



CHINA CLASSIFICATION SOCIETY

RULES FOR GREEN SHIPS

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FOREWORD

The Rules aims to advocate the development and application of green technologies, promote the structural optimization and upgrading of shipbuilding, related manufacturing and shipping industries, promote the use by shipping companies of cost-effective technologies and management measures to new and existing ships so as to increase the green grade in the operation of their fleets and, with safety as the precondition, achieve the goals of low consumption, low emissions, low pollution and comfortable working environment for their ships.

The goals of green ships cover the three aspects of environmental protection, energy efficiency and working environment:

- (1) The goal of environmental protection: Reducing pollution or damage by ships to ocean, land and atmosphere.
- (2) The goal of energy efficiency: Reducing carbon dioxide emissions from ship operations and increasing the energy efficiency level of ships.
- (3) The goal of working environment: Improving working and living conditions of crew and reducing the labor intensity of crew.

The functional requirements for achieving the goals of green ships consist of:

1 Basic safety requirements:

- (1) The strength, integrity and stability of ships in both intact and damaged conditions are to be adequate, and the construction and arrangement, machinery and electrical installations/systems, and safety equipment are to be suitable for the operation of ships.
- (2) The application of any green technology to ships is not to reduce the original safety level of ships.

2 The functional requirements for achieving the goal of environmental protection:

- (1) Ships are to meet all applicable requirements of MARPOL or the Regulations for the Statutory Surveys of Ships and Offshore Installations (Technical Regulations for the Statutory Surveys of Sea-Going Ships Engaged on Domestic Voyages) and in addition, further reduce risks of pollution by oil, sewage, grey water and garbage discharges and air pollution in terms of equipment, arrangement, operations and maintenance.
- (2) The anti-fouling system of ships is not to contain any biocide.
- (3) Ships are to meet all applicable requirements of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (if applicable) and in addition, further reduce risks of pollution by harmful aquatic organisms and pathogens via ballast water in terms of equipment, arrangement and operations.
- (4) Materials harmless to humans and marine ecosystems are to be used in the design, construction and repairs of ships.

3 The functional requirements for achieving the goal of energy efficiency:

- (1) The energy consumption of ships is to be reduced by design measures and effective operational control while achieving equivalent business benefits.

(2) The portion of clean energies in energies necessary for ship propulsion, domestic needs of persons living on the ship and the normal operation of shipboard auxiliary machineries is to be maximized, with safety as the precondition.

(3) For new ships, the energy efficiency is to be evaluated according to the Energy Efficiency Design Index (EEDI) and at least the applicable reference line requirements are to be met; for ships in operation, the improvement of the energy efficiency is to be evaluated according to the Energy Efficiency Operation Index (EEOI), and the Ship Energy Efficiency Management Plan (SEEMP) is to be available on board.

4 The functional requirements for achieving the goal of working environment:

(1) The structure, the arrangement of compartments and the installation of equipment of ships are to be such as to minimize risks of ship-generated vibrations and noises endangering human health.

(2) Automated equipment is to be used to minimize the labor intensity of personnel.

TERMS AND ABBREVIATIONS

The relevant terms of the Rules are abbreviated as follows:

- (1) AMPS: alternative maritime power supply;
- (2) AUT-0: machinery space periodically unattended;
- (3) BRC: remote control from bridge;
- (4) BWMP: ballast water management plan;
- (5) BWMS: ballast water management system;
- (6) CEEMC: Company Energy Efficiency Management Certificate;
- (7) CNG: compressed natural gas;
- (8) CO₂: carbon dioxide;
- (9) DFD: dual fuel diesel engine;
- (10) DWT: dead weight tonnage;
- (11) EEDI: energy efficiency design index;
- (12) FPSOs: floating Production, Storage and Offloading Units;
- (13) FSUs: floating storage units;
- (14) GPR: green passport for recycling;
- (15) GT: gross tonnage;
- (16) GWP: global warming potential;
- (17) HCFC: hydrogenated chlorofluorocarbon;
- (18) IACS: International Association of Class Societies;
- (19) IBC: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk;
- (20) IBTS: Integrated bilge water treatment system;
- (21) IMO: International Maritime Organization;
- (22) ITTC: International Towing Tank Conference;

- (23) LNG: liquefied natural gas;
- (24) LSFO: low sulphur fuel oil;
- (25) MARPOL: the International Convention for the Prevention of Pollution from Ships, 1973, developed by IMO, as modified by the 1978 and 1997 Protocols;
- (26) MCC: central control of machinery spaces;
- (27) MEPC: the Marine Environment Protection Committee of IMO;
- (28) MSC: the Maritime Safety Committee of IMO;
- (29) NLS: noxious liquid substance;
- (30) NO_x: nitrogen oxides;
- (31) ODP: ozone depletion potential;
- (32) PM: particulate matter;
- (33) SEEMC: Ship Energy Efficiency Management Certificate;
- (34) SEEMP: Ship Energy Efficiency Management Plan;
- (35) SOLAS: the International Convention for the Safety of Life at Sea, 1974, and the 1988 Protocol relating thereto;
- (36) SO_x: sulfur oxides;
- (37) SPV: solar photovoltaic system;
- (38) STS: transfer of oil cargo between oil tankers at sea;
- (39) VOC: Volatile Organic Compounds.

CHAPTER 1 GENERAL

1.1 General Requirements

1.1.1 The Rules applies to sea-going ships for which CCS Green Ship class notations, Energy Efficiency class notations or Green Technology notations are requested. The Rules is divided into two parts, of which, Part I applies to sea-going ships engaged on international voyages, and Part II applies to sea-going ships engaged on domestic voyages. For sea-going ships not flying the flag of China intended for navigating in restricted service and engaged on non-international voyages, the requirements for ships engaged on domestic voyages may be referred to.

1.1.2 The Rules provides supplementary requirements for CCS Rules for Classification of Sea-going Steel Ships and Regulations for Classification of Sea-going Ships Engaged on Domestic Voyages. The purpose of the Rules is to encourage the design, construction and operation of the ships classed with CCS to a higher level of environmental protection and energy saving, and to a more comfortable onboard working environment on the basis that international or national regulations on ship safety and environmental protection are complied with.

1.1.3 Ships, for which Green Ship class notations are requested, are also to comply with the applicable requirements of CCS Rules for Classification of Sea-going Steel Ships and those of Regulations for Classification of Sea-going Ships Engaged on Domestic Voyages.

1.1.4 In addition, ships, for which Green Ship class notations are requested, are to comply with the other relevant requirements of the flag State Administration.

1.2 Definitions

1.2.1 Unless provided otherwise, for the purpose of the Rules:

(1) *Oil residue (sludge)* means the residual waste oil products generated during the normal operation of a ship such as those resulting from the purification of fuel or lubricating oil for main or auxiliary machinery, separated waste oil from oil filtering equipment, waste oil collected in drip trays, and waste hydraulic and lubricating oils.

(2) *Oily bilge water* means water which may be contaminated by oil resulting from things such as leakage or maintenance work in machinery spaces. Any liquid entering the bilge system including bilge wells, bilge piping, tank top or bilge holding tanks is considered oily bilge water.

(3) *Oil residue (sludge) tank* means a tank which holds oil residue (sludge) from which sludge may be disposed directly through the standard discharge connection or any other approved means of disposal.

(4) *Oily bilge water holding tank* means a tank collecting oily bilge water prior to its discharge, transfer or disposal.

(5) Sewage (black water) means:

- .1 drainage and other wastes from any form of toilets and urinals;
- .2 drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises;
- .3 drainage from spaces containing living animals; or
- .4 other waste waters when mixed with the drainages defined above.

(6) *Grey water* means drainage from gallery, wash tubs, laundry and wash basins. It includes neither drainage from toilets, urinals, medical premises and spaces containing animals as defined in 1.2.1(5) of the Rules, nor drainage from cargo spaces.

(7) *Garbage* means all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, incinerator ashes, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and liable to be disposed of continuously or periodically.

(8) *Cargo residues* means the remnants of any cargo which are not covered by Annexes I, II and III to MARPOL Convention and which remain on the deck or in holds following loading or unloading, including loading and unloading excess or spillage, whether in wet or dry condition or entrained in wash water but does not include cargo dust remaining on the deck after sweeping or dust on the external surfaces of the ship.

(9) *Cooking oil* means any type of edible oil or animal fat used or intended to be used for the preparation or cooking of food, but does not include the food itself that is prepared using these oils.

(10) *Anti-fouling system* means a coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms.

(11) *Ballast water* means water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship.

(12) *Ballast Water Management System (BWMS)* means any system which processes ballast water such that it meets or exceeds the ballast water performance standard in regulation D-2. The BWMS includes ballast water treatment equipment, all associated control equipment, monitoring equipment and sampling facilities.

(13) *Noxious liquid substance (NLS)* means any substance indicated in the Pollution Category column of chapter 17 or 18 of the International Bulk Chemical Code, or specified in the present MEPC.2/Circular or provisionally assessed under the provisions of regulation 6.3 of MARPOL Annex II as falling into category X, Y or Z.

(14) *Domestic Regulations* means Regulations for the Statutory Surveys of Ships and Offshore Installations (Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Non-International Voyages) and the amendments thereto, developed by the Maritime Safety Administration of the People's Republic of China.

1.3 Class Notations for Green Ships

1.3.1 Class notation for green ships is a special identification of CCS classed ships complying with the relevant requirements of environmental protection, energy efficiency and working environment, which demonstrate the green elements in the three aspects of environmental protection, energy efficiency and working environment.

1.3.2 Class notations for green ships for sea-going ships engaged on international voyages and sea-going ships engaged on domestic voyages are indicated as follows, with each grade corresponding respectively to a specific requirement:

Sea-going ships engaged on international voyages: Green Ship I, Green Ship II, Green Ship III

Sea-going ships engaged on domestic voyages: Green Ship 1, Green Ship 2, Green Ship 3

1.3.3 Chapter 2 and Chapter 5 of the Rules specify respectively the requirements with regard to energy efficiency for design and energy efficiency for operation corresponding to the above Green Ship class notations for sea-going ships engaged on international voyages and sea-going ships engaged on domestic voyages. A corresponding class notation of energy efficiency may be assigned separately as follows:

Sea-going ships engaged on international voyages:	EEDI(I), EEDI(II), EEDI(II+), EEDI(III),	indicating energy efficiency for design
	SEEMP(I), SEEMP(II), SEEMP(III),	indicating energy efficiency for operation
Sea-going ships engaged on domestic voyages:	EEDI(1), EEDI(2), EEDI(3),	indicating energy efficiency for design
	SEEMP(1), SEEMP(2), SEEMP(3)	indicating energy efficiency for operation

1.3.4 The Rules encourages ships to apply green technology, e.g. LNG fuels, low sulphur fuel oils, high-voltage shore connection and solar energy, etc. CCS may, upon assessment, assign a specific green technology notation as follows.

1.3.4.1 DFD – the assignment of the class notation of dual fuel diesel engine used as power plant (applicable to LNG carriers) is to comply with the technical requirements in CCS Guidelines for Design and Installation of Dual Fuel Engine System.

1.3.4.2 LNG Fuel – the assignment of the class notation for liquefied natural gas used as fuel (applicable to ships other than passenger ships and ships carrying dangerous chemicals) is to comply with the technical requirements in CCS Rules for Natural Gas Fuelled Ships.

1.3.4.3 CNG Fuel – the assignment of the class notation for compressed natural gas used as fuel (applicable to ships other than passenger ships and ships carrying dangerous chemicals) is to comply with the technical requirements in CCS Rules for Natural Gas Fuelled Ships.

1.3.4.4 Dual Fuel – the assignment of class notation of dual fuel system for both natural gas as fuel and fuel oil burning, or burning of fuel oil and natural gas fuel simultaneously (applicable to ships other than passenger ships and ships carrying dangerous chemicals) is to comply with the technical requirements in CCS Rules for Natural Gas Fuelled Ships.

1.3.4.5 LSFO – the assignment of the class notation of low sulphur fuel oil is to comply with the technical requirements in CCS Guidelines for Use of Low Sulphur Fuel Oils in Ships.

1.3.4.6 AMPS – the assignment of the class notation of high-voltage shore connection system is to comply with the technical requirements in Chapter 19 of PART EIGHT in CCS Rules for Classification of Sea-going Steel Ships.

1.3.4.7 SPV – the assignment of the class notation of Solar photovoltaic system is to comply with the technical requirements in Chapter 2 in CCS Guidelines for Survey of Solar Photovoltaic Systems and Iron Phosphate Lithium Batteries.

1.3.5 The assignment methods of green ship class notations and energy efficiency class notations are to comply with the following principles.

(1) When a sea-going ship engaged on international voyages complies with the applicable requirements of one grade of green ship class notation corresponding to the green elements in three aspects of environmental protection, energy efficiency and working environment in Part I, the green ship class notation corresponding to such grade is to be assigned. If the ship complies respectively with the applicable requirements of different grades of green ship class notations corresponding to the green elements in three aspects of environmental protection, energy efficiency and working environment, the green ship class notation of the lowest grade is to be assigned.

(2) When a sea-going ship engaged on domestic voyages complies with the applicable requirements of one grade of green ship class notation corresponding to the green elements in the three aspects of environmental protection, energy efficiency and working environment in Part II, the green ship class notation for such grade is to be assigned. If the ship complies respectively with the applicable requirements of different grades of green ship class notations corresponding to the green elements in three aspects of environmental protection, energy efficiency and working environment, the green ship class notation of the lowest grade is to be assigned.

(3) For a ship to which the requirements of EEDI and SEEMP notations apply, the EEDI or SEEMP notation with which the ship complies is to be added after the green ship notation.

1.3.6 The assignment, maintenance, suspension, cancellation and reinstatement of Green Ship class notations are to be in accordance with the requirements of Section 9, Chapter 2, PART ONE of CCS Rules for Classification of Sea-going Steel Ships.

1.4 Requirements for plans and documents

1.4.1 In order to obtain the Green Ship notations or other notations specified in the Rules, the relevant plans and documents as specified in the Rules are to be submitted for approval or for reference. For easy retrieval, paragraphs of relevant documents with which the Green Ship notations of sea-going ships engaged on international voyages and sea-going ships engaged on domestic voyages as specified in the Rules are to comply are listed in Table 1.4.1.1 and Table 1.4.1.2 respectively.

Requirements for plans and documents
(for sea-going ships engaged on international voyages) **Table 1.4.1.1**

Green elements	Type of documents	Applicable paragraphs	Green Ship notations		
			Green ship I	Green ship II	Green ship III
Basic statutory requirements	Statutory certificates or evidential documents	3.2.2	√	√	√
Requirements of energy efficiency	Operational procedural documents	2.1.3	√	√	√
	Certificates or evidential documents	2.4.3		√	√
Requirements of environmental protection	Operational procedural documents	3.2.3	√	√	√
		3.3.9(1)		√	√
		3.4.8(3)			√
	Plans and documents	3.2.4	√	√	√
		3.3.9(2)		√	√
		3.4.8(1), (2)			√
Working environment	Plans and documents	4.1.3, 4.1.4	√	√	√

Requirements for plans and documents
(for sea-going ships engaged on domestic voyages) **Table 1.4.1.2**

Green elements	Type of documents	Applicable paragraphs	Green Ship notations		
			Green ship 1	Green ship 2	Green ship 3
Basic statutory requirements	Statutory certificates or evidential documents	6.2.2	√	√	√
Requirements of energy efficiency	Operational procedural documents	5.1.3	√	√	√
	Certificates or evidential documents	5.4.3		√	√
Requirements of environmental protection	Operational procedural documents	6.2.3	√	√	√
		6.3.8(1)		√	√
	Plans and documents	6.2.4	√	√	√
		6.3.8(2)		√	√
		6.4.7			√
Working environment	Plans and documents	7.1.3, 7.1.4	√	√	√

1.4.2 If any change, revision or deletion is made to the approved procedures, plans and documents as specified in relevant chapters of the Rules, the relevant details are to be re-submitted for approval.

1.5 Alteration and Repair

1.5.1 A ship having a CCS Green Ship class notation, which has undergone any alteration or repair of its construction or equipment in association with green elements, is to be subject to a survey, as appropriate, for confirming compliance with the technical requirements for the existing notation or the applied altered notation. In the case of a major conversion, attention is to be given to the relevant requirements of the flag State Administration.

Part I REQUIREMENTS FOR SHIPS ON INTERNATIONAL VOYAGES

CHAPTER 2 REQUIREMENTS FOR ENERGY EFFICIENCY

2.1 General Requirements

2.1.1 This Chapter specifies the relevant requirements of energy efficiency elements for Green Ship I, Green Ship II and Green Ship III class notations for sea-going ships engaged on international voyages.

2.1.2 The energy efficiency elements cover the energy efficiency in both the design and operation of ships. The associated class notations are as follows:

(1) Notation for the energy efficiency in ship design: EEDI (I), EEDI (II), EEDI (II+), EEDI (III);

(2) Notation for the energy efficiency in ship operation: SEEMP (I), SEEMP (II), SEEMP (III).

2.1.3 The following documents are to be submitted:

(1) Technical file of EEDI and calculation process and results of the Attained EEDI value of ships, or similar documents;

(2) Tank test plan or program (if applicable);

(3) Ship Energy Efficiency Management Plan (SEEMP).

2.2 Definitions and Application

2.2.1 For the purpose of this Chapter, the following definitions apply:

(1) *Bulk carrier* means a ship which is intended primarily to carry dry cargo in bulk, including ore carriers, as defined in SOLAS Regulation XII/1, but excluding combination carriers. For ships dedicated to carrying cement, woodchips, fly ash and sugar, they are of the ship type of bulk carrier.

(2) *Gas carrier* means a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas, but excluding LNG carriers.

(3) *Tanker* means an oil tanker as defined in MARPOL Annex I, regulation 1 or a chemical tanker or an NLS (noxious liquid substance) tanker as defined in MARPOL Annex II, regulation 1.

(4) *Container ship* means a ship designed exclusively for the carriage of containers in cargo spaces and on deck.

(5) *General cargo ship* means a ship with a multi-deck or single deck hull designed primarily for the carriage of general dry cargo. This definition excludes specialized dry cargo ships, which are not included in the calculation of reference lines for general cargo ships, namely livestock carriers, barge carriers, heavy load carriers, yacht carriers and nuclear fuel carriers.

(6) *Refrigerated cargo carrier* means a ship designed exclusively for the carriage of refrigerated cargoes in cargo spaces.

(7) *Combination carrier* means a ship designed to load 100% deadweight with both liquid and dry cargo (including ores) in bulk.

(8) *Passenger ship* means a ship which carries more than 12 passengers.

(9) *Ro-ro passenger ship* means a passenger ship with roll-roll spaces or special category spaces.

(10) *Ro-ro cargo ship (vehicle carrier)* means a multi-deck roll-roll cargo ship designed for the carriage of empty cars and trucks.

(11) *Ro-ro cargo ship* means a ship designed for the carriage of roll-roll cargo transportation units.

(12) *Offshore supply vessel* means:

- ① a ship primarily engaged in transporting stores, materials and equipment to and from an offshore platform; and
- ② a ship so designed that superstructures (accommodation spaces, navigation bridge, etc.) are located at its fore part and the exposed cargo deck for loading and unloading cargoes at sea at its aft part.

(13) *LNG carrier* means a cargo ship constructed or adapted and used for the carriage in bulk of liquefied natural gas (LNG).

(14) *Cruise passenger ship* means a passenger ship not having a cargo deck, designed exclusively for commercial transportation of passengers in overnight accommodations on a sea voyage.

(15) *Cargo ship having ice-breaking capability* means a cargo ship which is designed to break level ice independently with a speed of at least 2 knots when the level ice thickness is 1.0 m or more having ice bending strength of at least 500 kPa.

(16) *Conventional propulsion* means a method of propulsion where a main reciprocating internal combustion engine(s) is the prime mover and coupled to a propulsion shaft either directly or through a gear box.

(17) *Non-conventional propulsion* means a method of propulsion, other than conventional propulsion, including diesel-electric propulsion, turbine propulsion, and hybrid propulsion systems.

2.2.2 Paragraph 2.3 of this Chapter does not in principle apply to ship types having non-conventional propulsion as defined in (1) to (12) above.

2.2.3 For the purpose of cruise passenger ships as defined in (14) above, paragraph 2.3 of this Chapter only applies to cruise passenger ships having non-conventional propulsion systems.

2.2.4 Paragraph 2.3 of this Chapter does not apply to cargo ships having ice-breaking capability as defined in (15) above.

2.2.5 Except for paragraphs 2.2.2 to 2.2.4 of this Chapter, paragraph 2.3 does not apply to ship types other than that as defined in 2.2.1(1) to (14).

2.2.6 This Chapter does not apply to platforms (including FPSOs and FSUs) and drilling units and ships without mechanical propulsion systems, such as barges.

2.2.7 For ships to which paragraphs 2.3 to 2.4 of this Chapter do not apply, the assignment of Green Ship notations is not to be affected.

2.3 Energy Efficiency Requirements for Ship Design

2.3.1 For the purpose of energy efficiency in ship design, the Attained EEDI and Required EEDI are defined as follows:

(1) Attained EEDI is the EEDI value actually achieved by an individual ship.

(2) Required EEDI is the maximum value of the Attained EEDI permissible for a specific ship type and size.

2.3.2 The Reference line value (referred to as *RLV*) of a ship is to be determined by the following formula and the relevant parameters given in Table 2.3.2:

$$RLV = a \times b^{(-c)}$$

Parameters *a* and *c* for Determination of Reference Line Value (*RLV*) **Table 2.3.2**

Ship type	<i>a</i>	<i>b</i>	<i>c</i>
(1) Bulk carrier	961.79	DWT	0.477
(2) Gas carrier	1120.00	DWT	0.456
(3) Tanker	1218.80	DWT	0.488
(4) Container ship	174.22	DWT	0.201
(5) General cargo ship	107.48	DWT	0.216
(6) Refrigerated cargo carrier	227.01	DWT	0.244
(7) Combination carrier	1219.00	DWT	0.488
(8) Passenger ship	3542.3	GT	0.558
(9) Ro-ro passenger ship	752.16	GT	0.381
(10) Ro-ro cargo ship (vehicle carrier)	(DWT/GT) ^{-0.7} · 780.36 where DWT/GT < 0.3; 1812.63 where DWT/GT ≥ 0.3	DWT	0.471
(11) Ro-ro cargo ship	1405.15	DWT	0.498
(12) Offshore supply vessel	9992.2	DWT	0.619
(13) LNG carrier	2253.7	DWT	0.474
(14) Cruise passenger ship having non-conventional propulsion system	170.84	GT	0.214

2.3.3 The Attained *EEDI* value of a ship is to be less than or equal to the Required *EEDI* value corresponding to the ship, i.e.:

$$\text{Attained } EEDI \leq \text{Required } EEDI = (1 - X/100) \times RLV$$

where: *RLV* — reference line value of the ship;

X — reduction factor for determination of the Required *EEDI* for each energy efficiency design notation (see Table 2.3.3).

2.3.4 The Required *EEDI* value for energy efficiency design notations corresponding to each ship type is given in Table 2.3.3.

Energy Efficiency Requirements for Ship Design **Table 2.3.3**

Ship type	Applicable tonnage	Reduction factor X			
		EEDI (I)	EEDI (II)	EEDI (II+)	EEDI (III)
Bulk carrier	≥ 10000DWT	0	10	20	30
Gas carrier	≥ 2000DWT	0	10	20	30
Tanker	≥ 4000DWT	0	10	20	30
Container ship	≥ 10000DWT	0	10	20	30
General cargo ship	≥ 3000DWT	0	10	15	30
Refrigerated cargo carrier	≥ 3000DWT	0	10	15	30
Combination carrier	≥ 4000DWT	0	10	20	30
Passenger ship	≥ 1000GT	0	10	20	30
Ro-ro passenger ship	≥ 1000DWT	0	10	20	30
Ro-ro cargo ship (Vehicle carrier)	≥ 10000DWT	0	5	15	30
Ro-ro cargo ship	≥ 10000DWT	0	10	20	30
Offshore supply vessel	≥ 2000DWT	0	10	20	30
LNG carrier	≥ 10000DWT	0	10	20	30
Cruise passenger ship having non-conventional propulsion system	≥ 25000GT	0	10	20	30

2.3.5 Energy efficiency design notations corresponding to Green Ship notations are to be assigned as given in Table 2.3.5.

Table 2.3.5

Green Ship notation	Corresponding energy efficiency design notation
Green Ship I	EEDI (I)
Green Ship II*	EEDI (II)
	EEDI (II+)
Green Ship III	EEDI (III)

* Energy efficiency design notations corresponding to Green Ship II notations include two grades: EEDI (II) and EEDI (II+), of which EEDI (II+) represents better energy efficiency for ship design than EEDI (II).

2.3.6 If the design of a ship falls into more than one of the above ship types, the Required EEDI of the ship is to be the minimum required EEDI. However ships whose refrigerated cargo holds are dedicated for the carriage of juice are to be categorized as refrigerated cargo carriers.

2.3.7 The Attained EEDI is to be calculated in accordance with the relevant requirements of Appendix 1.

2.3.8 The Attained EEDI is to be verified in accordance with CCS *Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships*.

2.3.9 The installed propulsion power of ships is not to be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions. For bulk carriers, tankers, and combination carriers, the installed propulsion power of ships is to be determined in accordance with the relevant requirements of Appendix 3.

2.4 Energy Efficiency Requirements for Ship Operation

2.4.1 Energy efficiency operation notations corresponding to Green Ship notations are to be assigned as given in Table 2.4.1.

Table 2.4.1

Green Ship notation	Corresponding energy efficiency operation notation
Green Ship I	SEEMP (I)
Green Ship II	SEEMP (II)
Green Ship III	SEEMP (III)

2.4.2 Condition for assignment of SEEMP (I) notation

(1) The ship is to have a Ship Energy Efficiency Management Plan (SEEMP) developed in accordance with the relevant IMO guidelines (resolution MEPC.213(63)).

2.4.3 Condition for assignment of SEEMP (II) notation

(1) In addition to compliance of the ship with the requirement of paragraph 2.4.2 above, SEEMP is to be approved by CCS with a valid Ship Energy Efficiency Management Certificate (SEEMC).

(2) A ship energy efficiency management system is to be established by the Company or the Owner of the ship and certified by CCS with Company Energy Efficiency Management Certificate (CEEMC).

2.4.4 Condition for assignment of SEEMP (III) notation

(1) In addition to compliance of the ship with the requirement of paragraph 2.4.3 above, the ship is to have mature softwares capable of increasing ship energy efficiency, e.g. route optimization, optimal trim and hull biofouling softwares so as to monitor relevant parameters affecting ship energy efficiency and/or adjust energy efficiency measures in real time.

CHAPTER 3 REQUIREMENTS FOR ENVIRONMENTAL PROTECTION

3.1 General Requirements

3.1.1 This Chapter specifies the relevant requirements of environmental protection elements for Green Ship I, Green Ship II and Green Ship III class notations for sea-going ships engaged on international voyages.

3.1.2 The environmental protection elements cover the following:

- (1) prevention of pollution by oil;
- (2) prevention of pollution by noxious liquid substances;
- (3) prevention of pollution by harmful substances carried by sea in packaged form;
- (4) prevention of pollution by sewage and grey water;
- (5) prevention of pollution by garbage;
- (6) prevention of air pollution;
- (7) prevention of pollution by transfer of harmful aquatic organisms and pathogens via ballast water;
- (8) prevention of pollution by anti-fouling systems;
- (9) prevention of pollution by recycling of ships.

3.2 Technical Requirements for Green Ship I

3.2.1 Ships to be assigned the Green Ship I notation are to comply with the updated requirements of the following conventions and codes, as applicable:

- (1) MARPOL Annexes I to VI;
- (2) International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 and its guidelines (referred to as the BWM Convention);
- (3) International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001 (referred to as the AFS Convention);
- (4) Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 and its guidelines (referred to as the Hong Kong Convention).

3.2.2 Ships are to keep on board the following certificates or documents of compliance, as applicable:

- (1) Safety Management Certificate in accordance with the International Safety Management Code;
- (2) International Oil Pollution Prevention Certificate;
- (3) International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk or equivalent International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk;
- (4) International Sewage Pollution Prevention Certificate;

- (5) Documentation showing compliance with MARPOL Annex V;
- (6) International Air Pollution Prevention Certificate or Document of Compliance;
- (7) International Anti-Fouling System Certificate (or Document of Compliance) or Declaration on Anti-Fouling System;
- (8) International Ballast Water Management Certificate or Document of Compliance;
- (9) International Certificate on Inventory of Hazardous Materials or Document of Compliance.

3.2.3 The following operational procedural documents are to be approved and kept on board the ship:

- (1) Shipboard oil pollution emergency plan;
- (2) Ballast water management plan;
- (3) Garbage management plan;
- (4) Fuel oil change-over procedure, if applicable;
- (5) VOC management plan (for crude oil tankers);
- (6) Shipboard marine pollution emergency plan or shipboard marine pollution emergency plan for noxious liquid substances (for chemical tankers or NLS tankers);
- (7) STS operations plan (only for oil tankers conducting STS operations);
- (8) NO_x emission control/measurement procedures.

3.2.4 The following plans and information are to be submitted for approval:

- (1) Arrangement of cargo tanks and ballast tanks, including drawings showing cargo and ballast pipe systems, and overflow protection arrangement (for oil tankers, chemical tankers and NLS tankers);
- (2) Arrangement of fuel oil storage, settling and daily service tanks, including overflow protection arrangement;
- (3) Arrangement of fuel oil tanks and piping;
- (4) Capacity of bilge water holding tanks (if fitted), sludge tanks and slop tanks together with piping arrangement;
- (5) Arrangement of cargo oil and non-cargo-oil loading and unloading facilities, including connections, drip trays and drainage systems;
- (6) Arrangement of ballast water system, including details of ballast water treatment;
- (7) Arrangement and details of sewage system, including treatment equipment, capacity of holding tank and treatment capacity, etc.;
- (8) Sketch and details of incinerators and associated piping and monitoring equipment, if applicable;
- (9) Arrangement and details of exhaust gas cleaning system, if applicable;
- (10) Sketch and details of garbage storing or treatment system;

(11) Details of fire-extinguishing media used in fixed fire-extinguishing systems and portable fire extinguishers, including names, quantities, etc.;

(12) Arrangement and details of vapour emission collection system, if applicable;

(13) Any information related to additional environmental protection requirements of the flag State Administration or the Owner of the ship.

3.2.5 In addition, ships to be assigned the Green Ship I notation are to comply with the following requirements, as applicable:

(1) For ships with an aggregate oil fuel capacity of 600 m³ and above, the design of oil fuel tank is to comply with the requirements for oil fuel tank protection of regulation 12A of MARPOL Annex I.

(2) For diesel engines subject to NO_x emission control of MARPOL Annex VI, the NO_x emission is to comply with Tier II emission standard of MARPOL Annex VI.

(3) The use of ozone-depleting substances is prohibited in shipboard refrigerating systems (excluding stand-alone small refrigerators and air-conditioner for domestic purposes, etc.) and fire-extinguishing systems (including fixed fire-extinguishing systems and portable fire extinguishers), however hydrochlorofluorocarbons (HCFC) is allowed before 1 January 2020.

(4) Where the ship is provided with incinerators, they are to comply with the relevant requirements of resolution MEPC.76(40) and amendments related thereto.

(5) Where the ship is provided with sewage treatment plants, they are to comply with the requirements of resolution MEPC.159(55) or MEPC.227(64) and type approved by CCS or the flag State Administration.

(6) The ship is to be provided with a Ballast Water Management Plan approved by CCS or the Administration. This Ballast Water Management Plan is to be developed in accordance with the Guidelines for Ballast Water Management and Development of Ballast Water Management Plans adopted by IMO by resolution MEPC.127(53) or taking into account CCS Guidelines for Development of Ships' Ballast Water Management Plan (2006). The ship is also to be provided with a ballast water record book in the form given in the Ballast Water Management Convention.

3.3 Technical Requirements for Green Ship II

3.3.1 Ships to be assigned the Green Ship II notation are to comply with the following requirements of 3.3.2 to 3.3.9 in addition to the requirements of 3.2 above, as applicable.

3.3.2 The following requirements for the prevention of pollution by oil are to be met:

(1) The 15 ppm oil filtering equipment used for machinery space bilge water is to be provided with an alarm and an automatic stopping device so that alarm will be activated and the discharge overboard automatically stopped when the oil content of any effluent from oily bilge water in machinery spaces exceeds 15 ppm.

(2) The sludge tank discharge piping and bilge-water piping are not to be connected except that they may be connected to a common piping leading to the standard discharge connection.

(3) Deck connections of fueling stations of fuel oil, lubricating oil and other oils (e.g. hydraulic oil) are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(4) Vent piping and overflow piping of fuel oil tanks, lubricating oil tanks, hydraulic oil tanks and other tanks are to be provided with drip trays capable of collecting spilled oil. Means are to be provided to clean the spilled oil in order to prevent overboard discharge.

(5) The fueling tank of fuel oil, lubricating oil, hydraulic oil and other oils is to be provided with high level alarm to prevent overflow. Where the internal tank is so designed that in case of overflow, it will not lead to environmental pollution, the high level alarm may not be fitted.

(6) Cargo oil tanks are to be provided with high level alarm or overflow protection measures.

(7) Both sides of the main deck within the cargo area of oil tanker are to be fitted with continuous coaming from the fore end to the aft end of cargo area, in order to prevent the discharge into the sea of spilled oil during cargo operations on deck. The height of coaming is to be determined in accordance with the size, type, arch, trim and stability of the ship. The main deck within cargo areas is also to be provided with a drainage system of spilled oil capable of draining such oil into a deck collecting tank or slop tank.

(8) Connections of the cargo oil manifold on an oil tanker are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(9) For oil tankers of 600 tonnes deadweight and above but less than 5,000 tonnes deadweight, cargo oil tanks are to be protected by wing and double bottom tanks having a minimum protection distance required as follows:

① for wing tanks, the minimum width w is no less than specified below:

$$w = 0.4 + \frac{2.4DWT}{20000} (\text{m}), \text{ with a minimum value of } w = 0.76 \text{ m}$$

where DWT is deadweight of the ship;

② for double bottom tanks, the minimum height h is no less than specified below:

$$h = B/15, \text{ with a minimum value of } h = 0.76 \text{ m}$$

where B is moulded breadth of the ship.

3.3.3 The following requirements for the prevention of pollution by noxious liquid substances are to be met:

(1) Both sides of the main deck within the cargo area of chemical tanker are to be fitted with continuous coaming from the fore end to the aft end of cargo area, in order to prevent the discharge into the sea of leakage during cargo operations on deck. The height of coaming is to be determined in accordance with the size, type, arch, trim and stability of the ship. The main deck within cargo areas is also to be provided with a drainage system capable of collecting leakages during cargo operations and draining cargo leakages into a deck collecting tank or slop tank.

