	98	7474
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

Identification (model number or similar)	SX 100
Material of construction	Wood
Principal dimensions	
Length between perpendiculars (L_{PP})	4.625 m
Length of waterline (L_{WL})	4.700 m
Breadth (B)	0.806 m
Draught (T)	0.317 m
Design displacement (Δ) (kg, fresh water)	1008.7 kg
Wetted surface area	6.25 m^2
Details of turbulence stimulation	Sand strips
Details of appendages	rudder
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 7.4: characteristics of the stock propeller used during the tests

Identification (model number or similar)	Prop01
Materials of construction	aluminium
Blade number	4
Principal dimensions	
Diameter	147.5 mm
Pitch-Diameter Ratio (*P/D*)	0.68
Expanded blade Area Ratio (A_E/A_0)	0.60
Thickness Ratio (*t/D*)	0.036
Hub/Boss Diameter (d_h)	25 mm
Tolerances of manufacture	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.

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.

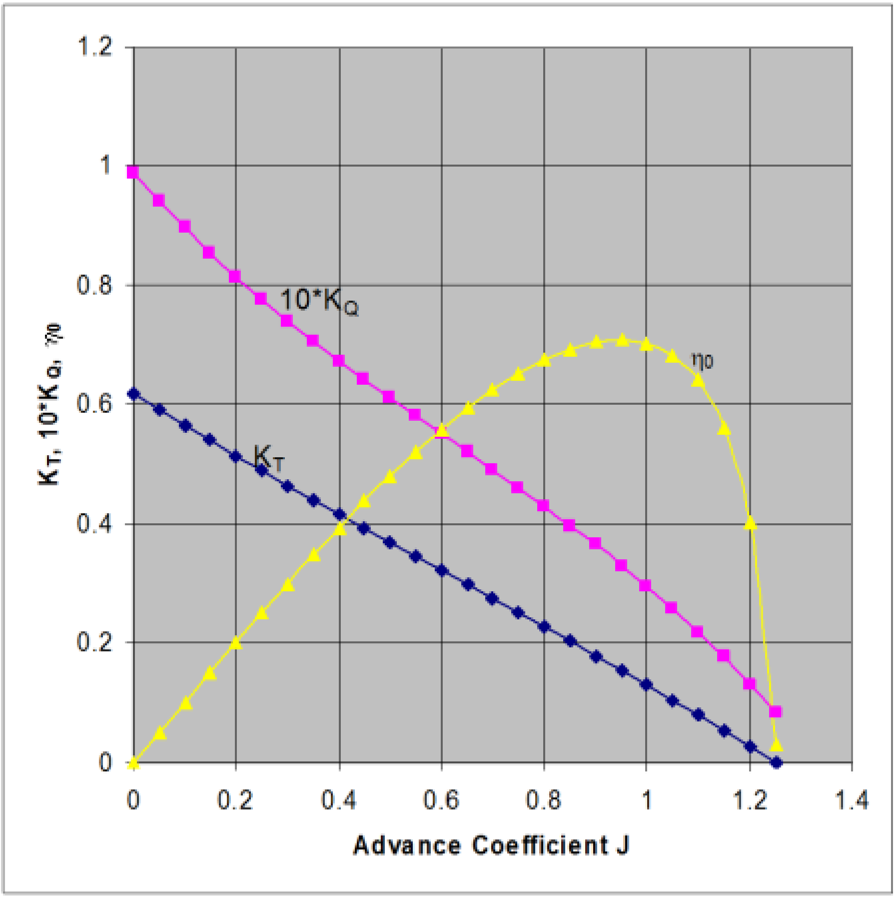


Figure 7.1: open water characteristics of ship propeller

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 $P_{AEeff(i)}$ 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 NO_x 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 11.1: Parameters in attained EEDI calculation

EEDI quantity	Value	Remarks
C_{FME}	3.206	Marine Diesel oil is used for shop test of the main engine
P_{ME}	6900 kW	No shaft generator installed (P_{PTO} = 0) MCR is 9200 kW PME = 0.75x9200 = 6 900 kW
SFC_{ME}	171 g/kWh	According to parent engine shop test report in ISO conditions (see 10.1)
CF_{AE}	3.206	Marine diesel oil is used for shop test of the auxiliary engine
P_{PTI}	0	No shaft motor installed
P_{AE}	381 kW	MCR of the engine is 9200 kW, less than 10000kW $P_{AE} = 0.05 \cdot \left(\sum_{i=1}^{nME} MCR_{MEi} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right)$ P_{AE} = 0.05*9200 = 460 kW According to electric power table included in table 5.1, ∑Pload(i) = 354 kW The weighted average efficiency of generators = 0.93 (KWelec/kWmech) P_{AE} = ∑Pload(i) / 0.93 = 381 kW The difference (460 – 381) KW is expected to vary EEDI by slightly

		more than 1%, so 381 kW is considered.
SFC_{AE} (at 75% MCR)	199 g/kWh	According to technical file of EIAPP certificate in ISO conditions (see 10.2). According to the IMO Calculation Guidelines, the SFC_{AE} at 75% MCR should be used when P_{AE} is estimated by the electric power table (EPT) for the reason that P_{AE} computed using the formula in the IMO Calculation Guidelines is significantly different from the total power used at normal seagoing
P_{eff}	0	No mechanical energy efficient devices The propeller boss cap fins act by reducing ship resistance
P_{AEeff}	0	No auxiliary power reduction
`f_{eff}		Not relevant here (see above)
f_j	1.0	The ship is a bulk carrier without ice notations. fj = 1.0
f_i	1.017	No ice notation f_{iICE} = 1.0 No voluntary structural enhancement for this ship f_{iVSE} = 1.0 The ship has the notation Bulk carrier CSR: $f_{iCSR} = 1 + 0.08*LWT_{CSR} / DWT_{CSR} = 1+0.08*11590/55000 = 1.017$ $fi = f_{iICE} \times f_{iVSE} \times f_{iCSR} = 1.017$
f_m	1.0	No ice notation
f_w	1.0	For attained EEDI calculation under regulation 22 and 24 of MARPOL Annex VI, f_w is 1.0
f_c	1.0	The ship is a bulk carrier not designed to carry light cargoes, f_c = 1.0
Capacity	55000	For a bulk carrier, Capacity is deadweight = 55 000 tons
V_{ref}	14.25 knots	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 $P_D = 1.0 \times P_{ME}$ = 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

11.2 Result

For this vessel, Attained EEDI is:

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

Attained EEDI = (6900*3.206*171+381*3.206*199) / (1.017*55000*14.25) = 5.05 g/t.nm

12 Required EEDI

According to MARPOL Annex VI, Chapter 4, Regulation 24, the required EEDI is: (1-x/100) x reference line value

The reference line value = $a*b^{-c}$ where a, b, c are given for a bulk carrier as:

a= 961.79 b = deadweight of the ship 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

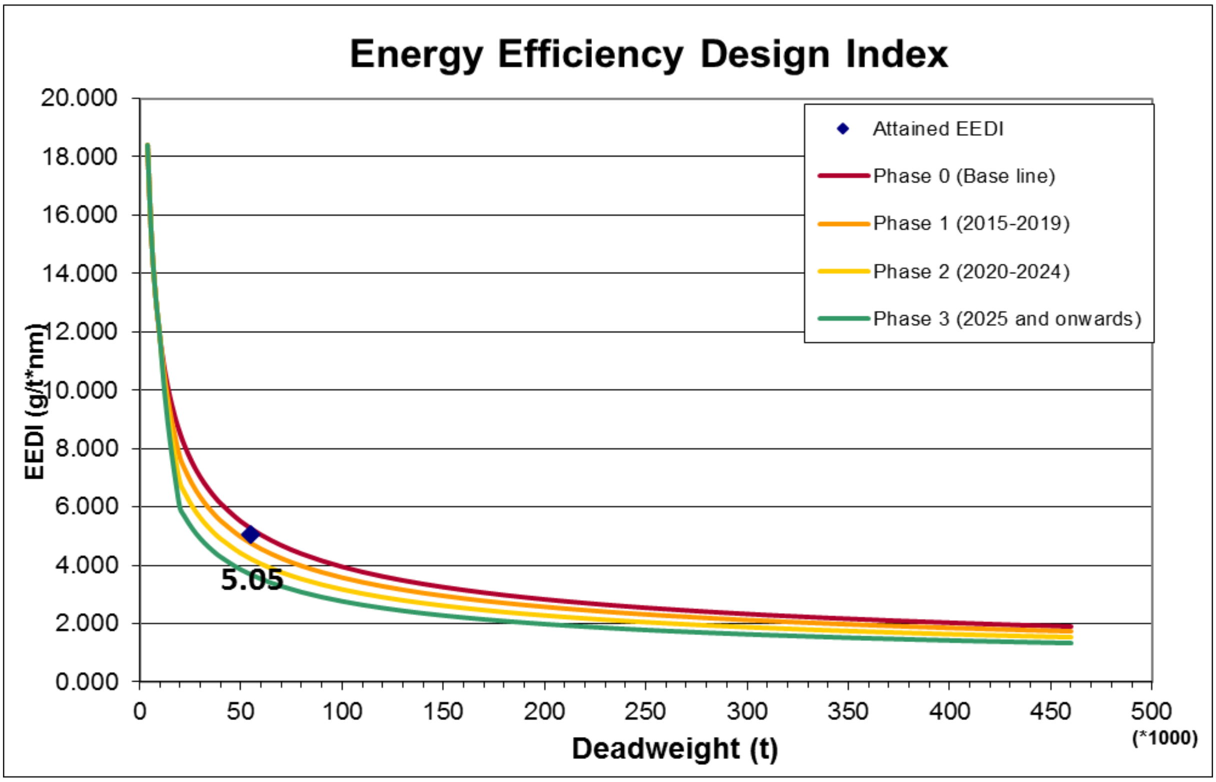


Figure 12.1: Required EEDI value

13 Calculation of attained $EEDI_{weather}$

Not calculated.

14 Lightweight check report

The lightweight check report is provided in annex 6. The final characteristics of the ship are:

Displacement	66171 tons
Lightweight	11621 tons
Deadweight	54550 DWT

15 Sea trial report with corrections

The sea trial report is provided in annex 7. The results of the sea trial follow the assessment guideline of ISO 15016:2015 are given on curve *Ballast,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)

EEDI quantity	Value	Remarks
C_{FME}	3.206	No change
P_{ME}	6900 kW	No change
SFC_{ME}	171 g/kWh	No change
CF_{AE}	3.206	No change
P_{PTI}	0	No change
P_{AE}	381 kW	The electric power table has been validated and endorsed (see the electric power table form in annex 8)
SFC_{AE} at 75% MCR	199 g/kWh	No change
P_{eff}	0	No change
P_{AEeff}	0	No change
f_{eff}		No change
f_j	1.0	No change
f_i	1.017	Deadweight and lightweight are computed from lightweight check: f_{iCSR} = 1 + 0.08*LWT_{CSR} / DWT_{CSR} = 1+0.08*11621/54550 = 1.017 fi = f_{iICE} x f_{iVSE} x f_{iCSR} = 1.017 (unchanged)
f_c	1.0	No change
f_m	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 = (6900*3.206*171+381*3.206*199) / (1.017*54550*14.65) = 4.95 g/t.nm

Required EEDI in Phase 0: 961.79*$54550^{-0.477}$ = 5.29 g/t.nm

Regulation criteria is satisfied with 6.4% margin

List of annexes to the Document

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

QM 4.10.5.1	**Measurement Equipment Card**	Laboratory Identification Number
Equipment	Manufacturer Serial No. Basic range	Model Date of Purchase
Work Instructions Calibration Instructions Verified at		**Status** Calibrated Indication Verified

Date of Check	Certificate. No.	Period	Date of Next Check	Responsible	Department	Approval

ANNEX 2: SAMPLE OF CALIBRATION CERTIFICATE.

QM 4.10.6.2	**CALIBRATION CERTIFICATE for** PROPELLER	**NO.**	
		LIN	
Calibration Instructions		Calibrated by :	
Date of calibration		Checked by :	
Measurement combination			
DYNAMOMETER	Manufacturer		Model	
LIN	Serial No		Date of purchased	
	Work instruction		Last calibration	
Cable				
AMPLIFIER	Manufacturer			
LIN	Serial No		hased	
	Work instruction		sducer	
	Excitation		Frequency of excit.	
Thrust :	Amp. gain		Zero not load	
Torque :	Amp. gain		Zero not load	
Cable				
A/C TRANSDUCER	Manufacturer		Model	
LIN	Serial No		Date of purchased	
	Work instruction		Certificate No	
MEASUREMENT STANDARDS	Mass		Certificate No	
	Length arm of force		Certificate No	
	Voltmeter		Certificate No	

QM 4.10.6.2

CALIBRATION RESULTS

Environmental condition

Place of test :				
Temperature :	initial		final	
Dampness :	initial		final	

Computation results of calibrations test

Executed program	procedure	certificate NO.

	Thrust	Torque
Drift :		
Non Linearity errors :		
Hysteresis :		
Precision errors :		
Total uncertainty :		
Calibration factor :		

Calibration requests:

Specified limits of	Thrust	Torque
errors :		
Maximum capacity :		
Minimum capacity :		

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 are 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 2.5x 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 (Δ) (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 de-sign 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 (A_E/A_0)
Thickness Ratio (t/D)
Hub/Boss Diameter (d_h)
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)
- ΔC_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)
- ΔC_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 2017). 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).

