Rules for Classification and Construction

VI Additional Rules and Guidelines

13 Energy Efficiency

1 Guidelines for Determination of the Energy Efficiency Design Index

Edition 2013

The following Guidelines come into force on 15 September 2013.

Alterations to the preceding Edition are marked by beams at the text margin.

Germanischer Lloyd SE

Head Office
Brooktorkai 18, 20457 Hamburg, Germany
Phone: +49 40 36149-0
Fax: +49 40 36149-200
headoffice@gl-group.com

www.gl-group.com

"General Terms and Conditions" of the respective latest edition will be applicable
(see Rules for Classification and Construction, I - Ship Technology, Part 0 - Classification and Surveys).

Published by: Germanischer Lloyd SE, Hamburg

Table of Contents

Table of Contents

Section 1 General Information

Preamble

Germanischer Lloyd SE (GL) is committed to the continuous improvement of the energy efficiency of ships and the sustainability of maritime activities, however always reflecting the needs of the maritime industry as a whole. There is a need for measures to reflect this continuous process. These Guidelines refer to the IMO requirements for the Energy Efficiency Design Index (EEDI) as amended in new chapter 4 of MARPOL Annex VI. The EEDI evaluates the ship efficiency by means of propulsion power and transport work. These guidelines address the attained EEDI only.

On request, the EEDI methodology as provided in these GL guidelines can be used to evaluate the efficiency of existing ships.

A General

A.1 Scope and application

A.1.1 The EEDI framework ist set out in Chapter 4, “Regulations on Energy Efficiency on Ships” in MARPOL Annex VI; Resolution MEPC.203(62). The verified EEDI confirms a ship’s design energy efficiency comprising verification of the design CO_2 emissions, capacity and corresponding reference speed according to IMO Resolution MEPC.212(63), Resolution MEPC.214(63), Resolution MEPC.224 (64), Resolution MEPC.23(65) and Resolution MEPC.233(65).

A.1.2 These Guidelines apply to ships as defined in Regulation 2.23 and Regulation 20 of MARPOL Annex VI of 400 GT and above:

- bulk carriers,
- tankers,
- gas carriers,
- LNG carriers,
- container ships,
- general cargo ships,
- refrigerated cargo ships,
- combination carriers,
- Ro-Ro cargo ships (vehicle carriers),
- Ro-Ro cargo and Ro-Ro passenger ships, and
- cruise passenger ships with non-conventional propulsion[1].

[1] "Non-conventional propulsion" means a method of propulsion, other than conventional propulsion, including diesel-electric propulsion, turbine propulsion, and hybrid propulsion systems

Note

Juice tankers are categorised as refrigerated cargo ships.

Ice-breaking cargo ships exceeding Finnish/Swedish ice-class "1A Super" are excluded from the EEDI-regime.

B Definitions

B.1 EEDI Technical File

The EEDI Technical File is the basic document for the EEDI certification and includes all EEDI relevant data and information, as well as the EEDI calculation. A sample EEDI Technical File is attached in Annex A.

B.2 Attained EEDI

The attained EEDI shall be calculated for all ships of 400 GT and above defined under A.1.2 (including ships where no required EEDI is stipulated). The attained EEDI is the actual calculated and verified EEDI value for an individual ship based on the data in the EEDI Technical File.

In the following EEDI-value is used synonymously for attained EEDI.

Note:

At design stage it has to be ensured that the EEDI requirements as well as the minimum required power demand for the manoeuverbility of the ship in adverse weather conditions are fulfiled.

B.3 Required EEDI

The required EEDI is the maximum allowable value of the attained EEDI as defined in Table 1.1. The required EEDI is calculated for all ship types using 100 % of the deadweight at summer load draft, except for passenger ships where GT is used. The reference value is defined by a line which is mathematically defined as:

Required EEDI = $a \cdot b^{-c}$

Table 1.1 lists the ship type depending calculation values for the required EEDI.

Table 1.1 Formulas for calculating the required EEDI

Ship type	a	b	c
Bulk carriers	961.79	DWT	0.477
Gas carriers	1120.20	DWT	0.456
Tankers	1218.80	DWT	0.488
Container ships	174.22	DWT	0.201
General cargo ships	107.48	DWT	0.216
Refrigerated cargo ships	227.01	DWT	0.244
Combination carriers	1219.00	DWT	0.488
Vehicle / car carriers	(DWT/GT)-0.7 · 780.36 where DWT/GT < 0.3; (DWT/GT)-0.7 · 1812.63 where DWT/GT ≥ 0.3	DWT	0.471

Ship type	a	b	c
Ro-Ro cargo ships	1405.15	DWT	0.498
Ro-Ro passenger ships	752.16	DWT	0.381
LNG carries	2253.7	DWT	0.474
Cruise passenger ships having non conventional propulsion	170.84	GT	0.214

The required EEDI will be reduced by X % each five years based on the initial value (Phase 0) and depending on the vessel size. Below a certain size no reduction applies. Above a certain ship size the reduction is in general 10 % for each reduction phase. In between of those sizes the reduction is linear interpolated.

Table 1.2 and Table 1.3 show the interpolation intervalls, i.e.. for all ships which are below the lower size threshold limit no reduction of the required EEDI will be made. All ships where the ships size is larger than the upper size value full reduction applies, e.g. 10 % each five years will be made based on required EEDI in phase 0.

Table 1.2 Interpolation interval for reduction of the required EEDI based on DWT

Ship type	Size in DWT	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carriers	10.000 – 20.000	n/a	0-10	0-20	0-30
Tankers	2.000 – 10.000	n/a	0-10	0-20	0-30
Gas carries	4.000 – 20.000	n/a	0-10	0-20	0-30
Container ships	10.000 – 15.000	n/a	0-10	0-20	0-30
General cargo ships	3.000 – 15.000	n/a	0-10	0-20	0-30
Refrigerated cargo ships	3.000 – 5.000	n/a	0-10	0-20	0-30
Combined carrier	4.000 – 20.000	n/a	0-10	0-20	0-30
Vehicle / car carriers [2]	10.000 and above	n/a	5	15	30
Ro-Ro cargo ships	1.000 – 2.000	n/a	0-5	0-20	0-30
LNG carries[3]	10.000 and above	n/a	10	20	30

[2] No interpolation intervall applies to Ro-Ro-cargo ships
[3] No interpolation intervall applies to LNG carriers

Table 1.3 Interpolation intervals for reduction of the required EEDI based on GT

Ship type	Size in GT	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Cruise passenger ships [4]	25.000 – 85.000	n/a	0-5	0-20	0-30
Ro-Ro passenger ships	1.000 – 4.000	n/a	0-5	0-20	0-30

The required EEDI for Phase 0 applies to all ships as defined in paragraph A.1.2, for which:

- the building contract date is placed in phase 0, and the delivery is before 1st January 2019; or
- the buidling contract is placed before phase 0 and the delivery is on or after 1st July 2015 and before 1st January 2019; or
- in absence of a building contract, the keel is laid or which is at similar stage of construction on or after the 1st July 2013 and before 1st July 2015 and delivery is before 1st January 2019.
- in absence of a building contract, the keel is laid or which is at similar stage of construction before the 1st July 2013 and the delivery is on or after 1st January 2015 and before 1st January 2019.

The required EEDI for Phase 1 applies to all ships defined in paragraph A.1.2 for which:

- the building contract date is placed in phase 1, and the delivery is before 1st January 2024; or
- the building contract is placed before phase 1 and the delivery is on or after 1st July 2019 and before 1st January 2024; or
- in absence of a building contract, the keel is laid or which is at similar stage of construction on or after the 1st July 2015 and before 1st July 2020 and delivery is before 1st January 2024.
- in absence of a building contract, the keel is laid or which is at similar stage of construction before the 1st July 2015 and the delivery is on or after 1st January 2019 and before 1st January 2024.

The required EEDI for Phase 2 applies to all ships defined in paragraph A.1.2 which:

- the building contract date is placed in phase 2, and the delivery is before 1st January 2029; or
- the buidling contract is placed before phase 2 and the delivery is on or after 1st July 2024 and before 1st January 2029; or
- in absence of a building contract, the keel is laid or which is at similar stage of construction on or after the 1st July 2020 and before 1st July 2025 and delivery is before 1st January 2029.
- in absence of a building contract, the keel is laid or which is at similar stage of construction before the 1st July 2020 and the delivery is on or after 1st January 2024 and before 1st January 2029.

The required EEDI for Phase 3 applies to all ships defined in paragraph A.1.2 which:

- the building contract date is placed in phase 3, or
- in absence of a building contract, the keel is laid or which is at similar stage of construction on or after the 1st July 2025, or
- delivery is after 1st January 2029

B.4 Capacity

Depending on the ship type, different units for capacity are used:

[4] having non conventional propulsion

- For bulk carriers, tankers, gas carriers, container ships, general cargo ships, refrigerated cargo ships, combination carriers, LNG carriers and all types of Ro-Ro ships deadweight (DWT) is used.
- For container ships the capacity is 70 % of DWT.
- For cruise passenger ships GT is used as capacity.

B.5 The deadweight is the difference between displacement and lightship weight at summer load draft.

B.6 EEDI condition is defined by the EEDI draft, trim at even keel, power and corresponding speed.

B.7 Applicant

The applicant is the party who applies for the EEDI verification.

C Terms and Abbreviations

Table 1.3 Abbreviations

EEDI	Energy Efficiency Design Index
EIAPP	Engine International Air Pollution Prevention
DWT	Deadweight
GT	Gross Tonnage
IEC	International Electro technical Commission
IEEC	International Energy Efficiency Certificate
ITTC	International Towing Tank Conference
MCR	Maximum Continuous Rating
MEPC	Marine Environmental Protection Committee
ME	Main engine
AE	Auxiliary engine

D Documents to be Submitted

In advance to the towing tank tests the model basin shall contact GL[5] for details on the “EEDI review & witness scheme” that include also detailed requirements on the tank test report of the model.

Before the performance of the model test, the test plan shall be submitted to and agreed by GL.

A tank test may only be omitted where the shipyard confirms that a sea trial will be conducted at ship type specific EEDI conditions

5 under email address: energy.efficiency@gl-group.com

Detailed lists of documents to be submitted in relation to the status of shipbuilding are published on GL's web page:

http://www.gl-group.com/pdf/International_Energy_Efficiency_Certificate_3.pdf

Tables 1.4, 1.5 and 1.6 provide an overview of the relevant documents.

Table 1.4 Documents to be submitted for preliminary examination on model tank test

Quality Management Certificate of the Tank Test facility
Tank test plan (prior to the model tank test a test plan shall be agreed with the verifier)
Tank test report (after completion of model tank test according to a.m. GL web-page)

Table 1.5 Documents to be submitted for preliminary EEDI examination

Preliminary EEDI Technical File, incl. all EEDI relevant parameters
EIAPP certificate and NO_x Technical File for main and auxiliary engines. If EIAPP is not available at time of pre-verification then documentation of parent engine is to be submitted. If parent engine documentation is also not available then manufacturers' documentation for engine specific fuel oil consumption and fuel oil type used with the addition of manufactures guaranteed tolerance (usually 5 %) is to be submitted.
Electrical power table (EPT) for ships where auxiliary power demand (P_{AE}) calculated in Section 2, C.2.2.1 is significantly different from the auxiliary power demand in normal sea going operation, e.g. cruise passenger ships.
Preliminary trim and stability booklet / Loading manual, alternatively a freeboard calculation.
If a power limitation for the propulsion train is applied, verified and comprehensive documentation of power limitation technical arrangement.
If gas is used as fuel, tank arrangements and capacities of all fuel sources on board.
If applied in the EEDI calculation, manufactures' documentation of innovative energy efficiency technologies in accordance with IEET-guidelines by IMO (Annex D).
Towing tank report
Additional information

Table 1.6 Documentation to be submitted for final EEDI verification

Updates of documentation listed in Table 1.5
Sea Trial programme
Sea Trial report
(Final) stability booklet (this includes the International Tonnage Certificate and the results of the inclining test / lightweight survey documentation)
Final speed-power curves, including comprehensive documentation of speed calculation for EEDI conditions
Final EEDI Technical File
Towing tank report
Additional information

E Certification

E.1 Character of certification

E.1.1 The verified EEDI shall be part of the supplement of the International Energy Efficiency (IEE) Certificate for new ships. New ship means a ship with:

- contract date on or after 01. January 2013
- in absence of a contract date the keel laying date on or after 01. July 2013
- in absence of both above dates the delivery date on or after 01. July 2015, and
- ships which have undergone a major conversion as determined by the Administration

E.1.1.1 GL issues an IEE-Certificate on behalf of the Flag State if the flag state is a party to MARPOL, Annex VI and GL is authorised by the Administration.