(2) Connections of the cargo manifold of chemical tankers are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(3) Cargo tanks of chemical tankers are to be provided with restricted gauging system, unless a closed gauging system is required due to the cargo categories.

3.3.4 The following requirements for the prevention of pollution by sewage are to be met:

(1) Any direct discharge into the sea of untreated sewage is prohibited. However sewage generated by single sanitary facility arranged in the working space which is far away from the accommodation space may be exempted from such requirement, provided that the discharge complies with the provisions of the flag State Administration.

(2) The ship is to be provided with a sewage treatment plant. Such plant is to be subject to type approval by CCS or the flag State Administration in accordance with resolution MEPC.159(55) or MEPC.227(64).

(3) A ship navigating in an area (e.g. specially protected area or port) where the discharge of sewage and grey water is prohibited is to be provided with holding tank(s) of sufficient capacity for the retention of all sewage and grey water generated by the ship in such area. The holding tank(s) for the retention of sewage and grey water may be independent from each other or may be combined. For the latter case, the discharge of the mixture of sewage and grey water is to be in accordance with the discharge requirements for sewage.

(4) The holding tank of sewage and grey water is to be provided with high level alarm and a means to indicate visually the amount of its contents.

(5) The ship is to keep on board a sewage/grey water management plan, which is to be approved by CCS. Such plan is to provide guidance to the crew on management of sewage treatment and discharge of sewage and grey water. The sewage/grey water management plan is at least to include the following:

- ① ship name and identification number;
- ② sketch of sewage treatment system, holding tanks of sewage and grey water and all relevant piping arrangement;
- ③ management and operational procedures of sewage and grey water;
- ④ means and method of recording all sewage discharges to shore reception facilities or to the sea. The recorded data is to include the date, place and quantity of such discharges; the speed of the ship and its nearest distance to shore are also to be recorded for discharges to the sea. For discharges from the sewage treatment system, the time of activating and stopping the system is to be recorded in lieu of the quantity discharged. The discharge of untreated sewage in emergency is also to be recorded;
- ⑤ the vent piping of sewage treatment system is to be independent from other vent piping.

3.3.5 The following requirements for the prevention of pollution by garbage are to be met:

(1) The ship is to keep on board a garbage management plan and complies with the requirements of resolution MEPC.220(63).

(2) The ship is to be provided with equipment and arrangement for categorization, reduction and retention of garbage.

(3) Garbage is to be grouped into minimum four categories for the purpose of its recycling and retention as follows:

- ① waste that cannot be recycled;
- ② waste that can be recycled;
- ③ waste that might cause harm to the ship or crew (e.g. oily rag, light bubble, acid, chemical, battery, etc.);
- ④ food waste.

3.3.6 The following requirements for ballast water management are to be met:

(1) The requirements of the Guidelines for Ballast Water Exchange Design and Construction Standards (G11) adopted by resolution MEPC.149(55) and the Guidelines for Design and Construction to Facilitate Sediment Control on Ship (G12) adopted by resolution MEPC.150(55) are to be taken into account in the design and construction of ships, so far as is practicable.

(2) Where the flow-through method is to be used for ballast water exchange, means are to be provided to avoid water overflowing directly onto decks.

(3) The ballast water management system fitted on ships for compliance with the D-2 standard is to have a type approval certificate issued by CCS or the Administration in accordance with resolution MEPC.174(58); or hold a copy of the Document of Compliance issued by the Administration in accordance with the Guidelines for Approval and Oversight of Prototype Ballast Water Treatment Technology Programmes (G10) adopted by resolution MEPC.140(54).

3.3.7 The following requirements for the prevention of air pollution are to be met:

(1) Emission of sulphur oxides (SO_x) and particulate matters (PM):

- ① The sulphur content of any fuel oil used on board ships is not to exceed 3.0% m/m.
- ② While ships are within SO_x emission control areas or in designated ports, the sulphur content of any fuel oil used on board ships is not to exceed 0.10% m/m.
- ③ While ships are in areas with stricter requirements for sulphur content of fuel oil, those stricter local requirements are to be complied with.
- ④ As an alternative to ①, ② and ③ above, an exhaust gas cleaning system may be used to control SO_x emissions at an equivalent level. The exhaust gas cleaning system is to be approved by CCS or the flag State Administration in accordance with the 2009 Guidelines for Exhaust Gas Cleaning Systems adopted by resolution MEPC.184(59).
- ⑤ The requirements of this paragraph for the sulphur content are to apply to the fuel oil used in diesel engines, oil-burning boilers and incinerators on board ships, except for sludge (oil residue) burning in incinerators.
- ⑥ The ship is to keep on board a fuel oil management plan, which is at least to include the following:
 - 1) ship name and identification number;
 - 2) description of demand for fuel oil quality;
 - 3) sulphur content of fuel oil used on board ships;
 - 4) change-over procedure and steps for fuel oils with different sulphur content;
 - 5) diagram of fuel oil system including fuel oil change-over detail;
 - 6) measures to be taken when a ship is at a fueling port or station where the fuel oil with required sulphur content is unavailable.

(2) Refrigerating systems:

- ① The requirements of this paragraph apply to refrigerated cargo installations, central air conditioning systems and centralized refrigeration systems of all ships. These requirements do not apply to stand-alone air conditioners and refrigerators for domestic purposes on board ships.
- ② Refrigerating systems are to be provided with suitable maintenance isolation means to prevent significant leaks of refrigerants during maintenance or repairs. However, unavoidable minimal release of refrigerants associated with refrigerant recovery is acceptable.
- ③ In order to recover refrigerants, compressors are to be capable of evacuating refrigerants within the system into a liquid receiver. Additionally, recovery units are to be capable of evacuating a system either into the existing liquid receiver or into suitable reservoirs dedicated for this purpose. The capacity of the liquid receiver or reservoirs is to be sufficient to contain all refrigerants of the largest refrigerating unit that can be isolated.

- ④ The annual refrigerant leakage rate of each system is to be less than 10% of its total charge. A leakage detection system is to be provided to monitor continuously the spaces into which the refrigerant could leak. An alarm is to be activated to give warning in a permanently manned location when the concentration of refrigerant in the space exceeds a predetermined limit (e.g. 25 ppm for ammonia). Remedial measures are to be implemented when any leak is detected.
- ⑤ Where different refrigerants are in use, means are to be provided to prevent them from being mixed.
- ⑥ The ship is to keep on board a refrigerant management plan mentioned in 3.3.9(1)②, which is at least to include the following:
 - 1) ship name and identification number;
 - 2) list of all refrigerating systems as well as sketch and component description (including leakage detection system);
 - 3) means adopted to manage and control consumption, leakage, evacuation and disposal of refrigerants together with the remedial measures in the event of any leakage as stated in ④ above;
 - 4) means and method of recording replacement, leakage, recovery, charging and disposal of refrigerants, including at least date, system type, refrigerant type, initial system charge and refrigerant level, charging amount, recovery amount, leakage type and remedial measures.
- ⑦ The ship is to establish and maintain a list of refrigerants on board and a record book required by ⑥4) above, which are to be kept throughout the life time of the system. The record of each item is to be kept on board for at least 3 years and available for check by the surveyor.

3.3.8 The following requirements for the control of ship's hazardous materials are to be met:

(1) Ships are to meet the relevant requirements for the class notation Green passport for recycling (GPR or GPR (EU)) in CCS Rules for Classification of Sea-going Steel Ships.

3.3.9 Additional requirements for operational procedures and plans and information:

(1) In addition, the following operational procedures are to be submitted for approval:

- ① sewage/grey water management plan;
- ② refrigerant management plan;
- ③ fuel oil management plan (in lieu of fuel oil change-over procedure mentioned in 3.2.3(4) above).

(2) In addition, the following plans and information are to be submitted for approval:

- ① general arrangement of the refrigerating system, capable of indicating the position and number of refrigerant leakage detectors.

3.4 Technical Requirements for Green Ship III

3.4.1 Ships to be assigned the Green Ship III notation are to comply with the following requirements of 3.4.2 to 3.4.7 in addition to the requirements of 3.3 above, as applicable.

3.4.2 The following requirements for the prevention of pollution by oil are to be met:

(1) The oil content of any oily bilge effluent from the engine room is not to exceed 5 ppm. The alarm device of bilge water is to be set at 5 ppm, which is to be calibrated at least once every 5 years. The calibration certificate or the complete calibration record is to be kept on board the ship and readily available for inspection.

(2) For management and discharge arrangement of engine-room bilge water, an integrated bilge water treatment system (IBTS) complying at least with IMO MEPC.1/Circ.676 and MEPC.1/Circ.642 as modified by MEPC.1/Circ.760 is to be used. A Statement on Installation of Integrated Bilge Water Treatment System issued by CCS is to be kept on board.

(3) For drip trays mentioned in 3.3.2(3) of this Chapter, the minimum capacity is to comply with the following requirements:

- ① for ships greater than 1600 GT: 0.16 m³;
- ② for ships between 300 GT and 1600 GT: 0.08 m³.

(4) For drip trays mentioned in 3.3.2(4) of this Chapter, the minimum capacity is to comply with the following requirements:

- ① for ships greater than 1600 GT: 0.08 m³;
- ② for ships between 300 GT and 1600 GT: 0.04 m³.

(5) For continuous coaming fitted on the deck within cargo area mentioned in 3.3.2(7) of this Chapter, the following height requirements are at least to be complied with:

- ① for oil tankers of 100000 DWT and above: the transverse coaming at the fore end is 0.25 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height;
- ② for oil tankers of less than 100000 DWT: the transverse coaming at the fore end is 0.10 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height.

(6) For drip trays mentioned in 3.3.2(8) of this Chapter, the arrangement and minimum size are to comply with the following requirements:

- ① length: to include the fore and the aft ends of manifolds;
- ② width: at least 1.8 m, and approximately 1.2 m beyond the end of flange of manifolds;
- ③ depth: at least 0.3 m.

(7) All oil fuel tanks (except for overflow tanks) with an individual capacity greater than 30 m³ are to be arranged to be protected by wing tanks and double bottom tanks. However the aggregate capacity of oil fuel tanks with an individual capacity not greater than 30 m³ is not to be greater than 600 m³. The requirements for protective positions of wing tanks and double bottom tanks are as follows:

- ① Oil fuel tanks are to be located above the moulded line of the bottom shell plating nowhere less than the distance h as specified below:

$$h = B/20 \text{ m or} \\ h = 2.0 \text{ m, whichever is the lesser.}$$

The minimum value of $h = 0.76 \text{ m}$.

In the turn of the bilge area and at locations without a clearly defined turn of the bilge, the oil fuel tank boundary line is to run parallel to the line of the midship flat bottom as shown in Figure 1.

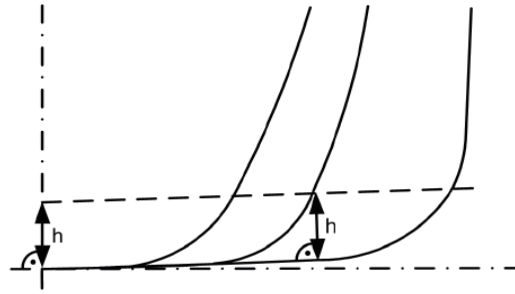


Figure 1

- ② For ships having an aggregate oil fuel capacity of less than 5,000 m³, oil fuel tanks are to be located inboard of the moulded line of the side shell plating, nowhere less than the distance W which, as shown in Figure 2, is measured at any cross-section at right angles to the side shell, as specified below:

$$W = 0.4 + 2.4C/20000 \text{ m}$$

where: C – Tank capacity, in m³.

The minimum value of $W = 1.0$ m; however, for individual tanks with an oil fuel capacity of less than 500 m³ the minimum value is 0.76 m.

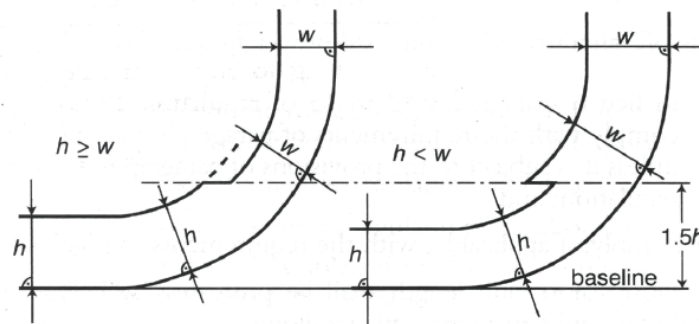


Figure 2

- ③ For ships having an aggregate oil fuel capacity of 5,000 m³ and over, oil fuel tanks are to be located inboard of the moulded line of the side shell plating, nowhere less than the distance W which, as shown in Figure 2, is measured at any cross-section at right angles to the side shell, as specified below:

$$W = 0.5 + C/20000 \text{ m or}$$

$$W = 2.0 \text{ m, whichever is the lesser.}$$

The minimum value of $W = 1.0$ m.

where: C – Tank capacity, in m³.

- ④ Lines of oil fuel piping located at a distance from the ship's bottom of less than h , as defined in ① above, or from the ship's side less than W , as defined in ② and ③, are to be fitted with valves or similar closing devices within or immediately adjacent to the oil fuel tank. These valves are to be capable of being brought into operation from a readily accessible enclosed space the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The valves are to close in case of remote control system failure and are to be kept closed at sea at any time when the tank contains oil fuel except that they may be opened during oil fuel transfer operations.

- ⑤ Suction wells in oil fuel tanks may protrude into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and the bottom shell plating is not less than $0.5h$.

(8) Cargo oil tanks of any oil tanker are to be arranged to be protected by double bottoms and double side skins. For oil tankers of less than 600 tonnes deadweight, cargo oil tanks are to be protected by wing tanks and double bottom tanks having a minimum protection distance required by 3.3.2(9) above.

3.4.3 The following requirements for the prevention of pollution by noxious liquid substances are to be met:

(1) The structural arrangement of chemical tankers is at least to comply with the requirements for double side skins and double bottoms of type 2 chemical tankers in Chapter 2 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, unless type 1 chemical tankers are required due to the cargo categories.

(2) The maximum allowable quantity of cargo residue remaining in the cargo tank of chemical tankers is not to exceed 50 L.

(3) Cargo tanks of chemical tankers are to be provided with a closed gauging system and overflow alarm device independent from the closed gauging system.

(4) For continuous coaming fitted on the deck within cargo area mentioned in 3.3.3(1) of this Chapter, the following height requirements are at least to be complied with:

- ① for chemical tankers of 100000 DWT and above: the transverse coaming at the fore end is 0.25 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height;
- ② for chemical tankers of less than 100000 DWT: the transverse coaming at the fore end is 0.10 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height.

(5) For drip trays mentioned in 3.3.3(2) of this Chapter, the arrangement and minimum size are to comply with the following requirements:

- ① length: to include the fore and the aft ends of manifolds;
- ② width: at least 1.8 m, and approximately 1.2 m beyond the end of flange of manifolds;
- ③ depth: at least 0.3 m.

3.4.4 The following requirements for the prevention of pollution by sewage and grey water are to be met:

(1) The discharge into the sea of all untreated grey water generated by the ship within 12 nautical miles from the nearest land is prohibited. Where the discharge is necessary, grey water is to be discharged into the sea after going through a sewage treatment system. The sewage treatment system is to comply with the requirements of 3.3.4(2) of this Chapter.

(2) The holding tanks of sewage and grey water provided on ship are to be of sufficient capacity for the retention of all sewage and grey water generated by the ship in an area where discharge is prohibited. The capacity of holding tanks is to be comprehensively considered based on ship type, number of persons certified to carry and service area.

3.4.5 The following requirements for the prevention of pollution by garbage are to be met:

(1) The disposal into the sea of food wastes is permitted when they have been passed through a comminuter or grinder. Such comminuted or ground food wastes are to be capable of passing through a screen with openings no greater than 25 mm.

3.4.6 The following requirements for ballast water management are to be met:

(1) The ship is to be provided with a ballast water management system which is type approved by CCS or the Administration in accordance with resolution MEPC.174(58).

(2) The ship is to keep on board a biofouling management plan complying with resolution MEPC.207(62), which may be combined with the ballast water management plan.

3.4.7 The following requirements for the prevention of air pollution are to be met:

(1) The sulphur content of any fuel oil used on board ships is not to exceed 0.5% m/m. While ships are within SO_x emission control areas or in designated ports, the sulphur content of any fuel oil used on board ships is not to exceed 0.1% m/m. Alternatively, an exhaust gas cleaning system may be used to control SO_x emissions at an equivalent level. The exhaust gas cleaning system is to be approved by CCS or the flag State Administration in accordance with the 2009 Guidelines for Exhaust Gas Cleaning Systems adopted by resolution MEPC.184(59)^①.

(2) While the ship is in port and it is feasible, the shore supply may be used as an alternative measure to lower sulphur content of (1) above.

(3) The use of any refrigerant containing ozone-depleting substances, including hydrochlorofluorocarbons (HCFCs), is prohibited for all ships.

(4) For refrigerated cargo installations, central air conditioning systems and centralized refrigeration systems of ships, the ozone depletion potential (ODP) is to be 0 and the global warming potential (GWP) less than 2000. Both ODP and GWP are to be determined according to the definitions given in the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987.

(5) The use of halons or halocarbons as fire-fighting media is to be prohibited for fixed fire-extinguishing systems and portable fire extinguishers. Natural substances are to be used as fire-fighting media for fire-extinguishing systems insofar as practicable, e.g., argon, nitrogen, water mist, carbon dioxide. Any other alternative product used is to have a GWP of less than 2000.

3.4.8 In addition, the following operational procedures or plans and information are to be submitted for approval:

(1) grey water treatment system with detailed effluent criteria;

(2) calculation of capacity of sewage/grey water holding tanks and relevant supporting documents (for information);

(3) biofouling management plan.

① Refer to the 2009 Guidelines for Exhaust Gas Cleaning Systems adopted by IMO by resolution MEPC.184(59).

CHAPTER 4 REQUIREMENTS FOR WORKING ENVIRONMENT

4.1 General Requirements

4.1.1 This Chapter specifies the relevant requirements of working environment elements for Green Ship I, Green Ship II and Green Ship III class notations for sea-going ships engaged on international voyages.

4.1.2 The working environment elements cover the grades of engine room automation and the levels of vibration and noise.

4.1.3 The following information is to be submitted:

(1) measurement procedures of vibration and noise, including arrangement of measurement points, loading condition, working condition of machinery, weather condition and measurement equipment;

(2) measurement report of vibration and noise, including measurement result of vibration and noise.

4.1.4 The general arrangement indicating the positions of measurement points of vibration and noise is to be submitted for information.

4.2 Technical Requirements for Green Ship I

4.2.1 Ships to be assigned the Green Ship I notation are to comply with the following requirements:

(1) The requirements relating to centralized control in machinery spaces (MCC) notation or remote control from bridge (BRC) notation in Chapter 4, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships are to be met.

(2) Shipborne noise is to meet the relevant requirements of IMO resolution MSC.337(91) on Code on Noise Levels on Board Ships.

(3) Shipborne vibration is to meet the relevant requirements of ISO 6954 (2000) Mechanical vibration – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.

(4) Accommodation of crew is to meet the relevant requirements of CCS Guidelines for Implementation of Inspections of Maritime Labour Conditions.

4.3 Technical Requirements for Green Ship II and Green Ship III

4.3.1 Ships to be assigned the Green Ship II and Green Ship III notations are to comply with the following requirements in addition to the requirements of 4.2.1(2) to (4) above.

(1) The requirements relating to periodically unattended machinery spaces for (AUT-0) notation in Chapter 3, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships are to be met.

Part II REQUIREMENTS FOR SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

CHAPTER 5 REQUIREMENTS FOR ENERGY EFFICIENCY

5.1 General Requirements

5.1.1 This Chapter specifies the relevant requirements of energy efficiency elements for Green Ship 1, Green Ship 2 and Green Ship 3 class notations for sea-going ships engaged on domestic voyages.

5.1.2 The energy efficiency elements cover the energy efficiency in both the design and operation of ships. The associated class notations are as follows:

- (1) Notation for the energy efficiency in ship design: EEDI(1), EEDI(2), EEDI(3);
- (2) Notation for the energy efficiency in ship operation: SEEMP(1), SEEMP(2), SEEMP(3).

5.1.3 The following documents are to be submitted:

- (1) Technical file of Energy Efficiency Design Index (EEDI) and calculation process of the Attained EEDI together with calculation results, or similar documents;
- (2) Tank test plan or program, if applicable;
- (3) Ship Energy Efficiency Management Plan (SEEMP).

5.2 Definitions and Application

5.2.1 For the purpose of this Chapter, the following definitions apply:

- (1) *Bulk carrier* means a ship which is constructed generally with single deck, top-side tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers.
- (2) *Tanker* means an oil tanker as defined in Chapter 2, or a chemical tanker or an NLS tanker as defined in Chapter 3 of PART FIVE of Technical Regulations for the Statutory Surveys of Sea-going Ships Engaged on Non-international Voyages
- (3) *Container ship* means a ship designed exclusively for the carriage of containers in cargo spaces and on deck.
- (4) *LNG carrier* means a cargo ship constructed or adapted and used for the carriage in bulk of liquefied natural gas.
- (5) *Conventional propulsion* means a type of propulsion where the main engine is the prime mover and it is connected to the thrust shaft directly or by means of the gearbox.
- (6) *Non-conventional propulsion* means a type of propulsion not belonging to the conventional propulsion, including diesel-electric propulsion, turbine propulsion or hybrid propulsion.

5.2.2 Paragraph 5.3 of this Chapter applies to sea-going ships engaged on domestic voyages of 1500 tonnes deadweight and above which fall within the ship types as defined in 5.2.1(1) to (3) above, as well as sea-going ships engaged on domestic voyages of 5000 tonnes deadweight and above which fall within the ship types as defined in 5.2.1(4) above.

5.2.3 Paragraph 5.3 of this Chapter does not apply to ships with non-conventional propulsion systems which fall within the ship types as defined in 5.2.1(1) to (3) above, however it applies to LNG carriers with diesel-electric propulsion and turbine propulsion systems.

5.2.4 Paragraph 5.4 of this Chapter does not apply to platforms (including FPSOs and FSUs) and drilling units, as well as ships without mechanical propulsion systems, such as barges.

5.2.5 For ships to which 5.3 and 5.4 of this Chapter are not applicable, the assignment of Green Ship notations is not affected.

5.3 Energy Efficiency Requirements for Ship Design

5.3.1 The Attained EEDI value of a ship is to be less than or equal to the Required EEDI value corresponding to the ship, i.e.:

$$\text{Attained EEDI} \leq \text{Required EEDI}$$

5.3.2 The Required EEDI values corresponding to class notations EEDI(1), EEDI(2) and EEDI(3) are to be determined according to the following formula and relevant parameters given in Table 5.3.2:

$$\text{Required EEDI} = a \times \text{Capacity}^{(-c)}$$

where: Capacity is as defined in 3.3 of Appendix 1-2 of the Rules.

Parameters a and c for Determination of Required EEDI

Table 5.3.2

EEDI notation	Bulk carrier		Tanker		Container ship		LNG carrier	
	a	c	a	c	a	c	a	c
EEDI (1)	749.9	0.4673	609.3	0.4337	1107.0	0.4406	2253.7	0.474
EEDI (2)	712.4	0.4673	548.3	0.4337	940.9	0.4406	2028.33	0.474
EEDI (3)	674.9	0.4673	487.4	0.4337	719.5	0.4406	1802.96	0.474

5.3.3 Energy efficiency design notations corresponding to Green Ship notations are to be assigned as given in Table 5.3.3.

Table 5.3.3

Green Ship notation	Corresponding energy efficiency design notation
Green Ship 1	EEDI (1)
Green Ship 2	EEDI (2)
Green Ship 3	EEDI (3)

5.3.4 If the design of a ship falls into more than one of the above ship types, the Required EEDI of the ship is to be the minimum required EEDI.

5.3.5 The Attained EEDI for ships engaged on domestic voyages is to be calculated in accordance with the relevant requirements of Appendix 1-2 of the Rules.

5.3.6 The Attained EEDI is to be verified in accordance with CCS Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships.

5.3.7 In design of a ship, it is to be considered that while fulfilling the corresponding Required EEDI, the ship still has sufficient installed power to maintain the manoeuvrability in adverse conditions.

5.4 Energy Efficiency Requirements for Ship Operation

5.4.1 Energy efficiency operation notations corresponding to Green Ship notations are to be assigned as given in Table 5.4.1.

Table 5.4.1

Green Ship notation	Corresponding energy efficiency operation notation
Green Ship 1	SEEMP(1)
Green Ship 2	SEEMP(2)
Green Ship 3	SEEMP(3)

5.4.2 Condition for assignment of SEEMP (1) notation

(1) The ship is to have a Ship Energy Efficiency Management Plan (SEEMP) developed in accordance with the relevant IMO guidelines (resolution MEPC.213(63)).

5.4.3 Condition for assignment of SEEMP (2) notation

(1) In addition to compliance of the ship with the requirement of paragraph 5.4.2 above, SEEMP is to be approved by CCS with a valid Ship Energy Efficiency Management Certificate (SEEMC).

(2) A ship energy efficiency management system is to be established by the Company or the Owner of the ship and certified by CCS with Company Energy Efficiency Management Certificate (CEEMC).

5.4.4 Condition for assignment of SEEMP (3) notation

(1) In addition to compliance of the ship with the requirement of paragraph 5.4.3 above, the ship is to have mature softwares capable of increasing ship energy efficiency, e.g. route optimization, optimal trim and hull biofouling softwares so as to monitor relevant parameters affecting ship energy efficiency and/or adjust energy efficiency measures in real time.

CHAPTER 6 REQUIREMENTS FOR ENVIRONMENTAL PROTECTION

6.1 General Requirements

6.1.1 This Chapter specifies the relevant requirements of environmental protection elements for Green Ship 1, Green Ship 2 and Green Ship 3 class notations for sea-going ships engaged on domestic voyages.

6.1.2 The environmental protection elements cover the following:

- (1) prevention of pollution by oil;
- (2) prevention of pollution by noxious liquid substances;
- (3) prevention of pollution by harmful substances carried by sea in packaged form;
- (4) prevention of pollution by sewage and grey water;
- (5) prevention of pollution by garbage;
- (6) prevention of air pollution;
- (7) prevention of pollution by anti-fouling systems;
- (8) prevention of pollution by recycling of ships.

6.2 Technical Requirements for Green Ship 1

6.2.1 Ships to be assigned the Green Ship 1 notation are to comply with the updated requirements of the following document, as applicable:

- (1) Domestic Regulations, PART FIVE.

6.2.2 Ships are to keep on board the following certificates or documents of compliance, as applicable:

- (1) Safety Management Certificate in accordance with Safety Management Code;
- (2) Oil Pollution Prevention Certificate;
- (3) Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk or equivalent Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk;
- (4) Sewage Pollution Prevention Certificate;
- (5) Documentation showing compliance with Chapter 6 of PART FIVE of the Domestic Regulations;
- (6) Air Pollution Prevention Certificate or Document of Compliance;

(7) Evidence showing compliance with the relevant requirements for anti-fouling system.

6.2.3 The following operational procedural documents are to be approved and kept on board the ship:

- (1) Shipboard oil pollution emergency plan;
- (2) Garbage management plan;
- (3) Fuel oil change-over procedure, if applicable;
- (4) Shipboard marine pollution emergency plan or shipboard marine pollution emergency plan for noxious liquid substances (for chemical tankers or NLS tankers);
- (5) STS operations plan (only for oil tankers conducting STS operations);
- (6) NO_x emission control/measurement procedures.

6.2.4 The following plans and information are to be submitted for approval:

- (1) Arrangement of cargo tanks and ballast tanks, including drawings showing cargo and ballast pipe systems, and overflow protection arrangement (for oil tankers, chemical tankers and NLS tankers);
- (2) Arrangement of fuel oil storage, settling and daily service tanks, including overflow protection arrangement;
- (3) Arrangement of fuel oil tanks and piping;
- (4) Capacity of bilge water holding tanks (if fitted), sludge tanks and slop tanks together with piping arrangement;
- (5) Arrangement of cargo oil and non-cargo-oil loading and unloading facilities, including connections, drip trays and drainage systems;
- (6) Arrangement and details of sewage system, including treatment equipment, capacity of holding tank and treatment capacity etc.;
- (7) Sketch and details of incinerators and associated piping and monitoring equipment, if applicable;
- (8) Arrangement and details of exhaust gas cleaning system, if applicable;
- (9) Sketch and details of garbage storing or treatment system;
- (10) Details of fire-extinguishing media used in fixed fire-extinguishing systems and portable fire extinguishers, including names, quantities, etc.;
- (11) Any information related to additional environmental protection requirements of the local Administration or the Owner of the ship.

6.2.5 In addition, ships to be assigned the Green Ship 1 notation are to comply with the following requirements, as applicable:

- (1) The design of oil fuel tank is to comply with the requirements for oil fuel tank protection in 2.4 of Chapter 2, PART FIVE of the Domestic Regulations.

(2) For diesel engines with a power output of more than 130 kW (excluding emergency engines, or engines fitted on lifeboats, or engines of apparatuses or devices used only in emergencies), nitrogen oxide (NO_x) emissions (calculated according to the total weighted NO_2 emissions) are at least to comply with the following limit values:

- ① 14.4 g/kWh for $n < 130$ r/min;
- ② $44.0 \times n^{(-0.23)}$ g/kWh for $130 \text{ r/min} \leq n < 2000 \text{ r/min}$;
- ③ 7.7 g/kWh for $n \geq 2000 \text{ r/min}$.

where n is rated engine speed (crankshaft revolutions per minute).

The test procedures and measurement methods are to comply with the requirements of CCS Guidelines for Testing and Survey of Emission of Nitrogen Oxides from Marine Diesel Engines.

(3) The sulphur content of any fuel oil used on board ships is not to exceed 3.5% m/m. While ships are in areas with stricter requirements for sulphur content of fuel oil, those stricter local requirements are to be complied with. As an alternative to low-sulphur oil, an exhaust gas cleaning system may be used to control SO_x emissions at an equivalent level. The exhaust gas cleaning system is to comply with CCS Guidelines for Testing and Survey of Exhaust Gas Cleaning Systems.

(4) The use of ozone-depleting substances is prohibited in shipboard refrigerating systems (excluding stand-alone small refrigerators and air-conditioner for domestic purposes, etc.) and fire-extinguishing systems (including fixed fire-extinguishing systems and portable fire extinguishers), however hydrochlorofluorocarbons (HCFC) is allowed before 1 January 2020.

(5) Where the ship is provided with incinerators, they are to comply with the relevant requirements of resolution MEPC.76(40) and amendments related thereto and to be type approved by CCS.

(6) Where the ship is provided with sewage treatment plants, they are to comply with the requirements of resolution MEPC.159(55) and to be type approved by CCS.

6.3 Technical Requirements for Green Ship 2

6.3.1 Ships to be assigned the Green Ship 2 notation are to comply with the following requirements of 6.3.2 to 6.3.8 in addition to the requirements of 6.2 above, as applicable.

6.3.2 The following requirements for the prevention of pollution by oil are to be met:

(1) The 15 ppm oil filtering equipment used for machinery space bilge water is to be provided with an alarm and an automatic stopping device so that alarm will be activated and the discharge overboard automatically stopped when the oil content of any effluent from oily bilge water in machinery spaces exceeds 15 ppm.

(2) The sludge tank discharge piping and bilge-water piping are not to be connected except that they may be connected to a common piping leading to the standard discharge connection.

(3) Deck connections of fueling stations of fuel oil, lubricating oil and other oils (e.g. hydraulic oil) are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(4) Vent piping and overflow piping of fuel oil tanks, lubricating oil tanks, hydraulic oil tanks and other tanks are to be provided with drip trays capable of collecting spilled oil. Means are to be provided to clean the spilled oil in order to prevent overboard discharge.

(5) The fueling tank of fuel oil, lubricating oil, hydraulic oil and other oils is to be provided with high level alarm to prevent overflow. Where the internal tank is so designed that in case of overflow, it will not lead to environmental pollution, the high level alarm may not be fitted.

(6) Cargo oil tanks are to be provided with high level alarm or overflow protection measures.

(7) Both sides of the main deck within the cargo area of oil tanker are to be fitted with continuous coaming from the fore end to the aft end of cargo area, in order to prevent the discharge into the sea of spilled oil during cargo operations on deck. The height of coaming is to be determined in accordance with the size, type, arch, trim and stability of the ship. The main deck within cargo areas is also to be provided with a drainage system of spilled oil capable of draining such oil into a deck collecting tank or slop tank.

(8) Connections of the cargo oil manifold on an oil tanker are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(9) For oil tankers of 600 tonnes deadweight and above but less than 5,000 tonnes deadweight, cargo oil tanks are to be protected by wing and double bottom tanks having a minimum protection distance as required by 3.6.4(3) of Chapter 2, PART FIVE of the Domestic Regulations.

6.3.3 The following requirements for the prevention of pollution by noxious liquid substances are to be met:

(1) Both sides of the main deck within the cargo area of chemical tanker are to be fitted with continuous coaming from the fore end to the aft end of cargo area, in order to prevent the discharge into the sea of leakage during cargo operations on deck. The height of coaming is to be determined in accordance with the size, type, arch, trim and stability of the ship. The main deck within cargo areas is also to be provided with a drainage system capable of collecting leakages during cargo operations and draining cargo leakages into a deck collecting tank or slop tank.

(2) Connections of the cargo manifold of chemical tankers are to be provided with drip trays having a closed drainage system leading to a deck collecting tank or slop tank.

(3) Cargo tanks of chemical tankers are to be provided with restricted gauging system, unless a closed gauging system is required due to the cargo categories.

6.3.4 The following requirements for the prevention of pollution by sewage are to be met:

(1) Any direct discharge into the sea of untreated sewage is prohibited.

(2) The ship is to be provided with a sewage treatment plant. Such plant is to be subject to type approval by CCS in accordance with resolution MEPC.159(55) .

(3) A ship navigating in an area (e.g. port) where the discharge of sewage water is prohibited is to be provided with holding tank(s) of sufficient capacity for the retention of all sewage water generated by the ship in such area.

(4) The holding tank of sewage water is to be provided with high level alarm and a means to indicate visually the amount of its contents.