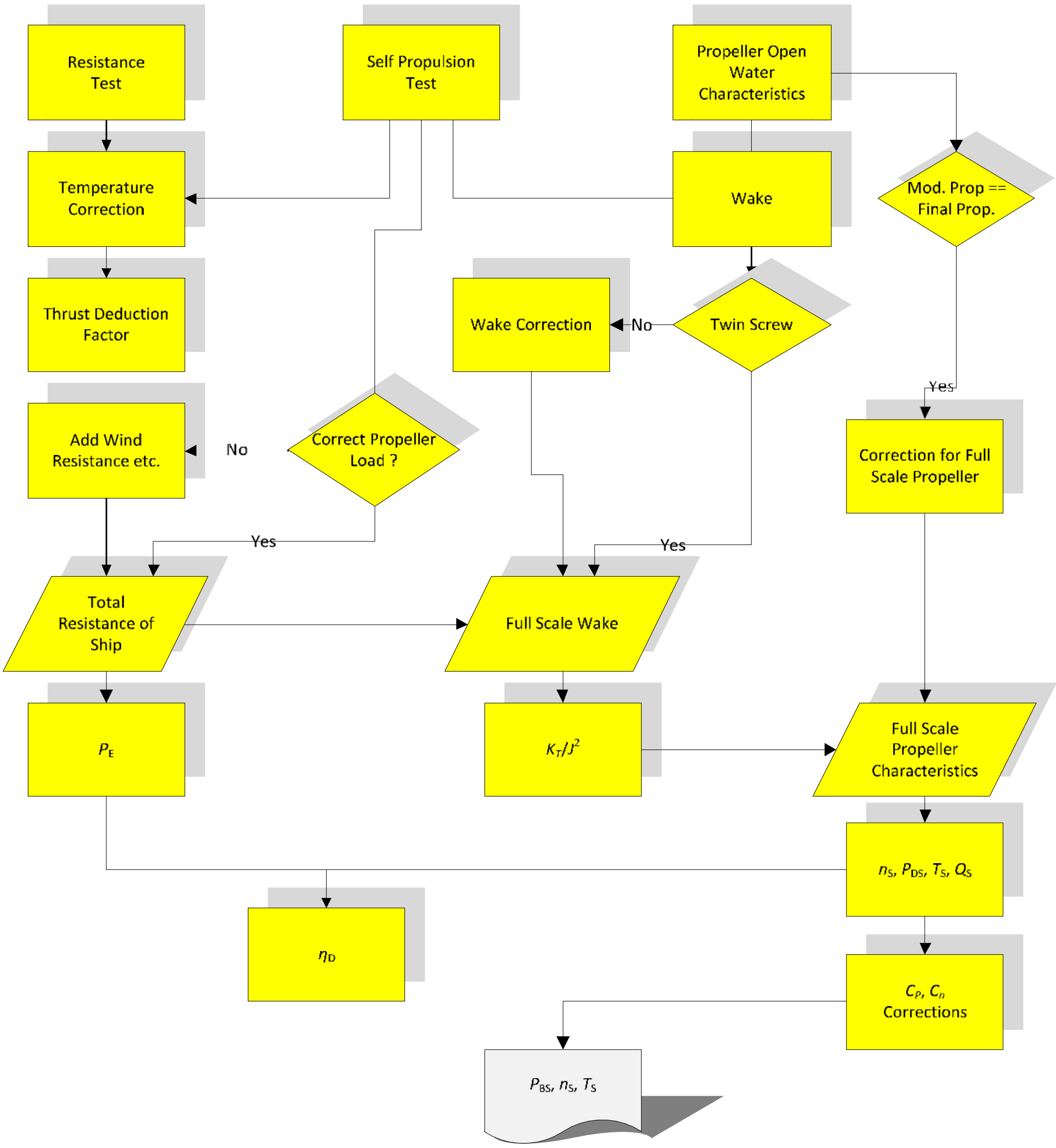
Model Propeller Specification:

- 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

Principle Scheme for Speed Trial Prediction

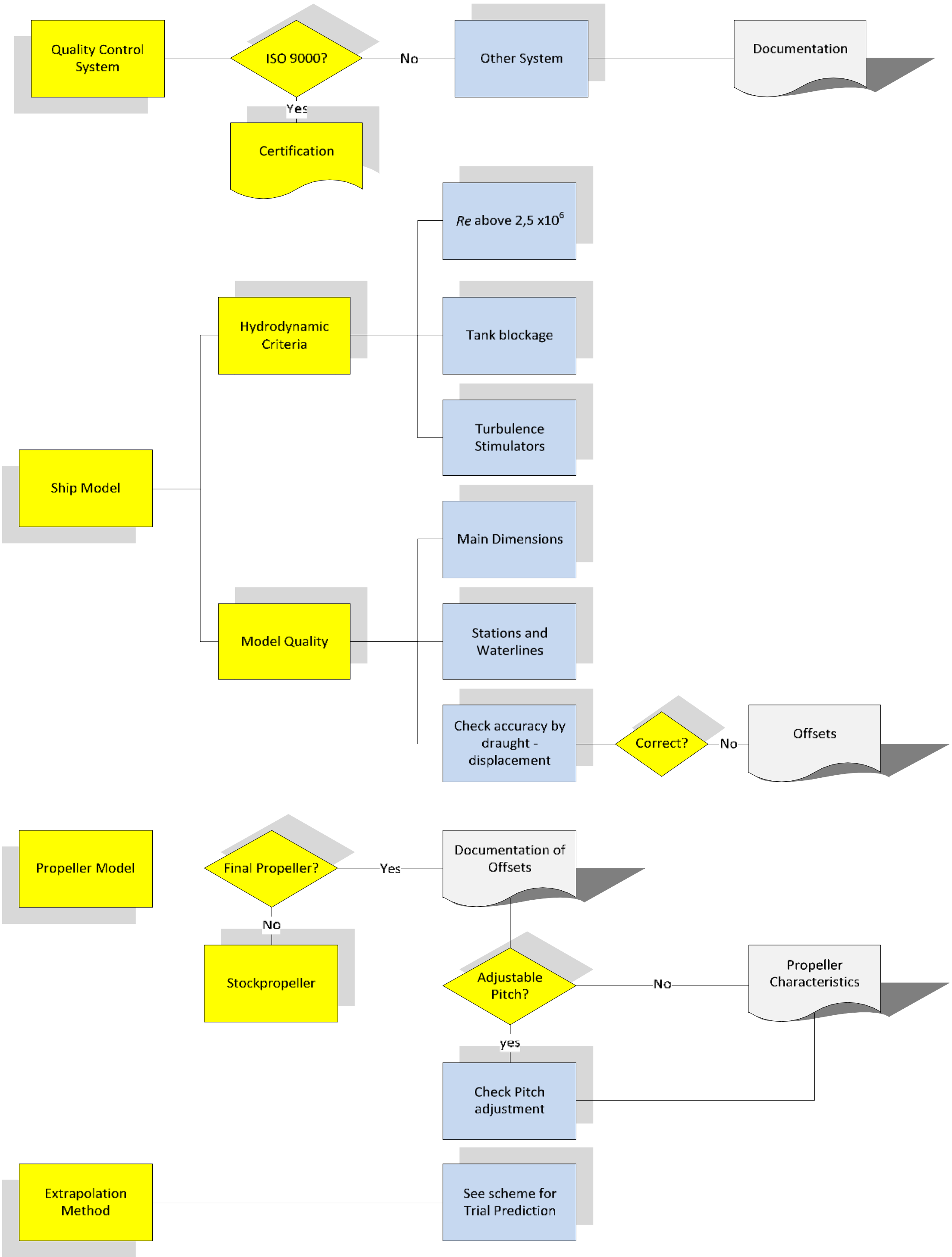


For each speed the following calculated data is to be given as a minimum:

- 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_D)
- Sinkage fore and aft, or sinkage and trim

Scheme for review and witnessing Model Tests

Checking of Model Testing Procedure



APPENDIX 5
Sample report "Preliminary Verification of EEDI"

ATTESTATION
PRELIMINARY VERIFICATION OF ENERGY EFFICIENCY DESIGN INDEX (EEDI) by *VERIFIER*

Statement N° EEDI/YYYY/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

Title	**ID and/or remarks**
EEDI Technical File	RRRR dated DD/MM/YYYY

This is to certify:

1 That the attained EEDI of the ship has been calculated according to the *2022 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, IMO resolution MEPC.364(79) as amended.

2 That the preliminary verification of the EEDI shows that the ship complies with the applicable requirements in regulation 22 and regulation 24 of MARPOL Annex VI as amended.

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
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:
$P_{ME} = 0$, $P_{PTI} \neq 0$, $P_{PTO} = 0$

1) Input

The table below lists the input information needed at the design stage and verified at the final stage:

Symbol	Name	Value	Source
MPP	Rated output of electric propulsion motors	2 x 20000 kW	From EEDI technical file
η_{PTI}	Efficiency of transformer + converter + propulsion motor at 75% of rated motor output	0.945	From electric power table
η_{GEN}	Power-weighted average efficiency of generators	0.974	Calculation from individual generator efficiencies given in electric power table: 0.975*19000+0.972*14000/(14000+19000)
$HLOAD_{Max}$	Consumed electric power excluding propulsion in cruise most demanding conditions	15 779 kW	From electric power table for the most demanding cruise contractual conditions (here extreme summer conditions 28°C during 80% of the time)
SFC_{AE}	Power-weighted average of specific oil consumption among all engines at 75% of the MCR power	185 g/kWh	From NOx technical file
GT	Gross Tonnage	160000 ums	From EEDI technical file

MCR of auxiliary diesel engines 19,000 kW x 2 + 14,000 kW x 2
MPP 20,000 kW x 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 ΣP_{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 2.2.5.3 of the "2022 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:

$$\sum P_{PTI(i)} = \frac{\sum(0.75 \times MPP(i))}{\eta_{PTI} \times \eta_{Gen}}$$
$$\sum P_{PTI(i)} = \frac{2 \times 0.75 \times 20{,}000}{0.945 \times 0.974}$$
$$\sum P_{PTI(i)} = 32{,}593kW$$

Where η_{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 η_{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 3 of the “2022 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.

$$P_{AE} = \frac{HLOAD_{MaX}}{\eta_{Gen}} = \frac{15{,}779kW}{0.974} = 16{,}200kW$$

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

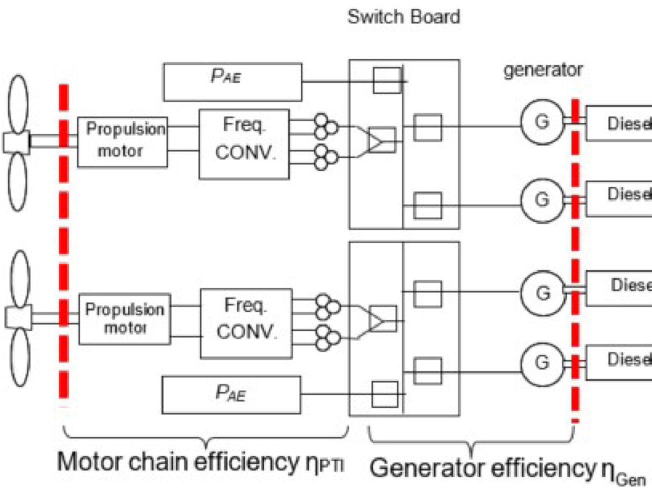
EEDI is calculated in accordance with paragraph 2 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”. The primary fuel is marine Gas Oil in this example.

$$EEDI = \frac{(P_{AE} + \sum_i P_{PTI}(i)) \cdot (C_{FAE} \cdot SFC_{AE})}{Capacity \cdot V_{ref}}$$
$$= \frac{(16200 + 32593) \times 185 \times 3.206}{160{,}000(\text{UMS}) \times 22.5(\text{kn})} = 8.04$$

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



2) Specifications

Chain efficiency of the electric motor η_{PTI} and generator efficiency η_{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 cosφ of the electric consumers.

SFC_{AE} is computed form 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 the paragraph 4.3.9 of "2022 guidelines on survey and certification of the energy efficiency design index (EEDI)" as amended. 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 "2022 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.

$$EEDI = \frac{(P_{AE} + \sum_i P_{PTI}(i)) \cdot (C_{FAE} \cdot SFC_{AE})}{Capacity \cdot V_{ref}}$$

$$= \frac{(16200 + 32593) \times 185 \times 3.206}{160{,}000(\text{UMS}) \times 22.7(\text{kn})} = 7.97$$

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 (kW) x 3 + 6,400 (kW) x 1
MPP_{Motor}	24,000 (kW)
$SFC_{ME(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$	162.0 (g/kWh) (for 10,000 (kW)-Engines) (SFC with the addition of the guarantee tolerance) 162.6 (g/kWh) (for 6,400 (kW)-Engine) (Ditto)
$SFC_{ME(i)\_Pilotfuel}$	6.0 (g/kWh) (for 10,000 (kW)-Engines), 6.1 (g/kWh) (for 6,400 (kW)-Engine)
Deadweight	75,000 (ton)

2) $\eta_{electrical}$ at design stage

$\eta_{electrical}$ is set as 0.913 in accordance with paragraph 2.2.5.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

3) Calculation of P_{ME}

P_{ME} is calculated in accordance with paragraph 2.2.5.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{ME} = 0.83 \times \frac{MPP_{Motor}}{\eta_{electrical}}$$

$$= 0.83 \times \frac{24,000}{0.913} = 21,818(kW)$$

4) Calculation of P_{AE}

P_{AE} is calculated in accordance with paragraph 2.2.5.6.1 and 2.2.5.6.3 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{AE} = \left(0.025 \times \sum_{i=1}^{nME} MCR_{ME(i)} + \sum_{i=1}^{nPTI} P_{PTI(i)} \Big/ 0.75\right) + 250 \qquad and/or\ ,$$

$$+CargoTankCapacity_{LNG} \times BOR \times COP_{reliquefy} \times R_{reliquefy} \quad (1)\ and/or, (Not\ Applicable)$$

$$+0.33 \sum_{i=1}^{nME} SFC_{ME(i),gasmode} \times \frac{P_{ME(i)}}{1000} \qquad (2)\ and/or\ , (Not\ Applicable)$$

$$= 0.02 \times \sum_{i=1}^{nME} PME_{(i)} \qquad (3)$$

$$= \{(0.025 \times 24,000) + 250\} + 0 + 0 + (0.02 \times 21,818)$$
$$= 1,286(kW)$$

Note:
*1: The value of MPP_{Motor} is used instead of MCR_{ME} in accordance with paragraph 2.2.5.6.3.3.