E.1.1.2 GL issues a Document of Compliance (DoC) on behalf of the Flag State if the flag state is not a party to MARPOL, Annex VI and GL is authorized by the administration.

E.1.2 The attained EEDI value is valid for the lifetime of the ship. Following major conversions (defined by flag administration), a reassessment of the EEDI will become necessary and a new certificate will need to be issued.

E.1.3 For ships which do not fall under paragraph E.1.1 the EEDI is not mandatory. When EEDI verification is applied on a voluntary basis a Statement of Compliance is issued by GL.

E.2 Survey and audits

E.2.1 The model tank test facility shall fulfil requirements for a certified quality management system according to ISO 9001 or equivalent, In any case the model tank test facility shall consult GL (energy.efficiency@gl-group.com).

E.2.2 In general, the key steps of the model tank tests shall be witnessed by a GL surveyor. Key steps will be defined with the applicant and towing tank facility, respectively, in accordance with the test plan. GL will witness if the towing tank tests are conducted acc. to certain quality standards such as ITTC guidelines. At the tank test the surveyor is permitted to take sample measurements or other quality control measures to assure that the lines plan is identical with the relevant model.

E.2.3 Alternatively to the procedure described in E.2.2, GL provides a “review & witness scheme” addressing the special needs and quality requirements of model tank test facilities and the conduct of model tests. Model tank test facilities shall contact GL under: energy.efficiency@gl-group.com for further information about the benefits of the “GL tank test review & witness scheme” and the auditing of the Quality Management System.

E.2.4 GL surveyor attends the sea/speed trails and spends in relation to the EEDI-requirements special attention on:

- the power measurement regarding correct installation and calibration,
- speed measurements, and
- environmental parameters, such as wave height and wind, are estimated and measured, respectively, acc. to ITTC recommended procedure part 1 and 2 (see F.10 and F.14) or ISO15016.

E.2.5 For voluntary EEDI verification of existing ships possible deviations from paragraph E.2.1 to E.2.4 shall be agreed with GL.

F Reference Documents

F.1 Resolution MEPC.212(63) – 2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, March 2012

F.2 Resolution MEPC.214(63) – 2012 Guidelines on survey and certification of the Energy Efficiency Design (EEDI), March 2012

F.3 Resolution MEPC.215(63) – Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI), March 2012

F.4 Resolution MEPC.224(64), "Amendment to the 2012 guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships", October 2012

F.5 Resolution MEPC. 231(65), "2013 guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI)", May 2013

F.6 Resolution MEPC.233(65), "2013 guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for cruise passenger ships having non-conventional propulsion", May 2013

F.7 MEPC.1/Circ.815, "Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI", June 2013

F.8 MEPC.1/Circ.795, "Unified interpretation to MARPOL Annex VI", October 2012

F.9 MEPC.1/Circ.796, "Interims Guidelines for the calculation of the coefficient f_w for decerase in ship speed in a representative sea condition for trail use", October 2012

F.10 MEPC 64/INF.6, "Additional information on ITTC Recommended Procedure 7.5-04-01-01.2, "Speed/power trials, part 2, analysis of speed/power trial data"", June 2012

F.11 MEPC 64/INF.22, "First version of industry guidelines on calculation and verification of the Energy Efficiency Design Index (EEDI)", July 2012

F.12 ISO 15016, "Ships and marine technology – Guidelines for the assessment of speed and power performance by analysis of speed trial data", February 2002

F.13 ISO 19019, "Sea-going vessels and marine technology – Instruction for planning, carrying out and reporting sea trial", April 2005

F.14 MEPC 65/INF.7, "ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials, Part 1, Preparation and Conduct", February 2013

F.15 MSC-MEPC.2/Circ.11. "Interim Guidelines for Determining Minimum Required Power to Maintain Manoeuvrability of Ships in Adverse Conditions", December 2012

Section 2 Energy Efficiency Design Index (EEDI) Certificate

A General

A.1 Objective

This Section describes the verification process of the attained EEDI.

A.2 Scope

A.2.1 The purpose of this section is to describe the level of documentation and the procedures for attained EEDI calculation and verification.

A.2.2 A preliminary examination is performed at the design stage based on the towing tank test results in order to document the EEDI-value before the start of the construction[1] of the ship.

This is to ensure that the envisaged EEDI-value is below the required EEDI values given by Section 1, Table 1.1.

A.2.3 Omission of tank tests is acceptable for a ship for which sea trials will be carried out under EEDI conditions upon agreement of ship owner, ship builder and with approval of the verifier.

A.2.4 The final verification is performed after the sea trials when the reference speed under EEDI condition has been determined.

A.3 Verification process

A.3.1 The EEDI verification is conducted in two stages. In the first stage, the preliminary EEDI-value is determined using basic design parameters, towing tank results and additional calculations.

In the second stage the final EEDI-value is determined based on the parameters of the installed engine(s) and results of the sea trial and additional information. An overview of the verification process is given in Fig. 2.1.

1 In this case construction means the cutting of first steel plate

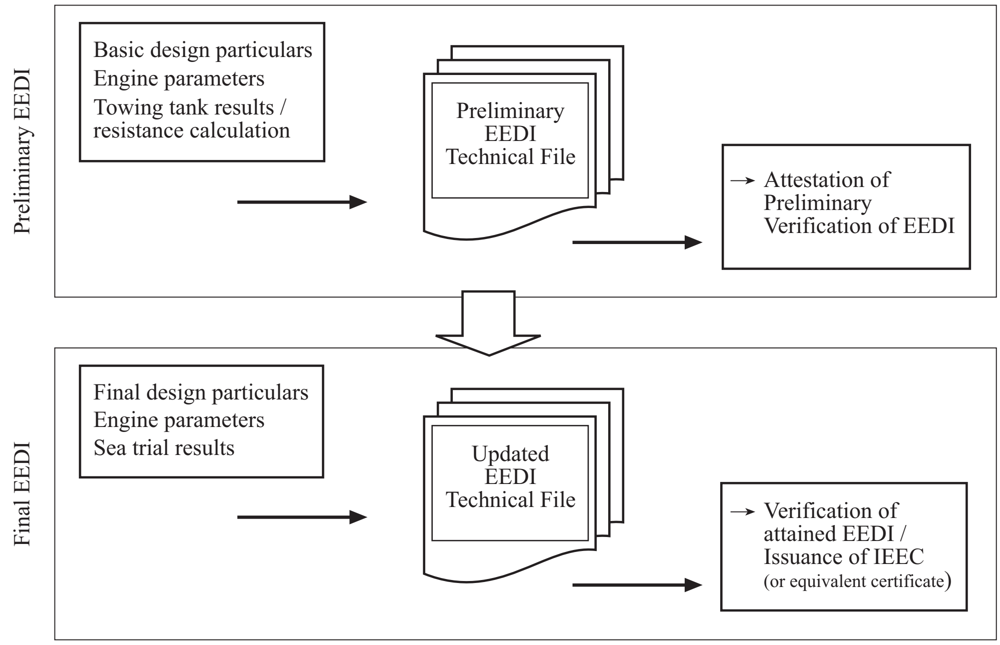


Fig. 2.1 EEDI verification process

B Required Information and Documents

B.1 EEDI Technical File

B.1.1 The EEDI Technical File shall include all EEDI relevant information. The information shall be clear and free of interpretation including a comprehensible EEDI calucation. A template for an EEDI Technical File is given in Annex A.

B.2 Preliminary Verification

B.2.1 A preliminary EEDI Technical File is to be submitted to GL for the preliminary examination of the EEDI-value. The information in the Technical File is the basis for the EEDI calculation. The Technical File shall include the principal particulars of the vessel and all items shown in Table 2.2. The calculation of the EEDI will be carried out according to C.

B.2.2 Additional Information is not included in the EEDI Technical File, but is needed for the verification. Additional information may affect Intellectual Property Rights (IPR) protection and is treated confidentially. If requested the Additional Information will be returned to the applicant following the final verification to safeguard intellectual property rights.

B.2.3 The determination of the speed-power curves for ballast and EEDI condition shall be achieved by the same method and procedure.

B.2.4 Towing tank test report will be accepted only with a written statement issued by GL to certify that the tank test has been carried out in compliance with applicable requirements and therefore can be used for EEDI verification.

B.2.5 Towing tank test of sister vessels will be accepted if it is documented that the ships are of same design.

Table 2.1 Data for preliminary EEDI Technical File

Parameter	Description	Unit
C_F	is the conversion factor of the fuel type used for EIAPP certification in NO_x Technical File of all main and auxiliary engines as defined in C.2.1.1	g CO_2/g fuel
Δ	is the displacement and shall be taken from the loading manual / preliminary trim and stability booklet.	t
DWT	is the deadweight and shall be taken from the loading manual / preliminary trim and stability booklet, alternatively a freeboard calculation.	t
$f_{eff(i)}$	is the availability factor for each innovative energy efficiency technology and shall be based on comprehensive documentation of the determination for each innovative energy efficiency technology For waste heat recovery systems $f_{eff(i)}$ shall be set to one.	
fi	fi is the capacity factor for any technical/regulatory limitation on capacity see Annex B	
fj	fj is a correction factor to account for ship specific design elements see Annex B	
f_W	the coefficient f_W expresses the descrease in ship speed in representative sea conditions and shall be calculated and documented acc. to MEPC.1/Circ.796, or amended guidelines / procedures developed by the committee, see Annex C	
GT	is the gross tonnage and shall be calculated acc. to the International Convention of Tonnage Measurements of ships 1969, corresponding documentation shall be submitted	
Lightweight	shall be taken from the loading manual / preliminary trim and stability booklet.	t
P_{AE}	is the auxiliary power which is theoretically necessary to operate the main engine periphery and accommodation of crew and is calculated acc. to C.2.2.1.	kW
$P_{AEeff(i)}$	is the elctrical power which is generated by innovative technologies and shall be calculated acc. to Annex D. Necessary information shall be based on manufacturer’s documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for auxiliary power reduction with innovative mechanical energy efficient technology.	kW
$P_{eff(i)}$	is the propulsion power which is generated by innovative technologies and shall be calculated acc. to Annex D. Necessary information shall be based on manufacturer’s documentation for power output of each innovative mechanical energy efficient technology.	kW
$P_{ME(i)}$	is the main engine power and shall be calculated acc. to C.2.1.1 and based on the EIAPP certificate to document MCR of main engine(s). Manufacturer’s documentation is required if an EIAPP certificate is not available at the design stage.	kW
$P_{PTI(i)}$	is the power of power take-in devices, e.g. shaft motor(s). Necessary information shall be based on manufacturer’s documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for power take-in devices. If a shaft motor is installed also the weighted average efficiency of the generators shall be documented	kW