(5) The ship is to keep on board a sewage water management plan, which is to be approved by CCS. Such plan is to provide guidance to the crew on management of sewage treatment and discharge of sewage water. The sewage water management plan is at least to include the following:

① ship name and identification number;

② sketch of sewage treatment system, holding tanks of sewage water and all relevant piping arrangement;

- ③ management and operational procedures of sewage water;
- ④ means and method of recording all sewage discharges to shore reception facilities or to the sea. The recorded data is to include the date, place and quantity of such discharges; the speed of the ship and its nearest distance to shore are also to be recorded for discharges to the sea. For discharges from the sewage treatment system, the time of activating and stopping the system is to be recorded in lieu of the quantity discharged. The discharge of untreated sewage in emergency is also to be recorded;
- ⑤ the vent piping of sewage treatment system is to be independent from other vent piping.

6.3.5 The following requirements for the prevention of pollution by garbage are to be met:

(1) The ship is to keep on board a garbage management plan and complies with the requirements of resolution MEPC.220(63).

(2) The ship is to be provided with equipment and arrangement for categorization, reduction and retention of garbage.

(3) Garbage is to be grouped into minimum four categories for the purpose of its recycling and retention as follows:

- ① waste that cannot be recycled;
- ② waste that can be recycled;
- ③ waste that might cause harm to the ship or crew (e.g. oily rag, light bubble, acid, chemical, battery, etc.);
- ④ food waste.

6.3.6 The following requirements for the prevention of air pollution are to be met:

(1) Emission of sulphur oxides (SO_x) and particulate matters (PM):

- ① The sulphur content of any fuel oil used on board ships is not to exceed 1.5% m/m.
- ② While ships are in areas with stricter requirements for sulphur content of fuel oil, those stricter local requirements are to be complied with.
- ③ As an alternative to ① and ② above, an exhaust gas cleaning system may be used to control SO_x emissions at an equivalent level. The exhaust gas cleaning system is to be approved by CCS in accordance with the 2009 Guidelines for Exhaust Gas Cleaning Systems adopted by resolution MEPC.184(59).
- ④ The requirements of this paragraph for the sulphur content are to apply to the fuel oil used in diesel engines, oil-burning boilers and incinerators on board ships, except for sludge (oil residue) burning in incinerators.
- ⑤ The ship is to keep on board a fuel oil management plan, which is at least to include the following:
 - 1) ship name and identification number;
 - 2) description of demand for fuel oil quality;
 - 3) sulphur content of fuel oil used on board ships;
 - 4) change-over procedure and steps for fuel oils with different sulphur content, where applicable;

5) diagram of fuel oil system including fuel oil change-over detail.

(2) Refrigerating systems:

- ① The requirements of this paragraph apply to refrigerated cargo installations, central air conditioning systems and centralized refrigeration systems of all ships. These requirements do not apply to stand-alone air conditioners and refrigerators for domestic purposes on board ships.
- ② Refrigerating systems are to be provided with suitable maintenance isolation means to prevent significant leaks of refrigerants during maintenance or repairs. However, unavoidable minimal release of refrigerants associated with refrigerant recovery is acceptable.
- ③ In order to recover refrigerants, compressors are to be capable of evacuating refrigerants within the system into a liquid receiver. Additionally, recovery units are to be capable of evacuating a system either into the existing liquid receiver or into suitable reservoirs dedicated for this purpose. The capacity of the liquid receiver or reservoirs is to be sufficient to contain all refrigerants of the largest refrigerating unit that can be isolated.
- ④ The annual refrigerant leakage rate of each system is to be less than 10% of its total charge. A leakage detection system is to be provided to monitor continuously the spaces into which the refrigerant could leak. An alarm is to be activated to give warning in a permanently manned location when the concentration of refrigerant in the space exceeds a predetermined limit (e.g. 25 ppm for ammonia). Remedial measures are to be implemented when any leak is detected.
- ⑤ Where different refrigerants are in use, means are to be provided to prevent them from being mixed.
- ⑥ The ship is to keep on board a refrigerant management plan which is at least to include the following:
 - 1) ship name and identification number;
 - 2) list of all refrigerating systems as well as sketch and component description (including leakage detection system);
 - 3) means adopted to manage and control consumption, leakage, evacuation and disposal of refrigerants together with the remedial measures in the event of any leakage as stated in ④ above;
 - 4) means and method of recording replacement, leakage, recovery, charging and disposal of refrigerants, including at least date, system type, refrigerant type, initial system charge and refrigerant level, charging amount, recovery amount, leakage type and remedial measures.
- ⑦ The ship is to establish and maintain a list of refrigerants on board and a record book required by ⑥4) above, which are to be kept throughout the life time of the system. The record of each item is to be kept on board for at least 3 years and available for check by the surveyor.

6.3.7 The following requirements for the control of ship's hazardous materials are to be met:

(1) Ships are to meet the relevant requirements for the class notation Green passport for recycling (GPR) in CCS Rules for Classification of Sea-going Steel Ships.

6.3.8 Additional requirements for operational procedures and plans and information:

(1) In addition, the following operational procedures are to be submitted for approval:

- ① sewage water management plan;

- ② refrigerant management plan;
- ③ fuel oil management plan.

(2) In addition, the following plans and information are to be submitted for approval:

- ① general arrangement of the refrigerating system, capable of indicating the position and number of refrigerant leakage detectors.

6.4 Technical Requirements for Green Ship 3

6.4.1 Ships to be assigned the Green Ship 3 notation are to comply with the following requirements of 6.4.2 to 6.4.7 in addition to the requirements of 6.3 above, as applicable.

6.4.2 The following requirements for the prevention of pollution by oil are to be met:

(1) For drip trays mentioned in 6.3.2(3) of this Chapter, the minimum capacity is to comply with the following requirements:

- ① for ships greater than 1600 GT: 0.16 m³;
- ② for ships between 300 GT and 1600 GT: 0.08 m³.

(2) For drip trays mentioned in 6.3.2(4) of this Chapter, the minimum capacity is to comply with the following requirements:

- ① for ships greater than 1600 GT: 0.08 m³;
- ② for ships between 300 GT and 1600 GT: 0.04 m³.

(3) For continuous coaming fitted on the deck within cargo area mentioned in 6.3.2(7) of this Chapter, the following height requirements are at least to be complied with:

- ① the transverse coaming at the fore end is 0.10 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height.

(4) For drip trays mentioned in 6.3.2(8) of this Chapter, the arrangement and minimum size are to comply with the following requirements:

- ① length: to include the fore and the aft ends of manifolds;
- ② width: at least 1.8 m, and approximately 1.2 m beyond the end of flange of manifolds;
- ③ depth: at least 0.3 m.

(5) All oil fuel tanks (except for overflow tanks) with an individual capacity greater than 30 m³ are to be arranged to be protected by wing tanks and double bottom tanks. However the aggregate capacity of oil fuel tanks with an individual capacity not greater than 30 m³ is not to be greater than 100 m³. The requirements for protective positions of wing tanks and double bottom tanks are as follows:

- ① Oil fuel tanks are to be located above the moulded line of the bottom shell plating nowhere less than the distance h as specified below:

$$h = B/20 \text{ m or}$$

$$h = 2.0 \text{ m, whichever is the lesser.}$$

The minimum value of $h = 0.76$ m.

In the turn of the bilge area and at locations without a clearly defined turn of the bilge, the oil fuel tank boundary line is to run parallel to the line of the midship flat bottom as shown in Figure 1.

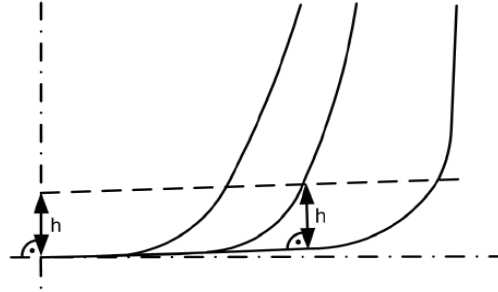


Figure 1

- ② For ships having an aggregate oil fuel capacity of less than 5,000 m³, oil fuel tanks are to be located inboard of the moulded line of the side shell plating, nowhere less than the distance W which, as shown in Figure 2, is measured at any cross-section at right angles to the side shell, as specified below:

$$W = 0.4 + 2.4C/20000 \text{ m}$$

The minimum value of $W = 1.0$ m; however, for individual tanks with an oil fuel capacity of less than 500 m³ the minimum value is 0.76 m.

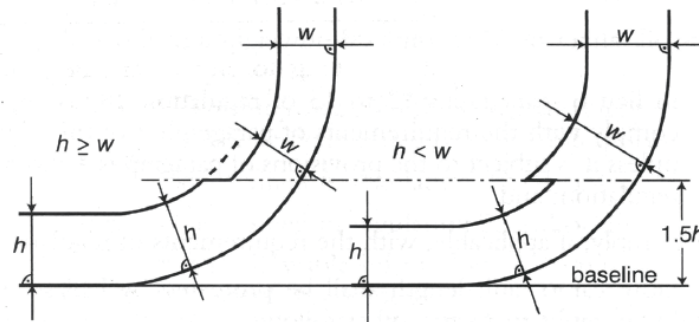


Figure 2

- ③ For ships having an aggregate oil fuel capacity of 5,000 m³ and over, oil fuel tanks are to be located inboard of the moulded line of the side shell plating, nowhere less than the distance W which, as shown in figure 2, is measured at any cross-section at right angles to the side shell, as specified below:

$$W = 0.5 + C/20000 \text{ m or}$$

$$W = 2.0 \text{ m, whichever is the lesser.}$$

where: C – Tank capacity, in m³.

- ④ Lines of oil fuel piping located at a distance from the ship's bottom of less than h , as defined in ① above, or from the ship's side less than W , as defined in ② and ③, are to be fitted with valves or similar closing devices within or immediately adjacent to the oil fuel tank. These valves are to be capable of being brought into operation from a readily accessible enclosed space the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The valves are to close in case of remote control system failure and are to be kept closed at sea at any time when the tank contains oil fuel except that they may be opened during oil fuel transfer operations.

- ⑤ Suction wells in oil fuel tanks may protrude into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and the bottom shell plating is not less than $0.5h$.

(4) Cargo oil tanks of any oil tanker are to be arranged to be protected by double bottoms and double side skins. For oil tankers of less than 600 tonnes deadweight, cargo oil tanks are to be protected by wing tanks and double bottom tanks having a minimum protection distance required by 6.3.2(9) above.

6.4.3 The following requirements for the prevention of pollution by noxious liquid substances are to be met:

(1) The structural arrangement of chemical tankers is at least to comply with the requirements for double side skins and double bottoms of type 2 chemical tankers in Chapter 2 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, unless type 1 chemical tankers are required due to the cargo categories.

(2) Cargo tanks of chemical tankers are to be provided with a closed gauging system and overflow alarm device independent from the closed gauging system.

(3) For continuous coaming fitted on the deck within cargo area mentioned in 6.3.3(1) of this Chapter, the following height requirements are at least to be complied with:

- ① the transverse coaming at the fore end is 0.10 m in height with transition gradually made towards the aft end of cargo area and connected to the transverse coaming at the aft end, which is 0.30 m in height.

(4) For drip trays mentioned in 6.3.3(2) of this Chapter, the arrangement and minimum size are to comply with the following requirements:

- ① length: to include the fore and the aft ends of manifolds;
- ② width: at least 1.8 m, and approximately 1.2 m beyond the end of flange of manifolds;
- ③ depth: at least 0.3 m.

6.4.4 The following requirements for the prevention of pollution by sewage and grey water are to be met:

(1) All grey water generated by the ship is to be discharged into the sea after going through a sewage treatment system. The sewage treatment system is to comply with the requirements of 6.3.4(2) of this Chapter.

(2) The holding tanks of sewage and/or grey water provided on ship are to be of sufficient capacity for the retention of all sewage and grey water generated by the ship in an area where discharge is prohibited. The capacity of holding tanks is to be comprehensively considered based on ship type, number of persons certified to carry and service area.

6.4.5 The following requirements for the prevention of pollution by garbage are to be met:

(1) The disposal into the sea of food wastes is permitted when they have been passed through a comminuter or grinder. Such comminuted or ground food wastes are to be capable of passing through a screen with openings no greater than 25 mm.

6.4.6 The following requirements for the prevention of air pollution are to be met:

(1) In lieu of the requirements of 6.3.6(1)① of this Chapter, the sulphur content of any fuel oil used on board ships is not to exceed 0.5% m/m.

(2) The use of halons or halocarbons as fire-fighting media is to be prohibited for fixed fire-extinguishing systems and portable fire extinguishers.

6.4.7 In addition, the following operational procedures or plans and information are to be submitted for approval:

(1) grey water treatment system with detailed effluent criteria;

(2) calculation of capacity of sewage/grey water holding tanks and relevant supporting documents (for information).

CHAPTER 7 REQUIREMENTS FOR WORKING ENVIRONMENT

7.1 General Requirements

7.1.1 This Chapter specifies the relevant requirements of working environment elements for Green Ship 1, Green Ship 2 and Green Ship 3 class notations for sea-going ships engaged on domestic voyages.

7.1.2 The working environment elements cover the grades of engine room automation and the levels of vibration and noise.

7.1.3 The following information is to be submitted:

(1) measurement procedures of vibration and noise, including arrangement of measurement points, loading condition, working condition of machinery, weather condition and measurement equipment;

(2) measurement report of vibration and noise, including measurement result of vibration and noise.

7.1.4 The general arrangement indicating the positions of measurement points of vibration and noise is to be submitted for information.

7.2 Technical Requirements for Green Ship 1

7.2.1 Ships to be assigned the Green Ship 1 notation are to comply with the following requirements:

(1) The requirements relating to centralized control in machinery spaces (MCC) notation or remote control from bridge (BRC) notation in Chapter 4, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships are to be met.

(2) Shipborne noise is to meet the relevant requirements of IMO resolution A.468, otherwise one of the following measures are to be taken:

- ① the source of excessive noise is to be suitably insulated or isolated;
- ② a refuge from noise is to be provided if the space is required to be manned.

Even if the above measures have been taken, ear protectors are to be provided for personnel required to enter such spaces, if necessary.

(3) Shipborne vibration is to meet the relevant requirements of ISO 6954 (2000) Mechanical vibration – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.

(4) Accommodation of crew is to meet the relevant requirements of PART SEVEN of the Domestic Regulations.

7.3 Technical Requirements for Green Ship 2

7.3.1 Ships to be assigned the Green Ship 2 notation are to comply with the following requirements in addition to the requirements of 7.2.1(2) to (4) above.

(1) The requirements relating to periodically unattended machinery spaces for (AUT-0) notation in Chapter 3, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships are to be met.

(2) The relevant requirements relating to shipborne noise for COMF (NOISE, 3) in Chapter 16, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships are to be met.

7.4 Technical Requirements for Green Ship 3

7.4.1 Ships to be assigned the Green Ship 3 notation are to comply with the following requirements in addition to the requirements of 7.2.1(2), (3) and 7.3.1(1) above.

(1) The relevant requirements relating to shipborne noise for COMF (NOISE, 2) in Chapter 16, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships are to be met.

Appendix 1 Guidelines for Calculation of the Attained EEDI

1 These Guidelines apply only to calculation of the Attained EEDI for the 14 ship types defined in 2.2.1 of the Rules. They do not apply to those having non-conventional propulsion systems of these ship types (except for cruise passenger ships and LNG carriers). For sea-going ships engaged on domestic voyages, Attained EEDI is to be calculated according to Appendix 1-2.

2 Attained EEDI calculation formula

The Attained EEDI means the attained ship Energy Efficiency Design Index, which is a measure of ship energy efficiency (g/t-nmile) and calculated by the following formula:

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

* If part of the normal maximum sea load is provided by shaft generators, for that part of the power, SFC_{ME} and C_{FME} may be used instead of SFC_{AE} and C_{FAE} .

When $0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} \leq P_{AE}$, $P_{AE} \cdot C_{FAE} \cdot SFC_{AE}$ may be replaced by:

$$(P_{AE} - 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)}) \cdot C_{FAE} \cdot SFC_{AE} + 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$$

When $0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} > P_{AE}$, $P_{AE} \cdot C_{FAE} \cdot SFC_{AE}$ may be replaced by:

$$P_{AE} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$$

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

3 Definition and selection of parameters in Attained EEDI calculation formula

3.1 Carbon conversion factor (C_F)

C_F is a non-dimensional conversion factor between fuel consumption and CO₂ emission based on carbon content, measured int-CO₂/t-Fuel. The subscripts MEi and AEi refer to the main and auxiliary engine(s) respectively. C_F corresponds to the fuel used when determining SFC listed in the applicable test report included in a Technical File as defined in NO_x Technical Code (hereinafter referred to as “test report included in a NO_x technical file”). The value of C_F is as follows:

Carbon Conversion Factor C_F

Table 3.1

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

In case of a ship equipped with a dual-fuel main or auxiliary engine, the C_F -factor for gas fuel and the C_F -factor for fuel oil are to apply and be multiplied with the specific fuel oil consumption of each fuel at the relevant EEDI load point.

Example:

$$CF_{Gas} = 2.750$$

$$CF_{Pilotfuel} = 3.114$$

$$SFCME_{Pilotfuel} = 6 \text{ g/kWh}$$

$$SFCME_{Gas} = 160 \text{ g/kWh}$$

$$EEDI = (PME \times (CF_{Pilotfuel} \times SFCME_{Pilotfuel} + CF_{Gas} \times SFCME_{Gas})) + \dots$$

$$EEDI = (PME \times (3.114 \times 6 + 2.750 \times 160)) + \dots$$

Calculation examples are set out in Appendix 1-1.

3.2 Ship speed (V_{ref})

V_{ref} is the ship speed, measured in knot, on deep water in the condition corresponding to the Capacity as defined in paragraph 3.3 (in case of passenger ships and ro-ro passenger ships, this condition is to be summer load draught as provided in paragraph 3.4) at the shaft power of the engine(s) as defined in paragraph 3.5 and assuming the weather is calm with no wind and no waves.

3.3 Capacity

Capacity is defined as follows for different ship types:

3.3.1 For bulk carriers, tankers, gas carriers, LNG carriers, ro-ro cargo ships (vehicle carriers), ro-ro cargo ships, ro-ro passenger ships, refrigerated cargo carriers, general cargo ships, combination carriers and offshore supply vessels, deadweight is to be used as capacity.

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

3.3.3 For containerships, 70% of the deadweight (DWT) is to be used as capacity. EEDI values for containerships are calculated as follows:

(1) Attained EEDI value is to be calculated using 70% DWT in accordance with EEDI formula;

(2) Required EEDI value is to be calculated using 100% DWT in accordance with reference line formula in 2.3.2 of the Rules.

3.4 Deadweight (DWT)

Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1,025 kg/m³ at the summer load draught and the lightweight of the ship. The summer load draught is to be taken as the maximum summer draught as certified in the stability booklet approved by the Administration or CCS.

3.5 Power (P)

P is the power of the main and auxiliary engines, measured in kW. The subscripts ME and AE refer to the main and auxiliary engine(s) respectively. The summation on i is for all engines with the number of engines (nME). Power related parameters involved in EEDI calculation formula are as follows:

3.5.1 $P_{ME(i)}$ is 75% of the rated installed power (MCR) for each main engine. The MCR value specified on the EIAPP certificate is to be used for calculation. If the main engines are not required to have an EIAPP certificate, the MCR value on the nameplate is to be used for calculation.

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

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

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

$\eta_{(i)}$ is to be taken as the product of electrical efficiency of generator, transformer, converter, and motor, taking into consideration the weighted average as necessary. The electrical efficiency, $\eta_{(i)}$, is to be taken as 91.3% for the purpose of calculating attained EEDI. Alternatively, if the value more than 91.3% is to be applied, the $\eta_{(i)}$ is to be obtained by measurement and verified by method approved by CCS.

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

3.5.2 $P_{PTO(i)}$ — In case where a shaft generator is installed, the shaft generator power ($P_{PTO(i)}$) is 75% of the rated electrical power output for each shaft generator. In case that shaft generator(s) are installed to steam turbine, $P_{PTO(i)}$ is 83% of the rated electrical output power and the factor of 0.75 is to be replaced to 0.83.

There are two options to calculate the effect of shaft generators:

(1) Option 1: The maximum allowable deduction for the calculation of $\sum P_{ME(i)}$ is to be no more than P_{AE} as defined in paragraph 3.5.4. For this case, $\sum P_{ME(i)}$ is calculated as:

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

(2) Option 2: Where an engine is installed with a higher rated power output than that which the propulsion system is limited to as verified by technical means, the value of $\sum P_{ME(i)}$ is to be 75% of that limited power for determining the reference speed V_{ref} defined in 3.2 and for EEDI calculation.

The following figure gives guidance for determination of $\sum P_{ME(i)}$.

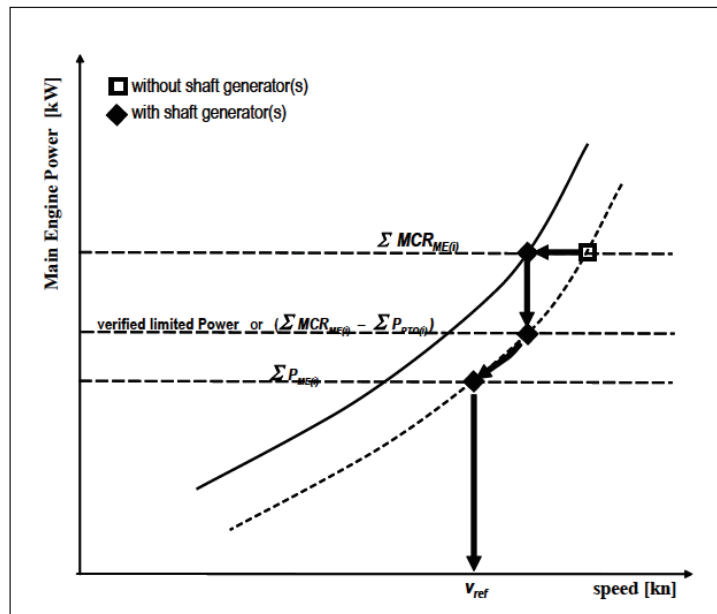


Figure 3.5.2 Determination of the Power $\sum P_{ME(i)}$ of a Main Engine

3.5.3 $P_{PTI(i)}$ — In case where shaft motor(s) are installed, $P_{PTI(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted average efficiency of the generator(s), as follows:

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

where: $P_{SM,max(i)}$ — is the rated power consumption of each shaft motor;
 η_{Gen} — is the weighted average efficiency of the generator(s).

In case that shaft motor(s) are installed to steam turbine, $P_{PTI(i)}$ is 83% of the rated power consumption and the factor of 0.75 is to be replaced to 0.83.

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

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

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

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

Where the total propulsion power as defined above is higher than 75% of the power the propulsion system is limited to by verified technical means, then 75% of the limited power is to be used as the total propulsion power for determining the reference speed, V_{ref} as defined in 3.2 and for EEDI calculation. Then,

$(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} + \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot C_{FAE} \cdot SFC_{AE})$ is to be replaced by 75% of the limited power multiplied by the weighted average value of $(SFC_{ME} \cdot C_{FME})$ and $(SFC_{AE} \cdot C_{FAE})$.

In case of combined *PTI/PTO*, the normal operational mode at sea will determine which of these is to be used in the EEDI calculation. For example, if this combined system is used as a shaft generator for ships in normal operation at sea, the P_{PTO} parameter is to be used in the EEDI calculation formula and P_{PTI} equals 0.

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

Calculation examples for engines provided with shaft generators and shaft motors are set out in Appendix 1-1.

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

P_{AE} used for the calculation of Attained EEDI of ships is to be calculated by the following experience-based formulae instead of the actual auxiliary engine power.

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

$$P_{AE} (\sum MCR_{ME(i)} \geq 10000kW) = \left(0.025 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right) + 250$$

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

$$P_{AE} (\sum MCR_{ME(i)} < 10000kW) = 0.05 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right)$$

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

- ① For ships having re-liquefaction system:

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

where: $CargoTankCapacity_{LNG}$ — the LNG Cargo Tank Capacity, in m³.

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

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

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

$COP_{cooling}$ — the coefficient of design performance of reliquefaction and 0.166 is to be used. Another value calculated by the manufacturer and verified by the Administration or CCS may be used.

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

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

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

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

where: COP_{comp} is the design power performance of compressor and 0.33 (kWh/kg) is to be used. Another value calculated by the manufacturer and verified by the Administration or an organization recognized by the Administration may be used.

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

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

With regard to the factor of 0.02, it is assumed that the additional energy needed to compress BOG for supplying to a 4-stroke dual fuel engine is approximately equal to 2% of P_{ME} , compared to the energy needed to compress BOG for supplying to a steam turbine.

For LNG carriers having diesel electric propulsion system, $MPP_{Motor(i)}$ is to be used instead $MCR_{ME(i)}$ for PAE calculation.

For LNG carriers having steam turbine propulsion system and of which electric power is primarily supplied by turbine generator closely integrated into the steam and feed water systems, P_{AE} may be treated as 0(zero) instead of taking into account electric load in calculating $SFC_{SteamTurbine}$.

(4) For ship where the P_{AE} value calculated by (1) or (2) above is significantly different from the total power used at the speed V_{ref} , e.g., in cases of passenger ships, the P_{AE} value is to be estimated by the consumed electric power (excluding propulsion) in conditions when the ship is engaged in a voyage at the reference speed (V_{ref}) as given in the electric power table, divided by the average efficiency of the generator(s) weighted by power.

The electric power table for EEDI calculation is to be examined and validated by CCS. Where ambient conditions affect any electrical load in the power table, the contractual ambient conditions leading to the maximum design electrical load of the installed system for the ship in general are to apply. See appendix 2 for the development of electric power tables.

3.5.5 $P_{eff(i)}$ is the output of the innovative mechanical energy efficient technology for propulsion at 75% main engine power.

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

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

In case of a ship equipped with a dual-fuel engine, the C_F and SFC are to be obtained according to 3.1 and 3.7.

3.5.6 $P_{AEff(i)}$ is the auxiliary power reduction due to innovative electrical energy efficient technology measured at $P_{ME(i)}$.

3.5.7 The simplified figure below illustrates a generic marine power plant and the power used for EEDI calculation.

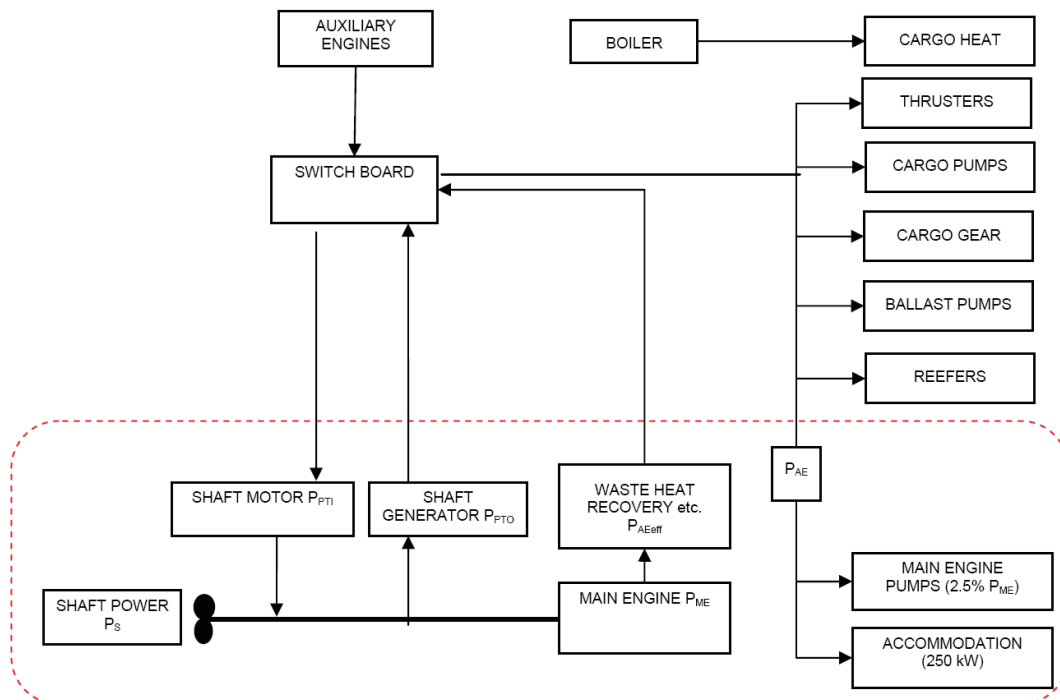


Figure 3.5.7a A Generic Marine Power Plant for Ships Having Conventional Propulsion

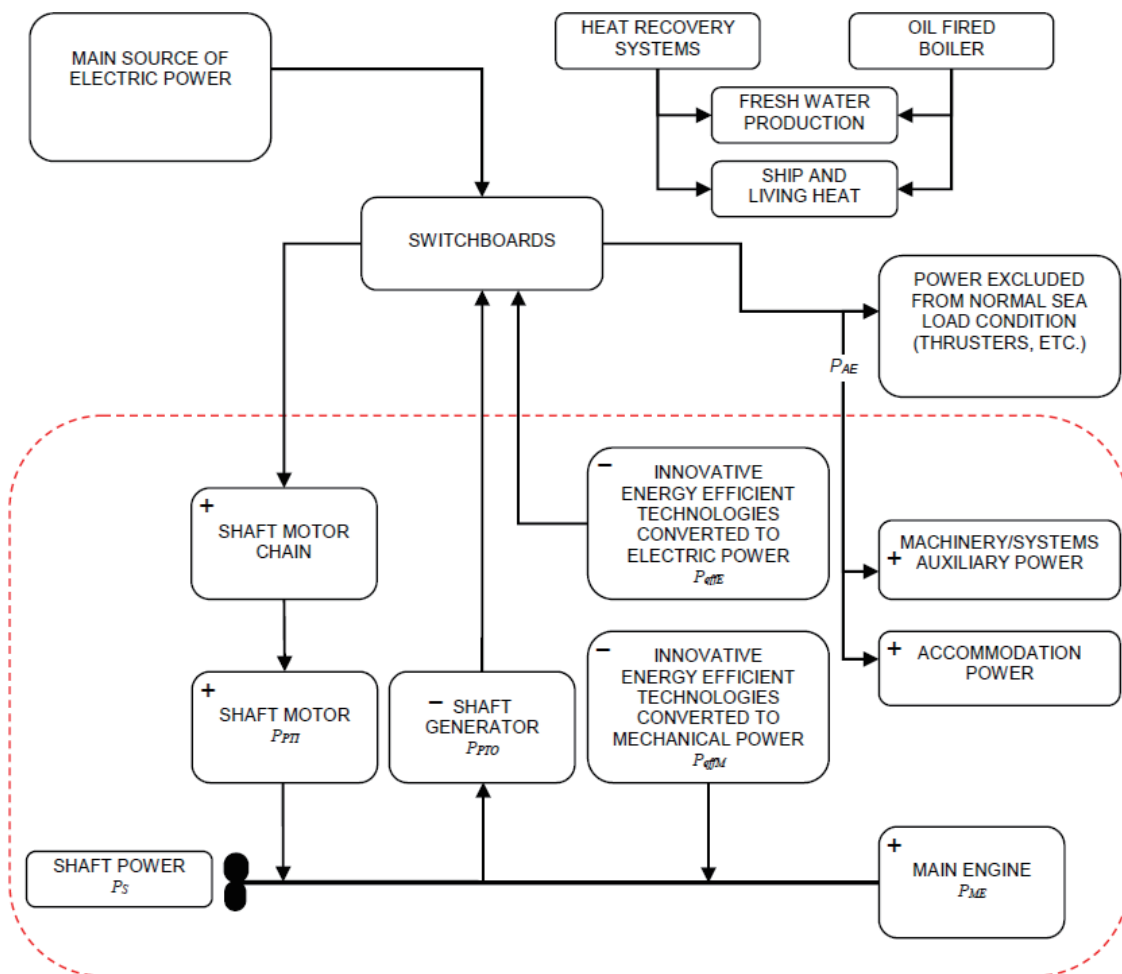


Figure 3.5.7b A Generic Marine Power Plant for a Cruise Passenger Ships Having Non-conventional Propulsion

3.6 The essential parameters V_{ref} , Capacity and P for determining EEDI for a ship are interrelated and should be consistent with each other. As for LNG carriers having diesel electric or steam turbine propulsion systems, V_{ref} is the relevant speed at 83% of MPP_{Motor} or $MCR_{SteamTurbine}$ respectively.

3.7 Specific Fuel Consumption (SFC)

SFC is the certified specific fuel consumption, measured in g/kWh, of the engines or steam turbines. SFC_{ME} and SFC_{AE} refer to the specific fuel consumption of the main and auxiliary engine(s) respectively.

3.7.1 For engines certified to the E2 or E3 duty cycles of the NO_x Technical Code 2008, the engine Specific Fuel Consumption ($SFC_{ME(i)}$) is that recorded in the test report included in a NO_x technical file for the engine(s) at 75% of MCR power or its torque rating.

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

3.7.3 If gas fuel is used as primary fuel in accordance with paragraph 2.3.3 of CCS *Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships*, *SFC* in gas mode is to be used. In case that installed engine(s) have no approved NO_x Technical File tested in gas mode, the *SFC* of gas mode is to be submitted by the manufacturer and confirmed by CCS.

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

3.7.5 For ships where the P_{AE} value calculated by 3.5.4.(1) or (2) above is significantly different from the total power used at normal seagoing, e.g., conventional passenger ships, the Specific Fuel Consumption (SFC_{AE}) of the auxiliary generators is that recorded in the test report included in a NO_x technical file for the engine(s) at 75% of MCR power or its torque rating.

3.7.6 SFC_{AE} is the power-weighted average among $SFC_{AE(i)}$ of the respective engines i .

3.7.7 For those engines which do not have a test report included in a NO_x technical file because its power is below 130 kW, the SFC specified by the manufacturer and endorsed by the Administration or CCS is to be used.

3.7.8 At the design stage, in case of unavailability of a test report in the NO_x file, the SFC specified by the manufacturer and endorsed by the Administration or CCS is to be used.

3.7.9 For LNG-driven engines, SFC measured in kJ/kWh is to be amended to SFC value measured in g/kWh by using the standard lower heat value of the LNG (48,000 kJ/kg) (Refer to 2006 IPCC Guidelines).

3.7.10 The $SFC_{SteamTurbine}$ is to be calculated by manufacturer and verified by the Administration or CCS as follows:

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

where:

(1) *Fuel consumption* is fuel consumption of boiler per hour (g/h). For ships of which electric power is primarily supplied by Turbine Generator closely integrated into the steam and feed water systems, not only P_{ME} but also electric loads corresponding to paragraph 3.5.4 are to be taken into account.

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

(3) In this correction, the difference of the boiler efficiency based on lower calorific value between test fuel and LNG is to be taken into account.