5) 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 18.4kn is obtained at 83% of MPP_{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 "2022 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, $SFC_{AE(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$ is equal to $SFC_{ME(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$, and $SFC_{AE(i)\_Pilotfuel}$ is equal to $SFC_{ME(i)\_Pilotfuel}$.

$$EEDI = \frac{P_{ME}\cdot(C_{FME\_Gas}\cdot SFC_{ME\_Gas} + C_{FME\_Pilotfuel}\cdot SFC_{ME\_Pilotfuel}) + P_{AE}\cdot(C_{FAE\_Gas}\cdot SFC_{AE\_Gas} + C_{FAE\_Pilotfuel}\cdot SFC_{AE\_Pilotfuel})}{Capacity\cdot V_{ref}}$$

$$= \frac{21{,}818\times(2.750\times162.1+3.206\times6.0)+1{,}286\times(2.750\times162.1+3.206\times6.0)}{75{,}000(\text{DWT})\times18.4(\text{kn})} = 7.79$$

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;

$$\frac{162.0\times10{,}000(\text{kW})\times3+162.6\times6{,}400(\text{kW})}{10{,}000(\text{kW})\times3+6{,}400(\text{kW})} = 162.1(\text{g/kWh})$$

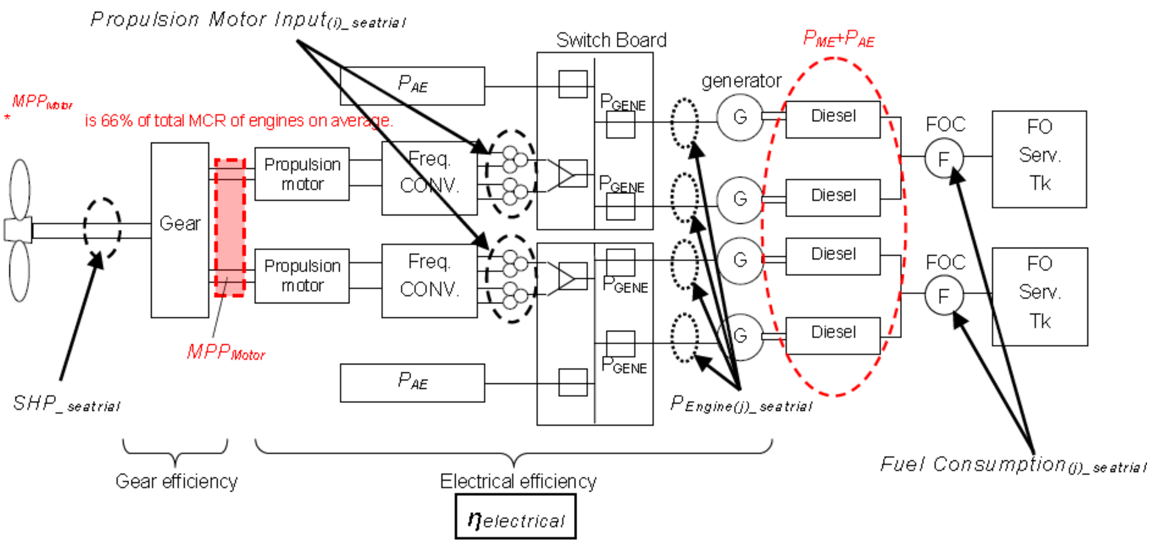
*2: The average weighed value of $SFC_{ME(i)\_Pilotfuel}$ and $SFC_{AE(i)\_Pilotfuel}$ is used;.

$$\frac{6.0\times10{,}000(\text{kW})\times3+6.1\times6{,}400(\text{kW})}{10{,}000(\text{kW})\times3+6{,}400(\text{kW})} = 6.0(\text{g/kWh})$$

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
MPP_{Motor}	24,000 (kW)
$SFC_{ME(i)\_electric, gas mode at 75\% of MCR}$	
	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)
$SFC_{ME(i)\_Pilotfuel}$	6.0 (g/kWh) (for 10,000 (kW)-Engines), 6.1 (g/kWh) (for 6,400 (kW)-Engine)
Deadweight	75,500 (ton)

3) $\eta_{electrical}$ at sea trial

$\eta_{electrical}$ is set as 0.913 in accordance with paragraph 2.2.5.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

***4)* Calculation of P_{ME}**

P_{ME} is calculated in accordance with paragraph 2.2.5.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{ME} = 0.83 \times \frac{MPP_{Motor}}{\eta_{electricity}}$$
$$= 0.83 \times \frac{24{,}000}{0.913} = 21{,}818(kW)$$

***5)* Calculation of P_{AE}**

P_{AE} is calculated in accordance with paragraph 2.2.5.6.1 and 2.2.5.6.3 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{AE} = \left(0.025 \times \sum_{i=1}^{nME} MCR_{ME(i)} + \sum_{i=1}^{nPTI} PTI(i) \Big/ 0.75\right) + 250 \qquad and/or;$$
$$+CargoTankCapacity_{LNG} \times BOR \times COP_{reliquery} \times R_{reliquery} \quad \ldots(1)\ and/or;\ (Not\ Applicable)$$
$$+0.33 \times \sum_{i=1}^{nME} SFC_{ME(i),gasmode} \times \frac{P_{ME(i)}}{1000} \quad \ldots(2)\ and/or;\ (Not\ Applicable)$$
$$+0.02 \times \sum_{i=1}^{nME} P_{ME(i)} \quad \ldots(3)$$
$$= \{(0.025 \times 24{,}000) + 250\} + 0 + 0 + (0.02 \times 21{,}818)$$
$$= 1{,}286(kW)$$

Note:
*1: The value of MPP_{Motor} is used instead of MCR_{ME} in accordance with paragraph 2.2.5.6.3.4

6) 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 “2022 guidelines on survey and certification of the energy efficiency design index (EEDI)” as amended. Suppose that V_{ref} of 18.5kn is obtained at 83% of MPP_{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 “2022 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, $SFC_{AE(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$ is equal to $SFC_{ME(i)\_electric,\ gas\ mode\ at\ 75\%\ of\ MCR}$, *and* $SFC_{AE(i)\_Pilotfuel}$ is equal to $SFC_{ME(i)\_Pilotfuel}$.

$$EEDI = \frac{P_{ME} \cdot (C_{FME\_Gas} \cdot SFC_{ME\_Gas} + C_{FME\_Pilotfuel} \cdot SFC_{ME\_Pilotfuel}) + P_{AE} \cdot (C_{FAE\_Gas} \cdot SFC_{AE\_Gas} + C_{FAE\_Pilotfuel} \cdot SFC_{AE\_Pilotfuel})}{Capacity \cdot V_{ref}}$$

$$= \frac{21{,}818 \times (2.750 \times 161.7 + 3.206 \times 6.0) + 1{,}286 \times (2.750 \times 161.7 + 3.206 \times 6.0)}{75{,}500(\mathrm{DWT}) \times 18.5(\mathrm{kn})} = 7.67$$

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;.

$$\frac{161.6 \times 10{,}000(\mathrm{kW}) \times 3 + 162.2 \times 6{,}400(\mathrm{kW})}{10{,}000(\mathrm{kW}) \times 3 + 6{,}400(\mathrm{kW})} = 161.7(\mathrm{g/kWh})$$

*2: The average weighed value of $SFC_{ME(i)\_Pilotfuel}$ and $SFC_{AE(i)\_Pilotfuel}$ is used;

$$\frac{6.0 \times 10{,}000(\mathrm{kW}) \times 3 + 6.1 \times 6{,}400(\mathrm{kW})}{10{,}000(\mathrm{kW}) \times 3 + 6{,}400(\mathrm{kW})} = 6.0(\mathrm{g/kWh})$$

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

$$\left[COP_{reliquefy} = \frac{425(kg/m^3) \times 511(kJ/kg)}{24(h) \times 3600(sec) \times COP_{cooling}} = 15.142\right]$$

$R_{reliquefy}$	1
$Deadweight$	109,000 (ton)

2) Calculation of P_{ME}

P_{ME} is calculated in accordance with paragraph 2.2.5.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{ME(i)} = 0.75 \times MCR_{ME(i)}$$
$$= 0.75 \times (18{,}660 + 18{,}660) = 27{,}990(\text{kW})$$

3) Calculation of P_{AE}

P_{AE} is calculated in accordance with paragraph 2.2.5.6.1 and 2.2.5.6.3 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

P_{AE} = 0.025 x Σ 0.0$_{ME(i)}$ + 250
+ $CargoTankCaipacity_{LNG}$ x BOR x $COP_{reliquefy}$ x $R_{reliquefy}$
= 0.025 x 37,320 +250
+ 211,900 x 0.15/100 x 15.142 x 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 “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$EEDI = \frac{P_{ME} \cdot C_{FME} \cdot SFC_{ME} + P_{AE} \cdot C_{FAE} \cdot SFC_{AE}}{Capacity \cdot V_{ref}}$$

$$EEDI = \frac{27{,}990 \times 3.206 \times 165.0 + 5{,}996 \times 3.206 \times 198.0}{109{,}000(DWT) \times 19.7(kn)} = 8.668$$

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

$MCR_{ME(i)}$	18,660 x 2 (kW) = 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

$$COP_{reliquefy} = \frac{425\,(kg/m^3) \times 511\,(kJ/kg)}{24\,(h) \times 3600\,(\sec) \times COP_{cooling}} = 15.142$$

$R_{reliquefy}$	1
Deadweight	109,255 (ton)

$SFC_{ME(i)\_at\ 75\%\ of\ MCR}$ and $SFC_{AE(i)\_at\ 50\%\ of\ MCR}$ are in accordance with paragraph 2.2.7.1 of the "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

Deadweight is in accordance with paragraph 4.3.10 of the "2022 guidelines on survey and certification of the energy efficiency design index (EEDI)" as amended.

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} is calculated in accordance with paragraph 2.2.5.1 of the "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

$$P_{ME\,(i)} = 0.75 \times MCR_{ME\,(i)}$$
$$= 0.75 \times (18{,}660 + 18{,}660) = 27{,}990(\text{kW})$$

4) Calculation of P_{AE}

P_{AE} is calculated in accordance with paragraph 2.2.5.6.3.1 of the "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

P_{AE} = 0.025 x $\Sigma\, 0.0_{ME(i)}$ + 250
+ $CargoTankCaipacity_{LNG}$ x *BOR* x $COP_{reliquefy}$ x $R_{reliquefy}$
= 0.025 x 37,320 +250
+ 211,900 x 0.15/100 x 15.142 x 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"2022 guidelines on survey and certification of the energy efficiency design index (EEDI)" as amended.

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 "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

$$EEDI = \frac{P_{ME} \cdot C_{FME} \cdot SFC_{ME} + P_{AE} \cdot C_{FAE} \cdot SFC_{AE}}{Capacity \cdot V_{ref}}$$

$$EEDI = \frac{27{,}990 \times 3.206 \times 165.5 + 5{,}996 \times 3.206 \times 198.5}{109{,}255(DWT) \times 19.8(kn)} = 8.629$$

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

$MCR_{Steam\ turbine}$	25,000 (kW)
$SFC_{Steam\ turbine}$	241.0 (g/kWh)
Deadweight	75,000 (ton)

2) Calculation of P_{ME}

P_{ME} is calculated in accordance with paragraph 2.2.5.1 of the“2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

$$P_{ME} = 0.83 \times MCR_{SteamTurbine}$$
$$= 0.83 \times 25{,}000 = 20{,}750(\mathrm{kW})$$

3) Calculation of P_{AE}

P_{AE} is treated as 0(zero) because electric load ($P_{generator\_seatrial}$) is supposed to be included in $SFC_{SteamTurbine}$, in accordance with paragraph 2.2.5.6.5 and 2.2.7.2.1 of the “2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships”.

P_{AE} = 0

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 18.7kn is obtained at 83% of $MCR_{SteamTurbine}$, 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 “2022 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.

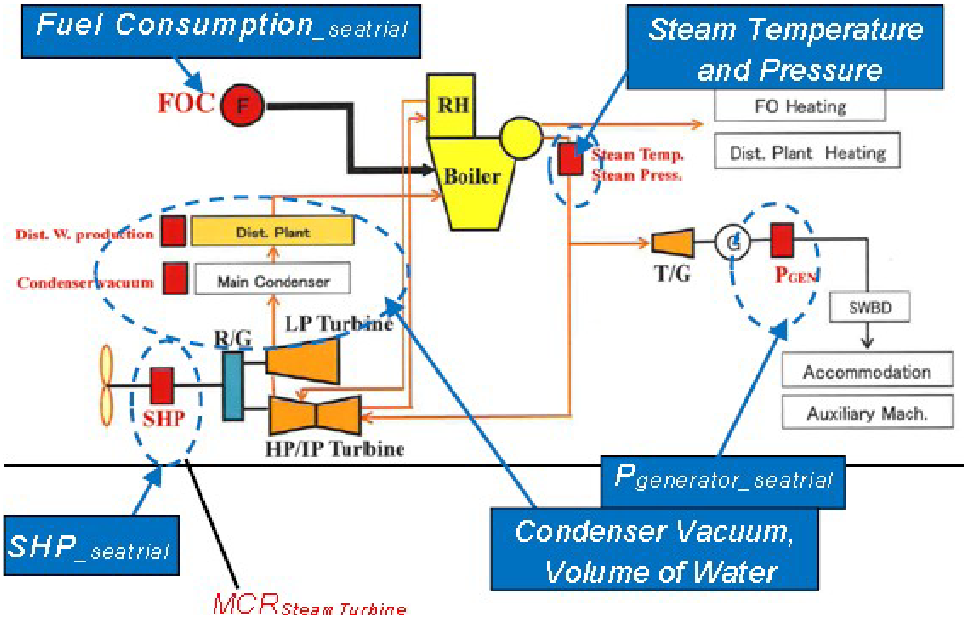
$$EEDI = \frac{P_{ME} \cdot C_{FME} \cdot SFC_{ME} + P_{AE} \cdot C_{FAE} \cdot SFC_{AE}}{Capacity \cdot V_{ref}}$$

$$EEDI = \frac{20{,}750 \times 2.750 \times 241.0 + 0}{75{,}000(DWT) \times 18.7(kn)} = 9.81$$

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 $SFC_{SteamTurbine}$, in accordance with paragraph 2.2.5.6.5 and 2.2.7.2.1 of the " 2022 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 2.2.7.2 of the "2022 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 $SFC_{SteamTurbine}$ at sea trial

$SFC_{SteamTurbine}$ is calculated in accordance with paragraph 2.2.7.2 of the "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

$$SFC_{SteamTurbine\_SeaTrial(i)} = \frac{FuelConsumption_{SeaTrial}}{SHP_{SeaTrial}}$$

$$= \frac{5.95 \times 10^6}{21{,}520} \times C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6 \times C_7^{*1}$$

$$= \frac{5.95 \times 10^6}{21{,}520} \times 0.9871 \times 0.8756 \times 1.0010 \times 1.0010 \times 1.0035 \times 0.9999 \times 1.0028$$

$$= 240.7\ (g/kWh)$$

Note:

*1: *SFC* should be corrected to the value corresponding to SNAME and EEDI conditions, in accordance with paragraph 2.2.7.2 .2 and .3 of the "2022_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

$P_{AE} = 0.025 \times MCR_{Steam\ turbine} + 250 = 875$ (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

$SFC_{SteamTurbine}$ 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 $SFC_{SteamTurbine}$ at around the EEDI power are obtained at the sea trial. However in this example calculation, all $SFC_{SteamTurbine\ (i)}$ are supposed to the same value of 240.7 g/kWh.

***5)* Calculation of P_{ME}**

P_{ME} is calculated in accordance with paragraph 2.2.5.1 of the "2022 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships".

$$P_{ME} = 0.83 \times MCR_{SteamTurbine}$$

$$= 0.83 \times 25{,}000 = 20{,}750\ (kW)$$

6) Calculation of P_{AE}

P_{AE} is treated as 0(zero) because electric load ($P_{generator\_seatrial}$) is supposed to be included in $SFC_{SteamTurbine}$, in accordance with paragraph 2.2.5.6.5 and 2.2.7.2.1 of the "2022 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 "2022 guidelines on survey and certification of the energy efficiency design index (EEDI)" as amended.