Parameter	Description	Unit
$P_{PTO(i)}$	is the power of the power take-off devices, i.e. shaft generator. Necessary information shall be based on manufacturer's documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for power take-off devices (e.g. shaft generator) and their efficiency. Alternatively a fixed value of 0.9 could be used as efficiency.	kW
$SFC_{AE(i)}$	is the specific fuel oil consumption of the auxiliary engine(s) and shall be taken from the EIAPP certificate and NO_x Technical File acc. NO_x Technical Code to document specific fuel oil consumption at 50% of MCR power of auxiliary engine(s) and corrected acc. to ISO 3046. Parent engine documentation is required if an EIAPP certificate is not available at the design stage. In absends of both manufacture's documentation is required. For this case, an addition of the guarantee tolerance will be added for preliminary EEDI calculation. If no EIAPP Certificate for an engine is available because its power is below 130 kW, the SFC specified by the manufacturer and endorsed by a competent authority should be used.	g/kWh
$SFC_{ME(i)}$	is the specific fuel oil consumption of the main engine(s) and shall be taken from the EIAPP certificate and Technical File acc. NO_x Technical Code to document specific fuel oil consumption at 75% of MCR power of main engine(s) and corrected acc. to ISO 3046. Manufacturer's documentation is required if an EIAPP certificate is not available at the design stage. For this case, an addition of the guarantee tolerance will be added for preliminary EEDI calculation.	g/kWh
V_{ref}	A speed-power curve from towing tank test for a) EEDI conditions, and b) Ballast conditions at sea trial The documentation shall include the description of the test procedure, uncorrected measured data of the tank tests, standard model-ship extrapolation and correlation method, propeller open water characteristics, photo documentation of the tests showing at least the full model, the submerged model, wave spectrum of the model at different speeds. Further the report shall contain the speed power curves and error estimation. Preferably the tank test shall be conducted acc. to ITTC requirements.	kn

Note

For dual fuel engines IMO has not yet defined a procedure to determine the specific fuel oil consumption SFC and conversion factor C_F.

B.3 Final verification

B.3.1 The final verification of the attained EEDI will be conducted subsequently to the sea trial of the ship. The EEDI Technical File shall be updated by the results of the sea trial and data of the built ship.

B.3.2 The final EEDI Technical File shall be submitted to GL. The documentation for the final EEDI verification shall include all items of Section 1, Table 1.6. The final EEDI Technical File shall include all data specified in Table 2.2.

Table 2.2 Data for final EEDI Technical File

Parameter	Description	Unit
C_F	is the conversion factor of the fuel type used for EIAPP certification in NO_x Technical File of all main and auxiliary engines as defined in MEPC.1/Circ.681	g CO_2/g fuel
Δ	is the displacement and documented in displacement tables as given in the final stability booklet or from the results of the inclining test	t
DWT	is the deadweight of summer load draft as outlined in the final stability booklet.	t
$f_{eff(i)}$	Is the availablity factor of innovative technologies. Documentation on availability for each innovative energy efficiency technology and method used	
f_i	f_i is the capacity factor for any technical/regulatory limitation on capacity see Annex B	
f_j	is a correction factor to account for ship specific design elements see Annex B	
f_W	is the coefficient for decrease of speed in enhanced weather conditions, see Annex C.	
GT	is the gross tonnage and documented in the International Tonnage Certificate	
Lightweight	is the lightweight of the ship and is derived in the inclining test. Alternatively, a lightweight survey documentation	t
P_{AE}	is the auxiliary power which is theoretically necessary to operate the main engine periphery and accommodation of crew and is calculated acc. to C.2.2.1. Only if the P_{AE} value calculated by the standard method is significantly different[2] from the total power used at normal seagoing, documentation of consumed electric power (excluding propulsion) in EEDI condition at reference speed (V_{ref}), according to guidelines.	kW
$P_{AEeff(i)}$	is the elctrical power which is generated by innovative technologies and shall be calculated acc. to Annex D. Necessary information shall be based on manufacturer's documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for auxiliary power reduction with innovative mechanical energy efficient technology.	kW
$P_{eff(i)}$	is the propulsion power which is generated by innovative technologies and shall be calculated acc. to Annex D. Necessary information shall be based on manufacturer's documentation for power output of each innovative mechanical energy efficient technology.	kW
$P_{ME(i)}$	is the main engine power and shall be calculated acc. to C.2.1.1 and based on the EIAPP certificate to document MCR of main engine(s). Manufacturer's documentation is required if an EIAPP certificate is not available at the design stage. PME shall be documented by measurements on the ship's sea trial.	kW

2 Significantly different shall be interpreted as at least 1 % of MCR main engine

Parameter	Description	Unit
$P_{PTI(i)}$	is the power of power take-in devices, e.g. shaft motor(s). Necessary information shall be based on manufacturer's documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for power take-in devices. If a shaft motor is installed also the weighted average efficiency of the generators shall be documented	kW
$P_{PTO(i)}$	is the power of the power take-off devices, i.e. shaft generator. Necessary information shall be based on manufacturer's documentation acc. to existing IEC and ISO standards incl. factory acceptance test data for power take-off devices (e.g. shaft generator) and their efficiency. Alternatively a fixed value of 0.9 could be used as efficiency.	kW
SFC_{AE}	is the specific fuel oil consumption of the auxiliary engine(s) and shall be taken from the EIAPP certificate and Technical File acc. NOx Technical Code to document specific fuel oil consumption at 50 % of MCR power of auxiliary engine(s) and corrected acc. to ISO 3046.	g/kWh
$SFC_{ME(i)}$	is the specific fuel oil consumption of the main engine(s) and shall be taken from the EIAPP certificate and Technical File acc. NOx Technical Code to document specific fuel oil consumption at 75 % of MCR power of main engine(s) and corrected acc. to ISO 3046.	g/kWh
V_{ref}	Measured speed acc. to ITTC recommended procedure part 1 or ISO 15016 and ISO 19019 at sea trials for EEDI condition or for ballast draft corresponding to the towing tank tests, speed calculation, documentation of the calculation procedure used to determine V_{ref}. Documentation of sea trial with measurement protocol incl. list of measurement equipment, measuring method, and speed-power curves. For the development of the speed-power curves the speed shall be measured at least 5 different engine loads for the 1st of a series of ships. The range of different engine loads shall vary from 50 to 90 % MCR. For sister vessel the speed at least 3 different engine loads shall be conducted, covering 75 % MCR. The correction of environmental conditions, e.g. wind, waves, shallow water should conducted acc. to ITTC recommended procedure, or ISO 15016. The speed trial should not be conducted if the wind conditions exceed 5 Bft.	kn

C EEDI Calculation Procedure

C.1 Scope

C.1.1 The following gives advice how to calculate the attained EEDI and which terms of the EEDI formula are to applied.

C.1.2 The EEDI formula consists of four terms which address different ship design criteria. In the following these terms are explained and advice is given when they should be applied.

$$EEDI_{attained} = \Bigg\{ \overbrace{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{n_{ME}} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right)}^{\text{Main engine(s) } CO_2 \text{ emissions}}$$

$$+ \overbrace{\left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{n_{PTI}} P_{PTI(i)} - \sum f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right)}^{\text{Auxiliary engine(s) } CO_2 \text{ emissions}}$$

$$- \overbrace{\left(\sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}^{CO_2 \text{ emission reduction due to Innovative technology(s)}} \Bigg\} \cdot \frac{1}{\underbrace{f_i \cdot f_l \cdot f_w \cdot f_c \cdot \text{Capacity} \cdot v_{ref}}_{\text{Transport work}}}$$

C.2 Procedure

C.2.1 Determination of main engine(s) CO_2 emissions

C.2.1.1 The CO_2 emissions for all installed main engines shall be calculated as follows:

$$\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{n_{ME}} C_{FME_i} \cdot SFC_{ME_i} \cdot P_{ME_i}\right)$$

Where:

C_{FME} : conversion factor fuel oil to CO_2 , depends on the fuel type documented in the NO_x Technical File. Commonly used marine fuels according to IGF-code are given in the table below:

Type of fuel	Reference	Carbon Content	C_F [t-CO_2 / t-Fuel]
Diesel/Gas Oil	ISO 8217 Grades DMX to DMB	0.8744	3.206
Light Fuel Oil (LFO)	ISO 8217 Grades RMA to RMD	0.8594	3.151
Heavy Fuel Oil (HFO)	ISO 8217 Grades RME to RMK	0.8493	3.114
Liquefied Petroleum Gas (LPG)	Propane Butane	0.8182 0.8264	3.000 3.030
Liquefied Natural Gas (LNG)		0.7500	2.750

SFC_{ME} : specific fuel oil consumption of the main engine at 75 % MCR acc. to NO_x Technical File

P_{ME} : 75 % of MCR_i of the main engine, if a shaft generator is installed two options are available to calculate its effect:

Option 1:

MCR of the main engine can be reduced by P_{PTOi} but not more than the maximum value of P_{AE} as defined in C.2.2.1

P_{PTOi} is 75 % of the mechanical rated power of the shaft generator divided by the relevant efficiency of the shaft generator

$$P_{MEi} = 75\,\%(MCR_{(i)} - P_{PTO})$$

with $P_{PTO} = 75\%\ (\text{Output shaft generator})$

Option 2:

When an engine is installed with higher rated power output than the propulsion system is limited to by verified technical means, then the value of $P_{ME(i)}$ is 75 % of that limited power for determining the reference speed, V_{ref} and for EEDI calculation.

$$P_{ME(i)} = 0.75 \cdot P_{Shaft\ limit}$$

i : represents each installed main engine

f_j : correction factor to account for ship specific design elements, if no ship specific design elements are installed the factor is set to 1

For ice class see Annex B

n_{ME} : number of installed main engines

Output shaft generator: rated output power of the shaft generator in kW

C.2.2 Determination of auxiliary engine(s) CO_2 emissions

C.2.2.1 The auxiliary engine power and its corresponding CO_2-emissions are calculated as follows:

$$C_{FAE} \cdot SFC_{AE} \cdot P_{AE}$$

Where:

C_{FAE} : conversion factor fuel oil to CO_2 and analogous to use as describe for the main engine

If engines with different fuel types are installed CF should be the weighted average of the conversion factors of the different engines.

$$C_{FAE} = \frac{\sum_{i=1}^{nAE} C_{FAE(i)} \cdot MCR_{AE(i})}{\sum_{i=1}^{nAE} MCR_{AE(i)}}$$

is the specific fuel oil consumption of the main engine at 50 % MCR acc. to NO_x Technical File

SFC_{AE} : weighted average among $SFC_{AE(i)}$ of the respective auxiliary engines i.

$$SFC_{AE} = \frac{\sum_{i=1}^{n_{AE}} SFC_{AE(i)} \cdot MCR_{AE(i)}}{\sum_{i=1}^{n_{AE}} MCR_{AE(i)}}$$

MCR_{AE} is the maximum continous rating of each (i) auxiliary engine acc. to its EIAPP certificate

n_{AE} is the total number of auxiliary engines installed on board.