3.8 Correction factor f_j

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

3.8.1 For ice-classed ships, the power of the main engine is to be increased due to navigation in ice. Therefore an additional correction factor is applied to compensate for negative effects caused by the increased power on EEDI of such ships. This factor is to be taken as the greater value of f_{j0} and $f_{j,min}$ as tabulated in Table 3.8.1, but not to be greater than 1.0.

3.8.2 The factor f_j , for shuttle tankers with propulsion redundancy is to be $f_j = 0.77$. This correction factor applies to shuttle tankers with propulsion redundancy and having a deadweight of 80,000 ~ 160,000 tonnes. The shuttle tankers with propulsion redundancy are tankers used for loading of crude oil from offshore installations and equipped with dual-engine and twin-propellers, need to meet the requirements for dynamic positioning and redundancy propulsion class notation.

Correction Factor f_j for Ice-Classed Ships

Table 3.8.1

Ship type	f_{j0}	$f_{j,min}$ depending on ice class			
		IC	IB	IA	IA Super
Tanker	$\frac{0.308L_{pp}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.70L_{pp}^{0.06}$	$0.45L_{pp}^{0.13}$	$0.27L_{pp}^{0.21}$	$0.15L_{pp}^{0.30}$
Bulk carrier	$\frac{0.639L_{pp}^{1.754}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.87L_{pp}^{0.02}$	$0.73L_{pp}^{0.04}$	$0.58L_{pp}^{0.07}$	$0.47L_{pp}^{0.09}$
General cargo ship	$\frac{0.0227L_{pp}^{2.483}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.67L_{pp}^{0.07}$	$0.56L_{pp}^{0.09}$	$0.43L_{pp}^{0.12}$	$0.31L_{pp}^{0.16}$
Refrigerated cargo ships	$\frac{0.639L_{pp}^{1.754}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.87L_{pp}^{0.02}$	$0.73L_{pp}^{0.04}$	$0.58L_{pp}^{0.07}$	$0.47L_{pp}^{0.09}$

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

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

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

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

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

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

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

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

where:

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

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

3.8.5 For other ship types not included in the above table, f_j is to be taken as 1.0.

3.9 Correction factor f_i

f_i is the capacity correction factor for any technical/regulatory limitation on capacity, which is used to compensate for negative effects on EEDI due to the loss of capacity, and can be assumed 1.0 if no necessity of the factor is granted.

3.9.1 For ice-classed ships, the capacity is decreased due to the increased ship weight resulting from the increased steel plate thickness for guaranteeing their ice breaking capability. Therefore this capacity correction factor is applied to compensate for the loss of capacity. This factor is to be taken as the lesser value of f_{i0} and $f_{i,max}$ as tabulated in Table 3.9.1, but not to be less than 1.0.

Correction Factor f_i for Ice-Classed Ships

Table 3.9.1

Ship Type	f_{i0}	$f_{i,max}$ depending on ice class			
		IC	IB	IA	IA Super
Tanker	$\frac{0.00138L_{PP}^{3.331}}{capacity}$	$1.27L_{PP}^{-0.04}$	$1.47L_{PP}^{-0.06}$	$1.71L_{PP}^{-0.08}$	$2.10L_{PP}^{-0.11}$
Bulk carrier	$\frac{0.00403L_{PP}^{3.123}}{capacity}$	$1.31L_{PP}^{-0.05}$	$1.54L_{PP}^{-0.07}$	$1.80L_{PP}^{-0.09}$	$2.10L_{PP}^{-0.11}$
General cargo ship	$\frac{0.0377L_{PP}^{2.625}}{capacity}$	$1.28L_{PP}^{-0.04}$	$1.51L_{PP}^{-0.06}$	$1.77L_{PP}^{-0.08}$	$2.18L_{PP}^{-0.11}$
Container ship	$\frac{0.1033L_{PP}^{2.329}}{capacity}$	$1.27L_{PP}^{-0.04}$	$1.47L_{PP}^{-0.06}$	$1.71L_{PP}^{-0.08}$	$2.10L_{PP}^{-0.11}$
Gas carrier	$\frac{0.0474L_{PP}^{2.590}}{capacity}$	$1.25L_{PP}^{-0.04}$	$1.60L_{PP}^{-0.08}$	$2.10L_{PP}^{-0.12}$	1.25

3.9.2 For ships with voluntary structural enhancements, f_{iVSE} is to be expressed as follows:

$$f_{iVSE} = \frac{DWT_{reference\ design}}{DWT_{enhanced\ design}}$$

where: $DWT_{reference\ design} = \Delta_{ship} - lightweight_{reference\ design}$;

$$DWT_{enhanced\ design} = \Delta_{ship} - lightweight_{enhanced\ design}.$$

For this calculation, the same displacement (Δ) is to be taken for reference and enhanced designs.

Note: Structural and/or additional class notations such as, but not limited to, “strengthened for discharge with grabs” and “strengthened bottom for loading/unloading aground”, which result in a loss of deadweight of the ship, are also seen as examples of “voluntary structural enhancements”.

(1) DWT before enhancements ($DWT_{reference\ design}$) is the deadweight prior to application of the structural enhancements. DWT after enhancements ($DWT_{enhanced\ design}$) is the deadweight following the application of voluntary structural enhancements.

(2) A change of material (e.g. from aluminum alloy to steel) or a change in grade of the same material (e.g. in steel types, grades, properties and conditions) between reference design and voluntarily enhanced design is not to be allowed for the f_{iVSE} calculation.

(3) Two sets of structural plans of the ship (one set for the reference design and the other set for the enhanced design) are to be submitted to CCS for assessment. As an alternative, only one set of structural plans of the reference design with annotations of voluntary structural enhancements may be submitted. Both sets of structural plans are to comply with the applicable regulations for the ship type and intended trade.

3.9.3 For bulk carriers and oil tankers which are constructed according to Common Structural Rules (CSR) and assigned the CSR notation, the following capacity correction factor f_{iCSR} is to be used:

$$f_{iCSR} = 1 + (0.08 \times \frac{LWT_{CSR}}{DWT_{CSR}})$$

where: DWT_{CSR} is ship's deadweight;
 LWT_{CSR} is ship's lightweight.

3.9.4 For other ship types not included in the table above, f_i is to be taken as 1.0.

3.9.5 The above factor f_i may be accumulated (multiplied).

3.10 Cubic capacity correction factor f_c

f_c is the cubic capacity correction factor and is to be taken as 1.0 if no necessity of the factor is granted. It is calculated as follows:

3.10.1 For chemical tankers, the cubic capacity correction factor f_c is to be:

$$f_c = R^{(-0.7)} - 0.014 \text{ for } R < 0.98; \text{ or}$$

$$f_c = 1.00 \quad \text{for } R \geq 0.98$$

where: R is the ratio of the ship's DWT (in tonnes) to the total cubic capacity (in m³) of its cargo tanks (m³).

3.10.2 For gas carriers which are constructed or adapted to carry liquefied natural gas in bulk and with propulsion systems directly driven by diesel engines, the capacity correction factor f_{cLNG} is to be:

$$f_{cLNG} = R^{-0.56}$$

where: R is the ratio of the ship's DWT (in tonnes) to the total cubic capacity (in m³) of its cargo tanks.

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

3.10.3 For ro-ro passenger ships having a DWT/GT -ratio of less than 0.25, the following cubic capacity correction factor, f_{cRoPax} is to apply:

$$f_{cRoPax} = 1 + \left(\frac{(DWT/GT)}{0.25} \right)^{-0.8}$$

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

3.11 Correction factor f_w

f_w is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed (e.g., Beaufort Scale 6).

3.11.1 f_w is to be taken as 1.0 in calculation of the Attained EEDI specified in 2.3.3 of Chapter 2.

3.11.2 Where the Owner requests on a voluntary basis the application of f_w , the Attained EEDI value using f_w is to be referred to Attained EEDI_{weather} and confirmed by CCS, and indicated in the related certificate. f_w is to be determined as follows:

(1) f_w can be determined by conducting the ship-specific simulation of its performance at representative sea conditions. The simulation methodology is to be that as prescribed in the Guidelines developed by IMO and the method and outcome for an individual ship is to be verified by the Administration or CCS.

(2) In case where the simulation is not conducted, f_w value is to be taken from the “Standard f_w ” table/curve prescribed in the Guidelines developed by IMO.

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

3.11.3 f_w and Attained EEDI_{weather} together with the representative sea conditions are to be indicated in the EEDI technical file to make a distinction from Attained EEDI required in 2.3.3 of Chapter 2.

3.12 Energy efficiency factor f_{eff}

f_{eff} is the availability factor of each innovative energy efficiency technology. f_{eff} for waste energy recovery system is to be taken as 1.0.

3.13 Length between perpendiculars (L_{pp})

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

3.14 Correction factor f_l

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

$$f_l = f_{cranes} f_{sideloader} f_{ro-ro}$$

where: $f_{cranes} = 1$ if no cranes are present;
 $f_{sideloader} = 1$ if no side loaders are present;
 $f_{ro-ro} = 1$ if no ro-ro ramp is present.

3.14.1 Definition of f_{cranes} :

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

where: SWL — Safe Working Load, as specified by crane manufacturer in metric tonnes;
 $Reach$ — Reach at which the Safe Working Load can be applied in metres;
 n — Number of cranes.

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

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

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

The weight of the side loaders and ro-ro ramps is to be based on a direct calculation, in analogy to the calculations as made for factor f_{ivse} .

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

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

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

3.18 g is the gravitational acceleration, 9.81m/s^2 .

Appendix 1-1 EEDI Calculation Examples

1 EEDI calculation examples for use of conventional fuel oil and dual fuel engines

Standard main engine (HFO), standard auxiliary engines (HFO), no shaft generator:

$$MCR_{ME} = 15,000 \text{ kW}$$

$$Capacity = 25,000 \text{ DWT}$$

$$C_{FME} = 3.114$$

$$C_{FAE} = 3.114$$

$$SFC_{ME} = 190 \text{ g/kWh}$$

$$SFC_{AE} = 215 \text{ g/kWh}$$

$$v_{ref} = 18 \text{ kn}$$

$$P_{ME} = 0.75 MCR_{ME} = 0.75 \times 15,000 \text{ kW} = 11,250 \text{ kW}$$

$$P_{AE} = (0.025 \times MCR_{ME}) + 250 \text{ kW} = 625 \text{ kW}$$

$$EEDI = [(P_{ME} \times C_{FME} \times SFC_{ME}) + (P_{AE} \times C_{FAE} \times SFC_{AE})] / (v_{ref} \times Capacity)$$

$$EEDI = [(11,250 \times 3.114 \times 190) + (625 \times 3.114 \times 215)] / (18 \times 25,000)$$

$$EEDI = 15.721 \text{ gCO}_2/\text{tnm}$$

Dual-fuel main engine and auxiliary engine (LNG, pilot fuel MDO; no shaft generator), LNG condition for tank capacity and/or operating time is fulfilled:

$$MCR_{ME} = 15,000 \text{ kW}$$

$$Capacity = 25,000 \text{ DWT}$$

$$C_{F,Gas} = 2.750$$

$$C_{FPilotfuel} = 3.206$$

$$SFC_{MEPilotfuel} = 6 \text{ g/kWh}$$

$$SFC_{MEGas} = 160 \text{ g/kWh}$$

$$SFC_{AEPilotfuel} = 7 \text{ g/kWh}$$

$$SFC_{AEGas} = 180 \text{ g/kWh}$$

$$v_{ref} = 18 \text{ kn}$$

$$P_{ME} = 0.75 \times MCR_{ME} = 0.75 \times 15,000 \text{ kW} = 11,250 \text{ kW}$$

$$P_{AE} = (0.025 \times MCR_{ME}) + 250 \text{ kW} = 625 \text{ kW}$$

$$EEDI = [(P_{ME} \times (C_{FPilotfuel} \times SFC_{MEPilotfuel} + C_{F,Gas} \times SFC_{MEGas})) + (P_{AE} \times (C_{FPilotfuel} \times SFC_{AEPilotfuel} + C_{F,Gas} \times SFC_{AEGas}))] / (v_{ref} \times Capacity)$$

$$EEDI = [(11,250 \times (3.206 \times 6 + 2.750 \times 160)) + (625 \times (3.206 \times 7 + 2.750 \times 180))] / (18 \times 25,000)$$

$$EEDI = 12.200 \text{ gCO}_2/\text{tnm}$$

2 EEDI calculation examples for use of shaft generators and shaft motors

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

$$MCR_{ME} = 20,000 \text{ kW}$$

$$Capacity = 20,000 \text{ DWT}$$

$$C_{F,ME} = 3.206$$

$$C_{F,AE} = 3.206$$

$$SFC_{ME} = 190 \text{ g/kWh}$$

$$SFC_{AE} = 215 \text{ g/kWh}$$

$$v_{ref} = 20 \text{ kn (without shaft generator/motor)}$$

2.1 One main engine, no shaft generator

$$MCR_{ME} = 20,000 \text{ kW}$$

$$P_{ME} = 0.75 \times MCR_{ME} = 0.75 \times 20,000 \text{ kW} = 15,000 \text{ kW}$$

$$P_{AE} = (0.025 \times 20,000) + 250 \text{ kW} = 750 \text{ kW}$$

$$EEDI = ((15,000 \times 3.206 \times 190) + (750 \times 3.206 \times 215)) / (20 \times 20,000) \\ = 24.1 \text{ g CO}_2 / \text{tnm}$$

2.2 One main engine, with shaft generator, $0.75 \times P_{PTO} < P_{AE}$, option 1

$$MCR_{PTO} = 500 \text{ kW}$$

$$P_{PTO} = 500 \text{ kW} \times 0.75 = 375 \text{ kW}$$

$$MCR_{ME} = 20,000 \text{ kW}$$

$$P_{ME} = 0.75 \times (MCR_{ME} - P_{PTO}) = 0.75 \times (20,000 \text{ kW} - 375 \text{ kW}) = 14,719 \text{ kW}$$

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

$$v_{ref} = 19.89 \text{ kn: the speed at } P_{ME} \text{ determined from the power curve}$$

$$EEDI = ((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME})) + ((P_{AE} - 0.75 \times P_{PTO}) \times C_{F,AE} \times SFC_{AE}) / (DWT \times v_{ref}) \\ = 23.8 \text{ g CO}_2 / \text{tnm} \quad \approx 1\%$$

2.3 One main engine with shaft generator, $0.75 \times P_{PTO} = P_{AE}$, option 1

$$MCR_{PTO} = 1,333 \text{ kW}$$

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

$$MCR_{ME} = 20,000 \text{ kW}$$

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

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

$$v_{ref} = 19.71 \text{ kn: the speed at } P_{ME} \text{ determined from the power curve}$$

$$EEDI = ((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME})) / (DWT \times v_{ref}) \\ = 23.2 \text{ g CO}_2 / \text{tnm} \quad \approx 4\%$$

2.4 One main engine with shaft generator, $0.75 \times P_{PTO} > P_{AE}$, option 1

$$MCR_{PTO} = 2,000 \text{ kW}$$

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

$$MCR_{ME} = 20,000 \text{ kW}$$

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

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

$$v_{ref} = 19.71 \text{ kn: the speed at } P_{ME} \text{ determined from the power curve}$$

$$EEDI = ((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (0.75 \times P_{PTO} \times C_{F,ME} \times SFC_{ME})) / (DWT \times v_{ref}) \\ = 23.2 \text{ g CO}_2 / \text{tnm} \quad \approx 4\%$$

2.5 One main engine with shaft generator, $0.75 \times P_{PTO} > P_{AE}$, option 2

$$MCR_{PTO} = 2,000 \text{ kW}$$

$$MCR_{ME} = 20,000 \text{ kW}$$

$$P_{Shaft,limit} = 18,000 \text{ kW}$$

$$P_{ME} = 0.75 \times (P_{Shaft,limit}) = 0.75 \times (18,000 \text{ kW}) = 13,500 \text{ kW}$$

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

$$v_{ref} = 19.41 \text{ kn: the speed at } P_{ME} \text{ determined from the power curve}$$

$$\begin{aligned} EEDI &= \left((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (P_{AE} \times C_{F,ME} \times SFC_{ME}) \right) / (DWT \times v_{ref}) \\ &= 22.4 \text{ g CO}_2 / \text{t nm} \quad \approx 7\% \end{aligned}$$

2.6 One main engine with shaft motor

$$MCR_{ME} = 18,000 \text{ kW}$$

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

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

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

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

$$\eta_{PTI} = 0.97$$

$$\eta_{Gen} = 0.93$$

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

$$v_{ref} = 20 \text{ kn}$$

$$\begin{aligned} EEDI &= \left((P_{ME} \times C_{F,ME} \times SFC_{ME}) + (P_{AE} \times C_{F,AE} \times SFC_{AE}) + (P_{PTI} \times C_{F,AE} \times SFC_{AE}) \right) / (DWT \times v_{ref}) \\ &= 24.6 \text{ g CO}_2 / \text{t nm} \quad \approx -2\% \end{aligned}$$

Appendix 1-2 Guidelines for Calculation of the Attained EEDI for Sea-going Ships Engaged on Domestic Voyages

1 These Guidelines apply only to calculation of the Attained EEDI for the 4 ship types defined in 5.2.1 of the Rules. They do not apply to those having diesel-electric propulsion, turbine propulsion or hybrid propulsion systems of these ship types (except for LNG carriers).

2 Attained EEDI calculation formula

The Attained EEDI means the attained ship Energy Efficiency Design Index, which is a measure of ship energy efficiency (g/t-nmile) and calculated by the following formula:

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

* If part of the normal maximum sea load is provided by shaft generators, for that part of the power, SFC_{ME} and C_{FME} may be used instead of SFC_{AE} and C_{FAE} .

If $0.75 \cdot \sum_{i=1}^{nPTO} P_{PTO(i)} \leq P_{AE}$, $P_{AE} \cdot C_{FAE} \cdot SFC_{AE}$ may be replaced by:

$$(P_{AE} - 0.75 \cdot \sum_{i=1}^{nPTO} P_{PTO(i)}) \cdot C_{FAE} \cdot SFC_{AE} + 0.75 \cdot \sum_{i=1}^{nPTO} P_{PTO(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$$

If $0.75 \cdot \sum_{i=1}^{nPTO} P_{PTO(i)} > P_{AE}$, $P_{AE} \cdot C_{FAE} \cdot SFC_{AE}$ may be replaced by:

$$P_{AE} \cdot C_{FME(i)} \cdot SFC_{ME(i)}$$

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

3 Definition and selection of parameters in Attained EEDI calculation formula

3.1 Carbon conversion factor (C_F)

C_F is a non-dimensional conversion factor between fuel consumption and CO₂ emission based on carbon content, measured int-CO₂/t-Fuel. The subscripts MEi and AEi refer to the main and auxiliary engine(s) respectively. C_F corresponds to the fuel used when determining SFC listed in the applicable test report included in a Technical File as defined in NO_x Technical Code (hereinafter referred to as “test report included in a NO_x technical file”). The value of C_F is as follows:

Carbon Conversion Factor C_F

Table 3.1

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

In case of a ship equipped with a dual-fuel main or auxiliary engine, the C_F -factor for gas fuel and the C_F -factor for fuel oil are to apply and be multiplied with the specific fuel oil consumption of each fuel at the relevant EEDI load point.

Calculation examples are set out in Appendix 1-1.

3.2 Ship speed (V_{ref})

V_{ref} is the speed of steam turbines of the ship, measured in knot, on deep water in the condition corresponding to the Capacity as defined in paragraph 3.3 (in case of passenger ships and ro-ro passenger ships, this condition is to be summer load draught as provided in paragraph 3.4) at the shaft power of the engine(s) as defined in paragraph 3.5 and assuming the weather is calm with no wind and no waves.

3.3 Capacity

Capacity is defined as follows for different ship types:

3.3.1 For bulk carriers, tankers and LNG carriers, deadweight (DWT) is to be used as capacity.

3.3.2 For containerhips, 70% of the deadweight (DWT) is to be used as capacity. EEDI values for containerhips are calculated as follows:

(1) Attained EEDI value is to be calculated using 70% DWT in accordance with EEDI formula;

(2) Required EEDI value is to be calculated using 100% DWT in accordance with reference line formula in 5.3.2 of the Rules.

3.4 Deadweight (DWT)

Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1,025 kg/m³ at the summer load draught and the lightweight of the ship. The summer load draught is to be taken as the maximum summer draught as certified in the stability booklet approved by the Administration or CCS.

3.5 Power (P)

P is the power of the main and auxiliary engines, measured in kW. The subscripts ME and AE refer to the main and auxiliary engine(s) respectively. The summation on i is for all engines with the number of engines (nME). Power related parameters involved in EEDI calculation formula are as follows:

3.5.1 $P_{ME(i)}$ is 75% of the rated installed power (MCR) for each main engine. The MCR value specified on the EIAPP certificate is to be used for calculation. If the main engines are not required to have an EIAPP certificate, the MCR value on the nameplate is to be used for calculation.

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

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

where:

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

$\eta_{(i)}$ is to be taken as the product of electrical efficiency of generator, transformer, converter, and motor, taking into consideration the weighted average as necessary. The electrical efficiency, $\eta_{(i)}$, is to be taken as 91.3% for the purpose of calculating attained EEDI. Alternatively, if the value more than 91.3% is to be applied, the $\eta_{(i)}$ is to be obtained by measurement and verified by method approved by CCS.

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

3.5.2 $P_{PTO(i)}$ — In case where a shaft generator is installed, the shaft generator power ($P_{PTO(i)}$) is 75% of the rated electrical power output for each shaft generator. In case that shaft generator(s) are installed to steam turbine, $P_{PTO(i)}$ is 83% of the rated electrical output power and the factor of 0.75 is to be replaced to 0.83.

There are two options to calculate the effect of shaft generators:

(1) Option 1: The maximum allowable deduction for the calculation of $\sum P_{ME(i)}$ is to be no more than P_{AE} as defined in paragraph 3.5.4. For this case, $\sum P_{ME(i)}$ is calculated as:

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

(2) Option 2: Where an engine is installed with a higher rated power output than that which the propulsion system is limited to as verified by technical means, the value of $\sum P_{ME(i)}$ is to be 75% of that limited power for determining the reference speed V_{ref} defined in 3.2 and for EEDI calculation.

The following figure gives guidance for determination of $\sum P_{ME(i)}$.

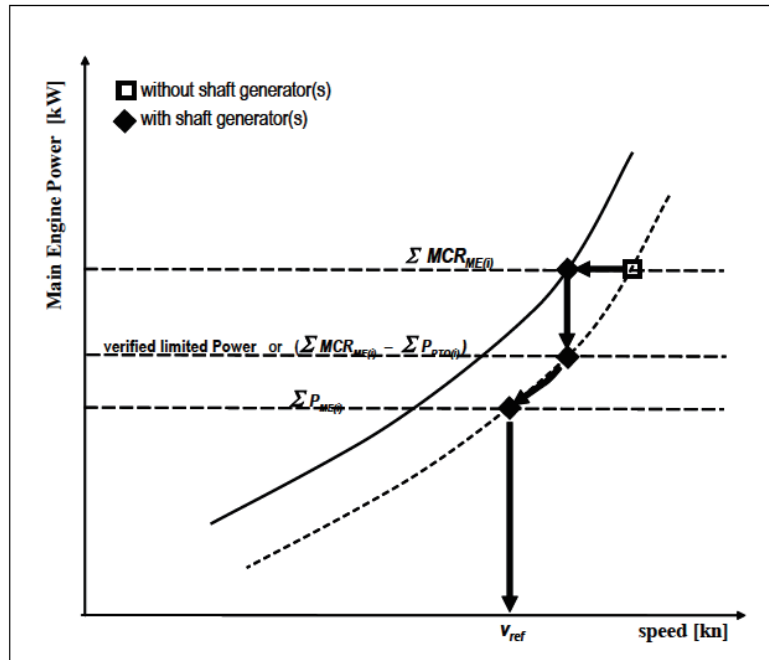


Figure 3.5.2 Determination of the Power $\sum P_{ME(i)}$ of a Main Engine

3.5.3 $P_{PTI(i)}$ — In case where shaft motor(s) are installed, $P_{PTI(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted average efficiency of the generator(s), as follows:

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

where: $P_{SM,max(i)}$ — is the rated power consumption of each shaft motor;

η_{Gen} — is the weighted average efficiency of the generator(s).

In case that shaft motor(s) are installed to steam turbine, $P_{PTI(i)}$ is 83% of the rated power consumption and the factor of 0.75 is to be replaced to 0.83.

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

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

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

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

Where the total propulsion power as defined above is higher than 75% of the power the propulsion system is limited to by verified technical means, then 75% of the limited power is to be used as the total propulsion power for determining the reference speed, V_{ref} as defined in 3.2 and for EEDI calculation. Then,

$(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} + \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot C_{FAE} \cdot SFC_{AE})$ is to be replaced by 75% of the limited power multiplied by the weighted average value of $(SFC_{ME} \cdot C_{FME})$ and $(SFC_{AE} \cdot C_{FAE})$.

In case of combined *PTI/PTO*, the normal operational mode at sea will determine which of these is to be used in the EEDI calculation. For example, if this combined system is used as a shaft generator for ships in normal operation at sea, the P_{PTO} parameter is to be used in the EEDI calculation formula and P_{PTI} equals 0.

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

Calculation examples for engines provided with shaft generators and shaft motors are set out in Appendix 1-1.

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

P_{AE} used for the calculation of Attained EEDI of ships is to be calculated by the following experience-based formulae instead of the actual auxiliary engine power.

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

$$P_{AE}(\sum MCR_{ME(i)} \geq 10000kW) = \left(0.025 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right) + 250$$

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

$$P_{AE}(\sum MCR_{ME(i)} < 10000kW) = 0.05 \times \left(\sum_{i=1}^{nME} MCR_{ME(i)} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right)$$

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

① For LNG carriers having re-liquefaction system:

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

where: $CargoTankCapacity_{LNG}$ — the LNG Cargo Tank Capacity, in m³.

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

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

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

$COP_{cooling}$ — the coefficient of design performance of reliquefaction and 0.166 is to be used. Another value calculated by the manufacturer and verified by the Administration or CCS may be used.

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

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

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

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

where: COP_{comp} is the design power performance of compressor and 0.33 (kWh/kg) is to be used. Another value calculated by the manufacturer and verified by the Administration or an organization recognized by the Administration may be used.

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

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

With regard to the factor of 0.02, it is assumed that the additional energy needed to compress BOG for supplying to a 4-stroke dual fuel engine is approximately equal to 2% of P_{ME} , compared to the energy needed to compress BOG for supplying to a steam turbine.

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

For LNG carriers having steam turbine propulsion system and of which electric power is primarily supplied by turbine generator closely integrated into the steam and feed water systems, P_{AE} may be treated as 0(zero) instead of taking into account electric load in calculating $SFC_{SteamTurbine}$.

3.5.5 $P_{eff(i)}$ is the output of the innovative mechanical energy efficient technology for propulsion at 75% main engine power.

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

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

In case of a ship equipped with a dual-fuel engine, the C_F and SFC are to be obtained according to 3.1 and 3.7.

3.5.6 $P_{AEff(i)}$ is the auxiliary power reduction due to innovative electrical energy efficient technology measured at $P_{ME(i)}$.

3.5.7 The simplified figure below illustrates a generic marine power plant and the power used for EEDI calculation.

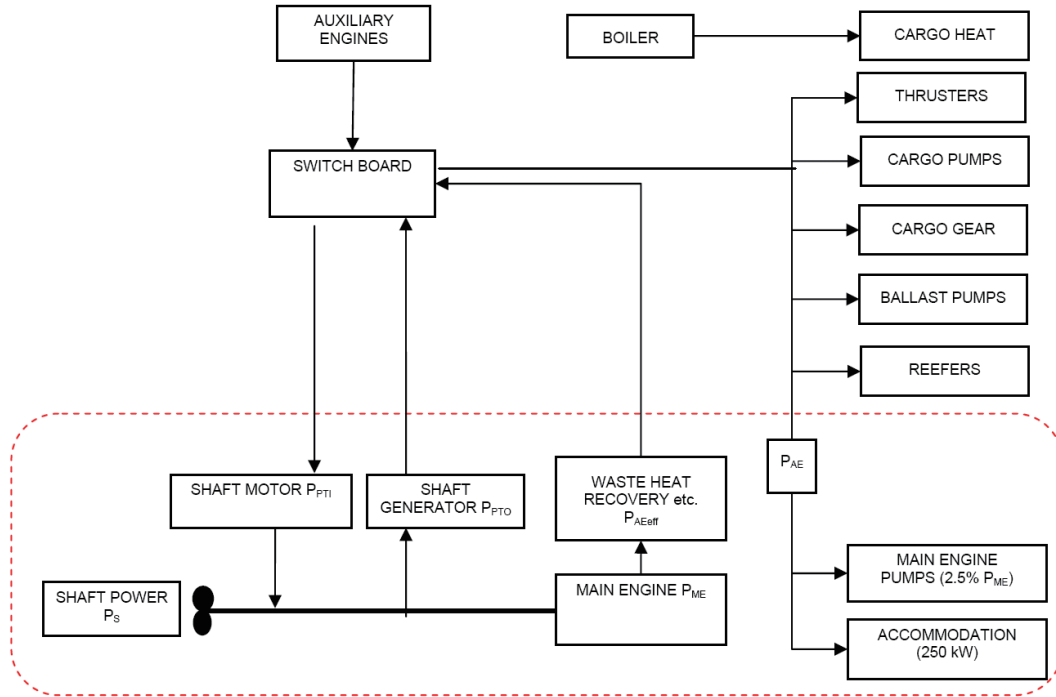


Figure 3.5.7 A Generic Marine Power Plant for Ships Having Conventional Propulsion

3.6 The essential parameters V_{ref} , Capacity and P for determining EEDI for a ship are interrelated and should be consistent with each other. As for LNG carriers having diesel electric or steam turbine propulsion systems, V_{ref} is the relevant speed at 83% of MPP_{Motor} or $MCR_{SteamTurbine}$ respectively.

3.7 Specific Fuel Consumption (SFC)

SFC is the certified specific fuel consumption, measured in g/kWh, of the engines or steam turbines. SFC_{ME} and SFC_{AE} refer to the specific fuel consumption of the main and auxiliary engine(s) respectively.

3.7.1 For engines certified to the E2 or E3 duty cycles of the NO_x Technical Code 2008, the engine Specific Fuel Consumption ($SFC_{ME(i)}$) is that recorded in the test report included in a NO_x technical file for the engine(s) at 75% of MCR power or its torque rating.

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

3.7.3 If gas fuel is used as primary fuel in accordance with paragraph 2.3.3 of CCS *Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships*, SFC in gas mode is to be used. In case that installed engine(s) have no approved NO_x Technical File tested in gas mode, the SFC of gas mode is to be submitted by the manufacturer and confirmed by CCS.

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

3.7.5 For ships where the P_{AE} value calculated by 3.5.4.(1) or (2) above is significantly different from the total power used at normal seagoing, e.g., conventional passenger ships, the Specific Fuel Consumption (SFC_{AE}) of the auxiliary generators is that recorded in the test report included in a NO_x technical file for the engine(s) at 75% of MCR power or its torque rating.

3.7.6 SFC_{AE} is the power-weighted average among $SFC_{AE(i)}$ of the respective engines i .

3.7.7 For those engines which do not have a test report included in a NO_x technical file because its power is below 130 kW, the SFC specified by the manufacturer and endorsed by the Administration or CCS is to be used.

3.7.8 At the design stage, in case of unavailability of a test report in the NO_x file, the SFC specified by the manufacturer and endorsed by the Administration or CCS is to be used.

3.7.9 For LNG-driven engines, SFC measured in kJ/kWh is to be amended to SFC value measured in g/kWh by using the standard lower heat value of the LNG (48,000 kJ/kg) (Refer to 2006 IPCC Guidelines).

3.7.10 The $SFC_{SteamTurbine}$ is to be calculated by manufacturer and verified by the Administration or CCS as follows:

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

where:

(1) Fuel consumption is fuel consumption of boiler per hour (g/h). For ships of which electric power is primarily supplied by Turbine Generator closely integrated into the steam and feed water systems, not only P_{ME} but also electric loads corresponding to paragraph 3.5.4 are to be taken into account.

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

(3) In this correction, the difference of the boiler efficiency based on lower calorific value between test fuel and LNG is to be taken into account.

3.8 Correction factor f_j

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

3.8.1 For ice-classed ships, the power of the main engine is to be increased due to navigation in ice. Therefore an additional correction factor is applied to compensate for negative effects caused by the increased power on EEDI of such ships. This factor is to be taken as the greater value of f_{j0} and $f_{j,min}$ as tabulated in Table 3.8.1, but not to be greater than 1.0.

Correction Factor f_j for Ice-Classed Ships

Table 3.8.1

Ship type	f_{j0}	$f_{j,min}$ depending on ice class			
		B3	B2	B1	B1*
Tanker	$\frac{0.308L_{pp}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.70L_{pp}^{0.06}$	$0.45L_{pp}^{0.13}$	$0.27L_{pp}^{0.21}$	$0.15L_{pp}^{0.30}$
Bulk carrier	$\frac{0.639L_{pp}^{1.754}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.87L_{pp}^{0.02}$	$0.73L_{pp}^{0.04}$	$0.58L_{pp}^{0.07}$	$0.47L_{pp}^{0.09}$

Note: B1*, B1, B2 and B3 are ice class notations specified in CCS Rules for Classification of Sea-going Steel Ships, which correspond to IA Super, IA, IB, IC as specified in Finnish and Swedish Ice Class Rules (FSICR).

3.8.2 The factor f_j , for shuttle tankers with propulsion redundancy is to be $f_j = 0.77$. This correction factor applies to shuttle tankers with propulsion redundancy and having a deadweight of 80,000 ~ 160,000 tonnes. The shuttle tankers with propulsion redundancy are tankers used for loading of crude oil from offshore installations and equipped with dual-engine and twin-propellers, need to meet the requirements for dynamic positioning and redundancy propulsion class notation.

3.8.3 For other ship types not included in the above table, f_j is to be taken as 1.0.

3.9 Correction factor f_i

f_i is the capacity correction factor for any technical/regulatory limitation on capacity, which is used to compensate for negative effects on EEDI due to the loss of capacity, and can be assumed 1.0 if no necessity of the factor is granted.

3.9.1 For ice-classed ships, the capacity is decreased due to the increased ship weight resulting from the increased steel plate thickness for guaranteeing their ice breaking capability. Therefore this capacity correction factor is applied to compensate for the loss of capacity. This factor is to be taken as the lesser value of f_{i0} and $f_{i,max}$ as tabulated in Table 3.9.1, but not to be less than 1.0.