Suppose that V_{ref} of 18.8kn is obtained at 83% of $MCR_{SteamTurbine}$, 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 "2022 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.

$$EEDI = \frac{P_{ME} \cdot C_{FME} \cdot SFC_{ME} + P_{AE} \cdot C_{FAE} \cdot SFC_{AE}}{Capacity \cdot V_{ref}}$$

$$= \frac{20{,}750 \times 2.750 \times 240.7 + 0}{75{,}000(DWT) \times 18.8(kn)} = 9.74$$

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MEPC.1/Circ.896
14 December 2021

2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI

1 The Marine Environment Protection Committee, at its seventy-seventh session (22 to 26 November 2021), approved the *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI*, as set out in the annex.

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.

3 The Committee agreed to keep this Guidance under review in light of experience gained in its application.

4 This circular supersedes MEPC.1/Circ.815.

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ANNEX

2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI

TABLE OF CONTENTS

1 General

1.1 The purpose of this guidance is to assist manufacturers, shipbuilders, shipowners, verifiers and other interested parties relating to Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI) 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. Although the term EEDI only is used through the whole guidance, it applies to both the EEDI and the EEXI calculations, as applicable.

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 systems on the grounds 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 *2018 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships* (resolution MEPC.308(73), as amended).

2.2 *EEDI Survey Guidelines* means *2014 guidelines on survey and certification of the energy efficiency design index (EEDI)* (resolution MEPC.254(67), as amended by resolution MEPC.261(68) and resolution MEPC.309(73)).

2.3 P_p is the propulsion power and is defined as ΣP_{ME} (In case where shaft motor(s) are installed, $\Sigma P_{ME} + \Sigma P_{PTI(i),\mathrm{shaft}}$, as shown in paragraph 2.2.5.3 of EEDI Calculation Guidelines).

2.4 In addition to the above, definitions of the words in this guidance are the 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 do 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.

(C) Emission reduction through the auxiliary power reduction by generating electricity for normal maximum sea load(P_{AEeff})

(B) Emission reduction through the propulsion power reduction (P_{eff})

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

(A) The combination of P_P and V_{ref} as reflected in the power curve (knot-kW curve)

Innovative Energy Efficiency Technologies				
Reduction of Main Engine Power			Reduction of Auxiliary Power	
Category A	***Category B-1***	***Category B-2***	***Category C-1***	***Category C-2***
Cannot be separated from overall performance of the vessel	Can be treated separately from the overall performance of the vessel		Effective at all time	Depending on ambient environment
	$f_{eff}=1$	$f_{eff}<1$	$f_{eff}=1$	$f_{eff}<1$
– low friction coating – bare optimization – rudder resistance – propeller design	– hull air lubrication system (air cavity via air injection to reduce ship resistance) (can be switched off)	– wind assistance (sails, Flettner-Rotors, kites)	– waste heat recovery system (exhaust gas heat recovery and conversion to electric power)	– photovoltaic cells

4 Calculation and Verification of effects of Innovative Energy Efficiency Technologies

4.1 General

4.1.1 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

4.2.1 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.

4.5 Average weighted value in the case of $P_{PTI(i)}$ >0

4.5.1 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 $\Sigma(f_{eff(i)} \cdot P_{eff(i)} \cdot C_{F.}\ SFC)$ in attained EEDI formula:

For shaft power(s):
$(\Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)}) \ / \ (\Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$,
where, if $(\Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ is taken negative value, the value $(\Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ should be fixed to zero; and

For main engine(s):
$\Sigma P_{ME(i)} \ / \ (\Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$,
where, if $\Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)}$ is taken negative value, the value $(\Sigma P_{PTI(i),shaft} - \cdot\Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ should be fixed to zero.

ANNEX 1[1]

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (B) INNOVATIVE TECHNOLOGIES

1 AIR LUBRICATION SYSTEM (CATEGORY (B-1))

1.1 Summary of innovative energy efficient technology

1.1.1 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.

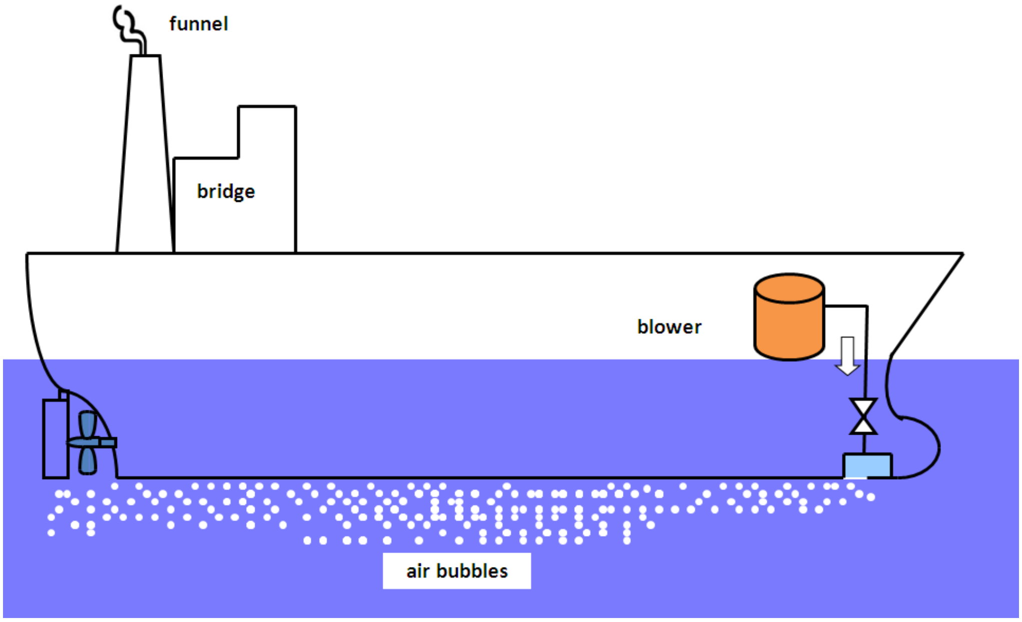


Figure 1 – Schematic illustration of an air lubrication system

1.2 Method of calculation

1.2.1 Power reduction due to air lubrication system

1.2.1.1 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.

$$P_{eff} = P_{PeffAL} - P_{AEeffAL} \frac{C_{FAE}}{C_{FME}} \frac{SFC_{AE}}{SFC_{ME}*} \quad (1)$$

* 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 this chapter are used solely to illustrate the proposed methods of calculation and verification.

1.2.1.2 P_{eff} is the effective power reduction in kW due to the air lubrication system at the 75% t of the rated installed power (MCR). In case that shaft generators are installed, P_{eff} should be calculated at the 75% MCR having after deducted any installed shaft generators in accordance with paragraph 2.2.5 of EEDI Calculation Guidelines. P_{eff} should be calculated both in the fully loaded and the sea trial conditions.

1.2.1.3 P_{PeffAL} is the reduction of propulsion power due to the air lubrication system in kW. P_{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.

1.2.1.4 $P_{AEeffAL}$ is additional auxiliary power in kW necessary for running the air lubrication system in the fully loaded condition. $P_{AEeffAL}$ should be calculated as 75% 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 $P_{AEeffAL}$ value may be estimated by an alternative method. In this case, the calculation process should be submitted to a verifier.

1.2.2 Points to keep in mind in calculation of attained EEDI with air lubrication system

1.2.2.1 V_{ref} in paragraph 2.2.2 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.

1.2.2.2 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.

1.3 Method of verification

1.3.1 General

1.3.1.1 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.

1.3.2 Preliminary verification at the design stage

1.3.2.1 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);

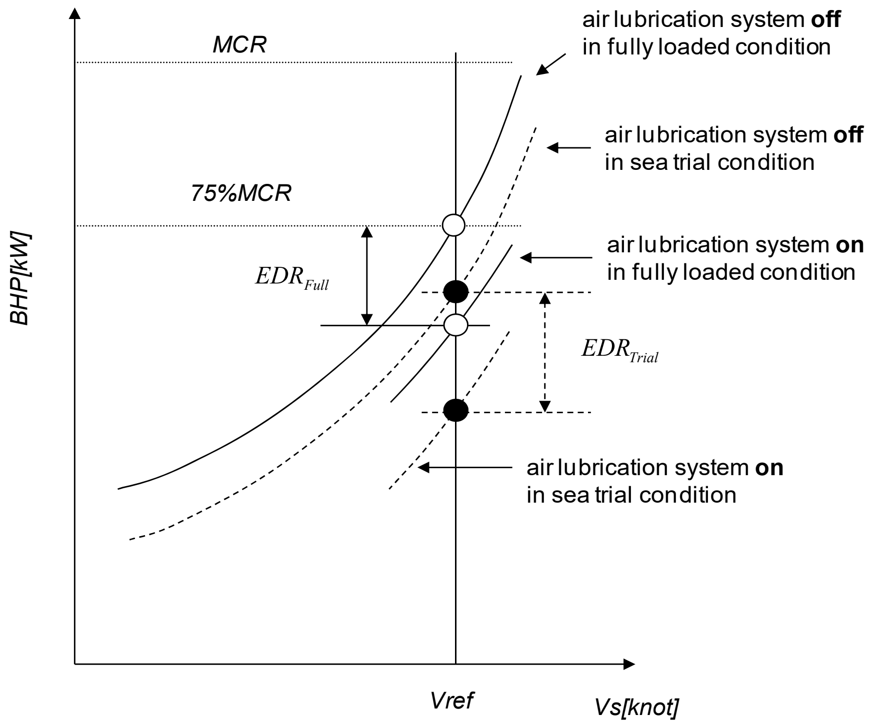


Figure 2 – Calculation of the reduction rate of propulsion power (EDR_{full} and EDR_{trial}) due to air lubrication system

.5 $P_{AEeffAL}$: 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.

1.3.2.2 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: $P_{AEeffAL}$.

1.3.3 Final verification of the attained EEDI at sea trial

1.3.3.1 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.

1.3.3.2 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.

1.3.3.3 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.

1.3.3.4 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}.

1.3.3.5 The following procedure should be conducted based on the power curve developed for air lubrication system OFF.

.1 ship speed at 75% 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% MCR having after deducted any installed shaft generators in accordance with paragraph 2.2.5 of EEDI Calculation Guidelines; and

.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.

1.3.3.6 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; and

.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.

$$ADR_{Full} = 1 - (1 - EDR_{Full}) \times \frac{1 - ADR_{Trial}}{1 - EDR_{Trial}} \qquad (2)$$

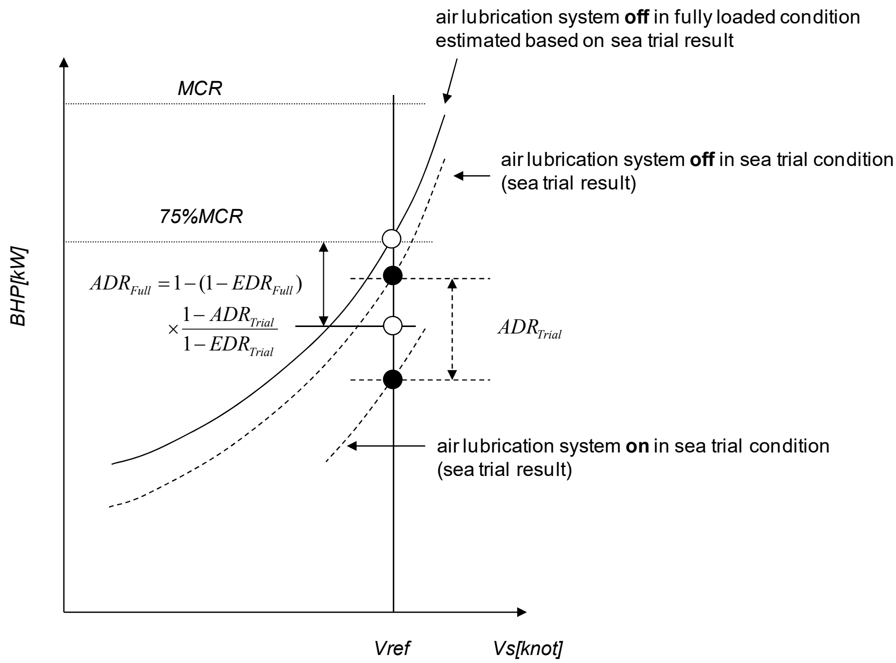


Figure 3 – Calculation of the actual reduction rate of propulsion power (ADR_{full} and ADR_{trial}) due to air lubrication system

1.3.3.7 The reduction of propulsion power due to the air lubrication system $P_{MEeffAL}$ in the fully loaded and the sea trial conditions should be calculated as follows:

$$P_{PeffAL\_Full} = ADR_{Full} \times P_P \tag{3}$$

$$P_{PeffAL\_Trial} = ADR_{Trial} \times P_P \tag{4}$$

1.3.3.8 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_{PeffAL} 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; and

.4 the calculated value of the EEDI for the air lubrication system ON in the fully loaded condition.

2 WIND ASSISTED PROPULSION SYSTEM (CATEGORY B-2)

2.1 Summary of innovative energy efficient technology

2.1.1 Wind assisted propulsion systems (WAPS) belong to innovative mechanical energy efficient technologies which reduce the CO_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 WAPS as the product of the reference speed and the sum of the wind assisted propulsion system force and the global wind probability distribution.

2.1.2 Secondary effects when applying the wind assisted propulsion system which might increase the ship resistance are ignored for the purpose of these guidelines. With this simplification effects as for instance additional drag due to leeway, rudder angle and heel or reduced propeller efficiency in light running condition are ignored without significant loss of accuracy. Nonetheless, the corresponding forces are considered to rule out conditions that do not allow a safe operation of the ship, for instance due to exceeding heel angles.

2.2 Definitions

2.2.1 For the purpose of these guidelines, the following definitions should apply:

.1 *available effective power* is the multiplication of effective power P_{eff} and availability factor f_{eff} , as defined in the EEDI calculation;

.2 *wind assisted propulsion systems (WAPS)* belong to innovative mechanical energy efficient technologies which reduce the CO_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 *wind propulsion system force matrix* is a two-dimensional matrix which expresses the force characteristic of a wind assisted propulsion system dependent on ship speed, wind speed and the wind angle relative to heading;

.4 *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 and represents the probability of wind conditions;

.5 *wind speed* is the speed of the wind in m/s measured at 10 m above sea level;

.6 *wind direction* is the North-oriented direction of the wind measured at 10 m above sea level and is subdivided into eight sectors (North, North-East, East, South-East, South, South-West, West, North-West);

.7 *wind angle* is the angle of the wind relative to the ship's heading at 10 m above sea level subdivided into 72 sectors of 5°-steps (0°, 5°,..., 355°); and

.8 the *main global shipping network* is a network of global shipping routes with the highest frequency of journeys.