Note

If part of the P_{AE} is provided by shaft generators, SFC_{ME} may – for that part of the power – be used instead of SFC_{AE}, i.e.:

if $P_{PTO} \geq P_{AE}$: $C_{FAE} \cdot SFC_{ME} \cdot P_{AE}$,

if $P_{PTO} \leq P_{AE}$: $C_{FME} \cdot SFC_{ME} \cdot P_{PTO} + C_{FAE} \cdot SFC_{AE} \cdot (P_{AE} - P_{PTO})$

P_{AE} : is the considered auxiliary power demanded for the operation of the main engine(s) and calculated as a share of the installed main engine power

$$P_{AE(MCR(ME)>10000\ kW)} = \left(0.025 \cdot \left(\sum_{i=1}^{nME} MCR_{Main\ engine} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75}\right)\right) + 250$$

$$P_{AE(MCR(ME)<10000\ kW)} = 0.05 \cdot \left(MCR_{Main\ engine} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75}\right)$$

C.2.2.2 Shaft motors, innovative electrical energy efficient technology and design restrictions due to ice class are calculated as follows:

$$\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum f_{eff(i)} P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}$$

Where:

f_j : correction factor to account for ship specific design elements, if no ship specific design elements are installed the factor is set to 1

For ice class, ships with voluntary enhancements, chemical tankers, gas carriers, general cargo ships, ships equipped with cranes and other cargo-related gear, and Ro-Ro ships see Annex B

P_{PTI} : 75 % of the rated mechanical power of the shaft motor(s) divided by the weighted efficiency of the generators

$$P_{PTI(i)} = 0.75 \cdot \frac{\text{rated power shaft motor (i)}}{\eta_{Gen}}$$

$$\eta_{Gen} = \frac{\sum_{i=1}^{nAE} \eta_{Gen(i)} \cdot \text{Output capacity}_{Gen(i)}}{\sum_{i=1}^{nAE} \text{Output capacity}_{Gen(i)}}$$

f_{AEeff} : availability factor for each innovative technology. The availability factor should be calculated acc. to Annex D.

P_{AEeff} : $P_{AEeff(i)}$ is the auxiliary power reduction due to innovative electrical energy efficient technology measured at $P_{ME(i)}$. Calcuation of P_{AEeff} is given in Annex D.

Note

It is recommended to calculate f_{eff} and P_{AEeff} as descriped in Annex D.

C.2.3 Determination of the CO_2 emission reduction due to innovative technologies

C.2.3.1 If technologies are installed which reduce the main engine power the following term can be applied:

$$\sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}$$

Where:

f_{eff} : availability factor for each innovative technology. The availability factor should be calculated acc. to Annex D.

P_{eff} : 75 % of the main engine power reduction due to mechanical energy efficiency technologies. The determination of P_{eff} should be documented comprehensively and be submitted to GL as described in Annex D.

Guidance to calculate f_{eff} and P_{eff} innovate energy efficiency technology is given in Annex D.

C_{FME} : conversion factor, as described in C.2.1.1

SFC_{ME} : specific fuel oil consumption, as described in C.2.1.1

Note

Energy efficiency technologies which reduce the main engine power mean, for example, additional sail or kite propulsion systems, or Flettner rotor systems, as outlined in Annex D. The application of innvative technologies which are not defined within Annex D need to be agreed with GL.

C.2.4 Calculation of the transport work

C.2.4.1 The transport work is calculated as follows:

$$f_i \cdot f_l \cdot f_w \cdot f_c \cdot Capacity \cdot v_{ref}$$

Where:

f_i : correction factor to account for ship specific design elements which reduce the capacity (see Annex B).

f_l : correction factor to account for general cargo ships (see Annex B)

Note

Voluntary structural enhancement means e.g. increased corrosion allowance, grab notation

Capacity : Depends on the ship type. For all ship types except (cruise) passenger ships within the EEDI framework deadweight should be used as capacity.

$$Capacity = DWT_{Summer\,load\,draft}$$

For container ships capacity is defined as 70 % of the deadweight at summer load draft

$$Capacity_{Container} = 0.7 \cdot DWT_{Summer\,load\,draft}$$

v_{ref} : reference speed of the ship at EEDI conditions

in case where shaft motor(s) are installed V_{ref} shall be determined at:

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

where:

$$\sum P_{PTI(i),\,Shaft} = \sum \left(P_{PTI(i)} \cdot \eta_{PTI(i)}\right) \cdot \eta_{\overline{Gen}}$$

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

$\eta_{\overline{Gen}}$ is the weighted efficiency of the generator(s)

f_w : correction factor to account the decrease of speed in representative sea conditions.

f_W is described in Annex C.

f_c : Cubic capacity correction factor for chemical tankers is described in Annex B

Annex A EEDI Technical File

Glossary

Abbreviations

DWT : Deadweight

PTI : Power take in

PTO : Power take off

MCR : Maximum continuous rating

MDO : Marine Diesel Oil

SFC : Specific fuel oil consumption

Subscripts

AE : Auxiliary engine

ME : Main engine

SG : Shaft generator

Symbols

NO_x : Nitrogen oxide

η_{SG} : Efficiency factor

A Tables

Table A.1 General information

IMO no.	
GL Reg. no.	
Ship name	
Ship type	
Ship builder	
Year of delivery	
Ice class	

Table A.2 Principal particulars

Parameter	Value	Unit	Remark
L_{pp}		m	
B moulded		m	
Depth moulded		m	
Draft summer load line		m	to be taken from stability booklet
Lightship weight		t	from the lightship weight survey
DWT_{design}		t	to be taken from stability booklet
$DWT_{summer\ load\ draft}$		t	
$DWT_{70\ \%\ summer\ load\ draft}$		t	only for container ships
$Displacement_{ballast}$		t	from the sea trial report
$Displacement_{70\ \%\ DWT\ summer\ load\ draft}$		t	only for container ships
$Displacement_{design}$		t	to be taken from stability booklet
$Displacement_{summer\ load\ draft}$		t	from the summer load draft stability booklet

Table A.3 Main engine(s) particulars

No. of engines		General arrangement
Manufacturer		to be taken from the NO_x Technical File
Type		
MCR		
SFC (corrected) at 75 % MCR		
Fuel type used for NO_x certification		

Table A.4 Auxiliary engine(s) particulars

No. of engines		General arrangement
Manufacturer		to be taken from the NO_x Technical File
Type		
MCR		
SFC (uncorrected) at 50 % MCR SFC (ISO corrected) at 50 % MCR		to be taken from the NO_x Technical File ISO 8178
Fuel type used for NO_x certification		to be taken from the NO_x Technical File

Table A.5 Particulars of shaft generator

No. of shaft generators		
Manufacturer		from the manufacturer's documentation
Power (PTO(i))		
Power (PTO(i))		
η_{SG}		

Table A.6 Particulars of shaft motors (PTI)

No. of PTI		
Manufacturer		from the manufacturer's documentation
Power (PTI(i))		
Power (PTI(i))		
Generator manufacture		
Generator type		
Generator electrical output		
Efficiency of the generators		

Table A.7 Particulars innovative electrical auxiliary systems

No. of systems		
Manufacturer		from the manufacturer's documentation
Output capacity		
Availability factor		

Table A.8 Particulars of innovative technologies reducing main engine power for propulsion

No. of systems		
Manufacturer		from the manufacturer's documentation
Mechanical output		
Availability factor		

Table A.9 Model test information

Model facility		Model test report
Model scale		
Measured drafts		

Table A.10 Reference speed

Speed at EEDI conditions	

B EEDI Calculation

The EEDI calculation shall be submitted. The calculation shall be complete and comprehensible as described in Section 2.

Annex B Determination of Correction Factors f_j, f_i and f_c

A Determination of Correction Factors f_j and f_i due to Ice Class

Table B.1 Translation of Finnish-Swedish ice classes into equivalent GL ice class notations

	Ice class equivalents			
Finnish-Swedish ice class	**IC**	**IB**	**IA**	**IA Super**
GL ice class notation	**E1**	**E2**	**E3**	**E4**

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 calculated in Table B.2 but not greater than $f_{j,max} = 1.0$.

Table B.2 Correction factor for power f_j for ice classed ships

Ship type	f_j	f_{jmin} **depending on ice class notion**			
		E4	**E3**	**E2**	**E1**
Tanker	$\dfrac{0.308L_{PP}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.15L_{PP}^{0.30}$	$0.27L_{pp}^{0.21}$	$0.45L_{pp}^{0.13}$	$0.70L_{pp}^{0.06}$
Bulk carrier	$\dfrac{0.639L_{PP}^{1.754}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.47L_{pp}^{0.09}$	$0.58L_{pp}^{0.07}$	$0.79L_{pp}^{0.04}$	$0.87L_{pp}^{0.02}$
General cargo ship	$\dfrac{0.0227L_{PP}^{2.483}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.31L_{pp}^{0.16}$	$0.43L_{pp}^{0.12}$	$0.56L_{pp}^{0.09}$	$0.67L_{pp}^{0.07}$

Note:

f_j, for shuttle tankers with propulsion redundancy should be $f_j = 0.77$. f_j can be applied for shuttle tankers with propulsion redundancy between 80.000 and 160.000 deadweight.

Table B.3 Capacity correlation factor f_i for ice classed ships

Ship type	f_i	f_{imax} depending on ice class notion			
		E4	E3	E2	E1
Tanker	$\frac{0.00138 L_{pp}^{3.331}}{capacity}$	$2.10 L_{pp}^{-0.11}$	$1.71 L_{pp}^{-0.08}$	$1.47 L_{pp}^{-0.06}$	$1.27 L_{pp}^{-0.04}$
Bulk carrier	$\frac{0.00403 L_{pp}^{3.123}}{capacity}$	$2.10 L_{pp}^{-0.11}$	$1.80 L_{pp}^{-0.09}$	$1.54 L_{pp}^{-0.07}$	$1.31 L_{pp}^{-0.05}$
General cargo ship	$\frac{0.0377 L_{pp}^{2.625}}{capacity}$	$2.18 L_{pp}^{-0.11}$	$1.77 L_{pp}^{-0.08}$	$1.51 L_{pp}^{-0.06}$	$1.28 L_{pp}^{-0.04}$
Container ship	$\frac{0.0377 L_{pp}^{2.329}}{capacity}$	$2.10 L_{pp}^{-0.11}$	$1.71 L_{pp}^{-0.08}$	$1.47 L_{pp}^{-0.06}$	$1.27 L_{pp}^{-0.04}$
Gas carrier	$\frac{0.0474 L_{pp}^{2.590}}{capacity}$	1.25	$2.10 L_{pp}^{-0.12}$	$1.60 L_{pp}^{-0.08}$	$1.25 L_{pp}^{-0.04}$

Note: Capacity for container ships is 70 % of DWT at summer load draft.

B Determination of Correction Factors f_i for Ship Specific Voluntary Enhancement

Ship specific voluntary enhancement means measures, which increases safety and fatigue life of a ship's structure, e.g. additional corrosion allowance.

$f_{i\ VSE}$ for ship specific voluntary structural enhancement shall be calculated as follows:

$$f_{i\ VSE} = \frac{DWT_{reference\ design}}{DWT_{enhanced\ design}}$$

Where:

$$DWT_{reference\ design} = \Delta_{ship} - \text{lightweight}_{reference\ design}$$

$$DWT_{enhanced\ design} = \Delta_{ship} - \text{lightweight}_{enhanced\ design}$$

For the calculation of $f_{i\ VSE}$ the displacement for reference and enhanced design shall be the same.

$DWT_{reference\ design}$ is the deadweight without structural enhancements. $DWT_{enhanced\ design}$ is the deadweight where voluntary structural enhancements are applied. Changes of material and a change in grade of the same material between reference and enhanced design shall be not considered for the calculation of $f_{i\ VSE}$.

C Determination of Correction Factors f_i for Bulk Carriers and Oil Tankers built according to Common Structural Rules

$f_{i\,CSR}$ for bulk carrier and tankers built acc. to Common Structural Rules (CSR) shall be calculated as follows:

$$f_{i\,CSR} = 1 + \left(0.08 \cdot \frac{LWT_{CSR}}{DWT_{CSR}}\right)$$

D Determination of Cubic Capacity Correction Factors f_c for Chemical Tankers and Gas Carriers

f_c for **chemical tankers** shall be determined as follows:

$f_c = R^{-0.7} - 0.014,$ where R is less than 0.98

or

$f_c = 1.000,$ where R is 0.98 and above

f_c for **gas carriers** shall be determined as follows:

$f_c = R^{-0.56}$ where R is the capacity ratio of the deadweight at summer load draft of the ship (tonnes) divided by the total cubic capacity of the cargo tanks of the ship (m^3).