Correction Factor f_i for Ice-Classed Ships

Table 3.9.1

Ship Type	f_{i0}	$f_{i,max}$ depending on ice class			
		IC	IB	IA	IA Super
Tanker	$\frac{0.00138L_{PP}^{3.331}}{capacity}$	$1.27L_{PP}^{-0.04}$	$1.47L_{PP}^{-0.06}$	$1.71L_{PP}^{-0.08}$	$2.10L_{PP}^{-0.11}$
Bulk carrier	$\frac{0.00403L_{PP}^{3.123}}{capacity}$	$1.31L_{PP}^{-0.05}$	$1.54L_{PP}^{-0.07}$	$1.80L_{PP}^{-0.09}$	$2.10L_{PP}^{-0.11}$
Container ship	$\frac{0.1033L_{PP}^{2.329}}{capacity}$	$1.27L_{PP}^{-0.04}$	$1.47L_{PP}^{-0.06}$	$1.71L_{PP}^{-0.08}$	$2.10L_{PP}^{-0.11}$

3.9.2 For ships with voluntary structural enhancements, f_{iVSE} is to be expressed as follows:

$$f_{iVSE} = \frac{DWT_{reference\ design}}{DWT_{enhanced\ design}}$$

where: $DWT_{reference\ design} = \Delta_{ship} - lightweight_{reference\ design}$;

$$DWT_{enhanced\ design} = \Delta_{ship} - lightweight_{enhanced\ design}$$

For this calculation, the same displacement (Δ) is to be taken for reference and enhanced designs.

Note: Structural and/or additional class notations such as, but not limited to, “strengthened for discharge with grabs” and “strengthened bottom for loading/unloading aground”, which result in a loss of deadweight of the ship, are also seen as examples of “voluntary structural enhancements”.

(1) DWT before enhancements ($DWT_{reference\ design}$) is the deadweight prior to application of the structural enhancements. DWT after enhancements ($DWT_{enhanced\ design}$) is the deadweight following the application of voluntary structural enhancements.

(2) Where any change is made to the material (e.g. from aluminum alloy to steel) or in steel grades of the same material (e.g. in steel types, grades, properties and conditions) between reference design and voluntarily enhanced design, f_{iVSE} is not to be used to correct the deadweight.

(3) Two sets of structural plans of the ship (one set for the reference design and the other set for the enhanced design) are to be submitted to CCS for assessment. As an alternative, only one set of structural plans of the reference design with annotations of voluntary structural enhancements may be submitted. Both sets of structural plans are to comply with the applicable regulations for the ship type and intended trade.

3.9.3 For other ship types not included in the table above, f_i is to be taken as 1.0.

3.9.4 The above factor f_i may be accumulated (multiplied).

3.10 Cubic capacity correction factor f_c

f_c is the cubic capacity correction factor and is to be taken as 1.0 if no necessity of the factor is granted. It is calculated as follows:

3.10.1 For chemical tankers, the cubic capacity correction factor f_c is to be:

$$f_c = R^{(-0.7)} - 0.014 \quad \text{for } R < 0.98; \text{ or}$$

$$f_c = 1.00 \quad \text{for } R \geq 0.98$$

where: R is the ratio of the ship's DWT (in tonnes) to the total cubic capacity (in m^3) of its cargo tanks (m^3).

3.11 Energy efficiency factor f_{eff}

f_{eff} is the availability factor of each innovative energy efficiency technology. f_{eff} for waste energy recovery system is to be taken as 1.0.

3.12 Length between perpendiculars (L_{pp})

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

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

Appendix 2 Guidelines for the Development of Electric Power Tables for EEDI (EPT-EEDI)

1 Introduction to the document “Electric Power Table for EEDI”

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

2 Auxiliary load power definition

2.1 P_{AE} is to be calculated as indicated in 3.5.4 of Appendix 1, together with the following additional three conditions:

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

3 Definition of the data to be included in the Electric Power Table for EEDI

3.1 The Electric Power Table for EEDI calculation is to contain the following data elements, as appropriate:

- (1) Load’s group;
- (2) Load’s description;
- (3) Load’s identification tag;
- (4) Load’s electric circuit Identification;
- (5) Load’s mechanical rated power “ P_m ” [kW];
- (6) Load’s electric motor rated output power [kW];
- (7) Load’s electric motor efficiency “ e ” [/];
- (8) Load’s Rated electric power “ P_r ” [kW];
- (9) Service factor of load “ kl ” [/];
- (10) Service factor of duty “ kd ” [/];

- (11) Service factor of time “ kt ” [/];
- (12) Service total factor of use “ ku ” [/], where $ku = kl \cdot kd \cdot kt$;
- (13) Load’s necessary power “ $Pload$ ” [kW], where $Pload = Pr \cdot ku$;
- (14) Notes;
- (15) Group’s necessary power [kW]; and
- (16) Auxiliaries load’s power P_{AE} [kW].

4 Data to be included in the Electric Power Table for EEDI

4.1 Load groups

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

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

All the ship’s loads have to be delineated in the document, excluding only P_{Aeff} , the shaft motors and shaft motors chain (while the propulsion services auxiliaries are partially included below in paragraph 4.1.2 B). Some loads (i.e. thrusters, cargo pumps, cargo gear, ballast pumps, maintaining cargo, reefers and cargo hold fans) still are included in the group for sake of transparency, however their service factor is zero in order to comply with the requirements for calculation of P_{AE} in 3.5.4 of Appendix 1, therefore making it easier to verify that all the loads have been considered in the document and there are no loads left out of the measurement.

4.1.1 A – Hull, deck, navigation and safety services

(1) Loads included in the hull services typically are: ICCP systems, mooring equipment, various doors, ballasting systems, bilge systems, stabilizing equipment, etc. Ballasting systems are indicated with service factor equal to zero to comply with the requirements for calculation of P_{AE} in 3.5.4 of Appendix 1;

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

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

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

4.1.2 B – Propulsion service auxiliaries

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

4.1.3 C – Auxiliary engine and main engine services

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

4.1.4 D – Ship's general services

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

4.1.5 E – Ventilation for engine rooms and auxiliaries room

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

4.1.6 F – Air Conditioning services

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

4.1.7 G – Galleys, refrigeration and laundry services

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

4.1.8 H – Accommodation services

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

4.1.9 I – Lighting and socket services

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

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

(2) power sockets for 1) cabins, 2) corridors, 3) technical rooms/stairs, 4) public spaces/stairs, 5) engine rooms and auxiliaries' room, 6) garages and 7) cargo spaces. All 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.).

4.1.10 L – Entertainment services

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

4.1.11 N – Cargo loads

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

4.1.12 M – Miscellaneous

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

4.2 Loads description

This identifies the loads (for example “sea water pump”).

4.3 Loads identification tag

This tag identifies the loads according to the shipyard's standards tagging system. For example, the “PTII fresh water pump” identification tag is “SYIYA/C” for an example ship and shipyard. This data provides a unique identifier for each load.

4.4 Loads electric circuit identification

This is the tag of the electric circuit supplying the load. Such information allows the data validation process.

4.5 Loads mechanical rated power " P_m " [kW]

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

4.6 Loads electric motor rated output power [kW]

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

4.7 Loads electric motor efficiency " e " [/]

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

4.8 Loads rated electric power " Pr " [kW]

Typically the maximum electric power absorbed at the load electric terminals at which the load has been designed for its service, as indicated on the maker's nameplate and/or in the 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].

4.9 Service factor of load " kl " [/]

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

4.10 Service factor of duty " kd " [/]

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 EPT for EEDI, this factor provides a correct summation of the loads. For example when two pumps serve the same circuit and they run in duty/standby, their kd factor will be $\frac{1}{2}$ and $\frac{1}{2}$. When three compressors serve the same circuit and one runs in duty and two in standby, then kd is $\frac{1}{3}$, $\frac{1}{3}$ and $\frac{1}{3}$.

4.11 Service factor of time " kt " [/]

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

4.12 Service total factor of use " ku " [/]

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

4.13 Loads necessary power “*Pload*” [kW]

The individual user contribution to the auxiliary load power is $Pload = Pr \cdot ku$.

4.14 Notes

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

4.15 Groups necessary power [kW]

The summation of the “loads necessary power” from group A to N. This is an intermediate step which is not strictly necessary for the calculation of 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.

4.16 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.

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

5 Layout and organization of the data indicated in the “Electric Power Table for EEDI”

5.1 The document “Electric Power Table for EEDI” is to include general information (i.e. ship’s name, project name, document references, etc.) and a table with:

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

An example of an Electric Power Table for EEDI for a cruise postal vessel which transports passengers 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.

ELECTRIC POWER TABLE FOR EEDI			HULL "EXAMPLE"		PROJECT "EXAMPLE"		Load electric motor efficiency "e" [%]	Load electric motor rated power "Pr" [kW]	service factor of load "kl" [%]	service factor of duty "kd" [%]	service factor of time "kt" [%]	service total factor of use "ku" [%]	Load necessary power "Pload" [kW]	Note
id	Load group	Load description	Load identification tag	Load electric circuit identification	Load mechanical rated power "Pm" [kW]	Load electric motor rated power [kW]								
1	A	Hull cathodic protection Fwd	xxx	yyy	n.a.	n.a.	n.a.	5.2	1	1	1*	1	5.2	*in use 24hours/day
2	A	Hull cathodic protection mid	xxx	yyy	n.a.	n.a.	n.a.	7.0	1	1	1*	1	7	*in use 24hours/day
3	A	Hull cathodic protection aft	xxx	yyy	n.a.	n.a.	n.a.	4.8	1	1	1*	1	4.8	*in use 24hours/day
4	A	Ballast pump 3	xxx	yyy	30	36	0.92	32.6	0.9	0.5	1	0*	0	*not in use at NMSL see para 2.5.6 of Circ.681
5	A	Fwd Sth mooring winch motor n.1	xxx	yyy	90	150	0.92	97.8	0.8	1	0*	0*	0	*not in use at NMSL see para 2.5.6 of Circ.681
6	A	WTDs system main control panel	xxx	yyy	n.a.	n.a.	n.a.	0.5	1	1	1*	1	0.5	*in use 24hours/day
7	A	WTD 1, deck D frame 150	xxx	yyy	1.2	3	0.91	1.3	0.7	1	0.104*	0.0728	0.096	*180 secs to open/close x 100 opening a day
8	A	WTD 5, deck D frame 210	xxx	yyy	1.2	3	0.91	1.3	0.7	1	0.156*	0.1092	0.14	*180 secs to open/close x 150 opening a day
9	A	Stabilisers control unit	xxx	yyy	n.a.	n.a.	n.a.	0.7	1	1	1*	1	0.7	*in use 24hours/day
10	A	Stabilisers Hydraulic pack power pump 1	xxx	yyy	80	90	0.9	88.9	0.9	1	0*	0	0	*NMSL=> calm sea=> stabiliser not in use
11	A	S-band Radar 1 controller	xxx	yyy	n.a.	n.a.	n.a.	0.4	1	1	1*	1	0.4	*in use 24hours/day
12	A	S-band Radar 1 motor	xxx	yyy	0.8	1	0.92	0.9	1	1	1*	1	0.9	*in use 24hours/day
13	A	Fire detection system bridge main unit	xxx	yyy	n.a.	n.a.	n.a.	1.5	1	1	1*	1	1.5	*in use 24hours/day
14	A	Fire detection system ECR unit	xxx	yyy	n.a.	n.a.	n.a.	0.9	1	1	1*	1	0.9	*in use 24hours/day
15	A	High pressure water fog control unit	xxx	yyy	n.a.	n.a.	n.a.	1.2	1	1	1*	1	1.2	*in use 24hours/day
16	A	High pressure water fog engines rooms pump 1a	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0	0	*NMSL=> not emergency => Load not in use
17	A	High pressure water fog engines rooms pump 1b	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0	0	*not emergency situations
18	B	PTI port fresh water pump 1	xxx	yyy	30	36	0.92	32.6	0.9	0.5*	1	0.45	14.7	* pump1,2 one is duty and one is stand-by
19	B	PTI port fresh water pump 2	xxx	yyy	30	36	0.92	32.6	0.9	0.5*	1	0.45	14.7	* pump1,2 one is duty and one is stand-by
20	B	Thrusters control system	xxx	yyy	n.a.	n.a.	n.a.	0.5	1	1	1*	1	0.5	in use 24hours/day (even if thruster motor isn't)
21	B	Bow thruster 1	xxx	yyy	3000	3000	0.96	3125.0	1	1	0*	0	0	*NMSL=>thrusters motor are not in use
22	B	PEM port cooling fan 1	xxx	yyy	20	25	0.93	21.5	0.9	1	n.a.	n.a	n.a.*	*this load is included in the propulsion chain data
23	C	HT circulation pump 1 DG 3	xxx	yyy	8	10	0.92	8.7	0.9	0.5*	1	0.45	3.9	* pump1,2 one is duty and one is stand-by
24	C	HT circulation pump 2 DG 3	xxx	yyy	8	10	0.92	8.7	0.9	0.5*	1	0.45	3.9	* pump1,2 one is duty and one is stand-by
25	C	DG3 combustion air fan	xxx	yyy	28	35	0.92	30.4	0.9	1	1*	0.9	27.4	*in use 24hours/day
26	C	DG3 exhaust gas boiler circulation pump	xxx	yyy	6	8	0.93	6.5	0.8	1	1*	0.8	5.2	*in use 24hours/day
27	C	Alternator 3 external cooling fan	xxx	yyy	3	5	0.93	3.2	0.8	1	1*	0.8	2.75	*in use 24hours/day
28	C	fuel feed fwd booster pump a	xxx	yyy	7	9	0.92	7.6	0.9	0.5*	1	0.45	3.4	* pump1,2 one is duty and one is stand-by
29	C	fuel feed fwd booster pump b	xxx	yyy	7	9	0.92	7.6	0.9	0.5*	1	0.45	3.4	* pump1,2 one is duty and one is stand-by
30	D	Fwd main LT cooling pump 1	xxx	yyy	120	150	0.95	126.3	0.9	0.5*	1	0.45	56.8	* pump1,2 one is duty and one is stand-by
31	D	Fwd main LT cooling pump 2	xxx	yyy	120	150	0.95	126.3	0.9	0.5*	1	0.45	56.8	* pump1,2 one is duty and one is stand-by
32	E	FWD engine room supply fan 1	xxx	yyy	87.8	110	0.93	94.4	0.95	1	1*	0.95	89.7	*in use 24hours/day
33	E	FWD engine room exhaust fan 1	xxx	yyy	75	86	0.93	80.6	0.96	1	1*	0.96	77.4	*in use 24hours/day
34	E	purifier room supply fan 1	xxx	yyy	60	70	0.93	64.5	0.96	0.5	1*	0.48	31.0	*in use 24hours/day
35	E	purifier room supply fan 2	xxx	yyy	60	70	0.93	64.5	0.96	0.5	1*	0.48	31.0	*in use 24hours/day
36	F	HVAC chiller a	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
37	F	HVAC chiller b	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
38	F	HVAC chiller C	xxx	yyy	1450	1600	0.95	1526.3	1	2/3*	1	0.66	1007.4	*1 Chiller is spare; see heat load dissipation doc.
39	F	A.H.U. Ac station 5.4 supply fan	xxx	yyy	50	60	0.93	53.8	0.9	1	1*	0.9	48.4	*in use 24hours/day
40	F	A.H.U. Ac station 5.4 exhaust fan	xxx	yyy	45	55	0.93	48.4	0.9	1	1*	0.9	43.5	*in use 24hours/day
41	F	Chilled water pump a	xxx	yyy	80	90	0.93	86.0	0.88	0.5*	1	0.44	37.8	* pump1,2 one is duty and one is stand-by
42	F	Chilled water pump b	xxx	yyy	80	90	0.93	86.0	0.88	0.5*	1	0.44	37.8	* pump1,2 one is duty and one is stand-by
43	G	Italian's espresso coffee machine	xxx	yyy	n.a.	n.a.	n.a.	7.0	0.9	1	0.2*	0.18	1.3	*in use 4.8hours/day
44	G	deep freezer machine	xxx	yyy	n.a.	n.a.	n.a.	20.0	0.8	1	0.16*	0.128	3.2	*in use 4hours/day
45	G	washing machine 1	xxx	yyy	n.a.	n.a.	n.a.	8.0	0.8	1	0.33*	0.264	3.2	*in use 8hours/day
46	H	lift pax mid 4	xxx	yyy	30	40	0.93	32.3	0.5	1	0.175*	0.0875	0.9	*in use 4hours/day
47	H	vacuum collecting system 4 pump a	xxx	yyy	10	13	0.92	10.9	0.9	1	1*	0.9	8.7	*in use 24hours/day
48	H	sewage treatment system 1 pump 1	xxx	yyy	15	17	0.93	16.1	0.9	1	1*	0.9	8.7	*in use 24hours/day
49	H	Gym running machine	xxx	yyy	n.a.	n.a.	n.a.	2.5	1	1	0.3*	0.3	0.8	*in use 7.2hours/day
50	I	Cabin's lighting MV23	n.a.	n.a.	n.a.	n.a.	n.a.	80*	1	1	1	1	80.0	* see explanatory note
51	I	corridors lighting MV23	n.a.	n.a.	n.a.	n.a.	n.a.	10*	1	1	1	1	10.0	* see explanatory note
52	I	Cabin's sockets MV23	n.a.	n.a.	n.a.	n.a.	n.a.	5*	1	1	1	1	5.0	* see explanatory note
53	L	Main Theatre audio booster amplifier	xxx	yyy	n.a.	n.a.	n.a.	15.0	1	1	0.3*	0.3	4.5	*in use 7.2hours/day
54	L	Video wall atrium	xxx	yyy	n.a.	n.a.	n.a.	2.0	1	1	0.3*	0.3	0.6	*in use 7.2hours/day
55	M	Car Garage supply fan1	xxx	yyy	28	35	0.92	30.4	0.9	1	1*	0*	0	*not in use at NMSL see para 2.5.6 of Circ.681
56	M	Fish transportation referer hold n.2	xxx	yyy	25	30	0.93	26.9	0.9	0.5	0*	0*	0	*not in use at NMSL see para 2.5.6 of Circ.681
57	N	Sliding glass roof	xxx	yyy	30	40	0.93	32.3	0.9	1	0.3*	0.27	0.2	*in use 7.2hours/day
ΣPload(i)=													3764	
PAE=3764/(weighted average efficiency of generator(s)) [kW] Group's necessary power (group A=22.9kW, B=29.8kW, C=49.9kW, D=113.7kW, E=229kW, F=3189kW, G=7.6kW, H=19kW, I=95kW, L=5.1kW, M=0kW, N=0.22kW)														

Appendix 3 Interim Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ships in Adverse Conditions

Purpose

The purpose of the interim guidelines is to provide guidance in verifying that ships, complying with EEDI requirements set out in 2.3 of the Rules, have sufficient installed propulsion power to maintain the manoeuvrability in adverse conditions.

1 Definition

1.1 “Adverse conditions” mean sea conditions with the following parameters:

Significant wave height h_s , m	Peak wave period T_p , s	Mean wind speed V_w , m/s
5.5	7.0 to 15.0	19.0

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

1.2 The following adverse condition is to be applied to ships defined as the following threshold value of ship size.

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

2 Applicability

2.1 The guidelines are to be applied in the case of all new ships of types as listed in Table 1.1 of the appendix required to comply with the requirements on Energy Efficiency for Ships according to 2.3 of the Rules.

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

2.3 These guidelines are intended for ships in unrestricted navigation.

3 Assessment procedure

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

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

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

4 Assessment level 1 – minimum power lines assessment

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

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

5 Assessment level 2 – simplified assessment

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

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

6 Documentation

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

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

Appendix

Assessment Procedures to Maintain the Maneuverability under Adverse Conditions

1 Minimum power lines

1.1 The minimum power line values of total installed *MCR*, in kW, for different types of ships are to be calculated as follows:

$$\text{Minimum Power Line Value} = a \times (DWT) + b$$

where: *DWT* is the deadweight of the ship in metric tons; and

a and *b* are the parameters given in Table 1.1 for tankers, bulk carriers and combination carriers.

Parameters *a* and *b* for determination of the minimum power line values for the different ship types

Table 1.1

Ship type	<i>a</i>	<i>b</i>
Bulk Carrier which DWT is less than 145,000	0.0763	3374.3
Bulk Carrier which DWT is 145,000 and over	0.0490	7329.0
Tanker	0.0652	5960.2
Combination Carrier	See tanker above	

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

2 Simplified assessment

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

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

2.3 The assessment procedure consists of two steps:

- .1 definition of the required advance speed in head wind and waves, ensuring course-keeping in all wave and wind directions; and
- .2 assessment whether the installed power is sufficient to achieve the required advance speed in head wind and waves.

Definition of required ship speed of advance

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

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

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

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

2.6 The minimum course-keeping speed in the simplified assessment, V_{ck} , is selected to facilitate course-keeping of the ships in waves and wind from all directions. This speed is defined on the basis of the reference course-keeping speed $V_{ck,ref}$ related to the submerged lateral area of the ship corrected for breadth effect, $A_{LS,cor}$, and the actual rudder area, A_R .

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

where: V_{ck} is the minimum course-keeping speed, in knots;

$V_{ck,ref}$ is the reference course-keeping speed, in knots;

$A_{R\%}$ is the actual rudder area, A_R , as percentage of the submerged lateral area of the ship corrected for breadth effect, $A_{LS,cor}$, calculated as $A_{R\%} = A_R / A_{LS,cor} \times 100\%$.

The submerged lateral area corrected for breadth effect is calculated as $A_{LS,cor} = L_{pp} T_m (1.0 + 25.0(B_{wl}/L_{pp})^2)$, where L_{pp} is the length between perpendiculars in m, B_{wl} is the water line breadth in m, T_m is the draft amidship in m. In case of high-lift rudders or other alternative steering devices, the equivalent rudder area to the conventional rudder area is to be used.

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

.1 9.0 knots for $A_{FW}/A_{LW} \leq 0.1$, and 4.0 knots for $A_{FW}/A_{LW} \geq 0.40$; and

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

Procedure of assessment of installed power

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

$$T = (R_{cw} + R_{air} + R_{aw} + R_{app}) / (1 - t) \quad (2)$$

2.9 The calm-water resistance for bulk carriers, tankers and combination carriers can be calculated neglecting the wave-making resistance as:

$$R_{cw} = (1 + k) C_F \frac{1}{2} \rho S V_s^2$$

where: k is the form factor, $C_F = \frac{0.075}{(\log_{10} R_e - 2)^2}$ is the frictional resistance coefficient, $R_e = \frac{V_s L_{pp}}{\nu}$ is Reynolds

number, ρ is water density in kg/m³, S is the wetted area of the bare hull in m², V_s is the ship advance speed in m/s, ν is the kinematic viscosity of water in m²/s.

2.10 The form factor k is to be obtained from model tests. Where model tests are not available the empirical formula below may be used:

$$k = -0.095 + 25.6 \frac{C_B}{(L_{PP} / B_{wl})^2 \sqrt{B_{wl} / T_m}} \quad (3)$$

where: C_B is the block coefficient based on L_{PP} .

2.11 Aerodynamic resistance can be calculated as:

$$R_{air} = C_{air} \frac{1}{2} \rho_a A_F V_{w,rel}^2$$

where: C_{air} is the aerodynamic resistance coefficient, ρ_a is the density of air in kg/m³, A_F is the frontal windage area of the hull and superstructure in m², $V_{w,rel}$ is the relative wind speed in m/s, defined by the adverse conditions in paragraph 1.1 of the interim guidelines, V_w , added to the ship advance speed, V_s . The coefficient C_{air} can be obtained from model tests or empirical data. If none of the above is available, the value 1.0 is to be assumed.

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

$$R_{aw} = 2 \int_0^\infty \frac{R_{aw}(V_s, \omega)}{\zeta_a^2} S_{\zeta\zeta}(\omega) d\omega \quad (4)$$

where: $R_{aw}(V_s, \omega) / \zeta_a^2$ is the quadratic transfer function of the added resistance, depending on the advance speed V_s in m/s, wave frequency ω in rad/s, the wave amplitude, ζ_a in m and the wave spectrum $S_{\zeta\zeta}$ in m²s. The quadratic transfer function of the added resistance can be obtained from the added resistance test in regular waves at the required ship advance speed V_s as per ITTC procedures 7.5-02 07-02.1 and 7.5-02 07-02.2, or from equivalent method verified by the Administration.

2.13 The thrust deduction factor t can be obtained either from model tests or empirical formula. Default conservative estimate is:

$$t = 0.7w$$

where: w is the wake fraction. Wake fraction w can be obtained from model tests or empirical formula; default conservative estimates are given in Table 2.13.

Recommended values for wake fraction w

Table 2.13

Block coefficient	One propeller	Two propellers
0.5	0.14	0.15
0.6	0.23	0.17
0.7	0.29	0.19
0.8 and above	0.35	0.23

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

$$T = \rho U_a^2 D_p^2 K_T(J) / J^2 \quad (5)$$

where: D_p is the propeller diameter, $K_T(J)$ is the open water propeller thrust coefficient, $J = U_a / n D_p$ and $U_a = V_s(1 - w)$. J can be found from the curve of $K_T(J)/J^2$.

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

$$n = U_a / (JD_p) \quad (6)$$

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

$$P_D = 2\pi\rho n^3 D_p^5 K_Q(J) \quad (7)$$

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

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

- .1 torque-speed limitation curve of the engine which is specified by the engine manufacturer; and
- .2 transmission efficiency η_s which is to be assumed 0.98 for aft engine and 0.97 for midship engine, unless exact measurements are available.

Appendix 4 Guidelines for Verification of Basic Design of EEDI Power Curves

Chapter 1 General

1.1 General

1.1.1 The purpose of these Guidelines is to provide guidance for the selection of main engine power and the calculation of required power curves in terms of Energy Efficiency Design Index (EEDI) at the basic design stage of ships, thereby verifying their design.

1.2 Definitions

1.2.1 The hull – engine – propeller interactions related to power parameters are shown in Figure 1.2.1.

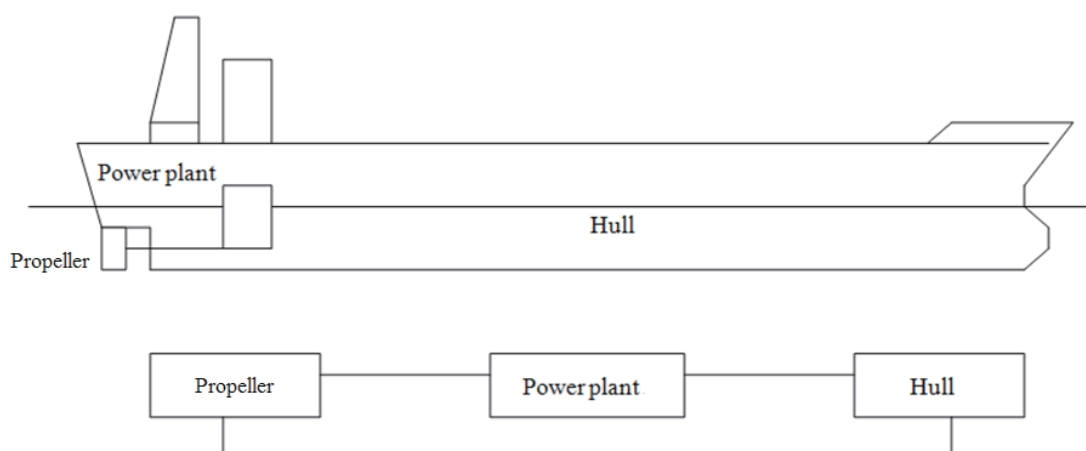


Figure 1.2.1 Hull – Engine – Propeller system

1.2.2 Power curve: a correlation curve (kW-knot) showing the ship speed achieved at different outputs (%MCR) of the main engine in specified loading conditions. The power curve may be developed by estimation or model test at the design stage. The final power curve is to be obtained from sea trial.

1.2.3 Power is defined in Figure 1.2.3.

(1) Effective power P_E : the power required for the ship to overcome resistance in water at speed V :

$$P_E = R \cdot V$$

where: R — resistance.

(2) Propulsion power P_T : the power supplied by the propeller at current speed in front of the propeller:

$$P_T = T \cdot V_A$$

where: T — propeller thrust:

$$T = R/(1 - t)$$

t — thrust deduction fraction;

V_A — speed of water flowing to propeller:

$$V_A = V \times (1 - w)$$

w — wake fraction.

(3) Delivered power P_D at propeller: output power of the main engine after deducting stern bearing and packing gland loss:

$$P_D = 2\pi Q \cdot n$$

where: Q — torque of propeller;
 n — rate of propeller revolutions.

Taking into account the transmission loss of the whole shafting, the delivered power may be approximately calculated as follows:

If the main engine is located amidship, $P_D = P_S/1.03$ or $P_D = P_B/1.05$;

If the main engine is located astern, $P_D = P_S/1.02$ or $P_D = P_B/1.03$.

(4) Brake power P_B : power measured by brake dynamometer at output end of the main engine.

(5) Shaft power P_S of main engine: brake power deducting loss due to attached pump(s), generator(s), air compressor(s) and reduction gear(s) which are driven by the main engine:

$$P_S = 2\pi M \cdot n = P_E / \eta_H \eta_O \eta_R \eta_S$$

where: M — torque transmitted from main propulsion engine to shafting;
 $\eta_H \eta_O \eta_R \eta_S$ — see 1.2.4(1), (2), (3).

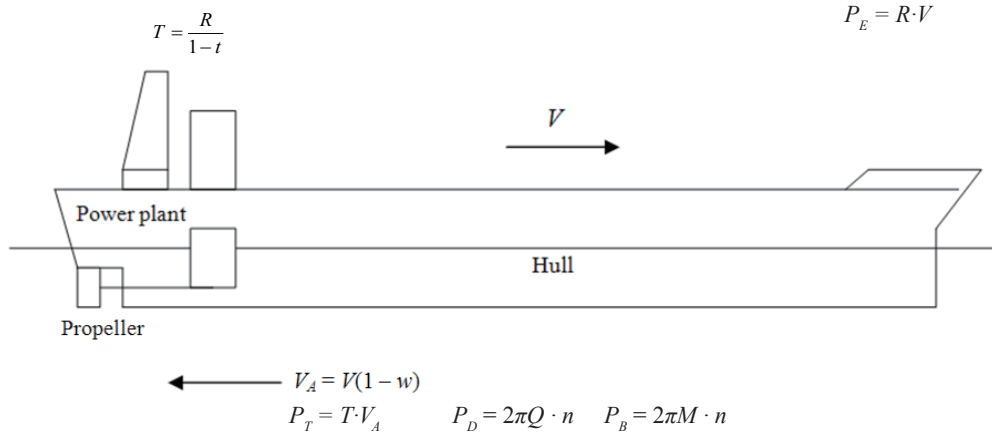


Figure 1.2.3 Definitions

1.2.4 The relationship between the powers is as follows:

(1) P_E/P_T — hull efficiency η_H :

$$\eta_H = \frac{P_E}{P_T} = \frac{R \times V}{T \times V_A} = \frac{R/T}{V_A/V} = \frac{1-t}{1-w}$$

(2) P_T/P_D — propeller open water efficiency η_O :

$$\eta_O = \frac{P_T}{P_D} = \frac{T \times V_A}{2\pi Q \times n} = \frac{J}{2\pi} \frac{K_T}{K_Q}$$

where: K_T, K_Q — propeller thrust coefficient and torque coefficient;
 J — advance coefficient of propeller:

$$J = \frac{V_A}{nD}$$

D — propeller diameter.

(3) P_D/P_B — shafting efficiency η_S : shafting transmission efficiency, taking into account transmission loss of the whole shafting (including intermediate bearing, thrust bearing and stern tube).

(4) P_E/P_D — propulsion efficiency (propulsion coefficient) η_D :

$$\eta_D = \frac{P_E}{P_D} = \eta_O \times \eta_H \times \eta_R$$

where: η_R — relative rotative efficiency, $\eta_R = \frac{1}{i_2}$, i_2 being effect of wake inhomogeneity on propulsion efficiency η_D .

1.3 Basic design information in the technical file submitted for EEDI verification

1.3.1 The basic design information submitted to CCS as the verifier by the shipbuilder/designer is to include at least, but not limited to:

(1) basic data of the designed ship, including:

- deadweight (DWT); deadweight (DWT) or gross tonnage (GT) for passenger ships and ro-ro passenger ships;
- shaft power of main and auxiliary engines;
- ship speed on deep water in the maximum design loading conditions at the 75% of the maximum continuous rating for the main engine (equivalent to maximum continuous operating condition of the main engine (rated installed power, MCR), considering 10% operational margin (OM) and 15% sea margin (SM));
- specific fuel consumption (SFC) of the main engine at the 75% of MCR power;
- specific fuel consumption (SFC) of the auxiliary engines at the 50% of MCR power;
- electric power tables for certain ship types;

(2) power curves (kW-knot) estimated under the fully-loaded condition and sea trial condition, as well as the estimation process and methodology.

Chapter 2 Estimation of Main Engine Power and Determination of Main Engine Type

2.1 General

2.1.1 For traditional design methods, where tank test data of a parent ship is not available for reference, the main engine power may be estimated by means of the admiralty constant, diagrams or calculation at the basic design stage of conventional ships. The admiralty constant is applied where tank test data and/or sea trial verification data of a parent ship are available for reference.

2.1.2 Where the designed ship is required to comply with EEDI, the concept of the parent ship is to be understood as follows:

(1) the block coefficient C_b , length displacement coefficient $L/\nabla^{1/3}$ and other dimensional coefficients, and the Froude number F_n of design speed are equal or approximate to those of the parent ship; and

(2) the EEDI is equal or approximate to that of the parent ship.

As a result, the EEDI of the designed ship would not always comply with the expected index where the main engine power is determined by means of the admiralty constant according to the traditional concept of the parent ship.

2.1.3 Based on the understanding in 2.1.2, the EEDI of the parent ship selected for the designed ship is at least not to be greater than the reference line value at the basic design stage.

2.1.4 Where a parent ship subject to 2.1.2 is available, it is recommended that the simplified EEDI method in 2.2 (or in conjunction with other methods) be used to estimate the main engine power.

2.1.5 The traditional means for estimation of the main engine power, i.e. the admiralty constant and diagrams are given in Appendix 4-1 for easy comparison.