2.3 Available effective power of wind assisted propulsion systems (WAPS)

2.3.1 The available effective power of wind assisted propulsion systems as innovative energy efficient technology is calculated by the following formula:

$$(f_{eff} \cdot P_{eff}) = \left(\frac{1}{\sum_{k=1}^{q} W_k}\right) \cdot \left(\left(\frac{0.5144 \cdot V_{ref}}{\eta_D} \sum_{k=1}^{q} F(V_{ref})_k \cdot W_k\right) - \left(\sum_{k=1}^{q} P(V_{ref})_k \cdot W_k\right)\right)$$

with $F_1 - F_k \geq 0 \wedge F_{k-1} - F_k \geq 0$

(sorting all force matrix elements in descending order)

and $\sum_{k=1}^{q-1} W_k < \frac{1}{2} \wedge \sum_{k=1}^{q} W_k \geq \frac{1}{2}$

(defining q: the number of elements added in the formula)

Where:

.1 (f_{eff} * P_{eff}) is the available effective power in kW delivered by the specified wind assisted propulsion system. f_{eff} and P_{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_{ref} is the ship reference speed measured in nautical miles per hour (knots), as defined in the EEDI calculation guidelines.

.4 η_D is the total efficiency of the main drive(s) at 75% of the rated installed power (MCR) of the main engine(s). η_D shall be set to 0.7, if no other value is specified and verified by the verifier;

.5 $F(V_{ref})_k$ is the force matrix of the respective wind assisted propulsion system for a given ship speed V_{ref}. Each matrix element represents the propulsion force in kilo newton (kN) for the respective wind speed and angle. The wind angle is given in relative bearings (with 0° on the bow);

.6 W_k is the global wind probability matrix. Each matrix element represents the probability of wind speed and wind angle relative to the ships heading. The sum over all matrix elements equals 1 and is non-dimensional; and

.7 $P(V_{ref})_k$ is a matrix with the same dimensions as $F(V_{ref})_k$ and W_k and represents the power demand in kW for the operation of the wind assisted propulsion system.

2.3.2 The fore 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 aft term contains the power requirement for the operation of the specific wind assisted propulsion system which has to be subtracted from the gained wind power.

2.4 Wind propulsion system force matrix $F(V_{ref})_k$

2.4.1 Measurement of the wind propulsion coefficients

2.4.1.1 The wind propulsion system force matrix is a table describing the average wind propulsion coefficients corresponding to the global wind probability matrix. Therefore, the measurement of the wind propulsion coefficients has to be carried out at first in order to obtain the wind propulsion system force matrix.

2.4.1.2 Various methods can be used to determine the aerodynamic forces of a wind assisted ship, depending firstly on the type of wind assisted propulsion system, but also size limitations and successful validation for the methods already shown in literature. The methods include:

.1 wind tunnel model test;

.2 CFD/numerical calculations; and

.3 full scale test.

2.4.1.3 The forces are to be determined for the combination of wind assisted propulsion system and ship unless that is not practical due to technical or economic reasons. In the latter case the conditions of 2.4.1.4 apply.

2.4.1.4 In the case of the installation of multiple wind assisted propulsion systems, the forces may be determined for the devices in isolation and by the summing the coefficients of each units comprising the system, provided that a validated method is in place to account for interaction effects between wind propulsors and between the ship and the wind propulsors.

2.4.1.5 Wind propulsion devices are to be analysed at their operational Reynolds number, as this has been shown to affect their performance.

2.4.1.6 The wind tunnel model test is a major method for measuring the aerodynamic force of a wind assisted ship propulsion system under typical states. Appendix 1 of this annex describes the testing methods of wind tunnel model tests. If the wind propulsion coefficients are measured by the wind tunnel model test, it should be conducted in accordance with the appendix 1.

2.4.1.7 For some types of wind assisted propulsion system wind tunnel model tests are not appropriate for measuring the wind propulsion coefficients. Therefore, numerical calculations, such as CFD-computation, can be accepted for estimating the wind propulsion coefficients, but the condition and the model of the numerical calculation should be referred to experimental representative results and the numerical calculation is to be carried out in accordance with defined quality and technical standards (ITTC 7.5-03-01-02 and ITTC 7.5-03-01-04 at their latest revisions or equivalent). If both of wind tunnel model tests and numerical calculation are inappropriate to estimate the coefficient, other testing method may be acceptable with the approval of the verifier.

2.4.1.8 When a test or calculation for determining the wind propulsion coefficients is carried out, the procedure of the test or calculation should be submitted to the verifier in advance of conducting the test or calculation. In addition, the detail report of the test and calculation procedure should also be submitted to the verifier after the test. The verifier may request the submitter to provide further documents/information as necessary to verify the wind propulsion coefficients.

2.4.1.9 The test of a ship model without wind assisted propulsion system mainly measures the wind forces of the ship model pointing to the bow under different wind directions. The test of a ship model with wind assisted propulsion system mainly measures the maximum wind propulsion of the ship model pointing to the bow under different wind directions, which is then used to calculate the wind propulsion coefficient of the wind propulsion system. The coefficients of the wind assisted propulsion system should be determined at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5°.

2.4.1.10 A single wind tunnel test may be accepted for several identical wind assisted propulsion systems and identical ships. The verifier may request that supporting documentation be produced.

2.4.2 Wind tunnel test methods and data processing

Option 1: Test on a ship model fitted with the full wind assisted propulsion system

2.4.2.1 When the wind tunnel test is carried out with the ship model and the wind assisted propulsion system model, the test method should follow the specifications given in appendix 1. The wind forces acting on the ship model are normalized as:

$$C_{Fx} = F_x / (0.5\ \rho\ V^2\ A)$$

2.4.2.2 The wind propulsion coefficients[2] of the wind assisted propulsion system can be determined as:

$$\Delta C_{Fx} = C_{Fx\text{-}with\ WPS} - C_{Fx\text{-}without\ WPS}$$

Where:

.1 C_{Fx} is the wind force coefficient of the model pointing to the bow;

.2 F_x is the wind force of the model pointing to the bow;

.3 ΔC_{Fx} is the wind propulsion coefficient of the wind assisted propulsion system;

.4 ρ is the air density of the model test;

.5 V is the wind velocity of the model test;

.6 A is the total projected area of the wind assisted propulsion system; and

.7 the subscript "with WAPS" means the state with wind assisted propulsion system of the ship model, while "without WAPS" means the state without wind assisted propulsion system of the ship.

2 The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

Option 2: Test with a single wind assisted propulsion unit

2.4.2.3 When the wind tunnel test is carried out with a single wind propulsion unit, the test method should follow the specifications given in appendix 1. The wind propulsion coefficients[3] of the model can be determined as:

$C_{Fx} = F_x / (0.5\ \rho\ V^2\ A)$

Where:

.1 C_{Fx} is the wind force coefficient of the model pointing to the bow;

.2 F_x is the wind force of the model pointing to the bow;

.3 ρ is the air density of the model test;

.4 V is the wind velocity of the model test; and

.5 A is the total projected area of the wind assisted propulsion system.

2.4.2.4 The wind propulsion coefficients ΔC_{Fx} of a multi-unit wind assisted propulsion system can be calculated by summing the coefficients of the units comprising the system, weighted by the effects of interaction and masking by superstructures.

For options 1 and 2: Calculation of the average power consumption coefficients of the active wind assisted propulsion system during the wind tunnel test

2.4.2.5 The power consumption of the wind assisted propulsion system should be measured and the power consumption matrix should be filled based on the measured values and the systems control plan.

2.4.3 Calculation of the wind propulsion system force matrix

2.4.3.1 The wind propulsion coefficients[4] of the ship's wind assisted propulsion system can be used to predict the wind propulsion system force matrix. Apparent wind is defined as the combination of wind relative to the ground and wind created by the ship's velocity. The steps to calculate the wind propulsion system force matrix are as follows:

.1 determine the velocity of the ship V_{ref};

.2 select the average wind speed corresponding to terms in W_k, the global wind probability matrix at 10 m height. For example, the average wind speed corresponding to the first wind speed range (0-1 m/s) of the wind probability matrix is selected as 0.5 m/s, the average wind speed corresponding to the second wind speed range (1-2 m/s) is selected as 1.5 m/s, etc.;

.3 extrapolate the wind speed to the reference height of the wind assisted propulsion systems taken as the aerodynamic centre of effort height or half height from the waterline:

[3] The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

[4] The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

$$v_{Zref} = v_{10m}\left(\frac{z_{ref}}{10}\right)^{\alpha} \ for\ z_{ref} < 300m$$

$$v_{Zref} = v_{10m}\left(\frac{300}{10}\right)^{\alpha} \ for\ z_{ref} \geq 300m$$

Where:

.1 z_{ref} is the reference height above the water line, to be equal to the point of mid-height of each sail, Flettner, etc. in wind assisted propulsion system;

.2 v_{10m} is the wind velocity at 10 m above sea level;

.3 v_{Zref} is the resulting wind velocity at the reference height; and

.4 α is taken as 1/9 conforming to ITTC recommendations.[5]

.4 according to the corresponding average wind speed, wind direction angle and the velocity of the ship, calculate the relative wind speed V_k and the relative wind direction angle of the ship;

.5 according to the relative wind direction angle, and the corresponding relationship between the relative wind direction angle and the wind propulsion coefficient ΔC_{Fx} obtained from the test, calculate the average wind propulsion coefficients $(\Delta C_{Fx})_k$ of the wind assisted propulsion system corresponding to W_k; and

.6 according to the average wind propulsion coefficient of the wind assisted propulsion system, calculate the terms of the wind propulsion system force matrix $F(V_{ref})_k$ of the full scale ship corresponding to W_k by following formula:

$F(V_{ref})_k = (\Delta C_{Fx})_k * (0.5\ \rho\ V_k^2\ A)$

Where:

.1 $(\Delta C_{Fx})_k$ is the average wind propulsion coefficients corresponding to W_k;

.2 ρ is the average air density in shipping environment, ρ=1.225 kg/m^3;

.3 V_k is the relative wind velocity of the full-scale ship corresponding to W_k;

.4 A is the total projected area of the wind assisted propulsion system;

.5 the settings of the wind propulsor may be varied in order to find the best $(\Delta CFx)_k$; this may be done using interpolation provided that increments in settings are sufficiently small;

[5] International Towing Tank Conference (ITTC), "ITTC – Recommended Procedures and Guidelines; Preparation, Conduct and Analysis of Speed/Power Trial," International Towing Tank Conference (ITTC), 7.5-04-01-01.1, 2017.

Annotation: ITCC provides no guidance for wind speeds above an altitude above 300 m. However, it is assumed in this guideline to be constant above 300 m altitude.

.6 the settings and deployment of the wind assisted propulsion system must adhere to the operational constraints as defined for the system (e.g. a maximum operational wind speed, if lower than provided by the global wind probability matrix, > Bf 8, 19 m/s);

.7 the potential wind drag induced by the system is to be accounted for, such as in unusable wind directions close to head wind and when the systems is not operational due to exceedance of operational limits; and

.8 if $F(V_{ref})_k$ exceeds the resistance of the ship, such that the propeller thrust would be negative, $F(V_{ref})_k$ is to be limited at the resistance value.

2.4.4 Consideration of the operational limits of the wind assisted propulsion system and the lateral forces and yawing moments

2.4.4.1 Force $F(V_{ref})_k$ must be calculated only when it is within the operational domain applicable to the wind assisted propulsion system. These operational limitations can be caused at a minimum by wind conditions or by the total forces generated by the wind assisted propulsion system and applied to the ship.

2.4.4.2 $F(V_{ref})_k$ must be zero for any pair (wind direction; wind force) not in conformity with the operational domain of the wind assisted propulsion system validated by the verifier in the operations manual of the wind assisted propulsion system and the ship.

2.4.4.3 The lateral forces exerted by the wind assisted propulsion system on the ship and the resulting yawing moment can affect the performance of the system, and therefore the EEDI calculation. The lateral forces on the ship and the yawing moments applied by the wind assisted propulsion system to the ship should therefore be documented by the shipbuilder and/or propulsion system manufacturer and observed by the verifier. They can be obtained without additional effort during the tests described in paragraph 2.4.1 of the present circular.

2.4.4.4 Conformity with the operational domain requires that for any pair (wind direction; wind force), and in consideration of the total forces generated by the wind assisted propulsion system (i.e. including lateral forces to the vessel and yawing moments), the strength of the wind assisted propulsion system, the forces at the embedment and the list of the ship conform with the structural design file and the stability file of the ship, respectively. Where the lateral forces and yawing moment are particularly significant, the verifier may request course keeping and rudder angle demonstrations to validate conformity with the operational domain.

2.5 The global wind probability matrix W_k

2.5.1 Wind probabilities

2.5.1.1 Wind conditions are not constant. Winds vary their speed and direction with time. Wind expectations are unequal in different regions of the earth.

2.5.1.2 However, every wind expectation can be expressed in a distinctive wind probability pattern for every particular position on the globe. There is always a certain probability for a certain wind direction and wind speed to occur. These probabilities are documented in wind charts. With this approach each geographical region has a distinctive wind chart.

2.5.2 Wind angles relative to the ship

2.5.2.1 For a wind assisted propulsion system, it is irrelevant if the wind is coming from North or South. Only the wind angle relative to a ship's heading is of importance. As a consequence, the wind directions given in the weather data have to be recalculated for ship headings on a trading route when applied to wind assisted propulsion systems, where 0° means the ship's bow, 90° its starboard side, 180° the stern and 270° port side.

2.5.3 Main global shipping network

2.5.3.1 To determine a global wind probability chart for the wind assisted propulsion system's EEDI calculation, the average of all wind conditions along the main global shipping routes is required.

2.5.3.2 Figure 1 shows the main global shipping network used to determine the global wind conditions. Along the shown routes, 106 wind condition charts were analysed. These charts are based on 868,500 individual wind data.

2.5.3.3 The wind condition charts for each position were first recalculated in ship heading coordinates and then averaged to form a global wind condition chart. The results are visualized in figure 2, the complete chart (the global wind probability matrix) is shown as the table in appendix 2 of this annex.

2.5.3.4 Each element of the matrix W_k represents the probability of the specific wind speed and wind angle relative to the ship. The sum of all matrix elements is one (1.0), representing 100% of all wind conditions.

2.5.3.5 The results show that winds to the bow or the stern occur more often than winds to the sides. There are two possible reasons to explain this phenomenon:

.1 shipping routes and global weather systems are more East-West than North-South oriented; and

.2 shipping routes and winds are influenced by shore lines, so they tend to be parallel in some regions.