E Determination of the Ro-Ro Cargo and Ro-Ro Passenger Ship Specific Correction Factor $f_{jRo\text{-}Ro}$

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

$$f_{jRo-Ro} = \frac{1}{Fn^{\alpha} \cdot \left(\frac{L_{BP}}{B}\right)^{\beta} \cdot \left(\frac{B_m}{T_s}\right)^{\gamma} \cdot \left(\frac{L_{BP}}{\sqrt{\nabla}}\right)^{\delta}}$$

Where:

Fn : Frounde number: $Fn = \frac{0.5144 \cdot V_{ref}}{\sqrt{L_{BP} \cdot g}}$

g : gravitational acceleration: 9.81m/s2

T_s : draught at summer load line

B_m : moulded breadth

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

F Determination of the Cubic Capacity Correction Factor $f_{cRo\text{-}Pax}$ for Ro-Ro Passenger Ships

For Ro-Ro passenger ships having a DWT/GT-ratio less than 0.25, the following cubic capacity correction factor, f_{cRoPax}, should apply:

$$f_{cRoPax} = \left(\frac{DWT/GT}{0.25} \right)^{0.08}$$

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.

G Determination of the Correction Factor f_j General Cargo Ships

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

$$f_j = \frac{0.174}{Fn_{\nabla}^{\ 2.3} \cdot C_b^{0.3}}$$

Fn_{∇} : Frounde number: $Fn_{\nabla} = \dfrac{0.5144 \cdot V_{ref}}{\sqrt{g \cdot \nabla^{\frac{1}{3}}}}$

c_B : block coefficient: $c_B = \dfrac{\nabla}{L_{pp} \cdot B_m \cdot T}$

∇ : Volumetric displacement, ∇, in cubic metres (m^3)

B_m : moulded breadth

H Determination of the Correction Factor for Ships equipped with Cranes and other Cargo-related Gear

f_j is the factor for ships equipped with cranes and other cargo-related gear to compensate in a loss of deadweight of the ship.

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

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.

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

SWL : Safe Working Load in metric tonnes

Reach : Reach at the Safe Working Load in metres

N : Number of cranes

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

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

Annex C Determination of Coefficient f_W Expressing the Decrease of Speed in Representative Sea Conditions

These guidelines for the calculation of the coefficient f_W are based on MEPC.1/Circ.796 “Interim guidelines for the calculation of the coefficient f_W for decrease of speed in representative weather condition for trial use.”

The coefficient f_W can be calculated by two alternatives, which are presented in the following:

Alternative 1: Calculation of f_W acc. to MEPC.1/Circ. 796 for decrease in ship speed in a representative sea condition, see chapter C

Alternative 2: Calculating the coefficient f_W from the standard f_W curves, see chapter D

A Definitions

Symbol	Parameter	Unit
ΔR_{wave}	Added resistance due to waves	kN
ΔR_{wind}	Added resistance due to wind	kN
A_L	Projected lateral area above the designated load condition	m^2
A_T	Projected transverse area above the designated load condition	m^2
B	Ship breath	m
B_f	Bluntness coefficient, which is derived from the shape of the water plane and wave direction	-
C	Distance from the midship section to the centre of the projected lateral area (A_L); a positive value of C means that the centre of the projected lateral area is located ahead of the midship section	m
C_{Dwind}	Drag coefficient due to wind	-
C_U	Coefficient of advanced speed, which is determined on the basis of guidance for tank tests	-
D	Angular distribution function	-
d	Ship draft	M
E	Directional spectrum	m^2s
F_n	Froude number $Fn = V/\sqrt{L_{PP}g}$	-
f_W	Non-dimensional coefficient representing the reduction in speed in a representative sea conditions of wave height, wave frequency and wind speed. f_W is expressed by the ratio of speed under sea conditions and EEDI reference speed in calm water conditions.	

Symbol	Parameter	Unit
g	Gravitational acceleration (9.81)	m/s^2
H	Significant wave height	m
$H(m)$	Function to be determined by the distribution of singularities which represent periodical disturbance by the ship	-
I_1	Modified Bessel function of the first kind of order	-
K	Wave number of regular waves	-
K_1	Modified Bessel function of the second kind of order 1	-
L_{OA}	Length over all	m
L_{PP}	Length between perpendiculars	m
P_B	Brake power	kW
P_D	Delivered power, propeller power	kW
P_E	Effective power, resistance power	kW
P_S	Shaft power, power measured on the shaft	kW
Q	Torque	Nm
R_T	Total resistance in a calm sea condition (no wind and no waves)	kN
S	Frequency spectrum	m^2s
T	Mean wave period	s
U_{wind}	Mean wind speed	m/s
V_{ref}	Reference ship speed as defined in Section 2, C.2.4.1 - EEDI Calculation Procedure	kn
V_w	ship speed in operation under the representative sea condition. Corresponding parameters are listed in Table C.1.	kn
α	Angle between ship course and propagation direction of regular waves (0° is defined as head waves)	° (deg)
α_d	Effect of draft and frequency	-
ζ_a	Amplitude of incident regular waves	m
η_D	Propulsion efficiency	-
η_S	Transmission efficiency	-
θ	Angle between ship course and mean propagation direction of irregular waves (0° is defined as head waves)	° (deg)
ρ	Sea water density (1025.0 kg/m^3 is to be used)	kg/m^3
ρ_t	Water density in model tests	kg/m^3
ρ_a	Air density (1.226)	kg/m^3
ω	Circular frequency of incident regular waves	rad/s

Abbreviations

Abbreviation	Parameter
CFD	Computational Fluid Dynamics
RANSE	Reynolds averaged Navier-Stokes equations

B Definition of Representative Sea Conditions

The sea condition to determine the $EEDI_{weather}$ and the coefficient f_W is defined at Beaufort 6. The parameters describing the sea condition are shown in Table C.1.

Table C.1 Representative sea condition

Wind force (Beaufort)	Mean wind speed U_{wind} [m/s]	Mean wind direction γ [deg]	Significant wave height H [m]	Mean wave period T [s]	Mean wave direction θ [deg]
6	12.6	0 (head wind)	3.0	6.7	0 (head sea)

Note:

T is defined for Beaufort 6 by the following formula:

$$T = 3.86\sqrt{H}$$

The directional spectrum (E) is composed of frequency spectrum (S) and angular distribution function (D)

$$E(\omega;\alpha;H;T;\theta) = S(\omega;H;T)D(\alpha;\theta)$$

$$S(\omega;H;T) = \frac{A_S}{\omega^5}\exp\left(\frac{B_S}{\omega^4}\right)$$

where

$$A_S : \frac{H^2}{4\pi}\left(\frac{2\pi}{T_z}\right)^4, \quad B_S = \frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4, \quad T_z = 0.920\,T$$

$$D(\alpha;\theta) : \begin{cases} \frac{2}{\pi}\cos^2(\theta-\alpha) & |\theta-\alpha| \le \frac{\pi}{2} \\ 0 & \text{otherwise} \end{cases}$$

C Alternative 1: Calculation of f_W acc. to MEPC.1/Circ. 796

C.1 General

The coefficient f_W is defined as:

$$f_W = V_W / V_{ref}$$

f_W is the ratio of the speed in sea condition (V_w) to the reference speed in calm water (V_{ref}). Both speeds are defined at P_{EEDI} (75 % MCR) and EEDI draft, Fig. C.1.

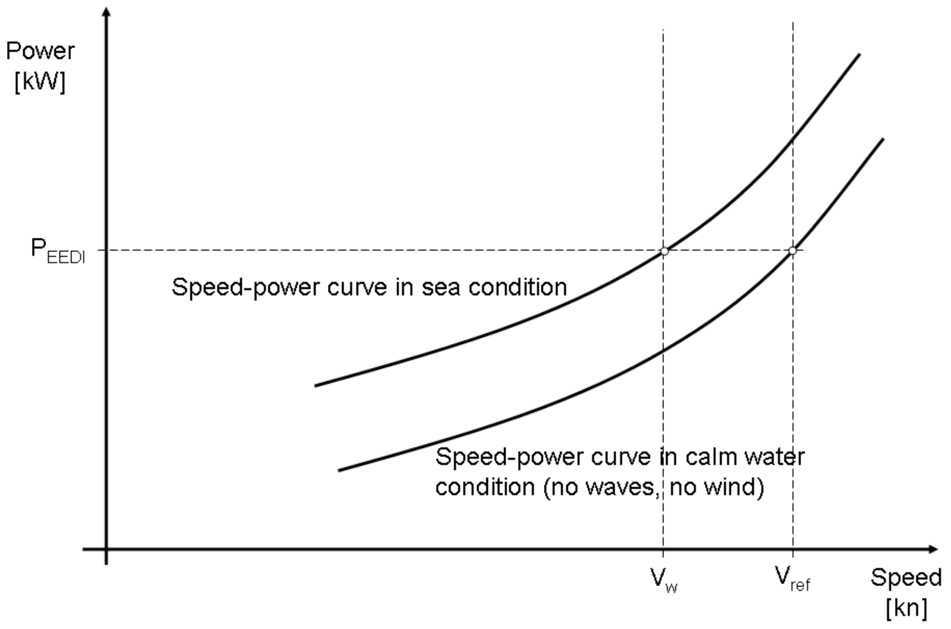


Fig. C.1 Speed-Power curves with and without added resistance due to sea condition

The applicable power for the calculation is the brake power delivered by the prime movers. The brake power is calculated as follows:

$$P_B = \frac{R_T V}{\eta_D \eta_S}$$

where

η_D	: P_E / P_D	–	Propulsive efficiency
η_S	: P_D / P_S	–	Shafting efficiency
P_D	: $Q \cdot \omega$	–	Delivered power at propeller
P_E	: $R \cdot V$	–	Effective power, resistance power; V in this formula is to be taken in m/s
P_S	:	–	Shaft power

C.2 Calculation of the total resistance in seaway

The total resistance in sea condition R_{Tw} is:

$$R_{Tw} = R_T + \Delta R_w$$

where

R_T : total resistance in calm water

ΔR_w : added resistance due to seaway

The total resistance in calm water is derived from model tank tests and sea trial following procedure described in Section 2 (for determination of V_{ref}) and shall be determined for different ship speeds.

The added resistance due to sea condition consists of added resistance due to wind ΔR_{wind} and added resistance due to waves ΔR_{wave}:

$$\Delta R_w = \Delta R_{wind} + \Delta R_{wave}$$

C.3 Added resistance due to wind

The added resistance due to wind is calculated as follows:

$$\Delta R_{wind} = 0.5\rho_a C_{Dwind} A_T \left(\left(U_{wind} + V_w \right)^2 - V_{ref}^{\ 2} \right)$$

The wind resistance coefficient C_{DWind} shall be based on data derived from model tests in a wind tunnel. Alternative methods, such as empirical data for similar vessels may be accepted upon agreement with the Administration.

C.4 Added resistance due to irregular waves

The added resistance due to irregular waves can be determined by tank tests following C.4.1 or equivalent methods in terms of accuracy following C.4.2.

C.4.1 Tank tests to determine added resistance in irregular waves

The tank tests shall be towed resistance tests in short-crested irregular head waves described in Annex B. The towing arrangement should not interfere with free pitch and heave motions.

The model is to be towed at the forward speeds from $0.6V_{ref}$ to V_{ref} with the interval not exceeding $0.1V_{ref}$. Calm-water resistance is to be measured at the corresponding speeds and subtracted from the total resistance.

The test procedures must be agreed upon by the Administration.