2.2 Simplified EEDI for estimation of main engine power (with parent ship)

2.2.1 The simplified energy efficiency index I_s based on main engine parameters is defined as CO₂ emission (g) for transportation per unit (t.kn):

$$I_s = \frac{P \times l \times SPC \times CF}{C \times v}$$

where: P — total installed power of main engines (maximum continuous rating (MCR)) after having deducted any installed shaft generator(s), in kW;

l — load of main engine as a percentage of MCR , to be taken as 75%. Where the value of 75% MCR is not available for the parent ship, to be taken as 85% or some other value;

SPC — specific fuel consumption at the above load of main engine, in g/kWh;

CF — carbon factor of fuel oil, i.e. CO₂ emission per unit mass of fuel oil, in g CO₂/g fuel oil;

C — deadweight corresponding to the summer load line draught, in t (gross tonnage for passenger ships and ro-ro passenger ships);

v — ship speed corresponding to the above load of main engine at the summer load line draught, in kn (1 kn = 1 nm/h).

2.2.2 Where the index I_{s2} of the designed ship is kept equal to the design index I_{s1} of the parent ship, its main engine power P_2 (excluding power of shaft generator(s)) is determined as follows:

$$P_2 = P_1 \times \frac{SPC_1}{SPC_2} \times \frac{CF_1}{CF_2} \times \frac{C_2}{C_1} \times \frac{v_2}{v_1}$$

where: subscript 1 indicates the relevant parameter of the parent ship and subscript 2 indicates that of the designed ship.

Where standard values of CF and SPC ($CF = 3.13$, $SPC = 190$ g/(kW · h)) are taken, the formula is:

$$P_2 = P_1 \times \frac{C_2}{C_1} \times \frac{v_2}{v_1}$$

2.3 Determination of main engine type by means of simplified EEDI/admiralty constant/diagrams

2.3.1 A characteristic diagram of the main engine power ~ rate of revolution is to be drawn for the design layout area (deduction layout area) of different types of main engines, as shown in Figure 2.3.1.

2.3.2 The optional main engine types may be basically identified according to the main engine power obtained from 2.2 or Appendix 4-1.

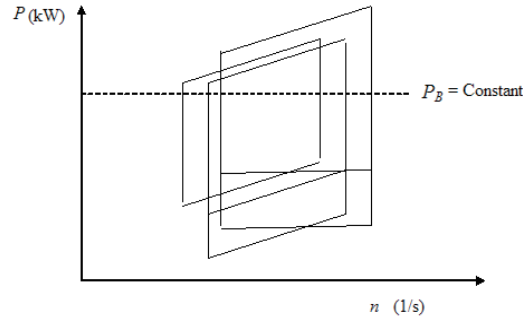


Figure 2.3.1 Selection of Main Engine Type

2.4 Calculation method for estimation of main engine power and determination of main engine type

2.4.1 The calculation method for estimation of the main engine power has relatively higher accuracy after the principal dimensional coefficients of the designed ship have been determined at the basic design stage.

2.4.2 According to the principal dimensional coefficients of the ship, its resistance R , wake fraction w and thrust deduction t may be estimated by calculation and the open water efficiency η_o determined in propeller diagrams, thereby obtaining the “constant speed curve”. Any point in the curve indicates a combination of power – rate of revolution, corresponds to a determined propeller and achieves the same speed, see Figure 2.4.2. The calculation of the “constant speed curve” is given in Appendix 4-2.

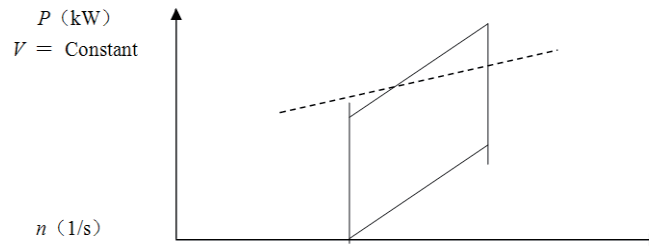
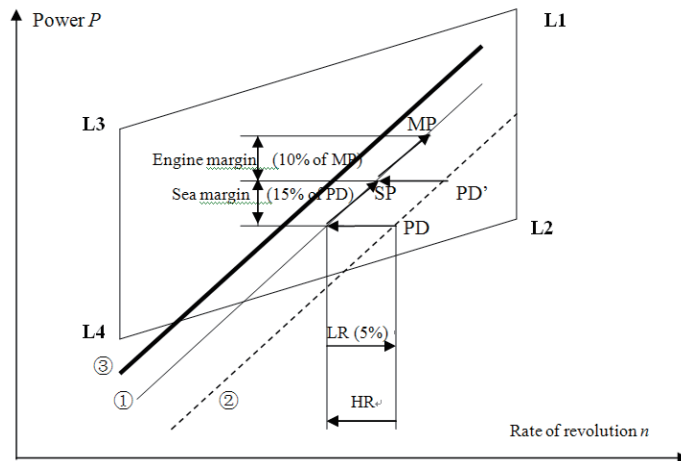


Figure 2.4.2 Main Engine Power Determined by “Constant Speed Curve”

2.4.3 As shown in Figure 2.4.3, the main engine is to be so selected that the propulsion point in use and the possible design point of propeller are within the design layout area (deduction layout area).



- Notes:
- ① Heavy load propeller curve: hull fouling and severe sea state (torque/limit rate of revolution)
 - ② Light load propeller curve: clean hull and calm sea state
 - ③ Curve of over load torque/limit rate of revolution
 - MP: limited propulsion point SP: normal (service) propulsion point
 - PD: propeller design point PD': optional propeller design point
 - LR: light load operating factor HR: heavy load operation

Figure 2.4.3 Propulsion Operating Point and Main Engine Deduction Layout Area of Designed Ship

Chapter 3 Calculation of Power Curves Required for EEDI Technical File

3.1 General

3.1.1 The power curve data in the EEDI technical file and additional information are to be calculated on the basis of determination of hull main dimensions, lines, resistance/efficient power, main engines and completion of propeller design, using the principle of hull-engine-propeller interrelationship. Direct calculation methods are shown in 3.3 and for calculation examples, see Appendix 4-6. For indirect calculation methods and calculation examples, see Appendix 4-7.

3.1.2 The power curves are to be calculated under EEDI condition and sea trial condition, as shown in Figure 3.1.2.

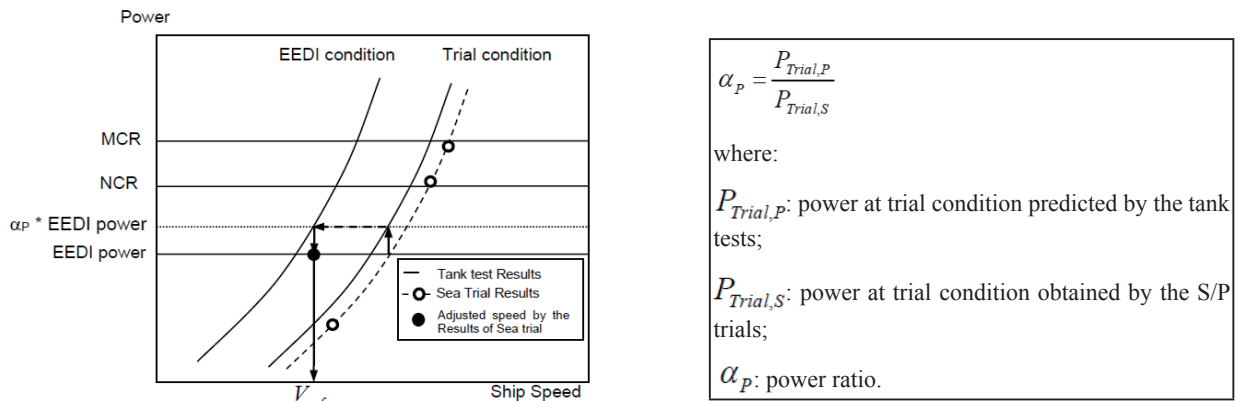


Figure 3.1.2 Power Curves

3.1.3 The known conditions for calculating power curves are as follows:

- resistance curve ($V_s \sim R$);
- wake fraction w ;
- thrust deduction fraction t ;
- relative rotative efficiency η_R ;
- propeller parameters (number of blades, diameter, pitch ratio, disk area ratio) and characteristic curves ($K_T, K_Q \sim J$);
- power data at MCR , NOR (85% MCR), 75% MCR and 50% MCR for the main engine.

3.2 Requirements for power curves

3.2.1 The power curve in each loading condition is to be developed by at least 4 groups of calculation values (kW-kn), see Table 3.2.1.

Calculation Values (kW-kn)		Table 3.2.1
Power P (kW)		Ship speed V (kn)
P_1	1.0 MCR	V_1
P_2	NOR (0.85 MCR)	V_2
P_3	0.75 MCR	V_3
P_4	0.50 MCR	V_4

3.3 Direct calculation of power curves based on hull-engine-propeller interactions

3.3.1 According to the principle of hull-engine-propeller interactions, the direct calculation of power curves under determined loading conditions is shown in Table 3.3.1.

Direct Calculation of Power Curves Based on Hull-Engine-Propeller Interactions Table 3.3.1

Assumed ship speed V_S (kn)	V_{S1}	V_{S2}	V_{S3}	V_{S4}
Calculated ship speed v_s (m/s)	$0.5144 V_{S1}$	$0.5144 V_{S2}$	$0.5144 V_{S3}$	$0.5144 V_{S4}$
Wake fraction w , see 3.6	w_1	w_2	w_3	w_4
Speed of water flowing to propeller $v_a = v_s (1-w)$ (m/s)	v_{a1}	v_{a2}	v_{a3}	v_{a4}
Ship resistance R (kN), see 3.4	R_1	R_2	R_3	R_4
Thrust deduction fraction t , see 3.6	t_1	t_2	t_3	t_4
Propeller thrust $T = R/(1-t)$ (kN)	T_1	T_2	T_3	T_4
$\ln \frac{T}{\rho v_a^2 D^2} (= \ln \frac{K_T}{J^2})$	$\ln \frac{T_1}{\rho v_{a1}^2 D^2}$	$\ln \frac{T_2}{\rho v_{a2}^2 D^2}$	$\ln \frac{T_3}{\rho v_{a3}^2 D^2}$	$\ln \frac{T_4}{\rho v_{a4}^2 D^2}$
$\ln \frac{K_T(J)}{J^2} \sim J$ curve developed according to propeller open water characteristics (see 3.3.2)				
Advance coefficient J read off from $\ln \frac{K_T(J)}{J^2} \sim J$ curve by $\ln \frac{T}{\rho v_a^2 D^2}$	J_1	J_2	J_3	J_4
Rate of propeller revolutions $n = \frac{v_a}{JD}$ (1/s)	n_1	n_2	n_3	n_4
Torque coefficient K_Q read off from characteristic curves of the propeller by J	K_{Q1}	K_{Q2}	K_{Q3}	K_{Q4}
Delivered power at propeller $P_D = 2\pi\rho n^3 D^5 K_Q$ (kW)	P_{D1}	P_{D2}	P_{D3}	P_{D4}
Required main engine power $P_B = \frac{P_D}{\eta_S \times \eta_R}$ (kW)	P_{B1}	P_{B2}	P_{B3}	P_{B4}
$V_S \sim P_B$ curve — estimated EEDI power curve developed according to assumed ship speed and main engine power				
Corresponding ship speed V_{S1} , V_{S2} , V_{S3} and V_{S4} read off from the $V_S \sim P_B$ curve by P_1 , P_2 , P_3 and P_4 in Table 3.2.1				

3.3.2 The $\ln \frac{K_T(J)}{J^2} \sim J$ curve of the propeller (see Figure 3.3.2(2)) is converted from its characteristic curve ($K_T \sim J$ curve, see Figure 3.3.2(1)).

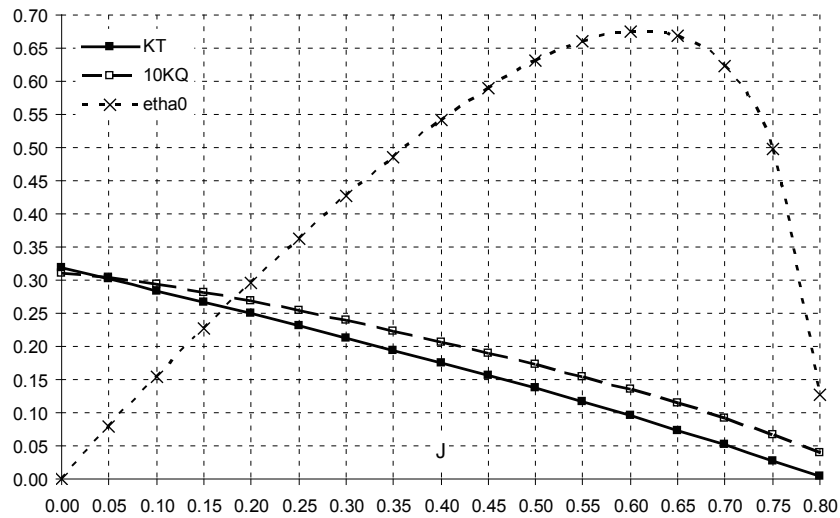


Figure 3.3.2(1) Characteristics Curves of Propeller

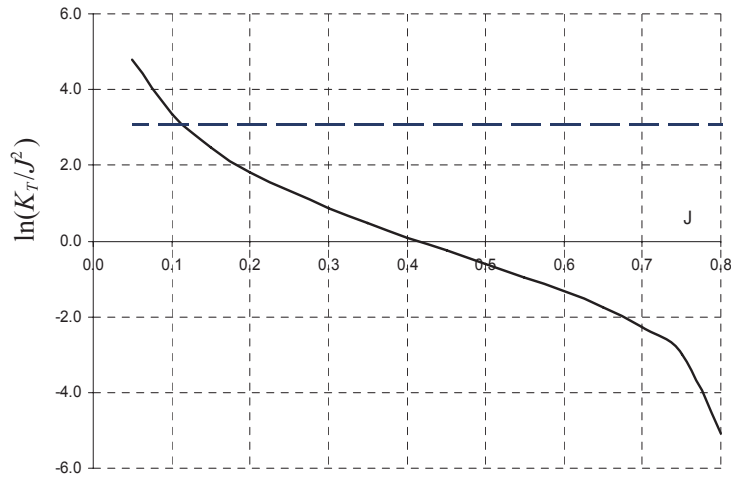


Figure 3.3.2(2) $\ln \frac{K_T(J)}{J^2} \sim J$ Curve of Propeller

3.3.3 The power curve calculation methods given in Table 3.3.1 are applicable to any loading condition.

3.3.4 In addition to the methods given in 3.3.1, CCS also accepts power curves obtained by means of equivalent characteristic curves under navigation, see Appendix 4-7.

3.3.5 For the full-load condition, based on power curves obtained from Table 3.3.1, the speed corresponding to 75% of *MCR* power of the main engine is basically to be the same as the design speed obtained from propeller design.

3.3.6 For the calculation of power curves according to Table 3.3.1 under ballasting conditions at the basic design stage, the wake fraction w , thrust deduction fraction t , shafting efficiency η_s and relative rotative efficiency η_R may generally be taken as those under the full-load condition.

3.3.7 For examples of power curve calculation, see Appendix 4-6.

3.4 Calculation of ship resistance

3.4.1 At the basic design stage, the ship resistance R required for propeller design and matching analysis of hull – engine – propeller is to be calculated by the following formula:

$$R = R_{cw} + R_{air} + R_{aw} + R_{app}$$

3.4.2 The still water resistance R_{cw} may be calculated as follows:

(1) displacement conversion by the parent ship:

$$R_{cw2} V_2 / R_{cw1} V_1 = (\Delta_2 / \Delta_1)^{7/6}$$

where: subscript 1 indicates the value of the parent ship and subscript 2 indicates the value of the designed ship.

Alternatively:

$$R_{cw} = (1+k) C_F \frac{1}{2} \rho S v_s^2 + R_R$$

where: k — form factor, determined by the parent ship or CFD analysis;
 ρ, S, v_s — seawater density, wetted hull area and ship speed respectively;
 C_F — frictional resistance coefficient, to be calculated as follows:

$$C_F = \frac{0.075}{(\log Re - 2)^2}$$

where: Re — Reynolds number, to be calculated as follows:

$$Re = v_s L_{WL} / \nu$$

where: ν — kinematic viscosity coefficient of seawater;
 R_R — residual resistance;

(2) calculation by means of resistance diagrams based on series tests, e.g. expanded Taylor series, Japanese full-formed ship type series, Guldhammer and Harvald diagrams, etc. Appendix 4-5 gives calculations by means of Guldhammer and Harvald resistance diagrams;

(3) regression calculation for series ship type, e.g. resistance regression analysis of 60 series, BSRA series, SSPA series and NPL coastal ship series etc.;

(4) resistance regression calculation for non-series ship models;

(5) calculation values based on the computational fluid dynamics (CFD).

3.4.3 Air resistance (no wind) R_{air} : the average value of the air resistance coefficient C_{air} may be taken according to the wind tunnel test as follows:

· General cargo ship	$C_{air} = 0.1 \times 10^{-3}$
· Bulk carrier	$C_{air} = 0.08 \times 10^{-3}$
· Oil tanker	$C_{air} = 0.08 \times 10^{-3}$
· VLCC	$C_{air} = 0.04 \times 10^{-3}$
· Passenger ship	$C_{air} = 0.09 \times 10^{-3}$
· Ferry	$C_{air} = 0.1 \times 10^{-3}$
· Container ship	$C_{air} = 0.08 \times 10^{-3}$ (no container on deck)
	$C_{air} = 0.1 \times 10^{-3}$ (containers on deck)

3.4.4 The wind resistance R_{air} may be calculated by Van Berlekom method or Isherwood method, see Appendix 4-3.

3.4.5 The resistance increase due to waves R_{aw} may be calculated by Gerritsma-Beukelman method (for ship types other than the full-formed type), Maruo Hajime method (for ship types other than the full-formed type) or Takahashi Yui method (for the full-formed type), see Appendix 4-4.

3.4.6 Appendage resistance R_{app} : the appendage resistance coefficient C_{app} is determined from statistics:

· Single screw ship	$C_{app} = 1.02 \sim 1.05$
· Twin screw ship	$C_{app} = 1.07 \sim 1.13$

The resistance of each type of appendages may also be estimated separately, including:

- Additional resistance of bilge keel
- Additional resistance of rudder
- Additional resistance of propeller shaft bracket
- Tail shaft (exposed on hull surface of twin crew ships)
- Shell bossing etc.

3.4.7 In order to consider wind, sea state, hull surface corrosion and fouling under service conditions, a margin (sea state margin or service margin) must be added to resistance R and effective power P_E , and this margin is related to the ship's operational route. If diagrams mentioned in 3.4.2 are used, it is recommended that the margin for the average service condition be taken as follows:

North Atlantic route, eastward:	15 ~ 20%
North Atlantic route, westward:	20 ~ 30%
Pacific Ocean route:	15 ~ 30%
South Atlantic and Australian route:	12 ~ 18%
East Asian route:	15 ~ 20%

3.4.8 It is to be noted that at the basic design stage, the resistance/effective power required for estimation of EEDI power curves corresponds with hull surface cleanliness, still water and conditions of no wind (only considering the wind resistance mentioned in 3.4.3) and no waves, and this is different from resistance/effective power data taken at propeller design. In the latter case, resistance increases due to wind and waves as well as the resistance addition for hull surface corrosion and fouling (or the margin for the average service condition as mentioned in 3.4.7) are also considered.

3.5 Estimation of resistance/effective power under ballast conditions

3.5.1 When speed trial is assumed under ballast conditions at the basic design stage, special consideration is to be taken where no data of any model test/parent ship are available for reference, because hull parameters, e.g. block coefficient C_B , ratio B/T (breadth/draught), displacement ∇ , under ballast conditions are different from those under the full-load condition (design condition).

3.5.2 The still water resistance/effective power under ballast conditions is generally to be calculated by means of diagrams or regression for series ships in the same way as that under the full-load condition, such as:

(1) the range of parameters under ballast conditions for resistance regression analysis of BSRA series:

$L_{PP}/\nabla^{1/3}$	5.10 ~ 7.717
B/T	3.44 ~ 6.39
C_B	0.592 ~ 0.766
x_{CB} (%)	-1.12 ~ 4.35;

(2) the range of parameters under ballast conditions for calculation regarding Japanese full-formed ship series:

Ballast displacement/full-load displacement	0.44
Trim by stern	0.02L;

(3) the method of approximate calculation used in estimating the effective power under ballast draft conditions from the effective power under the full-load draft condition, such as the Moor method;

(4) where effective power data of the parent ship under ballast draft conditions are available, the method in 3.4.2(1) may be used;

(5) if a method not including the calculation of resistance under ballast conditions is used, attention is to be paid to whether the method is applicable to the relevant parameters under ballast conditions (such as B/T and C_B).

3.6 Estimation of wake fraction w , thrust deduction fraction t and relative rotative efficiency η_R

3.6.1 At the basic design stage, the wake fraction w , thrust deduction fraction t and relative rotative efficiency η_R may be estimated by one of the following means:

- (1) model test data of the parent ship;
- (2) approximate calculation formula;
- (3) series test data of self-propulsion elements.

Appendix 4-1 Traditional Means of Estimation of Main Engine Power

1 Admiralty constant (with parent ship)

1.1 The delivered power P_D at propeller of the designed ship:

$$P_D = \frac{\Delta_D^{2/3} V_D^3}{A_C} \quad \text{kW}$$

where: Δ_D — displacement of the designed ship in the maximum design loading condition, in t;
 V_D — ship speed (service speed) on deep and still water at 85% of the maximum continuous rating (*MCR*) for the main engine of the designed ship in the maximum design loading condition, in kn;
 A_C — admiralty constant, to be calculated according to the parent ship:

$$A_C = \Delta^{2/3} V^3 / P$$

where: Δ — displacement of the parent ship in the maximum design loading condition, in t;
 V — ship speed (service speed) on deep and still water at 85% of the maximum continuous rating (*MCR*) for the main engine of the parent ship in the maximum design loading condition, in kn;
 P — delivered power at propeller of the parent ship, in kW.

1.2 The shaft power P_B of the main engine estimated for the designed ship:

$$P_B = \frac{P_D}{\eta_S \eta_R}$$

where: η_S, η_R — shafting efficiency and relative rotative efficiency, generally $\eta_S = 0.97, \eta_R = 1.0$.

Service allowance is to be added to the estimated shaft power of the main engine as required by the shipowner.

2 Diagrams (without parent ship)

2.1 Where the displacement Δ , length displacement volume coefficient $L/\nabla^{1/3}$ and block coefficient C_B of the designed ship are known, the shaft power P_B of the main engine corresponding to the service speed V_D may be estimated according to Figures 2.1(1) to 2.1(7). However, the power is estimated as a result of a standard ship in the standard condition and service allowance is to be added as required by the shipowner.

2.2 The application of Figures 2.1 to 2.7 is as follows:

- (1) displacement Δ : 100 t ~ 1000000 t;
- (2) length displacement volume coefficient $L/\nabla^{1/3}$: 4.0 ~ 5.0 ~ 6.0;
- (3) block coefficient C_B : 0.55 ~ 0.85;
- (4) ship speed V_S : 3.0 m/s ~ 13.4 m/s.

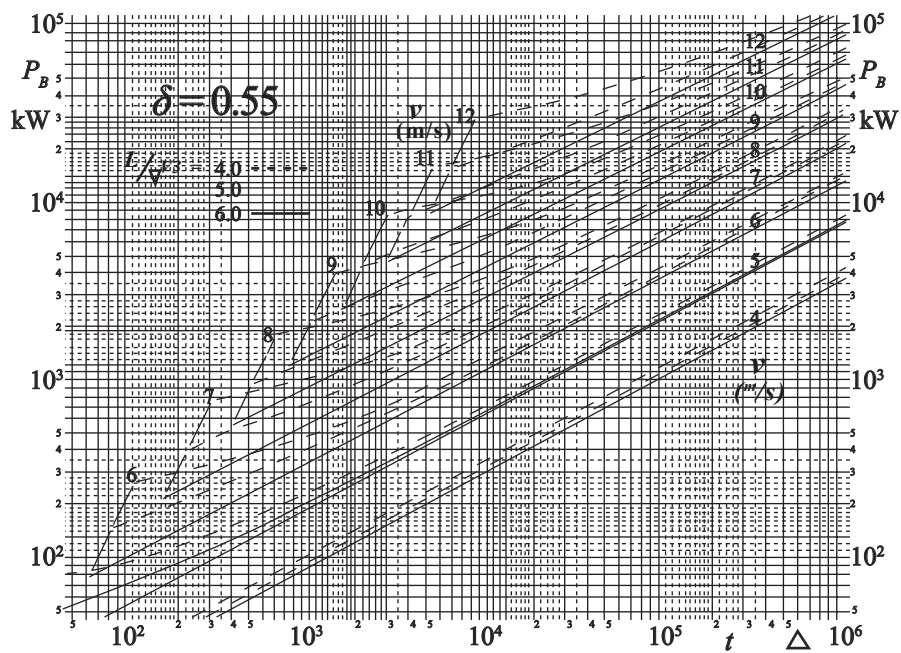


Figure 2.1(1) Power Diagram $C_B(\delta) = 0.55$

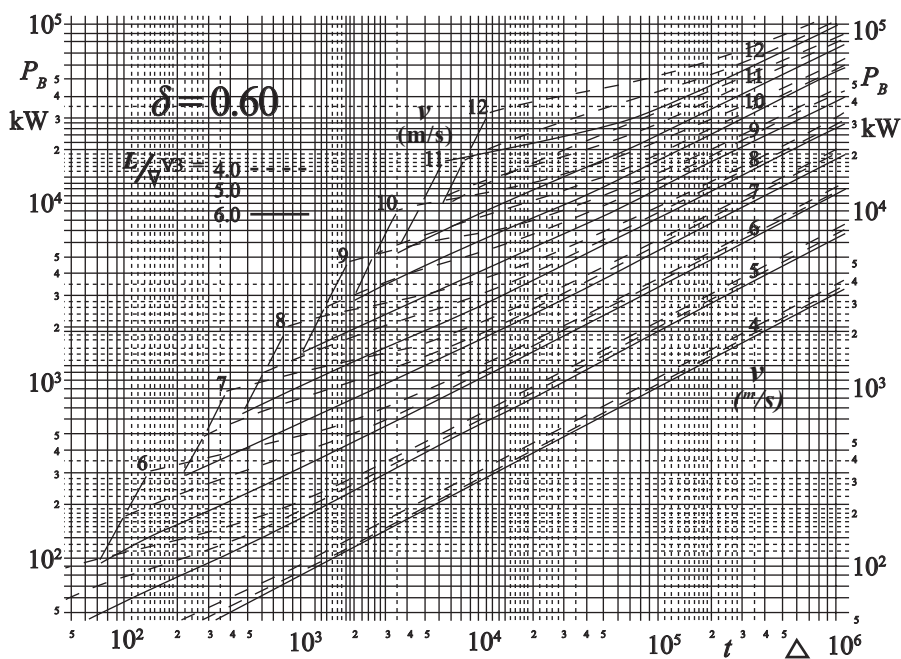


Figure 2.1(2) Power Diagram $C_B(\delta) = 0.60$

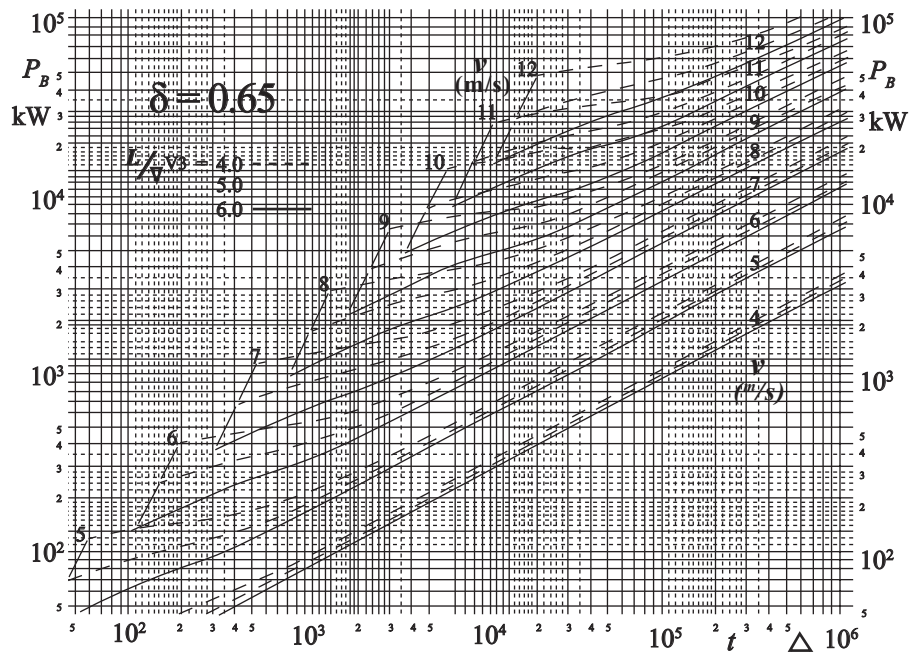


Figure 2.1(3) Power Diagram $C_B(\delta) = 0.65$

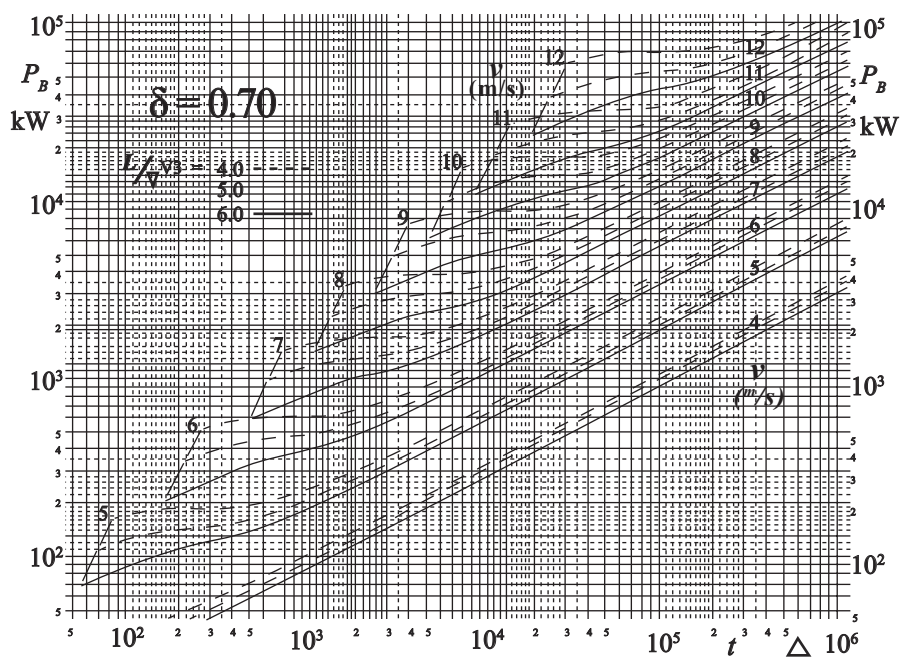


Figure 2.1(4) Power Diagram $C_B(\delta) = 0.70$

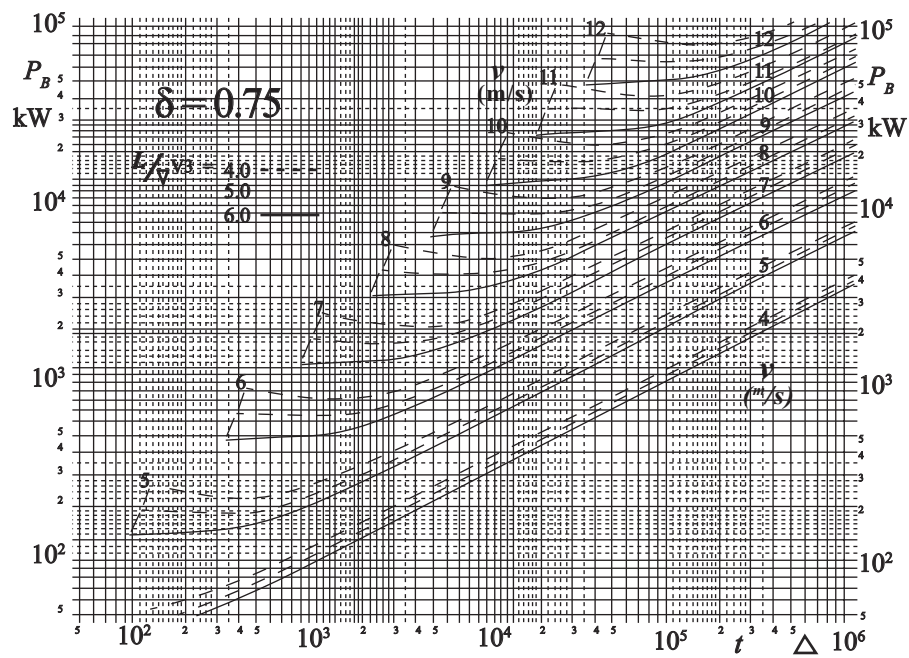


Figure 2.1(5) Power Diagram $C_B(\delta) = 0.75$

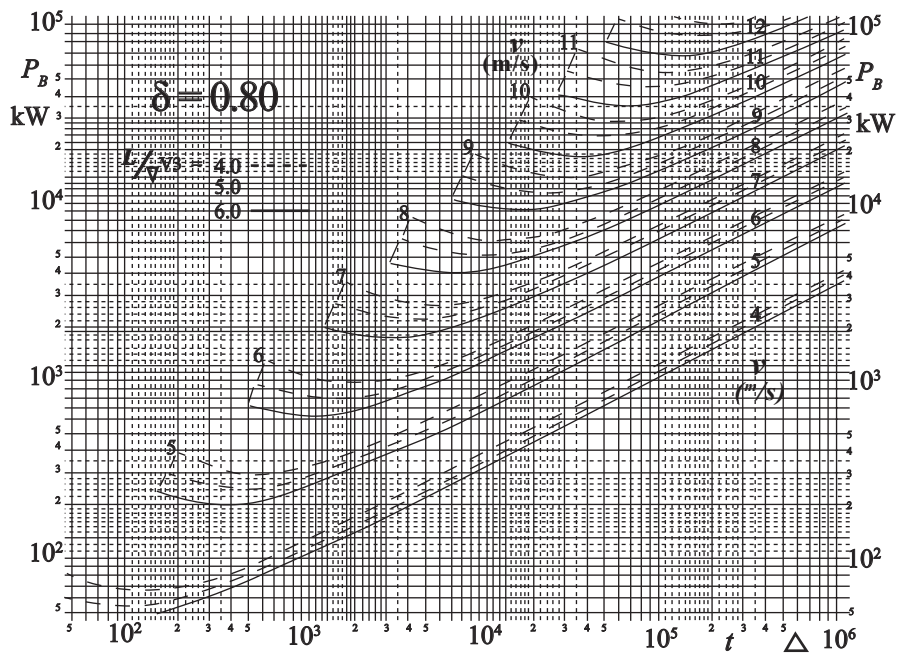


Figure 2.1(6) Power Diagram $C_B(\delta) = 0.80$

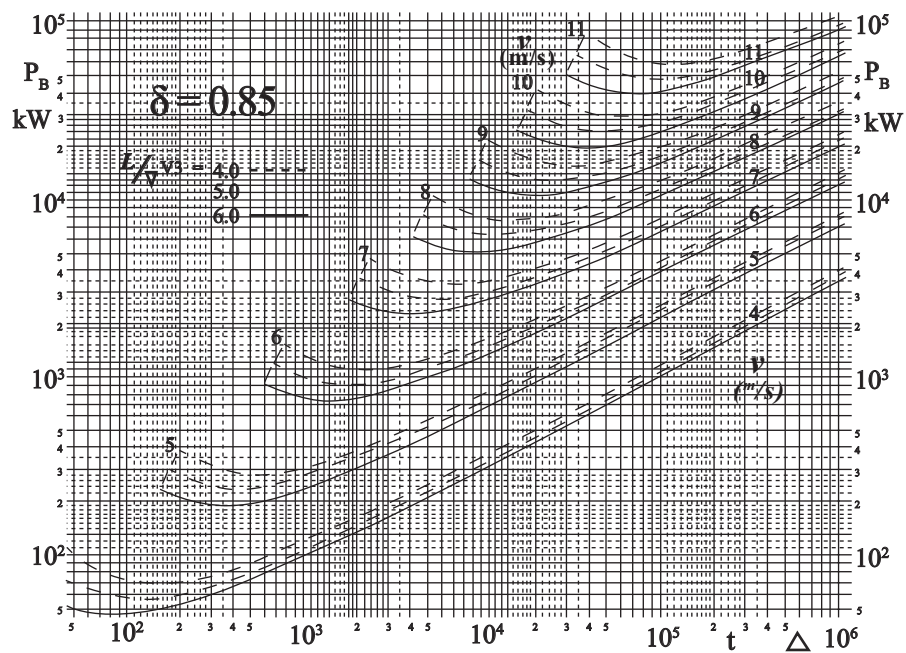


Figure 2.1(7) Power Diagram $C_B(\delta) = 0.85$

Appendix 4-2 Method of Calculation of Constant Speed Power Curves

1 Known conditions

- propeller diameter D ;
- number of propeller blades Z ;
- disk area ratio of propeller A_E/A_0 ;
- shafting efficiency η_s ;
- relative rotative efficiency η_R ;
- wake fraction w ;
- thrust deduction fraction t ;
- ship speed V_s ;
- effective power curve $V_s \sim P_E$.