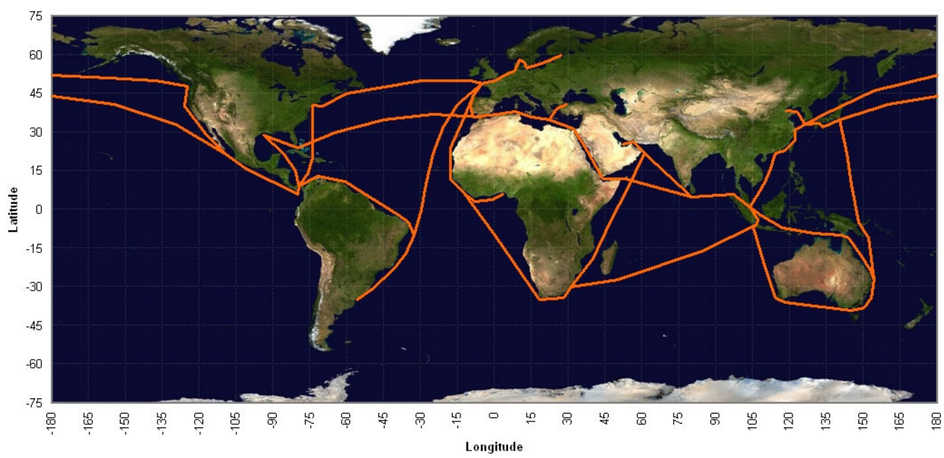
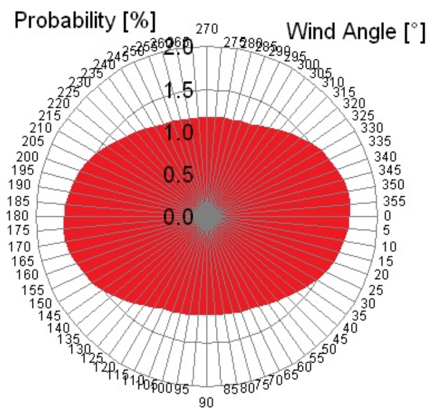


Figure 1 – The main global shipping network used for the wind chart



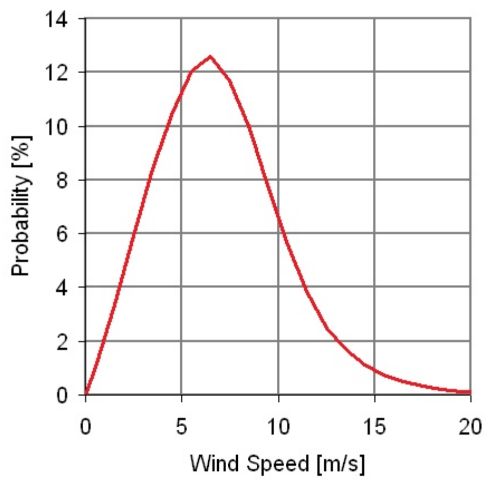


Figure 2 – Resulting wind curves on the main global shipping routes relative to the ship

2.6 Effective CO_2 reduction by wind assisted propulsion systems

2.6.1 For the calculation of the CO_2 reduction, the resulting available effective power (f_{eff} * P_{eff}) has to be multiplied with the conversion factor C_{FME} and SFC_{ME} , as contained in the original EEDI formula.

2.7 Verification of wind assisted propulsion systems in the EEDI certification process

2.7.1 General

2.7.1.1 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.

2.7.2 Preliminary verification at the design stage

2.7.2.1 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 assisted propulsion systems; and

.2 Calculated value of EEDI due to the wind assisted propulsion system.

2.7.2.2 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 $F(V_{ref})_k$ and results of performance tests.

2.7.2.3 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.

2.7.2.4 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.

2.7.3 Final verification of the attained EEDI

2.7.3.1 The total net power generated by wind assisted propulsion systems should be confirmed based on the documentation in the EEDI Technical File. For final verification, EEDI verifier should check that the configuration of the installed wind assisted propulsion system agrees with the system as described in the EEDI Technical File.

APPENDIX 1

METHOD OF WIND TUNNEL MODEL TEST

In accordance with section 2.4.1 of the present circular, two test methods are defined:

.1 option 1: test on a ship model fitted with the full wind assisted propulsion system; and

.2 option 2: test on a complete model of a single wind propulsion unit.

Option 1: Test on a ship model fitted with the full wind assisted propulsion system

1 Model

1.1 The wind assisted propulsion system model and the hull model should be made similarly to the real form, but appendages which do not affect the aerodynamic characteristics can be omitted from the model (e.g. handrails, windlass, etc.).

1.2 The draught condition of the hull model should be corresponding to the *Capacity* as defined in EEDI Calculation Guidelines.

1.3 The hull model is connected with the turntable by force balance, and the wind direction angle of the ship model is changed by changing the angle of the turntable.

2 Test condition

2.1 In addition to geometric similarity, the dynamic similarity criterion must be satisfied in the wind matrix wind tunnel model test of a ship's wind assisted propulsion system. That is, when the test wind speed is higher than a certain critical wind speed, the dimensionless wind coefficient tends to be stable, and the flow around the model is similar to the real ship. The measured wind coefficient can be directly extrapolated to the real ship. During the test, the critical wind speed is determined by a variable wind speed test.

2.2 In the wind tunnel model test, spires and roughness elements are arranged at the front of the test section, and the wind field of the atmospheric boundary layer on the ocean surface at the model scale for wind matrix test is obtained. Reynolds number of the test should be more than 1.0 x 10^6. The Reynolds number, *Re*, is expressed by the following formula:

$$\mu$$

where ρ and μ are the density and viscosity of the air, respectively, U is the wind speed, L_{pp} is the length between perpendiculars of the model ship.

2.3 The blockage ratio should not be more than 5%. The ratio is calculated by the transverse projected area of the model divided by the cross-sectional area of wind tunnel.

3 Test method

3.1 At the same hull wind direction, the wind propulsion coefficients of the wind assisted propulsion system are different at different angles of attack. In order to obtain the maximum wind propulsion coefficients of the wind assisted propulsion system at each hull wind direction angle, the test scheme should include:

.1 measurements of the aerodynamic force characteristics of the ship model without wind assisted propulsion system at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5°, potentially extended to 10° only for beam to stern;

.2 measurements of the aerodynamic force characteristics of the ship model with wind assisted propulsion system at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5° or 10°, attack angles of the wind assisted propulsion system range from 0° to 180°, spaced by an interval of 5° or 10° in every wind angle of the ship model. Smaller intervals of attack angles should be needed around the maximum wind propulsion coefficients; and

.3 in the case where the measurements are carried out with spaced by an interval of 10°, each intermediate force characteristic (i.e. F_X at 5°, 15°, 25°…) should be interpolated by using the measurement results.

3.2 In the case where the shape of the ship and wind assisted propulsion system are symmetrical on starboard side and port side, the wind propulsion coefficients are also symmetrical and thus, the measurements at a series of wind angles ranging from 0° to 180° or 180° to 360° can be omitted.

3.3 If the wind assisted propulsion system has a changeable and controllable structure, such as sails and rotors, the model of the wind assisted propulsion system can be arranged as the wind angle, the rotor speed, or other controllable structure to maximize the gained wind force or to minimize the wind resistance.

Option 2: Test on a complete model of a single wind propulsion unit

4 Model

4.1 The effects of the hull and superstructures should be taken into account by corrective actions taking into account the masked area and distance. If several wind propulsion units are installed on board the ship, the aerodynamic interactions between them should be taken into account by corrective actions. The verifier may request documentation from the test author to verify that these effects have been taken into account.

4.2 The wind propulsion unit model is connected to the turntable by means of a force balance, and the wind direction angle of the ship model is changed by changing the angle of the turntable.

5 Test conditions

5.1 In addition to geometric similarity, the dynamic similarity criterion must be satisfied in the wind matrix wind tunnel model test of a ship's wind assisted propulsion system. That is, when the test wind speed is higher than a certain critical wind speed, the dimensionless wind coefficient tends to be stable, and the flow around the model is similar to the real ship. The measured wind coefficient can be directly extrapolated to the real ship. During the test, the critical wind speed is determined by a variable wind speed test.

5.2 The maximum Reynolds number of the test should be more than 5.0×10^5. The Reynolds number, Re, is expressed by the following formula:

$$Re = \rho \,.\, U \,.\, C / \mu$$

where ρ and μ are the density and viscosity of the air, respectively, U is the wind speed, C is the mean chord length of the wind propulsion unit.

5.3 The blockage ratio should not be more than 5%. The ratio is calculated by the transverse projected area of the model divided by the cross-sectional area of wind tunnel.

6 Test method

6.1 In order to obtain the maximum wind propulsion coefficients of the wind assisted propulsion system at each ship wind direction angle, the test scheme should include measurements of the aerodynamic force characteristics for:

.1 a range of permissible angles of attack on the wind propulsion unit; and

.2 a range of permissible settings (profile camber, rotation speed, suction rate, reduced area, etc.).

6.2 The propulsive force on the ship is the aerodynamic force measured on the wind propulsion unit pointing to the bow.

APPENDIX 2

GLOBAL WIND PROBABILITY MATRIX W_k

Table 1 – Normalized global wind chart showing the probability of wind conditions relative to the ship's heading along the main global trading routes

Wind Angle [°] / Wind Speed [m/s]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
<1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
<3	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
<4	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0011	0.0011
<5	0.0017	0.0017	0.0017	0.0016	0.0016	0.0015	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
<6	0.0021	0.0020	0.0020	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014	0.0014	0.0014	0.0013	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015
<7	0.0022	0.0022	0.0021	0.0020	0.0020	0.0019	0.0018	0.0017	0.0017	0.0016	0.0015	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0015
<8	0.0020	0.0020	0.0020	0.0019	0.0019	0.0018	0.0017	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0014	0.0014	0.0014
<9	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012
<10	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0009	0.0009
<11	0.0010	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
<12	0.0007	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
<13	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
<14	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<15	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Wind Angle [°] / Wind Speed [m/s]	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235
<1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
<3	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
<4	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011
<5	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016	0.0015	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013
<6	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021	0.0021	0.0021	0.0020	0.0020	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014
<7	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0022	0.0022	0.0022	0.0021	0.0020	0.0020	0.0019	0.0018	0.0017	0.0017	0.0016	0.0015	0.0014
<8	0.0015	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021	0.0020	0.0020	0.0020	0.0019	0.0019	0.0018	0.0017	0.0016	0.0016	0.0015	0.0014	0.0014
<9	0.0012	0.0012	0.0013	0.0014	0.0014	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012
<10	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0010	0.0010
<11	0.0006	0.0006	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008
<12	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005
<13	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
<14	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
<15	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Wind Angle [°] / Wind Speed [m/s]	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	355
<1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
<3	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
<4	0.0011	0.0011	0.0011	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
<5	0.0013	0.0012	0.0012	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
<6	0.0014	0.0014	0.0014	0.0013	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021	0.0021
<7	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0015	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0022
<8	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021
<9	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0012	0.0013	0.0014	0.0014	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	0.0017
<10	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013
<11	0.0008	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0010
<12	0.0005	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0006	0.0007
<13	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
<14	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003
<15	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

ANNEX 2[6]

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (C) INNOVATIVE TECHNOLOGIES

1 WASTE HEAT RECOVERY SYSTEM FOR GENERATION OF ELECTRICITY (CATEGORY (C-1))

1.1 Summary of innovative energy efficient technology

1.1.1 This chapter 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 $P_{AEeff(i)}$). 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}.

1.1.2 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.

1.1.3 There are the following two methods of generating electricity by the waste heat energy technologies (electric generation type):

.1 (A) method to recover thermal energy by a heat exchanger and to drive the thermal engine which drives an electric generator; and

.2 (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.

[6] All examples in this chapter are used solely to illustrate the proposed methods of calculation and verification.

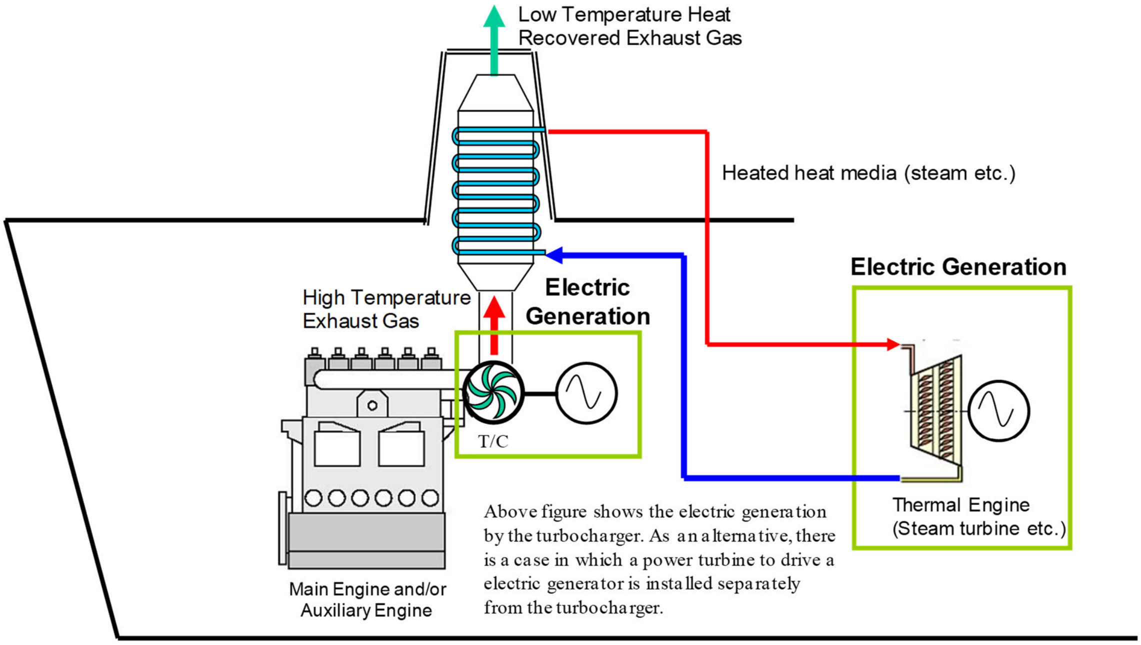


Figure 1 – Schematic illustration of Exhaust Heat Recovery

1.2 Method of calculation

1.2.1 Power reduction due to waste heating recovery system

1.2.1.1 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.

$$P_{AEeff} = P'_{AEeff} - P_{AEeff\_loss} \quad (1)$$

In the above equation, P'_{AEeff} is power produced by the waste heat recovery system. P_{AEeff_Loss} is the necessary power to drive the waste heat recovery system.