C.4.2 Determination of added resistance due to irregular waves using spectral approach

Irregular waves can be represented as superposition of regular waves. ΔR_{wave} is calculated by superposition of the directional spectrum (E) (see B Definition of Representative Sea Conditions) and added resistance in regular waves $\Delta R_{wave\ reg}$.

$$\Delta R_{wave}\left(H, T, \theta\right) = 2\int_0^{2\pi}\int_0^{\infty} \frac{R_{wave\ \ reg}\left(\omega, \alpha, V\right)}{\zeta_a^{\ 2}} E\left(\omega, \alpha, H, T, \theta\right) d\omega d\alpha$$

Irregular waves with significant wave height H, mean period T and mean wave direction θ are defined in Section B. $R_{wave\ reg}$ shall be determined for all variations of ω, α and V and integrated numerically with the following ranges and steps of integration:

ω from $\frac{3.6}{\sqrt{L_{PP}}}$ to $\frac{20.0}{\sqrt{L_{PP}}}$	with a step not exceeding $\frac{0.6}{\sqrt{L_{PP}}}$
α from $-90°$ to $90°$	with a step not exceeding $10°$
V from $0.6V_{ref}$ to V_{ref}	with a step not exceeding $0.1V_{ref}$

Two alternatives are considered for the determination of R_{wave}: model tank tests (C.4.2.1) and calculations (C.4.2.2).

C.4.2.1 Model tank tests in regular waves

Model tank tests can be used to determine $R_{wave\ \ reg}\left(\omega, \alpha, V\right)$ for the values of ω, α and V specified above. Wave height is selected corresponding to each ω from the interval $\frac{1.2}{\omega^2}$ to $\frac{3.0}{\omega^2}$. The model tank tests shall be resistance tests in regular waves. The towing arrangement shall not interfere with free heave and pitch motions. The calm-water resistance is to be defined for each forward speed V in the added resistance tests and subtracted from the total resistance.

The test procedures must be approved by the Administration.

C.4.2.2 Calculation of R_{wave} in regular waves

In the following a theoretic approach to calculate R_{wave} is introduced. Alternative methods for the determination of the added resistance due to waves can be used upon agreement with the Administration as well. In such cases, validation of the used methods by comparison with measurements for similar ships is to be demonstrated to satisfaction of the Administration.

Added resistance due to waves is calculated as

$$R_{wave} = R_{wm} + R_{wr}$$

where

R_{wm} : added resistance primary induced by ship motions in regular waves, and

R_{wr} : added resistance due to wave reflection in regular waves.

C.4.2.2.1 Calculation of R_{wm}

Added resistance primary induced by ship motions in regular waves R_{wm} can be calculated by established verified and validated methods approved by the Administration. Verification and validation shall include at least (1) detailed description of the numerical method, (2) grid dependency studies and (3) validation of the numerical method on the basis of comparison with reliable model tests to satisfaction of the Administration. Additional verification and validation may be requested by Administration when necessary. On request, Germanischer Lloyd will carry out additional verification and validation on its own.

C.4.2.2.2 Definition of R_{wr}

Two methods are allowed for the definition of the added resistance due to wave reflection in regular waves R_{wr}. The first method is based on the semi-empirical approach described in the *Interim Guidelines for the Determination of Coefficient f_W Expressing the Decrease of Speed in Representative Sea Condition*, MEPC.1/Circ796. The second method is based on numerical calculations.

Semi-empirical method for the definition of R_{wr}

The added resistance due to wave reflection in regular waves is calculated as follows:

$$R_{wr} = 0.5\rho g \zeta_a^2 B B_f \left(1 + C_U Fn\right)\alpha_d$$

where

$$\alpha_d = \frac{\pi^2 I_1^2\left(K_e d\right)}{\pi^2 I_1^2\left(K_e d\right) + K_1^2\left(K_e d\right)}$$

$$K_e = K\left(1 + \Omega\cos\alpha\right)^2$$

$$\Omega = \frac{\omega V}{g}$$

$$B_f = \frac{1}{B}\left[\int_I \sin^2\left(\alpha + \beta_w\right)\sin\beta_w \, dl + \int_{II} \sin^2\left(\alpha - \beta_w\right)\sin\beta_w \, dl\right]$$

Where dl represents a line element along the water plan, see Fig. C.2.

β_w is the angle of the line element tangent along the waterline and the body-axis parts.

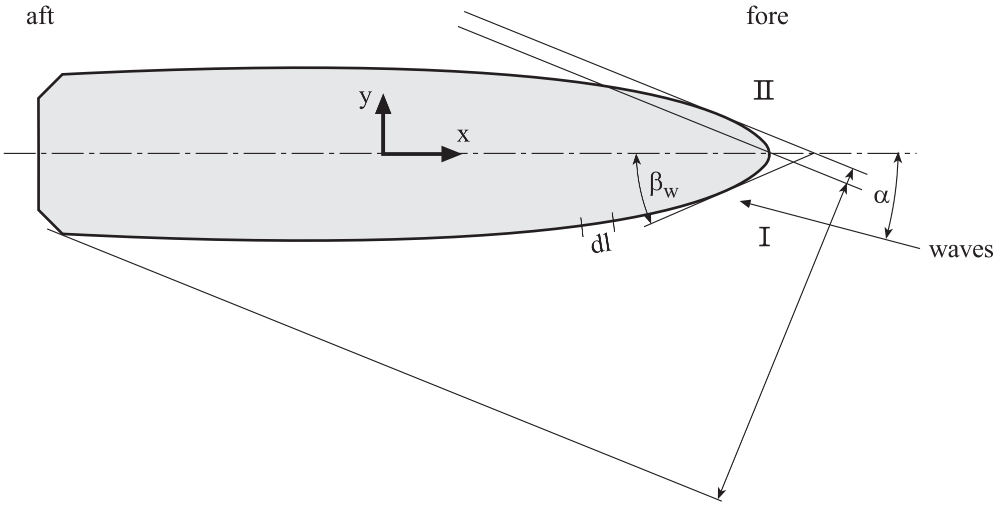


Fig. C.2 Coordinate system for wave reflection

The coefficient of advance speed in oblique waves $C_U(\alpha)$ is computed as

$C_U(\alpha)$ = max $[F_S, F_C]$

1. $B_f(\alpha = 0) = < B_{fc}$ or $B_f(\alpha = 0) < B_{fs}$

   $Fs = C_U(\alpha = 0) - 310\,[B_f(\alpha) - B_f(\alpha = 0)]$

   $F_C = \min\,[C_U(\alpha = 0), 10]$

2. $B_f(\alpha = 0) = \geq B_{fc}$ and $B_f(\alpha = 0) \geq B_{fs}$

   $Fs = 68 - 310 B_f(\alpha)$

   $F_C = C_U(\alpha = 0)$

where

$$B_{fc} = \frac{58}{310}; \quad B_{fs} = \frac{68 - C_U(\alpha = 0)}{310}$$

The coefficient of advance speed in head waves $C_U(\alpha = 0)$ shall be determined by tank tests. The test should be carried out in short waves with the wave length not exceeding $L_{pp}/2$.

This coefficient is derived from model test results following the equation

$$C_U = \frac{\alpha_U(Fn)}{Fn} = \left(\frac{R_{wave\ TT}(Fn)}{2\rho_t g \zeta_a^2 B B_f \alpha_d} - \frac{R_{wm}(Fn)}{2\rho g \zeta_a^2 B B_f \alpha_d} - 1 \right) \Big/ Fn$$

where

$R_{wave\ TT}$ is the added resistance determined by tank tests in regular head waves

R_{wm} is the added resistance due to ship motion in regular waves, as described above.

The coefficient of advanced speed $C_U(\alpha = 0)$ shall be determined by the least squares method against Fn for at least three different Fn, see Fig. C.3. The range of Fn shall include Fn corresponding to the speed in representative sea condition.

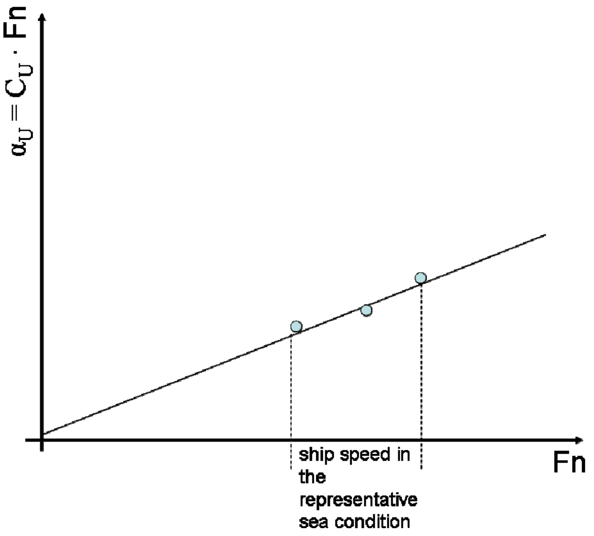


Fig. C.3 Determination of the coefficient of advanced speed

Numerical method for the definition of R_{wr}

The added resistance due to wave reflection in regular waves R_{wr} can be calculated by established verified and validated methods approved by the Administration. Verification and validation documentation shall include, at least (1) detailed description of the numerical method, (2) grid dependency studies and (3) validation of the numerical method on the basis of comparison with model tests to the satisfaction of the Administration. Additional verification and validation may be requested by the Administration when necessary. On request, Germanischer Lloyd will carry out additional verification and validation on its own.

D Alternative 2: Calculating the Coefficient f_W from the Standard f_W Curves

D.1 Application

In absence of towing tank tests and simulations described in Alternative 1 the coefficient f_W is calculated from a standard f_W curve.

D.2 Standard f_W curves

Standard f_W curves are available for three ship types:

- Bulk carrier
- Tanker
- Container ship.

For each ship type the standard f_W coefficient is calculated as follows:

Standard $f_W = a \cdot \ln(\text{capacity}) + b$

Where a and b are coefficients, see Table C.2 and capacity is the deadweight at summer load draft.

Table C.2 Parameters for determination of standard f_W

Ship type	a	b
Bulk carrier	0.0429	0.294
Container ship	0.0208	0.633
Tanker	0.0238	0.526

Annex D Determination of the Availability Factor and Power of Innovative Technologies

These guidelines for the calculation of the availability factor f_{eff} and the power delivered from innovated technologies P_{eff} are based on MEPC 64/4/8 “Guidance on treatment of innovate energy efficiency technologies for calculation and verification of the attained EEDI.”

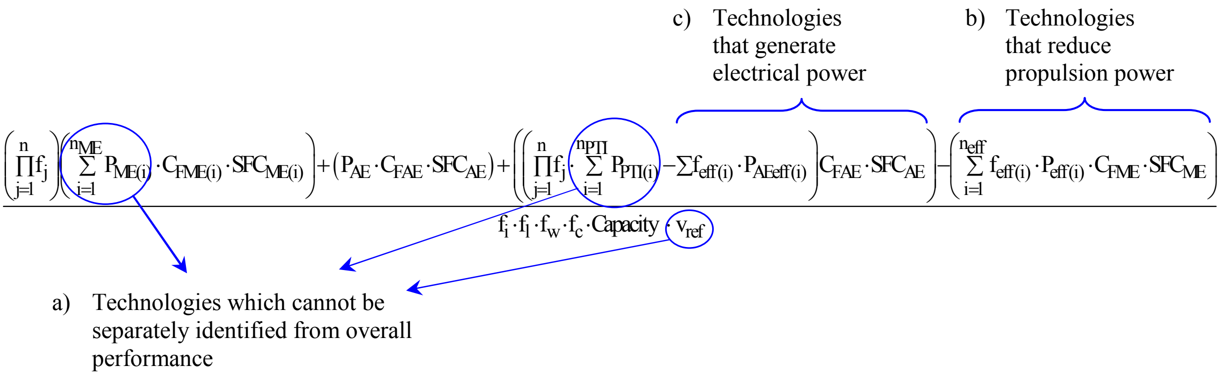
A Application

These guidelines are applicable to the determination of availability f_{eff} and power P_{eff} of emission reduction technologies for the calculation of the attained EEDI.