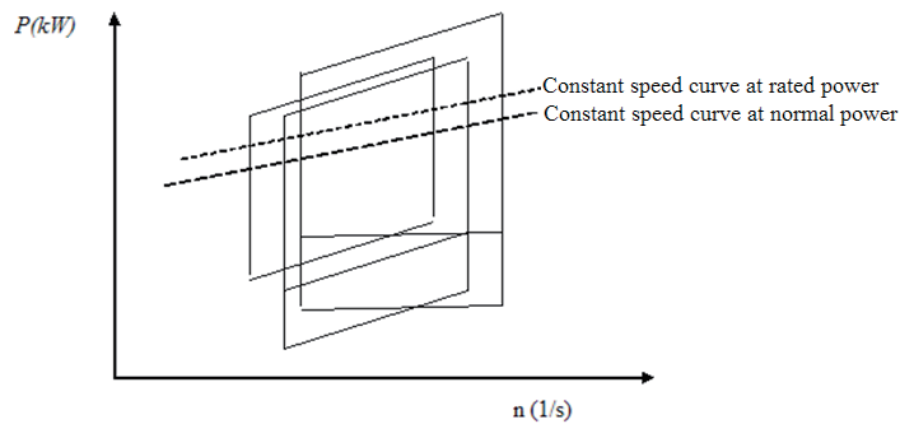
2 Calculation method and procedure

The calculation method and procedure for constant speed power curves are introduced as follows, taking the diagram of AU series propellers as an example:

No.	Name	Unit	Data			
1	Propeller diameter D (selected)	m	D			
2	Hull efficiency $\eta_H = \frac{1-t}{1-w}$		η_H			
3	Speed of water flow forward of propeller $V_A = V_s(1-w)$	kn	V_A			
4	Effective power P_E	kW	P_E			
5	Assumed rate of revolution n	r/min	n_1	n_2	n_3	n_4
6	Diameter coefficient $\delta = K'_{AU} \frac{nD}{V_A}$		δ_1	δ_2	δ_3	δ_4
7	The following are obtained from the intersection point of δ isoline and optimum efficiency curve with reference to $\sqrt{B_P} \sim \delta$ diagram: H/D η_P $\sqrt{B_P}$		$(H/D)_1$ η_{P1} $\sqrt{B_{P1}}$	$(H/D)_2$ η_{P3} $\sqrt{B_{P2}}$	$(H/D)_3$ η_{P3} $\sqrt{B_{P3}}$	$(H/D)_4$ η_{P4} $\sqrt{B_{P4}}$
8	Delivered power at propeller $P_D = \frac{B_P^2 V_A^5}{K_{AU}^2 n^2}$	kW	P_{D1}	P_{D2}	P_{D3}	P_{D4}
9	Main engine power $P = \frac{P_D}{\eta_s \eta_R}$	kW	P_1	P_2	P_3	P_4

3 Constant speed power curves

In accordance with the calculation results of A.2.2, the constant speed power curves may be developed on the characteristic diagram of main engine power $\sim$ rate of revolution as shown in the figure below:



Constant speed power curves

In the figure above, “constant speed curve at rated power” corresponds to 10% of power reserve: $P^*=P/0.9$.

Appendix 4-3 Method of Calculation of Wind Resistance

1 Van Berlekom method

1.1 The wind resistance R_{air} in head wind is to be calculated by the following formula:

$$R_{air} = 0.615 C_x L^2 V_R^2 \times 10^{-6} \quad \text{MN}$$

where: V_R — relative wind speed, in m/s;

C_x — wind coefficient in head wind, to be taken from Figure 1.1(1) and (2) according to ship type and projected cross-sectional area A_{TV}/L^2 of the ship above the waterplane.

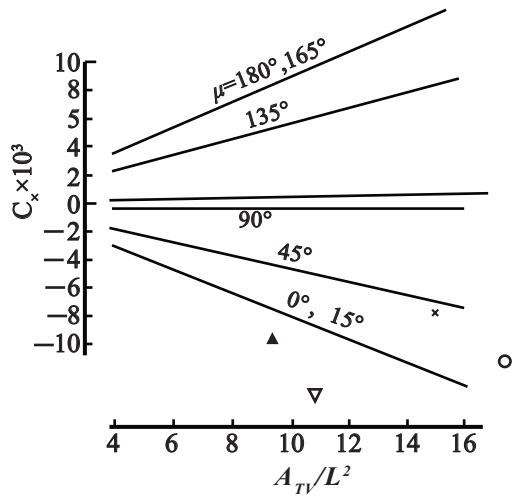


Figure 1.1(1) C_x of oil tanker

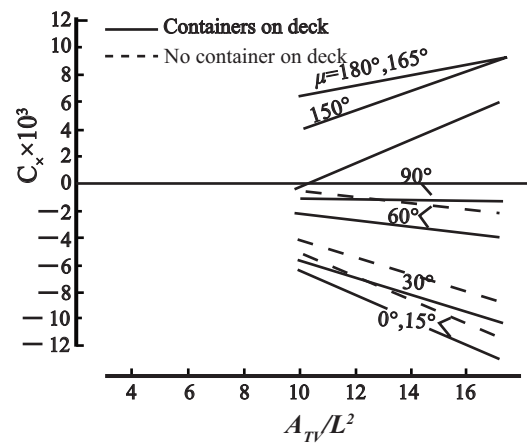


Figure 1.1(2) C_x of container ship and ro-ro ship

The range of A_{TV}/L^2 and A_{LV}/L^2 in Figure 1.1 is given in Table 1.1.

Range of Values of A_{TV}/L^2 and A_{LV}/L^2

Table 1.1

Ship type	$(A_{TV}/L^2) \times 10^3$	$(A_{LV}/L^2) \times 10^3$
Oil tanker	8.6 ~ 14.5	28.5 ~ 55.5
Ro-ro ship	16.6	76.6 ~ 95.0
Container ship	10.3	41.4 ~ 58.3

2 Isherwood method

2.1 The wind resistance R_{air} in head wind is to be calculated by the following formula:

$$R_{air} = 0.615 C_x L^2 V_R^2 \times 10^{-6} \quad \text{MN}$$

where: V_R — relative wind speed, in m/s;

C_x — wind coefficient in head wind, to be calculated by the following formula:

$$C_x = 2.152 - 5.00 \frac{2A_{LV}}{L_{OA}^2} + 0.243 \frac{2A_{TV}}{B^2} - 0.164 \frac{L_{OA}}{B} + 0.086$$

The parameters in the formula are to be taken from Table 2.1.

Parameters of Different Ship Types

Table 2.1

Ship type	$\frac{LV}{OA}$	$\frac{2A_{TV}}{B^2}$	$\frac{L_{OA}}{B}$
Passenger ship, ferry	0.192	1.95	7.66
Cargo ship with machinery spaces situated amidships (full load)	0.111	1.67	7.80
Cargo ship with machinery spaces situated amidships (ballast)	0.149	2.04	7.80
Cargo ship with machinery spaces situated astern (full load)	0.122	1.75	7.80
Cargo ship with machinery spaces situated astern (ballast)	0.151	2.06	7.80
Oil tanker and bulk carrier with bridge situated amidships (full load)	0.076	1.03	7.46
Oil tanker and bulk carrier with bridge situated amidships (ballast)	0.117	1.43	7.46
Oil tanker and bulk carrier with bridge situated astern (full load)	0.100	1.59	7.46
Oil tanker and bulk carrier with bridge situated astern (ballast)	0.121	1.68	7.46

Appendix 4-4 Method of Calculation of Resistance Increase due to Waves

1 Simplified method (applicable to ship sea trial conditions)

(1) For Kreitner's equation, resistance increase due to waves R_{AW} is to be calculated by the following formula:

$$R_{AW} = 0.64 \xi_w^2 B^2 C_B \rho g / L \quad \text{kN}$$

where: ξ_w — wave height, in m;
 ρ — specific gravity of seawater, in N/m³;
 L — length of waterline, in m;
 B — molded breadth, in m;
 C_B — block coefficient;
 g — gravity acceleration, in m/s².

(2) For improved equation, resistance increase due to waves R_{AW} is to be calculated by the following formula:

$$R_{AW} = f \times R_{AW(SEAS)} + (1 - f) \times R_{AW(SWELL)} \quad \text{kN}$$

where: f — coefficient, to be calculated by the following formula:

$$f = 1 - 0.08 \times H_{1/3(SWELL)}, \quad H_{1/3(SWELL)} \text{ to be taken as not more than 3 m}$$

where: $H_{1/3(SWELL)}$ — significant wave height of swell, in m;
 $R_{AW(SEAS)}$ — when wave height to be taken as $H_{1/3(SEAS)}$, resistance increase due to waves as calculated by Kreitner's equation, in kN;
 $R_{AW(SWELL)}$ — when wave height to be taken as $H_{1/3(SWELL)}$, resistance increase due to waves as calculated by Kreitner's equation, in kN.

2 Gerritsma-Beukelman method (for ship types other than full-formed type)

For navigation in regular head sea, the resistance increase R_{AW} due to waves may be obtained by means of strip method. The Gerritsma-Beukelman calculation formula is as follows:

$$R_{AW} = \frac{\pi}{\pi \omega_e} \int_0^L b^*(x) \left| \overline{\xi_r} \right|^2 (x) dx \quad (2)$$

where: $b^*(x)$ — total damping coefficient of any section along the ship length, to be calculated by the following formula:

$$b^*(x) = b_{33}(x) - V \left(\frac{da_{33}(x)}{dx} \right) \quad (3)$$

$\overline{\xi_r}(x)$ — vertical speed relative to wave surface at any section along the ship length, to be calculated by the following formula:

$$\overline{\xi_r}(x) = \dot{Z} - x\dot{\theta} + V\theta - \dot{\xi}_w \quad (4)$$

3 Maruo Hajime method (for ship types other than full-formed type)

For navigation in regular head sea, the resistance increase r_{AW} due to waves is to be calculated by the following formula:

$$r_{AW} = \frac{R_{AW}}{4\rho g(\xi_w)^2 B^2 / L} = \sum_{k=1}^{28} C_k D_k \left(\frac{\bar{Z}}{\xi_w} \right)^m \left(\frac{\bar{\theta}}{\xi_w} \right)^n \quad (5)$$

where: $(\bar{Z}/\xi_w)$ and $(\bar{\theta}/\xi_w)$ —amplitude frequency function for heaving and pitching respectively, to be calculated from the regular wave motion calculation program.

4 Takahashi Yui method (for full formed type)

For navigation in regular head sea, the resistance increase R_{AW} due to waves is to be calculated by the following formula:

$$R_{AW} = R_{AW(0)} + R_{AW(1)} \quad (6)$$

where: $R_{AW(0)}$ — resistance increase due to motion, to be calculated by formula (2) or (5);
 $R_{AW(1)}$ — resistance increase due to bow wave reflection, to be calculated by the following formulae:

$$R_{AW(1)} = \alpha_1(1 + \alpha_2) \frac{1}{2} \rho g \xi_w^2 \int_{-B/2}^{B/2} \sin^2 \beta dy \quad (7)$$

$$\text{where: } \alpha_1 = \frac{\pi^2 I_1^2(1.5kT)}{\pi^2 I_1^2(1.5kT) + k_1^2(1.5kT)} \quad (8)$$

I_1, k — corresponding to Bessel's function of Category I and II correction;

$$\alpha_2 = 3.5\sqrt{Fn} \quad (9)$$

$\sin^2 \beta$ — bluntness coefficient;

β — angle between the tangent of outer edge of bow on waterline and the centerline of waterplane.

$R_{AW(1)}$ may be calculated by the Kwon method.

5 Average resistance increase in irregular waves

The average resistance increase $\bar{R}_{AW}$ in irregular waves is to be calculated by the following formula:

$$\bar{R}_{AW} = 2 \int \left(\frac{R_{AW}(\omega_e)}{\xi_w^2} \right) S_\xi(\omega_e) d\omega_e \quad (10)$$

where: R_{AW} — to be calculated by 2 to 4.

6 Resistance increase due to waves for series 60 ship type

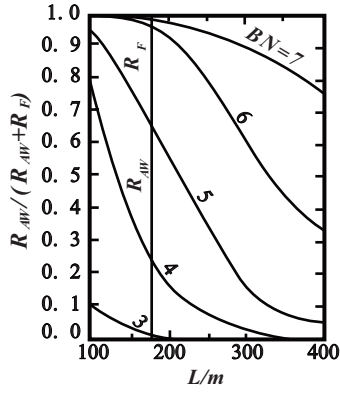
For series 60 ship type, the resistance increase due to waves in head sea may be calculated by means of Towson's diagrams. The calculation steps are as follows:

Step 1: calculating the wind resistance R_{air} by the Van Berlekom method in Appendix 4-3;

Step 2: obtaining $C = R_{AW}/(R_{AW} + R_F)$ from Figures 6(1) to 6(27) according to length L , block coefficient C_B , Froude number F_n , Beaufort wind scale BN and loading condition;

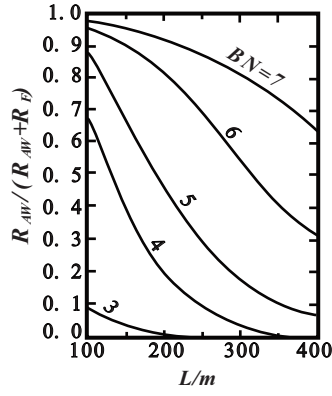
Step 3: calculating resistance increase due to waves, R_{AW} :

$$R_{AW} = \frac{C}{1-C} \times R_{air} \quad (11)$$



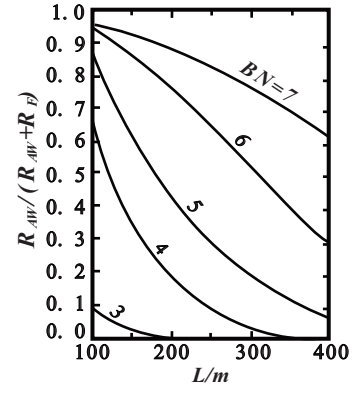
$C_B = 0.6, Fn = 0.10$, normal loading

Figure 6(1)



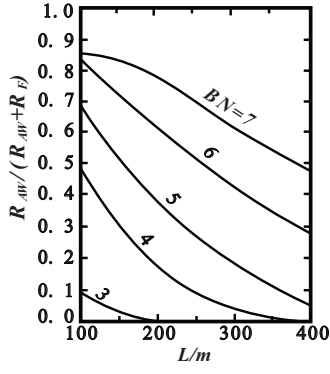
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Figure 6(2)



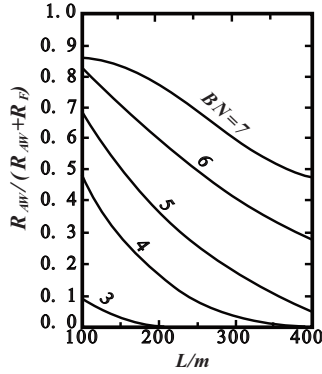
$C_B = 0.6, Fn = 0.20$, normal loading

Figure 6(3)



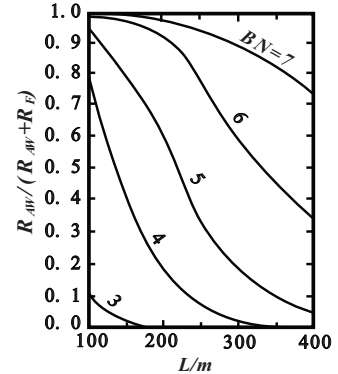
$C_B = 0.6, Fn = 0.25$, normal loading

Figure 6(4)



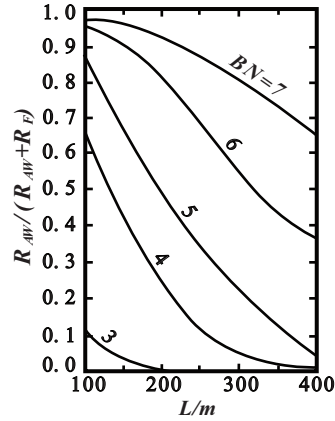
$C_B = 0.6, Fn = 0.30$, normal loading

Figure 6(5)



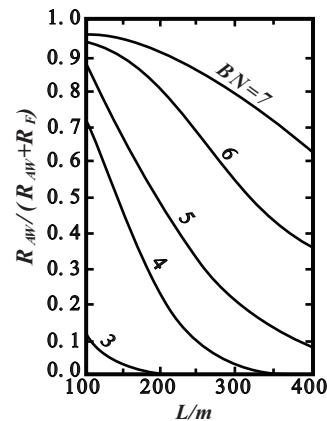
$C_B = 0.65, Fn = 0.10$, normal loading

Figure 6(6)



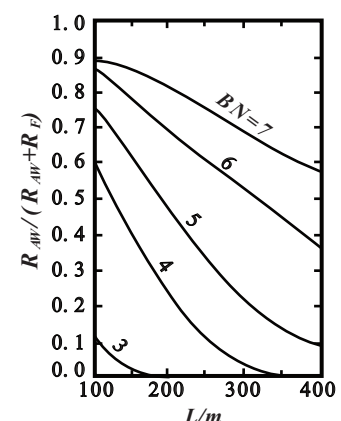
$C_B = 0.65, Fn = 0.15$, normal loading

Figure 6(7)



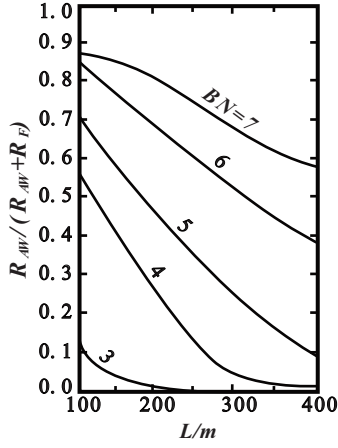
$C_B = 0.65, Fn = 0.20$, normal loading

Figure 6(8)



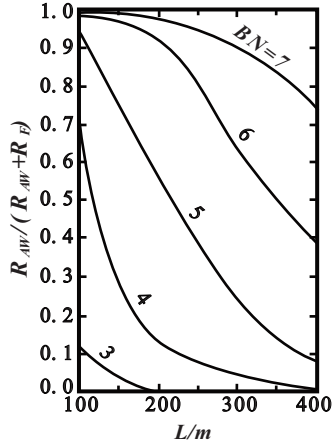
$C_B = 0.65, Fn = 0.25$, normal loading

Figure 6(9)



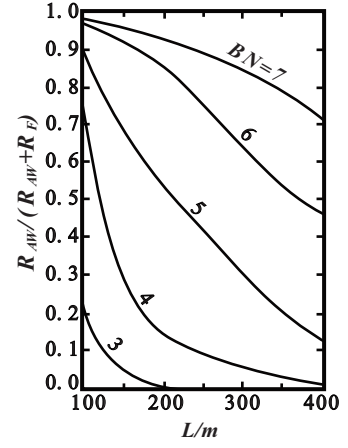
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Figure 6(10)



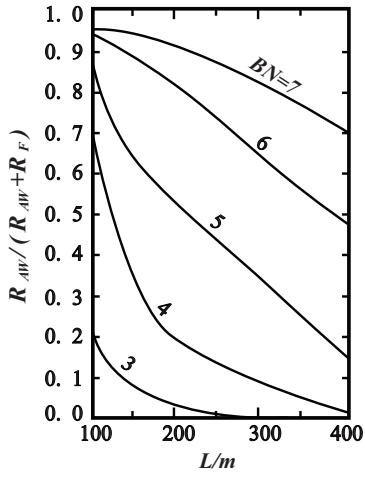
$C_B = 0.7, Fn = 0.10$, normal loading

Figure 6(11)



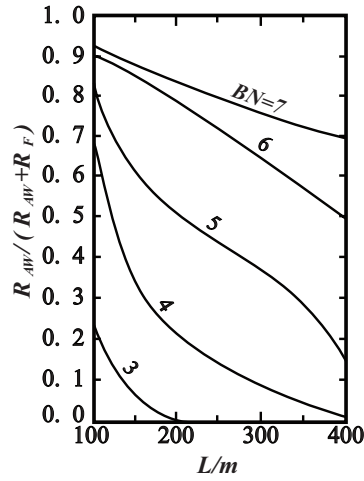
$C_B = 0.7, Fn = 0.15$, normal loading

Figure 6(12)



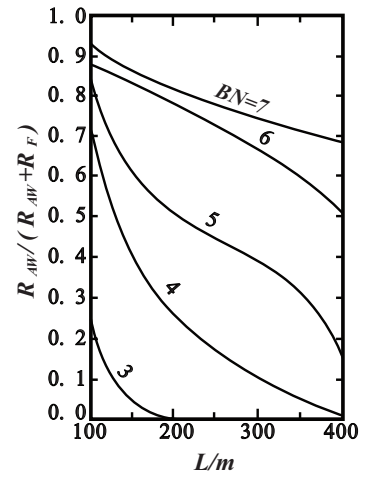
$C_B = 0.7, Fn = 0.20$, normal loading

Figure 6(13)



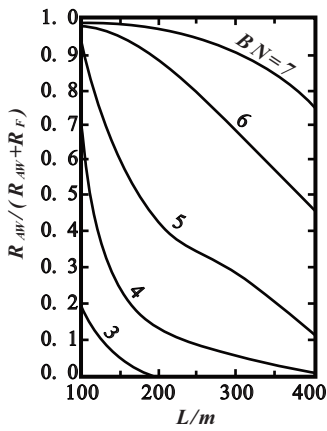
$C_B = 0.7, Fn = 0.25$, normal loading

Figure 6(14)



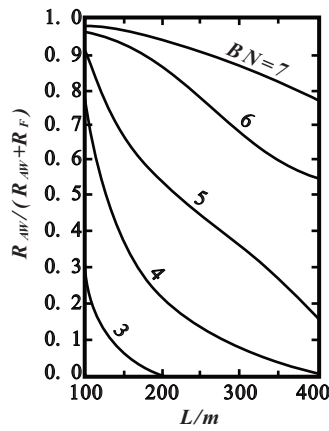
$C_B = 0.7, Fn = 0.30$, normal loading

Figure 6(15)



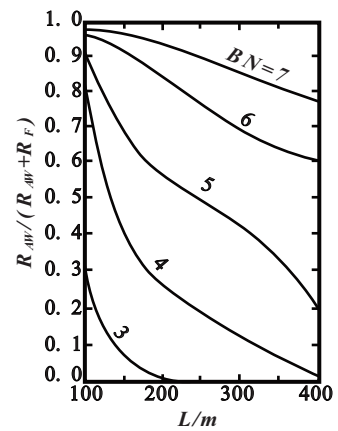
$C_B = 0.75, Fn = 0.10$, normal loading

Figure 6(16)



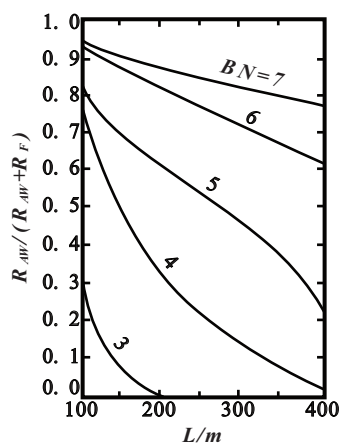
$C_B = 0.75, Fn = 0.15$, normal loading

Figure 6(17)



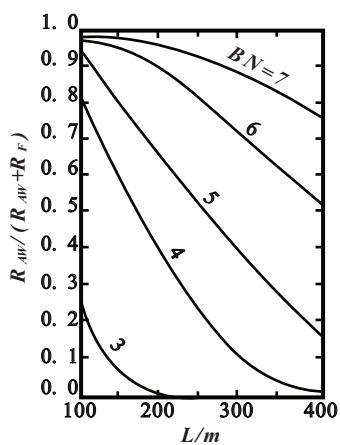
$C_B = 0.75, Fn = 0.20$, normal loading

Figure 6(18)



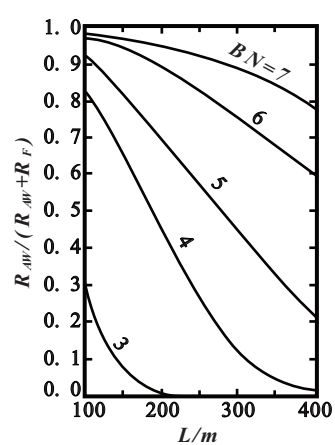
$C_B = 0.75, Fn = 0.25$, normal loading

Figure 6(19)



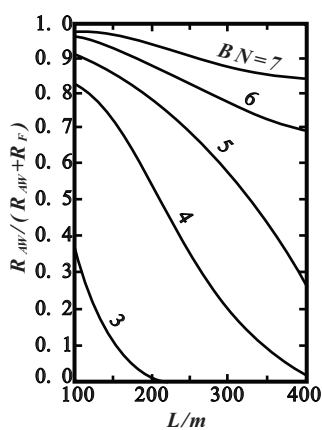
$C_B = 0.8, Fn = 0.10$, fully loaded

Figure 6(20)



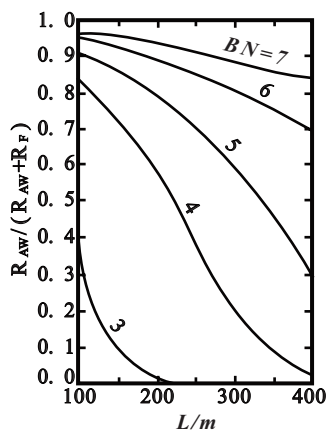
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Figure 6(21)



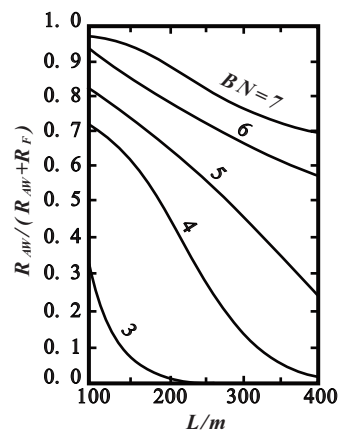
$C_B = 0.8, Fn = 0.20$, fully loaded

Figure 6(22)



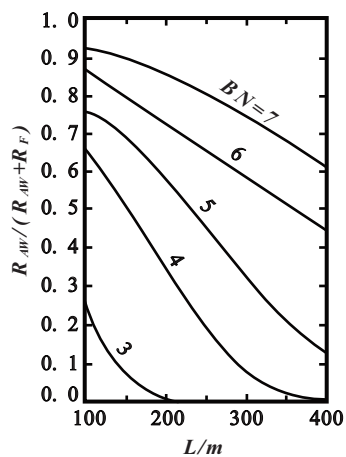
$C_B = 0.8, Fn = 0.25$, fully loaded

Figure 6(23)



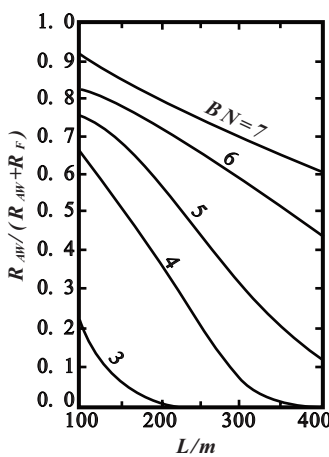
$C_B = 0.8, Fn = 0.10$, ballast

Figure 6(24)



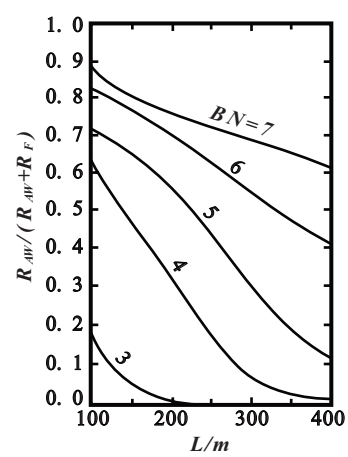
$C_B = 0.8, Fn = 0.15$, ballast

Figure 6(25)



$C_B = 0.8, Fn = 0.20$, ballast

Figure 6(26)



$C_B = 0.8, Fn = 0.25$, ballast

Figure 6(27)

Appendix 4-5 Calculation by Means of Guldhammer and Harvald Resistance Diagrams

1 Definitions and assumptions

1.1 All data are within the scope of ship models, and the ship model resistance R_m is analyzed by the speed function.

1.2 The total resistance coefficient C_{Tm} of the ship model:

$$C_{Tm} = \frac{R_{Tm}}{\frac{1}{2} \rho V_m^2 S_m}$$

where: ρ — water density;
 V_m — ship model speed;
 S_m — ship model wetted surface area.

1.3 Ship model residual resistance coefficient C_R :

$$C_R = C_{Tm} - C_{Fm}$$

where: C_{Fm} — ship model friction resistance coefficient, to be calculated according to ITTC 1957 ship model-full scale ship curve:

$$C_{Fm} = \frac{0.075}{(\log_{10} Re - 2)^2}$$

where: Re — Reynolds number, $Re = \frac{VL}{\nu}$, ν being kinematic viscosity coefficient of water, L being length of waterline.

1.4 C_R is expressed as function of Froude number Fn .

$$Fn = \frac{V}{\sqrt{gL}}$$

1.5 The diagrams are grouped according to the length displacement volume $L/\nabla^{2/3}$ and longitudinal prismatic coefficient φ :

$$\varphi = \frac{\nabla}{LBT\beta}$$

where: B — breadth of ship;
 T — draft;
 β — area coefficient of cross section amidships.

1.6 The main diagrams are curves showing the average value of C_R , with $B/T = 2.5$, standard longitudinal center of buoyancy (LCB), cross section of normal shape, medium level cruiser stern and raked bow, as presented in Figures 1.6(1) to 1.6(9).