1.2.1.2 P_{AEeff} 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 1.2.1.4 of this chapter).

1.2.1.3 P'_{AEeff} is defined by the following equation.

$$P'_{AEeff} = \frac{W_e}{\eta_g}, \quad (2)$$

where:

W_e : Calculated production of electricity by the waste heat recovery system
η_g : Weighted average generator efficiency

1.2.1.4 P_{AEeff} 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.

1.2.1.5 P_{AEeff_Loss} is the power (kW) for the pump, etc. necessary to drive the waste heat recovery system.

1.3 Method of verification

1.3.1 General

1.3.1.1 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.

1.3.2 Preliminary verification at the design stage

1.3.2.1 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.

1.3.2.2 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% 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 exhaust gas mass flow for turbo charger (kg/h);

.2 exhaust gas temperatures after turbo charger (C°);

.3 exhaust gas bypass mass flow available for power turbine, if any (kg/h);

.4 exhaust gas temperature for bypass flow (C°); and

.5 exhaust gas pressure for bypass flow (bar).

.2 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;

.3 estimation process of the heat energy recovered by the waste heat recovery system; and

.4 further details of the calculation method of P_{AEeff} defined in paragraph 1.2.1 of this chapter.

1.3.3 Final verification of the attained EEDI at sea trial

1.3.3.1 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.

1.3.3.2 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.

2 PHOTOVOLTAIC POWER GENERATION SYSTEM (CATEGORY (C-2))

2.1 Summary of innovative energy efficient technology

2.1.1 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.

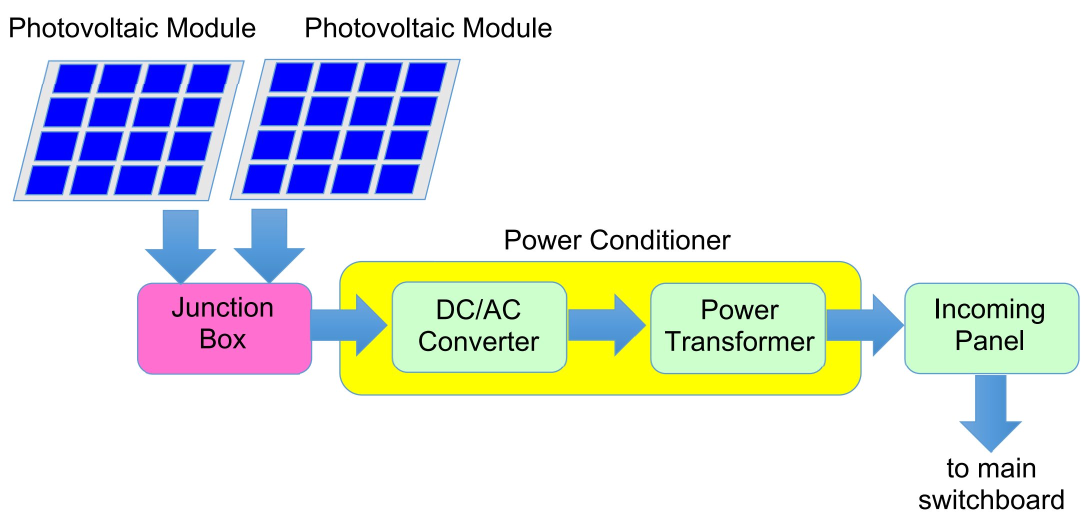


Figure 1 – Schematic diagram of photovoltaic power generation system

2.2 Method of calculation

2.2.1 Electric power due to photovoltaic power generation system

2.2.1.1 The auxiliary power reduction due to the PV power generation system can be calculated as follows:

$$f_{eff} \cdot P_{AEeff} = \{f_{rad} \times (1 + L_{temp} / 100)\} \times \{P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}\} \quad (1)$$

where $f_{eff} \cdot P_{AEeff}$ is the total net electric power (kW) generated by the PV power generation system.

2.2.1.2 Effective coefficient f_{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:

$$f_{eff} = f_{rad} \times (1 + L_{temp} / 100) \quad (2)$$

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.[7] 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^2. The average solar irradiance on main global shipping route is 200 W/m^2. Therefore, f_{rad} is calculated by the following formula:

$$f_{rad} = 200 \text{ W/m}^2 \div 1000 \text{ W/m}^2 = 0.2 \quad (3)$$

2.2.1.4 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[7]) as follows:

$$L_{temp} = f_{temp} \times (40°\text{C} - 25°\text{C}) \quad (4)$$

2.2.1.5 P_{AEeff} 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:

$$P_{AEeff} = P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}, \quad (5)$$

where η_{GEN} is the weighted average efficiency of the generator(s).

2.2.1.6 P_{max} is the nominal maximum generated PV power generation of a module expressed in kilowatt, specified based on IEC Standards.[7]

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7 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.

2.2.1.7 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% (the loss in the power conditioner: 5% 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.[8]

2.2.1.8 *N* is the numbers of modules used in a PV power generation system.

2.3 Method of verification

2.3.1 General

2.3.1.1 Verification of EEDI with innovative energy efficient technologies is conducted according to EEDI Survey Guidelines**.** This section provides additional requirements related to innovative technologies.

2.3.2 Preliminary verification at the design stage

2.3.2.1 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 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.

2.3.2.2 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 ($f_{eff} \cdot P_{AEeff}$) specified in section 2.2 in this guidance.

2.3.3 Final verification of the attained EEDI at sea trial

2.3.3.1 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.

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8 IEC 61683 "Photovoltaic systems – Power conditioners – Procedure for measuring efficiency".

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MEPC.1/Circ.901
24 June 2022

GUIDANCE ON METHODS, PROCEDURES AND VERIFICATION OF IN-SERVICE PERFORMANCE MEASUREMENTS

1 The Marine Environment Protection Committee, at its seventy-eighth session (6 to 10 June 2022), approved the *Guidance on methods, procedures and verification of in-service performance measurements* for the purpose of the EEXI calculation, as set out in the annex.

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.

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ANNEX

GUIDANCE ON METHODS, PROCEDURES AND VERIFICATION OF IN-SERVICE PERFORMANCE MEASUREMENTS

CONTENTS

1 Introduction

In cases where the speed-power curve is not available or the sea trial report does not contain the EEDI or design load draught condition, the ship speed V_{ref} can be obtained from the in-service performance measurement method for the purpose of the EEXI calculation, in accordance with paragraph 2.2.3.5 of the EEXI Calculation Guidelines, as set out in resolution MEPC.350(78).

2 Overview

2.1 When carrying out the in-service performance measurements, common international standards[1] should be referred to, unless explicitly specified in this guidance.

2.2 An overview of preparations and procedures are outlined in the table below. The preparations and the processes should be discussed and agreed at the pre-meeting, see section "Preparations".

Table 1: In-service performance sea trial preparations and procedures

In-service performance measurement analysis	
Step 1: Preparing sensors	• Speed log / GPS • Echosounder • Heading control • Fuel flow meter • Shaft torsion meter • Draft measurement • Gyro compass
Step 2: Pre-trial parameters	• Displacement • Forward/Aft draughts • Water depth • Air/Sea temperature • Seawater density • Anemometer height • Fuel density • Fuel LCV
Step 3: In-service performance measurement	• Sea state • Wind • Water depth • Currents
Step 4: During trial parameters	• Reported data • System prints • Equipment control • Fuel analysis
Step 5: Documentation	• Shaft RPM/Power • Heading • Ship's speed • Distance • Wind speed/direction • Current speed/direction • Wave height/period/direction

1 Such as ITTC quality procedures, ISO 15016:2002, ISO 15016:2015 and/or ISO 19030:2016.

2.3 When using the in-service performance measurement method, a meeting should be arranged between all stakeholders involved in the process: the owner, the possible consultant, the verifier and the authority before conducting the in-service performance measurements. An overview of the available information including but not limited to ship design, energy saving devices (ESD) and measurement sensors should be included. The plan for the period of the in-service performance measurements should be agreed upon and expectations regarding the delivery of the analysis and its format should be aligned.

3 Preparations

3.1 One of the most important aspects of a successful in-service performance measurement procedure is the preparation. Relevant instruments should be calibrated and their operational conditions prior to the commencement of the trials should be confirmed by the verifier.[2] The list below indicates the primary instruments to be used for collecting the data:

Table 2: Sensors for In-service performance trials

Sensor	Remarks
Shaft torque meter	The measurement system should be certified for power measurements with a bias error as small as practicable. Zero setting checked before and after test.
GPS	The GPS system should operate in the differential mode to ensure sufficient accuracy.
Anemometer	It should be clear of possible obstructions (superstructure, masts, funnel, etc.) and its height from sea level recorded.
Draft measurements	Draft measurement system (if available and calibrated): Otherwise, physical observation is required.
Speed log	The sensor should have been cleaned recently.
Echo sounder	Important for checking water depth for safety and ensuring there are no effects from shallow water on the ship performance.
Course recorder	Should be checked before the trial and be able to provide a course printout following each trial run.
Fuel flow meter	Either volume flow or mass flow meters to be fitted to ships. Both should be calibrated and cleaned/maintained as per manufacturer's recommendations.
Gyro compass	Record the ship's heading during the voyage and should be calibrated prior to the trials.

3.2 The ship should be equipped with a calibrated shaft torque meter, at least for the complete duration of the in-service performance measurement. For verification and cross checks, the detailed fuel properties information, the logged engine room conditions and the fuel oil consumption details will give an estimate of the power used at a certain fuel oil consumption value.

3.3 If an automated data acquisition system is installed on board, this should be checked for accuracy prior to the performance measurements, to ensure that the system has the required precision and measurement frequency, that can provide a trace of all the data required.

2 The Verifier is the flag Administration, or a competent organization delegated by the flag Administration.

3.4 Before the start of each performance measurement run, the following should be noted in the data logging template form (example appendix C):

Table 3: In-service environment and conditions

Parameter	Remarks
Displacement	Speed trials should be performed at displacement and draught conditions, which are comparable to those of the delivery sea trials or model tests or assumed ballast conditions. The trim shall be maintained within very narrow limits. For the even keel condition, the trim shall be less than 0.1 % of the length between perpendiculars. For the trimmed trial condition, the fore draught shall be within ± 0.1 m of the ship's ideal condition.
Draught forward, mid and aft	
Water depth	No remarks
Air temperature	Air temperature and pressure should be measured using a calibrated thermometer and barometer.
Air pressure	
Sea water temperature	The local seawater temperature and density at the trial site should be recorded to enable the calculation of the ship's displacement and corrections with regards to viscosity. The water temperature should be taken at the waterline level.
Sea water density	
Anemometer height	Its height from sea level should be recorded.
Fuel density	The fuel's density and LCV to be obtained from a laboratory's analysis report.
Fuel LCV	

3.5 The in-service performance measurements should be performed at the EEXI draught condition, and if data exists for a reference condition, then a set of in-service performance measurements may also be performed at this condition in order to better calibrate the speed-power relation.

.1 The reference condition is the condition for which the ship documentation exists, e.g. a sea trial curve in ballast or a sea trial/model test curve in design conditions. The in-service performance measurement result may be calibrated towards the reference condition curve. The use of a reference condition, if available, should not lead to overestimation of the Vref but can be a useful tool to verify and calibrate the speed-power relation. If a reference condition is used, this calibration result may also be used for the EEXI draught condition.

.2 The EEXI draught condition is the draught condition as provided by paragraph 2.2.2 of the *2018 Guidelines on the method of calculation of the attained EEDI for new ships* (resolution MEPC.308(73), as amended, the "EEDI Calculation Guidelines" hereafter). The performance measurements results are used with the same calibration factor as at the reference condition if available.

3.6 In case the exact EEXI draught condition cannot be met, the Admiralty Coefficient formula may be accepted to adjust the speed-power relation, only for displacement variations of up to 2%, or to the satisfaction of the verifier.

3.7 The ship should perform at least one set of in-service performance measurements for the EEXI draught condition, and at power settings equivalent to the EEDI trial conditions (set out in MEPC.1/Circ.855/Rev.2, as amended). If that is not possible, then at each of the following power settings of 30%, 60%, 75% and 90% of MCR, with a margin of +/– 5%. If data for a reference condition is available, another set of in-service performance measurements should also be carried out at this condition for calibration purposes.

3.8 In case where an overridable Shaft/Engine Power Limitation is installed, the power settings of 30%, 60%, 83% and 90% of the limited power may be used, with a margin of +/– 5% for both sets of in-service performance measurements, to the satisfaction of the verifier.

3.9 If the in-service performance measurements are performed at consecutive power settings, sufficient time in between change of settings should be considered, to be sure that steady state conditions are obtained.

3.10 The duration of each run should be performed according to table 4.

3.11 Prior to the in-service performance measurements, the weather forecast should be studied to ensure that favourable weather conditions will prevail during the trials (close to calm conditions).

3.12 Crew members involved in the execution should be familiar with the performance measurements and be aware of their tasks and the importance of the measurements collected.

3.13 Safety of the ship is paramount, and the performance measurements should be suspended should any risks to the ship and/or crew be detected. All rules and regulations, as well as good seamanship, are to be followed at all times.

3.14 The conditions and plans specified in this section should be examined and confirmed by the verifier prior to the in-service performance measurements.

3.15 The ship may experience fouling of the hull and the propeller, which may influence the performance of the ship. If the ship is heavily fouled during the in-service performance measurements, the V_{ref} attained may be less than expected and this will lead to a penalty in the attained EEXI. It is recommended to carry out in-service performance measurements when the ship has a clean hull and propeller.

3.16 The ship may have installed ESDs post delivery. This will affect the performance and the in-service measurement may be used to reflect the effect of ESDs, as provided in paragraph 2.2.3.7 of the EEXI Calculation Guidelines.

4 During the in-service performance measurements

4.1 Once the in-service performance measurements have begun, variations should be minimized, as the accuracy of the ship performance measurements can be influenced greatly by fluctuations in the parameters. Thus, all control levers should remain unchanged.

4.2 An experienced helmsman or adaptive autopilot will be required to maintain heading during each run. Minimum rudder angles are to be used while maintaining a steady heading. The helm corrections should be limited to five (5) degrees or less.

4.3 The following conditions should be met, in order to reduce the influence of corrections and obtain the best possible accuracy of the results of the performance measurements:

Table 4: Environmental conditions for in-service performance measurements

Parameter	Remarks
Sea state	Conditions as specified in ISO 15016: 2015
Wind speed	Conditions as specified in ISO 15016: 2015
Water depth	Conditions as specified in ISO 15016: 2015
Currents	Avoid areas with known high current values and variations. During the trials, the following condition should be met: $V_{GPS} - V_{STW} < 0.3\ knots$, or conditions as specified in ISO 15016: 2015
Trials period	Trials should be conducted in daylight
Duration	The run duration should be the same for all speed runs with a minimum of 10 minutes, see figure 1 below

4.4 If any of above conditions are no longer met during in-service performance measurements, it should be necessary to abandon the run.

