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 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 that the *2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships*, adopted by resolution MEPC.212(63), and, the amendments thereto, adopted by resolution MEPC.224(64),

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

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

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

1 ADOPTS 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;

5 SUPERSEDES the *2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* adopted by resolution MEPC.245(66), as amended by resolutions MEPC.263(66) and MEPC.281(70), and MEPC.1/Circ.866.

ANNEX

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

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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:

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

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 $\Sigma P_{ME(i)}$ is to be no more than P_{AE} as defined in paragraph 2.2.5.6. For this case, $\Sigma P_{ME(i)}$ is calculated as:

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

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 $\Sigma P_{ME(i)}$ is 75% of that limited power for determining the reference speed, V_{ref} and for EEDI calculation. The following figure gives guidance for determination of $\Sigma P_{ME(i)}$:

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:

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

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:

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

Where

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

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

[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:

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

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}:

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

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·kd·kt.*

Loads necessary power "Pload" (kW)

4.13 The individual user contribution to the auxiliary load power is *Pload=Pr·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=ΣPload(i)/(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} x (f_{DFgas} x ($C_{F\ Pilotfuel}$ x $SFC_{ME\ Pilotfuel}$ + $C_{F\ LNG}$ x $SFC_{ME\ LNG}$) + $f_{DFliquid}$ x C_{FMDO} 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	3.61

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	$(P_{MELNG} \times (C_{F\ Pilotfuel} \times SFC_{ME\ Pilotfuel} + C_{F\ LNG} \times SFC_{DF\ LNG}) + P_{MEMDO} \times C_{F\ MDO} \times SFC_{ME\ MDO} + P_{AE} \times (C_{FAE\ Pilotfuel} \times SFC_{AE\ Pilotfuel} + C_{F\ LNG} \times SFC_{AE\ LNG})) / (V_{ref} \times Capacity)$	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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