For this purpose innovative energy efficiency technologies are categorised into:

1. Technologies with an impact on the speed-power curve of a vessel which cannot be separately identified from overall performance i.e. change the proportion of propulsion power and reference speed V_{ref} due to ship design and applied materials. Hence these effects shall not be calculated under this guideline, rather than treated as a part of the EEDI calculation guideline in Section 2, determination of power and corresponding reference speed.
2. Technologies that reduce the propulsion power (excluding generation of electricity). The saved propulsion power is P_{eff}. It is differentiated between technologies which may operate at any time and technologies operating under limited conditions.
3. Technologies that generate electrical power. The generated electrical power is P_{AEeff}. It is differentiated between technologies which may operate at any time and technologies operating under limited conditions.

The affected terms of the EEDI formula with corresponding category are displayed below:



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

An overview of category and availability is given in Table D.1. Innovative energy efficiency technologies displayed in the table are examples, but is not limited to these.

Table D.1 Innovative energy efficiency technologies

	Reduction of propulsion engine power			**Generation of electrical power**	
Category	Cannot be separated from overall performance of the ship	Can be treated separately from the overall performance of the vessel			
	a)	b)		c)	
		1) Effective at all time	2) Depending on ambient environment	1) Effective at all time	2) Depending on ambient environment
		$f_{eff} = 1$	$f_{eff} < 1$	$f_{AEeff} = 1$	$f_{AEeff} < 1$
Examples	low friction coating bare optimisation low resistance rudder Optimised 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

B Calculation of Availability and Power of Innovative Technologies

B.1 Calculation of power reduction of technologies reducing the propulsion power

B.1.1 Application

The power reduction P_{eff} is calculated for the EEDI conditions (draft, deadweight) and the reference speed V_{ref} at P_{ME}.

B.1.2 Category b-1) – Air lubrication systems

B.1.2.1 Scope

The propulsion power reduction through air lubrication systems is calculated in the following. Air lubrication systems are systems where frictional resistance is reduced by covering the submerged part of the ship or parts of it with air bubbles. These air bubbles are injected from the bottom of the ship by blowers.

B.1.2.2 Method of calculation

For this innovative technology the availability factor f_{eff} is 1.0. The power reduction P_{eff} is calculated as follows:

$$P_{eff} = P_{PeffAL} - P_{AEeffAL} \frac{C_{FAE} \cdot SFC_{AE}}{C_{FME} \cdot SFC_{ME}}$$

where

P_{PeffAL} : reduction of propulsion power due to the air lubrication system at V_{ref}

$P_{AEeffAL}$: additional auxiliary power demand necessary to run the air lubrication system at 75 % of the rated output of the blower based on manufacture's test report

C_F : conversion factor fuel to CO_2

SFC : specific full oil consumption

The subscripts AE and ME refer to auxiliary and main engine, respectively.

B.1.2.3 Documentation of parameters at design stage

Additionally to the requirements of Section 2, Table 2.1 and 2.2 the EEDI Technical File shall included the propulsion power P_{effAL} and necessary auxiliary power $P_{AEeffAL}$ with the air lubrication system switched on at the ship's reference speed V_{ref} and EEDI draft conditions. The ship's reference speed V_{ref} should be determined and calculated when the air lubrication system is switched off. This is to avoid double counting of the system.

B.1.2.4 Documentation of parameters at final stage

Additionally to the requirements of in Section 2, Table 2.5 the final EEDI shall include the propulsion power P_{effAL} and necessary auxiliary power $P_{AEeffAL}$ with switched on air lubrication system shall be documented at the ship's reference speed V_{ref} and EEDI and sea trail draft conditions. The ship's reference speed V_{ref} should be determined and calculated when the air lubrication system is switched off. The P_{effAL} and $P_{AEeffAL}$ shall be determined on sea trial.

The power reduction P_{effAL} shall be calculated as difference between P_{ME} as defined in Section 2, C.2.1.1 and the brake power at V_{ref} when the air lubrication system is switched on (see Fig. D.1).

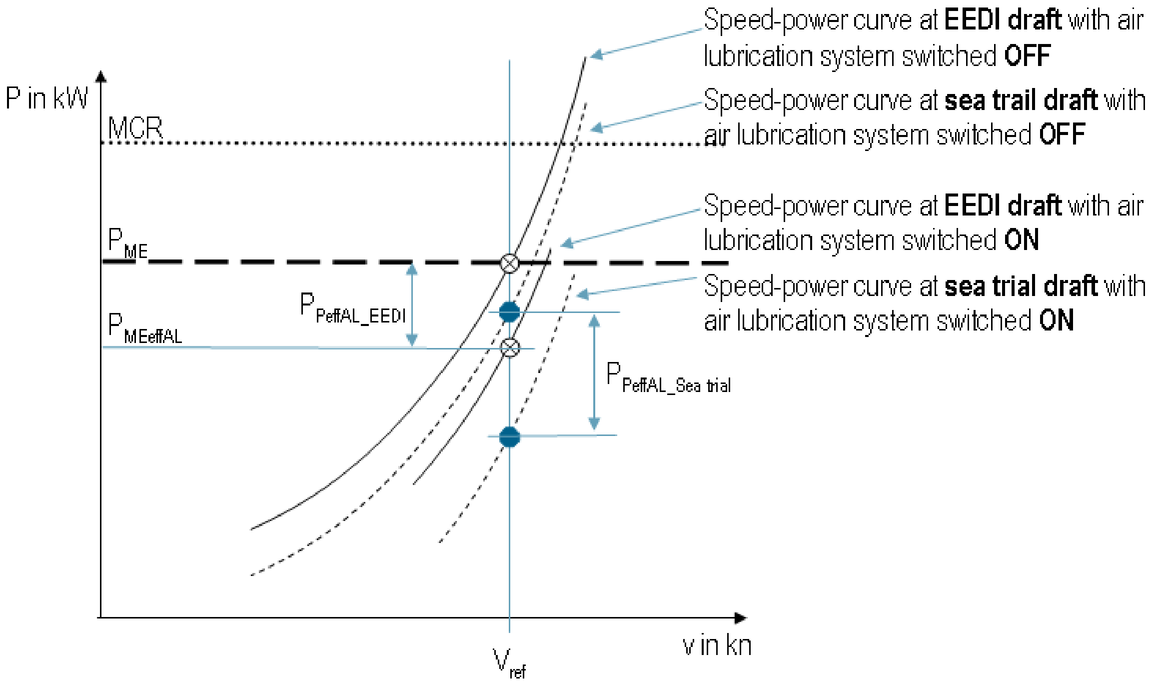


Fig. D.1 Calculation of the reduction of the propulsion power due to air lubrication system

The engine output and speed shall be measured and documented for the switched on and switched off air lubrication system. The speed power curves shall be developed as described in Section 2, Table 2.5 with air lubrication system on and off.

B.1.3 Category b-2) – Wind propulsion systems

B.1.3.1 Application

These guidelines apply to all kinds of wind propulsion technologies, such as sails, wings and kites, which generate forces dependent on wind condition. This technical guidance defines the available effective power of wind propulsion systems as the product of the reference speed and the sum of the wind propulsion system force and the global wind probability distribution.

B.1.3.2 Definitions

For the purpose of these guidelines, the following definitions should apply:

The available effective power is the multiplication of effective power P_{eff} and availability factor f_{eff} as defined in the EEDI calculation.

Wind propulsion systems 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.

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.

B.1.3.3 Calculation of available effective power of wind propulsion systems

The available effective power of wind propulsion systems as innovative energy efficient technology is calculated by the following formula:

$$\left(f_{eff} \cdot P_{eff}\right) = \left(\frac{0.5144 \cdot V_{ref}}{\eta_T} \sum_{i=1}^{m} \sum_{j=1}^{n} F(V_{ref})_{i,j} \cdot W_{i,j}\right) - \left(\sum_{i=1}^{m} \sum_{j=1}^{n} P(V_{ref})_{i,j} \cdot W_{i,j}\right)$$

where

$(f_{eff} \cdot P_{eff})$ is the available effective power delivered by the specified wind propulsion system. f_{eff} and P_{eff} are not differentiated in the calculation because availability and power are included in the global wind matrix and wind propulsion system force matrix addressing each wind condition with a probability and a specific wind propulsion system force.

V_{ref} is the ship reference speed measured in nautical mile per hour (knot), as defined in the EEDI calculation guidelines.

η_T is the total efficiency of the main drive(s) at 75 % of the rated installed power (MCR) of the main engine(s). η_T shall be set to 0.7, if no other value is specified and verified by the verifier.

$F(V_{ref})_{i,j}$ is the force matrix of the respective wind propulsion system for a given ship speed V_{ref}. The $F(V_{ref})_{i,j}$ matrix shall be provided by the applicant.

$W_{i,j}$ is the global wind probability matrix.

$P(V_{ref})_{i,j}$ is a matrix with the same dimensions as $F(V_{ref})_{i,j}$ and $W_{i,j}$ and represents the power demand in kW for the operation of the wind propulsion system.

The factor 0.5144 represents the conversion factor from nautical miles [nm] to meters per second [m/s].

The first term of the formula defines the additional propulsion power to be considered for the overall EEDI calculation. The term contains the product of the ship specific speed, the force matrix and the global wind probability matrix. The second term contains the power requirement for the operation of the specific wind propulsion system which has to be subtracted from the gained wind power.

Every wind propulsion system has a distinctive force characteristic dependent on wind speed, ship speed and the wind angle relative to heading. This means that the force characteristic can be expressed in a two dimensional matrix, holding elements for any combination of wind speed, wind angle relative to heading and V_{ref}.

Each matrix element represents the propulsion force in kN for the respective wind speed and angle. The wind angle is relative to ship coordinates, where $0°$ represents ahead direction. Table D.2 gives guidance for the determination of the wind propulsion system force matrix. For the final determination of the CO_2 reduction of a system the force matrix must be approved by the verifier.

Table D.2 Lay-out of a force matrix in [kN] for a wind propulsion system at V_{ref}

wind angle [°] / wind speed [m/s]	0	5	…	355
< 1	$a_{1.1}$	$a_{1.2}$		$a_{1.72}$
2				
3				
…				
> 25				$a_{26.72}$

B.1.3.3.1 The global wind probability matrix $W_{i.j.}$

$W_{i.j.}$ represents the probability of wind direction and wind speed relative to ship coordinates. The wind probability matrix shall be gained from the wind probability on major trading routes.

Each matrix element represents the probability of wind speed and wind angle relative to the ship coordinates. The sum over all matrix elements equals 1 and is non-dimensional. The full wind probability matrix is shown in Table D.4

Table D.3 Simplified global wind probability matrix

wind angle [°] / wind speed [m/s]	0	5	…	355
< 1	$a_{1.1}$	$a_{1.2}$		$a_{1.72}$
2				
3				
…				
> 25				$a_{26.72}$

For the calculation of the CO_2 reduction the resulting f_{eff} and P_{eff} have to be multiplied with the conversion factor C_{fME} and SFC_{ME} as contained in the EEDI formula in Section 2.

B.1.3.4 Documentation of parameters

The documentation shall include the comprehensive description of the wind propulsion system. incl. drawings where the system is located.

The force matrix of the wind propulsion system shall be submitted to GL. It shall be comprehensively documented how the force matrix has been determined, incl. e.g. test bed measurements. etc.

At final stage of verification a surveyor confirms the installation of the system.