4.5 Each set of the in-service performance measurements in the respective load condition should be executed as at least one set of double runs. It is important that the ship is running on the same track and when the monitoring begins, the conditions are in steady state conditions. Each speed run should be commenced and completed at the same place.

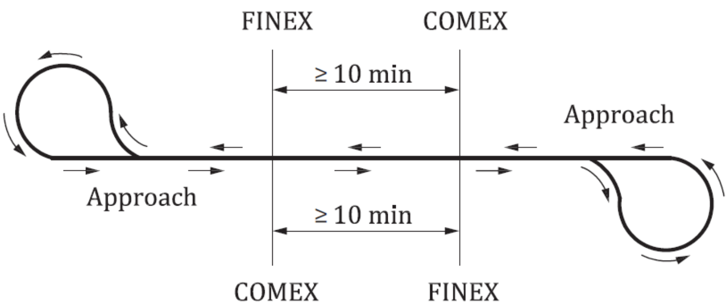

Figure 1: Sea trials with double runs

4.6 During the in-service performance measurements, accurate recordings of the required parameters are of great importance. Recording of parameters for each run should start when steady state ship conditions are met.

4.7 The following data should be collected at the beginning and end of each performance measurement run:

Main engine supply flowmeter reading	[ltr/h] or [kg/h]
Main engine supply flowmeter temperature	[deg]
Main engine return line flowmeter reading*	[ltr/h] or [kg/h]
Main engine return line flowmeter temperature*	[deg]

(*For ships fitted with flowmeter on return line)

4.8 The following data should be collected with a sampling rate of at least 1 Hz during the in-service performance measurement:

Table 5: Logged parameters during in-service performance measurements

Parameter	Unit
Date	dd-mm-yyyy
Time	hh:mm:ss
Revolution counter reading	[s^{-1}]
Shaft power	[kW]
Heading	[deg]
Ship's speed (GPS and Speed Log)	[knots]
Distance ("0" should be at the beginning of each run)	[nm]
Relative wind speed	[m/s]
Relative wind direction (coming from)	[deg]
Current speed	[knots]
Relative current direction (going to)	[deg]
Observed wave height	[m]
Observed wave period	[s]
Observed wave direction (going to)	[deg]

4.9 Apart from power, rpm and consumption, average prevailing values for the following main engine parameters should be provided for each run for the following:

Scavenge air temperature	[deg]
Scavenge air pressure	[kg/cm2]
Blower air inlet temperature	[deg]

4.10 These, as well as any other main engine data should be collected at local sensors' display and not their repeaters inside the ECR.

4.11 As far as practicable, the in-service performance measurement should be witnessed by the verifier. The verifier should be able to confirm that the in-service performance measurement was conducted in accordance with the agreed procedures.

5 After the in-service performance measurements

5.1 All information collected should be checked by the verifier and any errors/typos should be noted in supplementary documentation, including any corrected/replaced values clearly marked in the form. Data which is continually recorded should be provided "as is" and non-variable data should be noted at the beginning and the end of the in-service performance measurements in order to confirm that any changes are set to a minimum.

5.2 For each run the following should be submitted:

.1 one filled-in soft copy of the "In-service performance monitoring reporting form" (appendix C);

.2 printouts and/or soft copies from the performance monitoring system output;

.3 printouts and/or soft copies from the loading computer calculations representing the loading condition at which the run took place; and

.4 printouts and/or soft copies from the course recorder for the period covering the run.

5.3 Also, a copy of the fuel oil analysis for the fuel used during the in-service performance measurements should be submitted.

5.4 Any comments about the in-service performance measurements, including any large variations in environmental conditions, should be noted.

5.5 A summary of the required information to be submitted for verification can be found in appendix A, B, and C.

APPENDIX A

INFORMATION TO BE SUBMITTED PRIOR TO CONDUCTING THE IN-SERVICE PERFORMANCE MEASUREMENTS

The following information should be submitted prior to conducting the performance measurements.

Document	**Mandatory**	**Optional**
Hydrostatics	☐	☒
Shop tests of main engine	☒	☐
Sea trials (machinery and hull part)	☒	☐
Model tests	☐	☒
Propeller characteristics and structural drawings	☐	☒
GA drawing	☒	☐
Details of appendages and rudder	☐	☒
Fuel oil piping diagram	☐	☒

Ship's main particulars

IMO number:	
Date delivered:	
Ship's email address(s):	
Date ship was launched (when did ship enter the water):	
Ship's name:	
Owner:	
Managing company:	
Ship type:	
Ship capacity	
Yard:	
Length overall (m):	
Length between perpendiculars (m):	
Breadth moulded (m):	
Depth to upper deck (m):	
Design draft (m):	
Design displacement (mt):	
EEXI draft (m):	
Displacement at EEXI draft (mt)	
Lightship weight (mt)	

Design speed (knots):	

Dry-docking history (within the last five years):			
Date	Yard	Coating specs	Hull treatment
		Please attach	Please attach

Hull cleaning and propeller polishing history since last dry-dock:			
Date	Place	Brief description of works	Propeller polishing standard*

*only for propeller polishing events

Main engine(s)	
Maker:	
Type:	
Number:	
Type of fuel:	
MCR (kW):	
SMCR (kW) x RPM:	

Main engine modifications/upgrades		
	Yes	No
Derating	☐	☐
T/C cut offs	☐	☐
Part load tuning	☐	☐
Low load tuning	☐	☐
Retrofit (please provide details)	☐	☐
Other modifications (please provide details)	☐	☐

Propeller(s) including modifications/upgrades			
Type: (FP or CPP)			
Diameter (m)			
Pitch (m)			
Number			
		Yes	No
Trimmed		☐	☐
Other (please state)		☐	☐

Propulsion improvement devices		
	Yes	No
Ducts	☐	☐
Fins	☐	☐
Other (please provide details)	☐	☐

Power measurements		
	Yes	No
By torsion meter	☐	☐
(Details of torsion meter including last calibration)		
By load indicator diagrams	☐	☐
Other method (please provide details)		

Performance monitoring systems		
	Yes	No
PMS	☐	☐
please provide details of type and maker		

Fuel measurements		
	Yes	No
By volume flowmeter	☐	☐
(Details of flowmeter including last calibration)		
By mass flowmeter	☐	☐
(Details of flowmeter including last calibration)		
Soundings	☐	☐

Other instruments & gauges used for data collection	
	Dates of Calibration
Speed log	
DGPS	
Anemometer Provide height of anemometer in metres:	
Other (please provide details)	

Additional information		
	Yes	No
Reduction gear	☐	☐
(please provide details)		
Shaft motor	☐	☐
(please provide details)		
Shaft generator	☐	☐
(please provide details)		

Person to be contacted for further info:	

APPENDIX B

INFORMATION TO BE SUBMITTED FOR VERIFICATION AFTER THE IN-SERVICE PERFORMANCE MEASUREMENTS

The following information needs to be submitted after conducting the in-service performance measurements.

Document	Mandatory	Optional
Calibration certificate of torquemeter	☒	☐
Calibration certificate of flowmeters	☐	☒
Calibration certificate of anemometer	☐	☒
Calibration certificate of speed log	☐	☒
Calibration certificate of GPS	☐	☒
Calibration certificate of echosounder	☐	☒
Calibration certificate of gyro compass	☐	☒
Fuel oil analysis	☒	☐

Furthermore, for each run, the following needs to be submitted:

Document	Mandatory	Optional
Sea trial reporting form	☒	☐
A printout of course recorder	☒	☐
A printout of ME load indicator (depicting the loading condition of the ship during the trials)	☐	☒ *
A printout/soft copy of the anemometer output (if the anemometer is digital)	☐	☒ *

* Optional, but highly recommended outputs

APPENDIX C

EXAMPLE OF THE IN-SERVICE PERFORMANCE MEASUREMENTS REPORTING FORM

The form below includes all in service measurements at one loading condition.

In-service Performance Monitoring reporting form

Vessel name ____________ IMO # ____________

Air temperature [°C]		SW temp [°C]		SW density [ton/m3]			
Draught fore [m]		Draught aft [m]		Displacement [ton]			
Fuel density [kg/m3]		Fuel LCV [kJ/kg]		Anemometer height [m]		Water depth [m]	

				Engine Room								Bridge						
Observation #	Run #	Obs. Start	Elapsed time	ME Supply Flowmeter Reading	ME Supply Flowmeter Temperature	ME Return Flowmeter Reading	ME Return Flowmeter Temperature	Revolution Counter Reading	Shaft Power	Heading	Speed	Distance	Relative Wind Speed	Relative Wind Direction	Current Speed	Observed Wave height	Observed Wave Period	Obverved Wave Direction
		hh.mm	mm	ltr(1)	°C	ltr(1)	°C	rounds	kW	°True	knots	nm	knots	coming from °Relative	going to knots	m	sec	going to °True
1	1		10															
	2		10															
2	1		10															
	2		10															
3	1		10															
	2		10															
4	1		10															
	2		10															

Average Value for power setting #1	Scavenging Air Temperature		°C	Scavenging Air Pressure		kg/cm²	Blower Air Inlet temperature		°C
Average Value for power setting #2	Scavenging Air Temperature		°C	Scavenging Air Pressure		kg/cm²	Blower Air Inlet temperature		°C
Average Value for power setting #3	Scavenging Air Temperature		°C	Scavenging Air Pressure		kg/cm²	Blower Air Inlet temperature		°C
Average Value for power setting #4	Scavenging Air Temperature		°C	Scavenging Air Pressure		kg/cm²	Blower Air Inlet temperature		°C

____

PROCEDURE FOR CALCULATION AND VERIFICATION OF THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)

CONTENTS:

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.

1 Definitions

Industry Guidelines – means the "*2022 Industry Guidelines for calculation and verification of the Energy Efficiency Design Index (EEDI)*" as submitted to MEPC 80 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 "*2022 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)*" as amended.

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.

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 "*2022 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, as amended*" and Part II of the Industry Guidelines, as amended.

Note:
1. This Procedural Requirement applies from 1 July 2013.
2. Rev.1 of this Procedural Requirement applies from 1 July 2016.
3. Rev.2 of this Procedural Requirement applies from 1 July 2019.
4. Rev.3 of this Procedural Requirement applies from 1 April 2021.
4. Rev.4 of this Procedural Requirement applies from 1 April 2023.

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 "*2022 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)*" as amended 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 "*2022 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 2.2.18) 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 certified according to a recognized scheme or with experience acceptable to the Verifying Society may be accepted by the Verifying Society.

6.1 Attachment

2022 Industry Guidelines for calculation and verification of the Energy Efficiency Design Index (EEDI), see Chapter 8 of this Publication.

THE TERM OF "HEAVY LOAD CARRIER"
FOR THE APPLICATION OF EEDI/EEXI AND CII

1 General

This document provides recommendations on the term of "heavy load carrier" for the consideration to the application of EEDI/EEXI and CII, associated with the definition in Regulation 2.2.15 of MARPOL Annex VI.

2 Background

2.1 The application of EEDI/EEXI and CII is specified in Regulation 22.1, 23.1, 24.1, 25.1, 26.3, 28.1 and 28.4 of MARPOL Annex VI as amended by Res. MEPC.328(76). General cargo ship which is defined in Regulation 2.2.15 is to be subject to these Regulations of EEDI/EEXI and CII.

2.2 Regulation 2.2.15 of MARPOL Annex VI defines "General cargo ship" as stated below. As per this definition General cargo ship, excludes livestock carrier, barge carrier, heavy load carrier, yacht carrier and nuclear fuel carrier, towards EEDI/EEXI and CII regulations ; however, "heavy load carrier" is not defined in the regulation.

> *".15 General cargo ship means a ship with a multi-deck or single deck hull designed primarily for the carriage of general cargo. This definition excludes specialized dry cargo ships, which are not included in the calculation of reference lines for general cargo ships, namely livestock carrier, barge carrier, heavy load carrier, yacht carrier, nuclear fuel carrier."*

2.3 According to Table 2 in Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) (Res. MEPC. 231(65)), the following ships are not included in the calculation of reference lines for use with the EEDI.

> *"Heavy load carrier, semi-submersible: A heavy load carrier which is semi-submersible for the float on loading/unloading of the cargoes."*

> *"Heavy load carrier: 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."*

3 Recommendation

3.1 Following may be considered as "heavy load carrier" in the context of regulation 2.2.15 of MARPOL Annex VI :

a) (Heavy Load) Deck Carriers[1]
b) Semi-submersible Project Cargo Carriers
c) Semi-submersible (Heavy load) Deck Carriers[2] (including dock lift ships)

3.2 In addition to 3.1, the following may be considered as "heavy load carrier" subject to endorsement by the Flag Administration:

a) Heavy Lift Multi-Purpose ships (Refer 3.2.1 below)
b) Premium Project carriers (Refer 3.2.1 below) and
c) Project Cargo Carriers (Refer 3.2.2 below)

Footnotes:

[1] Vessels, which do not feature a cargo hold and carry project cargo on a flat deck; Not fitted with cargo coamings/ chutes/ tippers.
[2] Normally regarded as Heavy Load Carrier by IHS Fairplay

3.2.1 Heavy Lift Multi-Purpose ships and Premium Project carriers, which are fulfilling the adapted criterion of "Ships engaged in lifting operations" as per 2008 IMO IS Code (as amended by MSC.413(97)), as follows:

$$SWL \times Outreach \geq 0.67 \times Displacement \times (D - T) / B$$

Where:

SWL	=	maximum safe working load of crane of one single crane
Outreach	=	outreach from turning axis of crane
Displacement	=	displacement of vessel at draft T
T	=	freeboard draft
B	=	the moulded breadth of the vessel measured amidships at draft T
D	=	depth for freeboard

3.2.2 Project Cargo Carriers with or without cargo gear, for which the flag Administration may base their decision on a design and operation-specific application compiled by the Owner/Company.

The application is submitted by RO with descriptions of the criteria of a Project Cargo Carrier that are implemented on the subject design and operation, which justify the vessel to be considered as a "heavy load carrier".

3.3 In cases other than the above , it is encouraged to seek endorsement by the Flag Administration on consideration of a general cargo ship as a "heavy load carrier" in the context of Regulation 2.2.15 of MARPOL Annex VI.

List of amendments effective as of 1 January 2024

Item	Title/Subject	Source
Chapter 2	Added Guidelines on Numerical Calculations for the purpose of deriving the V_{ref} in the framework of the EEXI Regulation	IACS.REC 173
Chapter 3	Added SEEMP/CII Implementation Guidelines	IACS.REC 175