Table D.4 Global wind probability matrix

Wind Speed [m/s] \ Wind Angle [°]	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

Table D.4 Global wind probability matrix *(continued)*

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

Table D.4 Global wind probability matrix *(continued)*

Wind Speed [m/s] \ Wind Angle [°]	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

Note

The entries in the global wind probability matrix are rounded to the 4th digit. The global wind probability matrix can be provided by GL on request.

B.1.4 Category c-1) – Waste heat recovery systems for the generation of electrical power

B.1.4.1 Application

These guidelines apply to high temperature waste heat recovery systems generating electrical power related to the reduction of auxiliary power.

B.1.4.2 Calculation of innovative electric power

As described in Table D.1 the availability factor f_{eff} can be set to 1 for waste heat recovery systems. The electrical power P_{AEeff} shall be calculated as

$$P_{AEeff} = P'_{AEeff} - P_{AEeff\ loss}$$

where

P'_{AEeff} : power produced by the waste heat recovery system

$P_{AEeff\ loss}$: necessary power to drive the waste heat recovery system

In case more than one waste heat recovery system is used P_{AEeff} is the sum of the values of each system.

The produced electrical power P'_{AEeff} is calculated as:

$$P'_{AEeff} = \frac{W_e}{\eta_g}$$

where

W_e : calculated product of the electricity generated by the waste heat recovery system.

η_g : weighted average generator efficiency as per manufacturer's documentation.

B.1.4.3 Documentation for preliminary verification

In addition to the requirements outlined in Section 2 the following items shall be included in the EEDI Technical File preliminary verification:

- 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
- deduction of the saved energy from the auxiliary engine power by the waste heat recovery system
- exhaust gas data for the main engine at 75 per cent MCR (and/or the auxiliary engine at the measurement condition of SFC) at different ambient air inlet temperatures. e.g. 25 °C which consist of
  - exhaust gas mass flow for turbo charger (kg/h)
  - exhaust gas temperatures after turbo charger (C°)
  - exhaust gas bypass mass flow available for power turbine. if any (kg/h)
  - exhaust gas temperature for bypass flow (C°)
  - exhaust gas pressure for bypass flow (bar)
- in the case of system using heat exchanger, expected output steam flows and steam temperatures for the exchanger, based on the exhaust gas data from the main engine
- estimation process of the heat energy recovered by the waste heat recovery system

B.1.4.4 Documentation for final verification

Additionally to the items described in Section 2 the EEDI Technical File shall include:

The deduction of the saved energy from the auxiliary engine power by the waste heat recovery system. This is to be verified by the results of shop tests of the waste heat recovery system's principal components.

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 is to be documented by measurements of 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.

B.1.5 Category c-2) – Photovoltaic power generation system

B.1.5.1 Application

These guidelines apply to photovoltaic (PV) power systems providing electrical power on board of a ship.

B.1.5.2 Calculation of electrical power generated by photovoltaic systems

The electrical power generated by PV systems shall be calculated as:

$$\left(f_{eff} \cdot P_{AEeff}\right) = \left[f_{rad} \times \left(1 + L_{temp}/100\right)\right] \times \left[P_{max} \times \left(1 - L_{others}/100\right) \times N\right]$$

where

$f_{eff} \cdot P_{eff}$: net electrical power of the PV system in kW

f_{rad} : ratio of the average solar irradiance on main global shipping routes to the nominal solar irradiation specified by the manufacture. Based on IEC 61215 standard test conditions the nominal solar irradiance is 1000 W/m^2 and the solar irradiance on global shipping routes is 200 W/m^2. Hence f_{rad} is derived as:

$$f_{rad} = \frac{200\ \ W/m^2}{1000\ W/m^2} = 0.2$$

L_{temp} : correction factor. which is usually in minus and derived from the temperature of PV modules, and the value is expressed in percent. 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} (%/K) specified by the manufacturer (See IEC 61215) as follows:

$$L_{Temp} = f_{temp} \cdot \left(40°C - 25°C*\right)$$

* temperature of the PV module

P_{AEeff} : generated PV power under the condition specified by the manufacturer and expressed as follows:

$$P_{AEeff} = P_{max} \cdot \left(1 - \frac{L_{other}}{100}\right) \cdot N$$

P_{max} : nominal maximum generated PV power generation of a module expressed in kilowatt. based on IEC 61215.

L_{others} : summation of other losses expressed by percent and includes the losses in a power conditioner, at contact, by electrical resistance, etc. Based on experiences. it is estimated that L_{others} is 10 per cent (the loss in the power conditioner: 5 % 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 61683.

N : numbers of modules used in a PV power generation system.

B.1.5.3 Documentation for preliminary verification

In addition to the requirements set out in Section 2 the EEDI Technical File shall include:

- outline of the PV power generation system
- power generated by the PV power generation system
- detailed calculation process of the auxiliary power reduction by the PV power generation system and
- detailed calculation process of the total net electric power ($f_{eff} \cdot P_{AEeff}$) specified in this Annex

Documentation for final verification

The EEDI Technical File shall include all specifications of the actual installed PV system as described for the documentation for the preliminary verification. Prior to the sea trial the installation is confirmed by a surveyor.

Annex E Determination of the Auxiliary Power from an Electrical Load Balance Table

These guidelines for the calculation of the auxiliary power P_{AE} from an electrical load balance table (ELBT) are based on the “Guidelines for the Development of Electrical Power Tales for EEDI (EPT-EEDI).

A Application

These guidelines shall be applied if the actual auxiliary power demand in normal operating sea conditions (NOSC) is significantly higher than the P_{AE} value calculated under Section 2, C.2.2.1 of these guidelines. If the auxiliary power demand is significantly higher than calculated P_{AE} value under Section 2, C.2.2.1 of these guidelines the Electrical Load Balance Table (ELBT) shall be used for the determination of P_{AE} for the EEDI calculation.

These guidelines apply for P_{AE} for the EEDI calculation under following conditions:

- no emergency situation,
- evaluation time frame of 24 h, and
- the ship is fully loaded of passenger and/or cargo and crew.

B Data to be included in the Electrical Load Balance Table for EEDI

Load shall are defined in groups to allow breakdown of the auxiliaries. The following load groups shall be included in the ELBT:

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 service
5. E – Ventilation for engine rooms and auxiliary rooms
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
12. M – Miscellaneous.

B.1 Explanation of load groups

B.1.1 A – Hull, Deck, Navigation and Safety services

Loads included in the Hull services typically are: Impressed Current Cathodic Protection (ICCP) systems, mooring equipment, various doors, ballasting systems, bilge systems, stabilizing equipment, etc. ballasting systems are indicated with service factor equal

Loads included in the deck services typically are: deck and balcony

Washing systems, rescue systems, cranes, etc.

Loads included in the navigation services typically are: navigation systems,

Navigation’s external and internal communication systems, steering systems, etc.; and

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

B.1.2 B – Propulsion, service auxiliaries

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 equipments such as manoeuvring thrusters and their auxiliaries whose service factor is to be set to zero.

B.1.3 C – Auxiliary engine and main engine services

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.

B.1.4 D – Ship’s general service

Loads are included 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.

B.1.5 E – Ventilation for engine rooms and auxiliary rooms

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.

B.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.

B.1.7 G – Galleys, refrigeration, and laundries services

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.

B.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 equipments, etc.

B.1.9 I – Lighting and socket services

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 have to be divided by main vertical zone; and

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 have to be divided by main vertical zone.

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)

B.1.10 L – Entertainment services

Public spaces audio and video equipments, theatre stage equipments, IT systems for offices, video games, etc.

B.1.11 N – Cargo loads

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.

B.1.12 M – Miscellaneous

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.

B.2 Descriptions of loads and service factors

B.2.1 Load description

Each item in the EEDI electrical load balance table shall have a distinct description of the component, e.g. “sea water pump 1”.

B.2.2 Load identification

Each item in the EEDI load balance table shall have a distinct identification, which is represents a unique identifier.

B.2.3 Load electric circuit identification

The circuit of each load shall have a distinct identification.

B.2.4 Loads mechanical rated power P_m [kW]

P_m is the rated power of the mechanical device driven by an electric motor and shall be documented in the EEDI electrical load balance table.

B.2.5 Loads electric motor rated output power [kW]

The output power of the electric motor as per maker's name plate or technical specification shall be documented in the EEDI electrical load balance tale.

B.2.6 Loads electric motor efficiency "e" [/]

The electric motor efficiency is the efficiency of an electric motor driving a mechanical load.

B.2.7 Loads rated electric power "Pr" [kW]

The loads rate electric power Pr is 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].

B.2.8 Service factor of load "kl" [/]

The service factor of load kl 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. E.g., 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.

B.2.9 Service factor of duty "kd" [/]

Service factor of duty kd is a factor of duty is to be used when a function is provided by more than one load. As all loads have to be included in the ELBT for the 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 ⅓, ⅓ and ⅓.

B.2.10 Service factor of time "kt" [/]

Service factor of time kt is a factor of time based on the shipyard's evaluation about the load duty along 24 hours of ship's electrical systems.

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 V_{ref}. As a consequence $kt = 1$.

B.2.11 Service total factor of use "ku" [/]

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

B.2.12 Loads necessary power "P_{load}" [kW]

The loads necessary power P_{load} is the power of the individual user contribution to the auxiliary load power is $P_{load} = Pr \cdot ku$.

C Determination of P_{AE}

C.1.1 Groups necessary power [kW]

The "Loads necessary power" is the summation of P_{load} of the load groups A to N. This is an intermediate step which is not strictly necessary for the calculation of P_{AE}. However, it is useful to allow a quantitative analysis of the P_{AE}, providing a standard breakdown for analysis and potential improvements of energy saving.

C.1.2 Auxiliaries load's power P_{AE} [kW]

Auxiliaries load's power P_{AE} 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.

$P_{AE} = \Sigma P_{load(i)}$ / (average efficiency of the generator(s) weighted by power)

D Layout and Organization of the Data indicated in the EEDI Electric Load Balance Table

The document "Electric power table for EEDI" shall include general information such as. ship's name, project name, document references, etc. and a table with:

13. one row containing column titles
14. one Column for table row ID,
15. one Column for the groups identification ("A", "B", etc.) as described in B.1,
16. one Column for the group descriptions as indicated as described in B.1, e.g. “Hull, Deck, Navigation and Safety services”,
17. one column each for items in B.2 of this guideline (e.g. “Load identification” etc.),
18. one row dedicated to each individual load,
19. the summation results (i.e. summation of powers) including data from C, and
20. explanatory notes.

Table E.1 gives an example of an EEDI electrical load balance table for a cruise postal vessel which transports passenger and have a car garage and reefer holds for fish trade transportation is indicated below. The data indicated and the type of ship is for reference only.

Table E.1 Example of an EEDI electrical load balance table

ID	Load group	Load description	Load ID	Load electric circuit ID	Loads mechanical rated power P_m	Loads electric motor rated output power	Loads electric motor efficiency "e"	Loads rated electric power "P_r"	Service factor of load "k_l"	Service factor of duty "k_d"	Service factor of time "k_t"	Service total factor of use "k_u"	Loads necessary power "P_{load}"	Note
					[kW]	[kW]		[kW]					[kW]	
1	A	ICCP system	Abc1	Xyz1	n/a	n/a	n/a	6.3	1	1	1	1	6.3	in use 24 h
2	A	Ballast pump[1]	Def1	Tvw2	50	55	0.9	55.5	0.5	1	0	0	0	Not in use at NOSC
3	B	Port fresh water pump[1]	Ghi2	Tvw2	30	35	0.9	33.3	0.5	0.5	1	0.25	8.3	
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
n	M	…	…	…	…	…	…	…	…	…	…	…	…	…
												Σ P_{load}	###.##	kW

$P_{AE} = \Sigma P_{load}$ / weighted average efficiency of generator(s) = ###.## kW