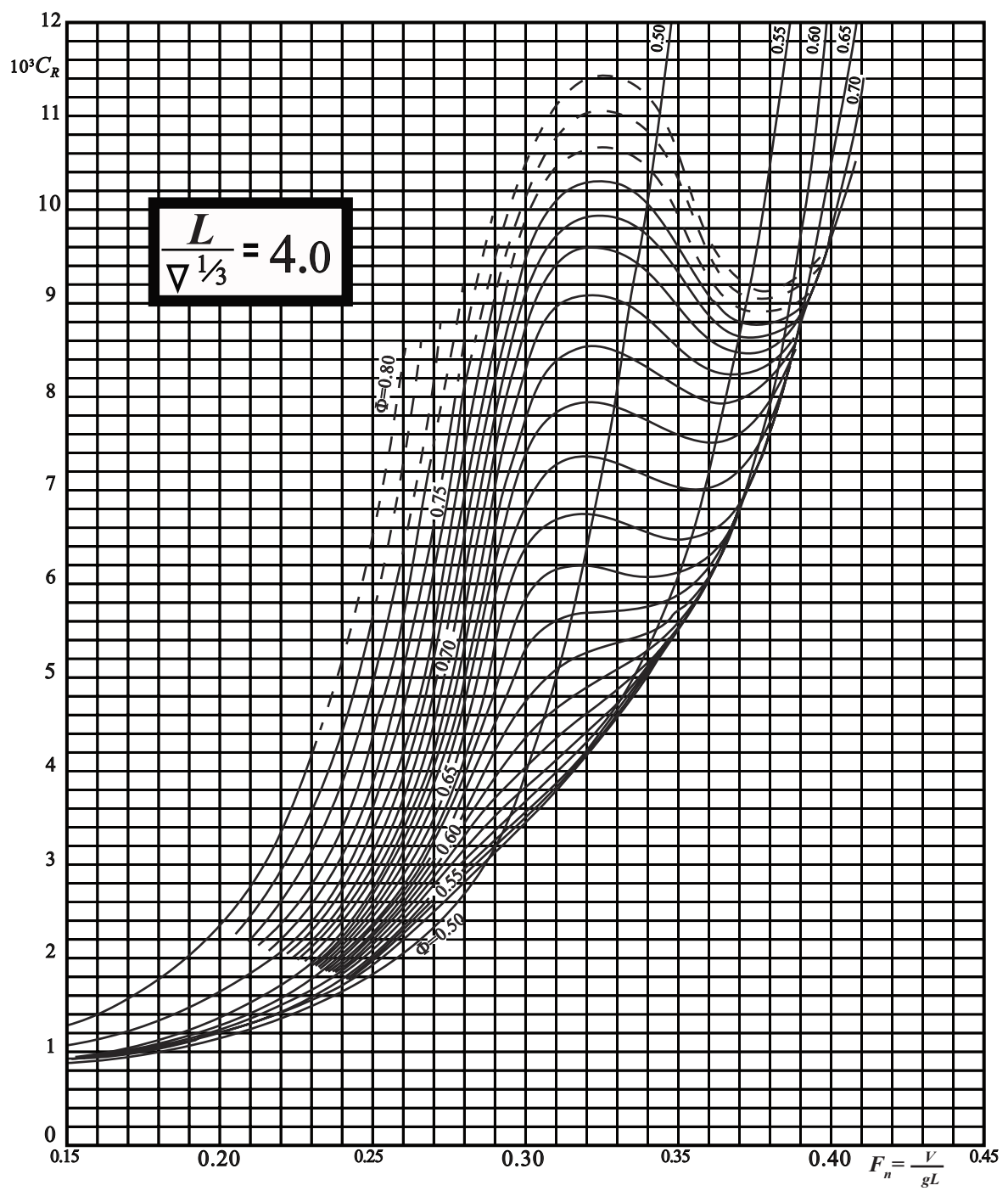


Figure 1.6(1) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 4.0$

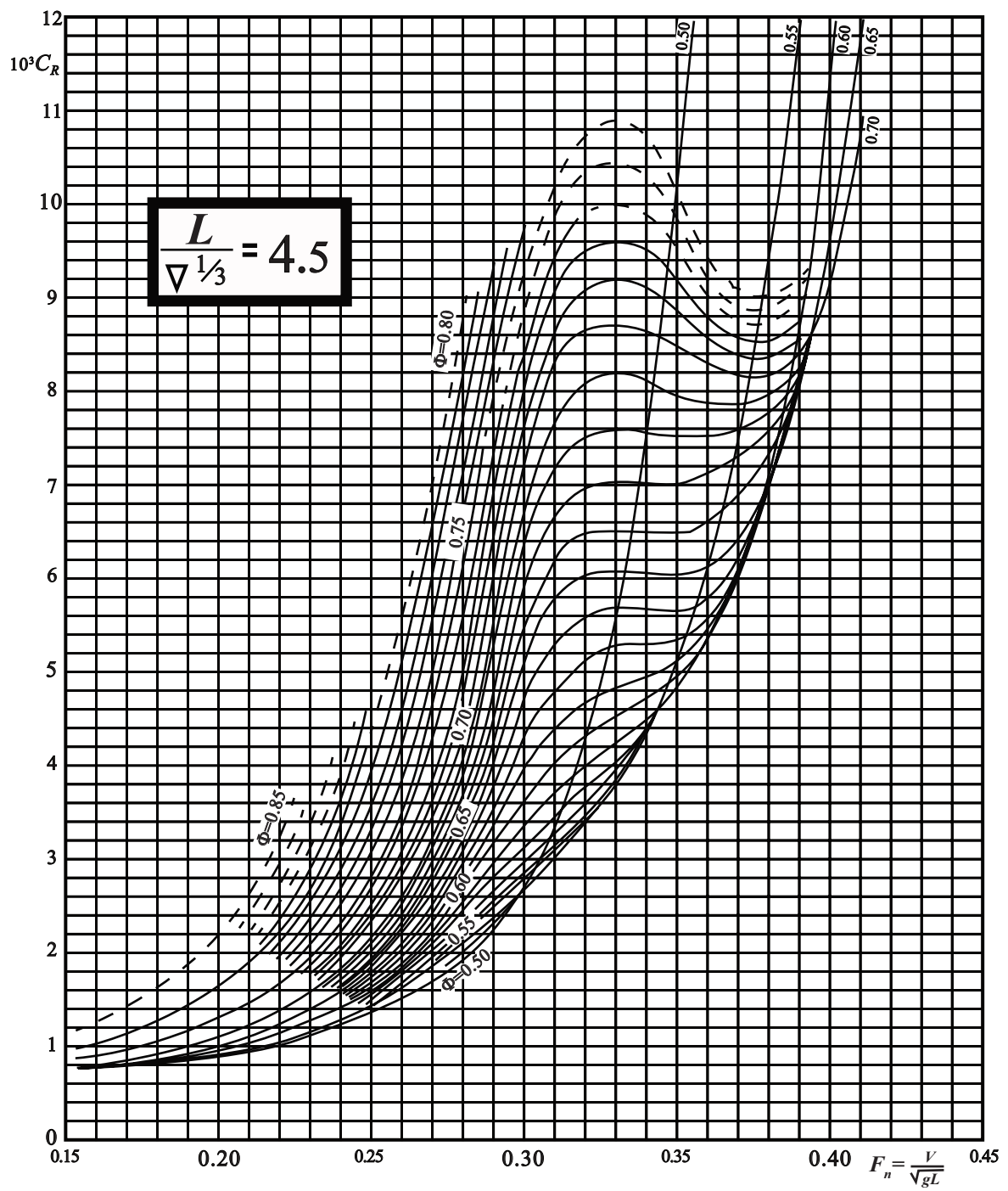


Figure 1.6(2) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 4.5$

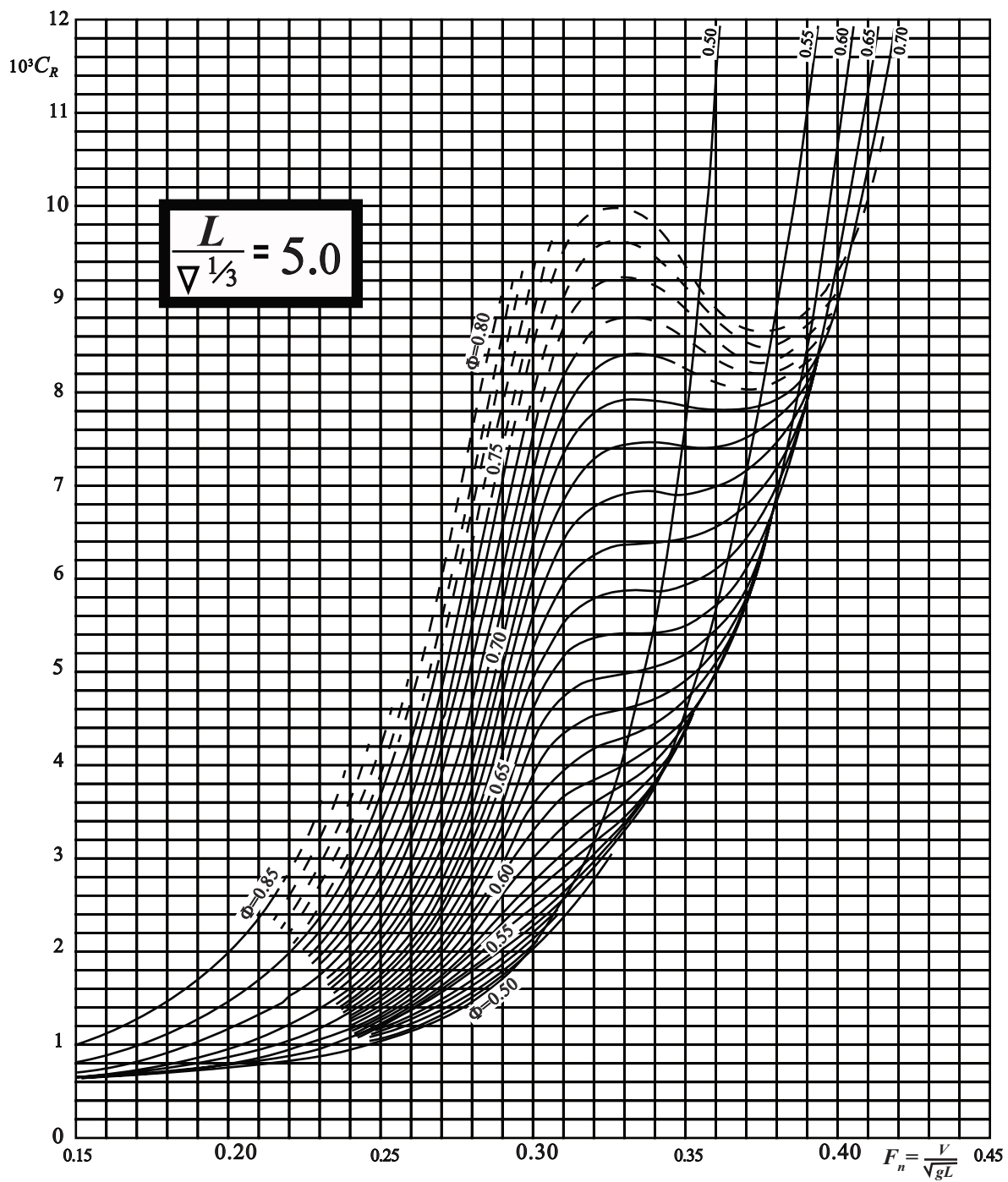


Figure 1.6(3) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 5.0$

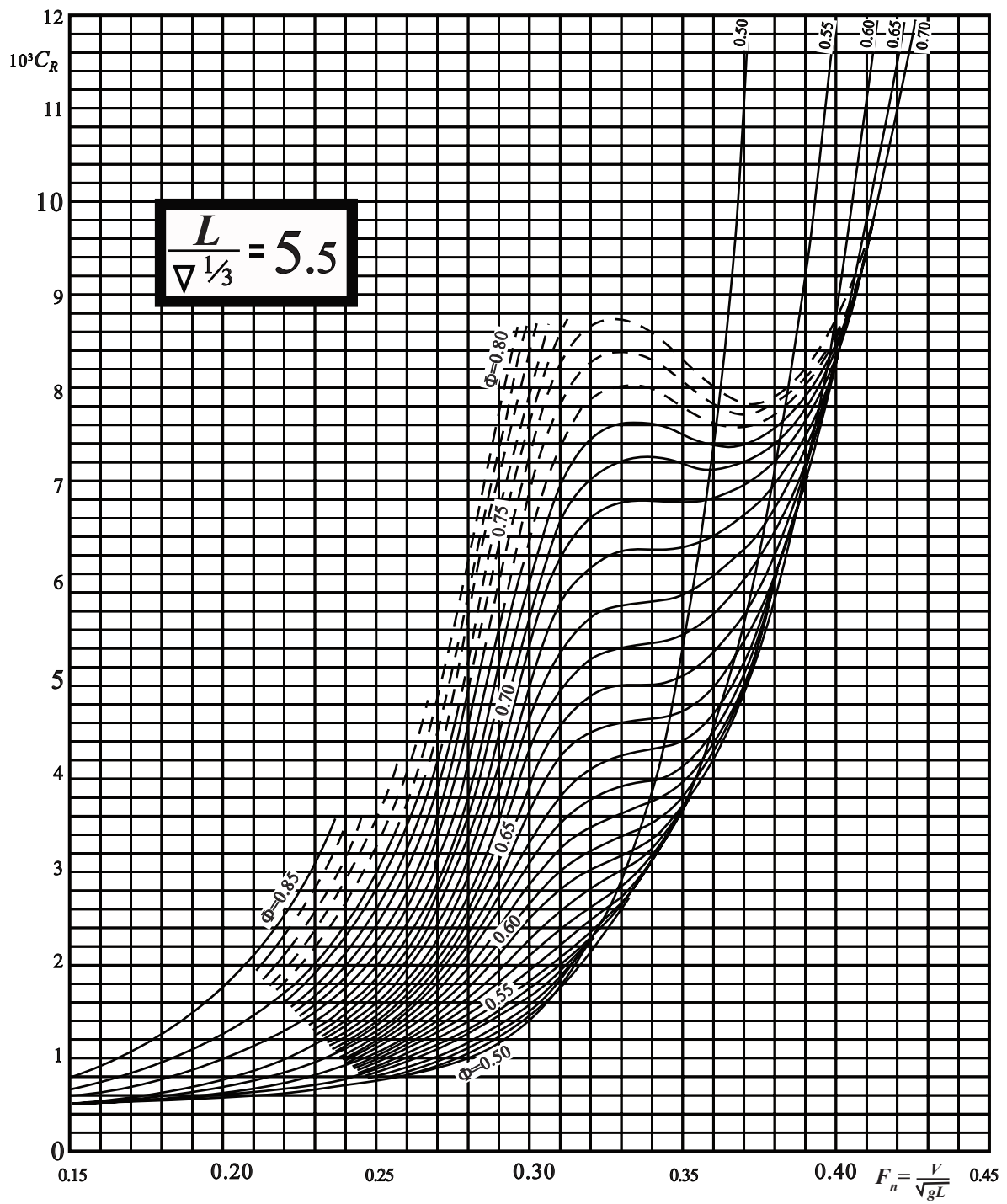


Figure 1.6(4) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 5.5$

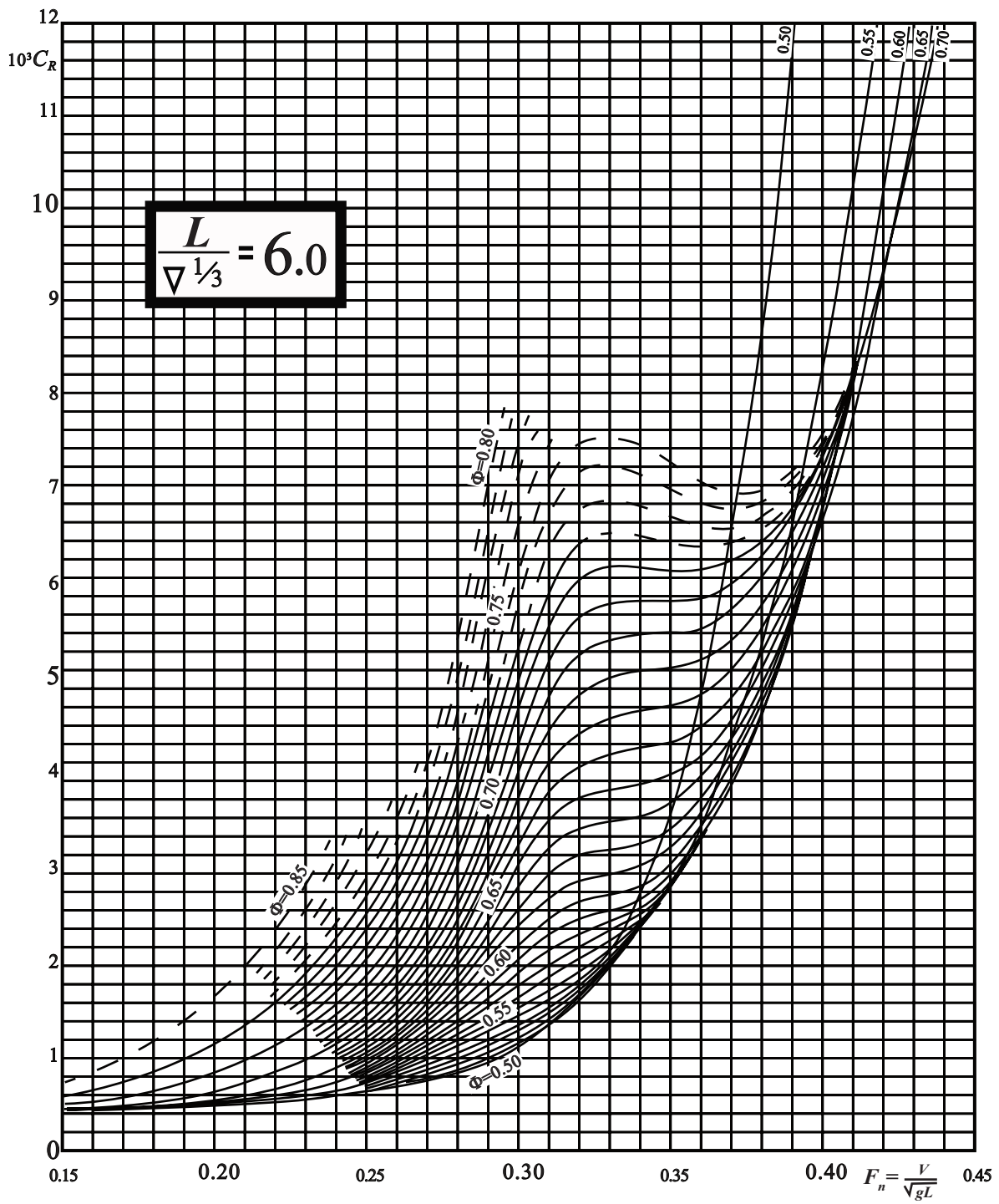


Figure 1.6(5) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 6.0$

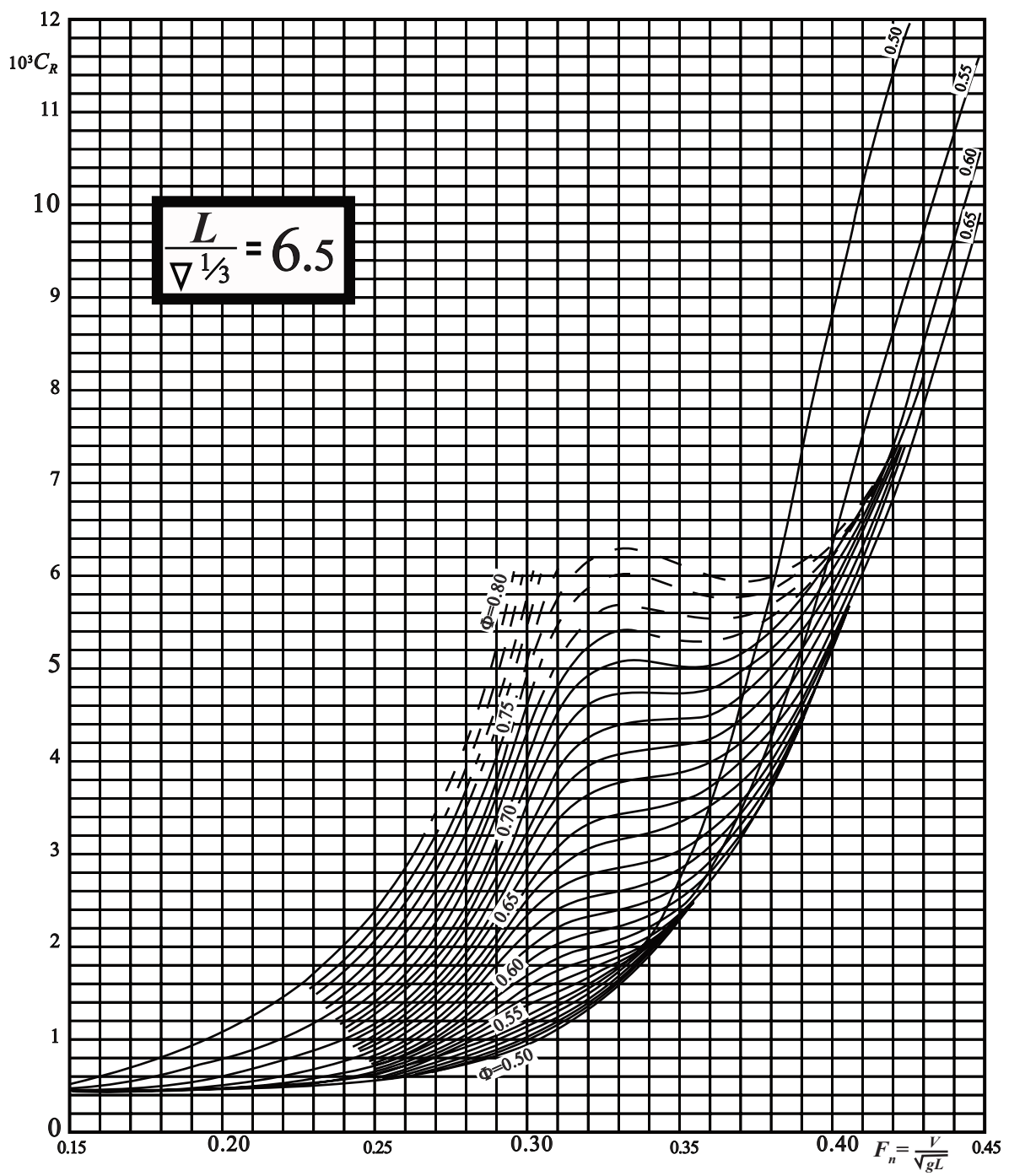


Figure 1.6(6) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 6.5$

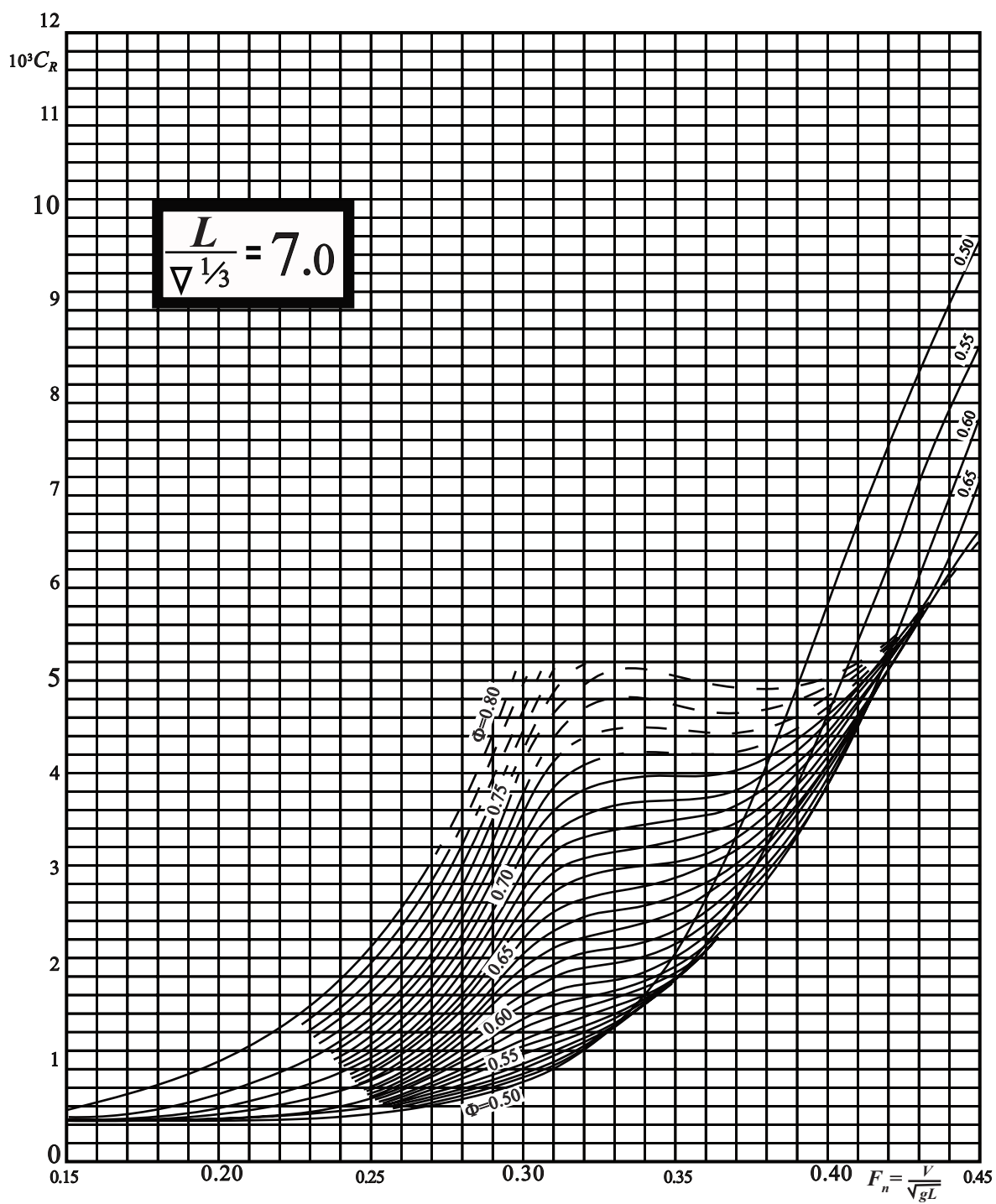


Figure 1.6(7) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 7.0$

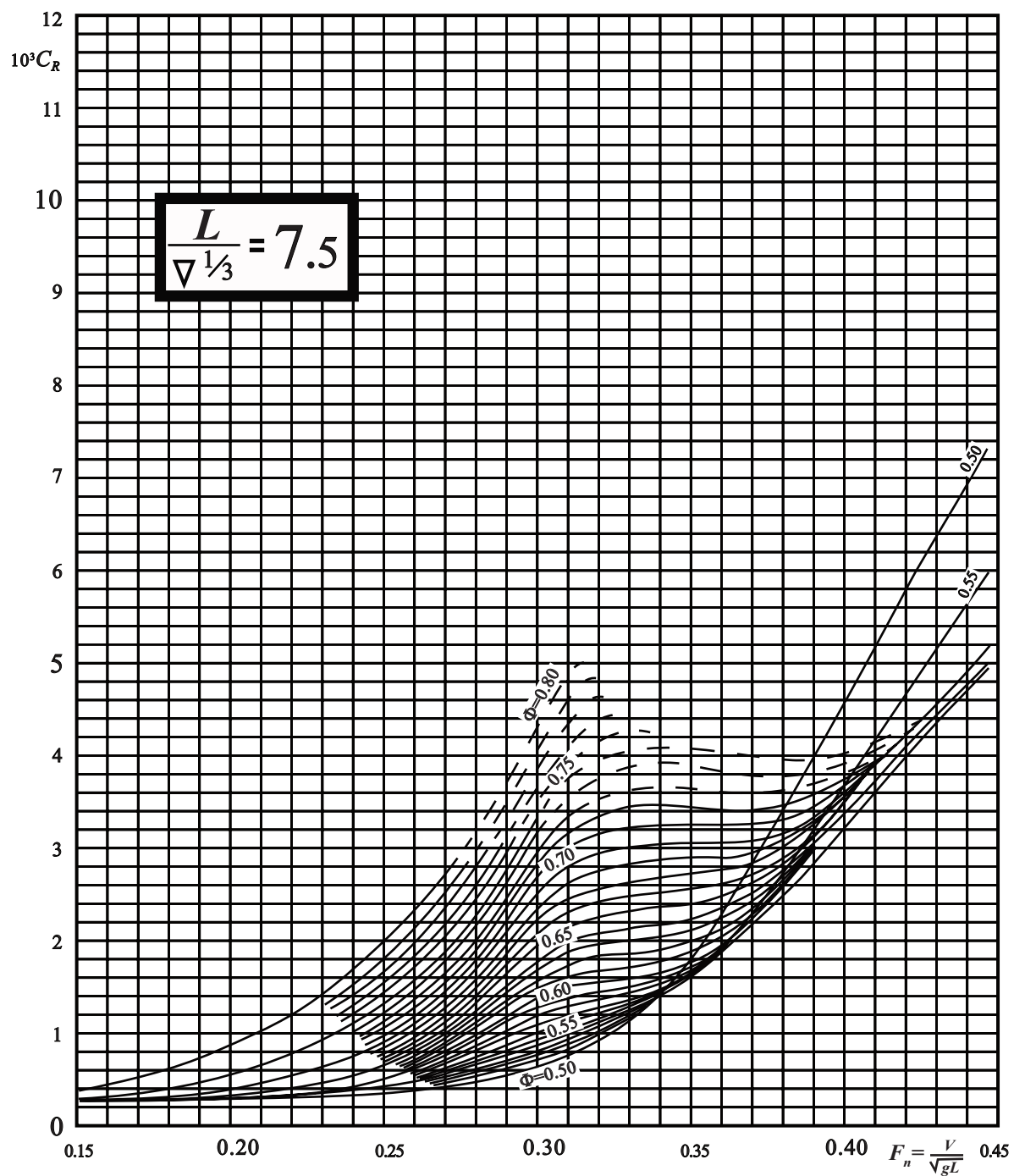


Figure 1.6(8) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 7.5$

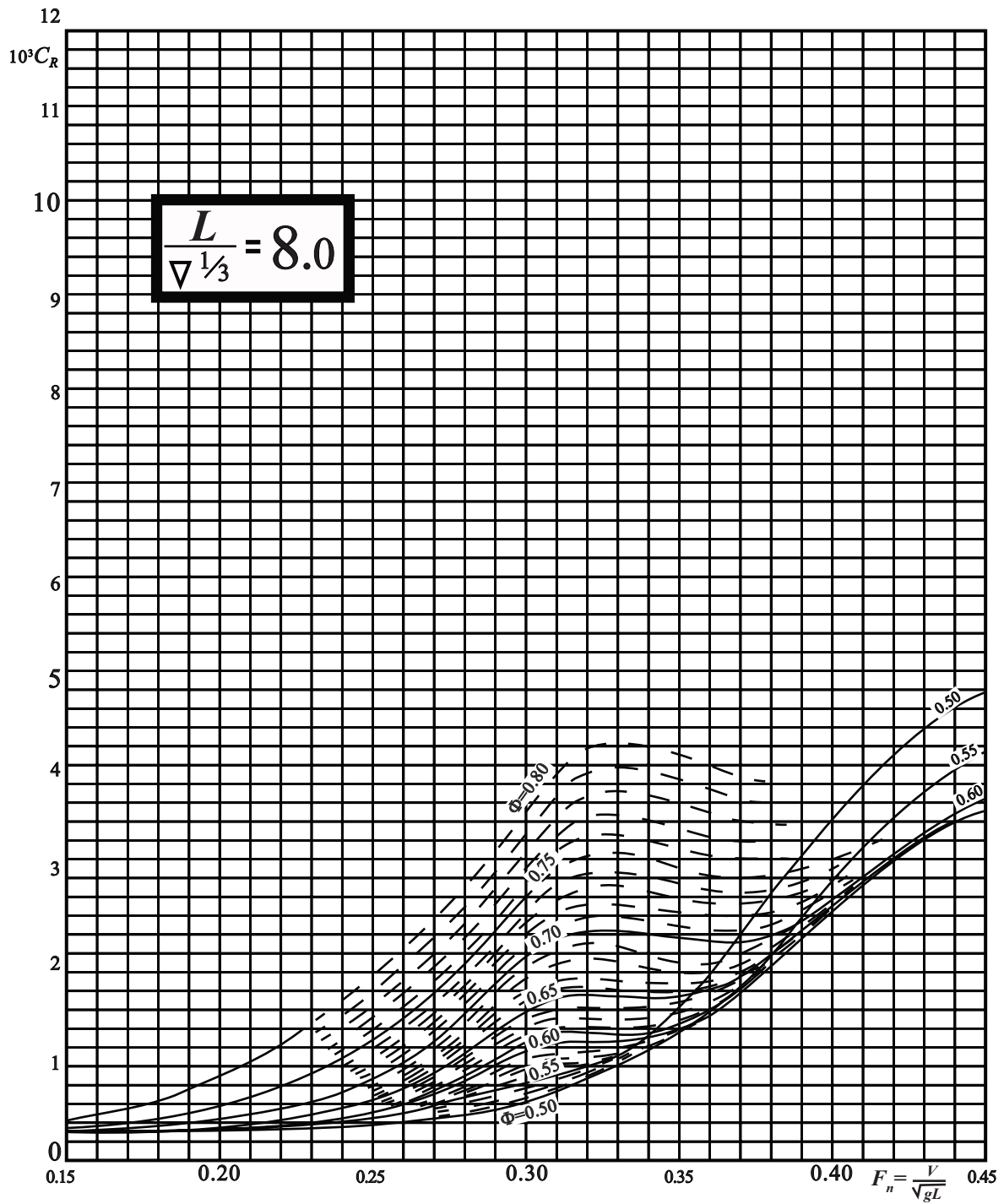


Figure 1.6(9) Guldhammer and Harvard Resistance Diagram $L/\nabla^{1/3} = 8.0$

2 Calculation of resistance R and effective power P_E of new ships

2.1 The resistance R is to be calculated by the following formula:

$$R = C_T \times \left(\frac{1}{2} \rho V^2 S \right) \quad \text{N}$$

2.2 The effective power P_E is to be calculated by the following formula:

$$P_E = R \times V \quad kW$$

2.3 The total resistance coefficient C_T is to be calculated by the following formula:

$$C_T = C_R + C_F + C_A$$

where: C_R — residual resistance coefficient, to be obtained from Figures 1.6(1) to 1.6(9) according to φ , $L/\nabla^{2/3}$ and F_n for “standard ship type”.

C_F — friction resistance coefficient, to be calculated by the following formula:

$$C_F = \frac{0.075}{(\log_{10} Re - 2)^2}$$

C_A — additional resistance coefficient, usually a fixed value, i.e. $C_A = 0.0004$.

2.4 B/T correction: when B/T is greater or less than 2.5, the relation between C_R and the standard $C_{R(B/T=2.5)}$ is as follows:

$$10^3 C_R = 10^3 C_{R(B/T=2.5)} + 0.16 \left(\frac{B}{T} - 2.5 \right)$$

2.5 LCB correction: when LCB is after the standard LCB , no correction. When LCB is before the standard LCB , the following steps are to be taken:

(1) The deviation ΔLCB between LCB and the standard LCB is to be calculated by the following formula:

$$\Delta LCB = LCB - \text{standard } LCB$$

where: LCB is expressed as % L , being positive before middle and negative after middle.

The standard LCB is to be obtained from Figure 2.5 by Froude number F_n :

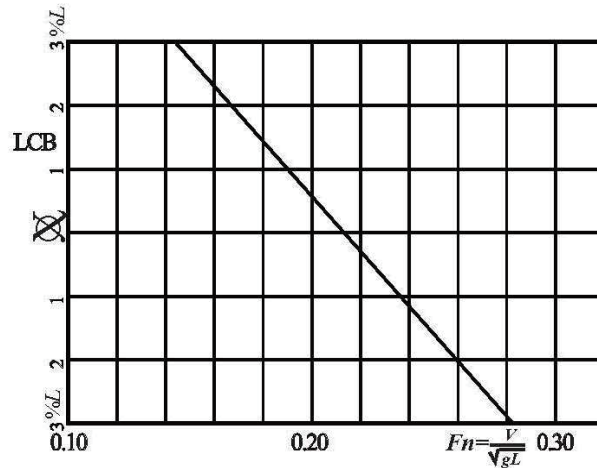


Figure 2.5 Standard LCB

where the standard LCB straight line can be expressed as:

$$\text{standard } LCB = 9.375 - 43.75 \times F_n$$

(2) After obtaining ΔLCB from (1), $\frac{\partial 10^3 C_R}{\partial LCB}$ is obtained from Figure 2.2.

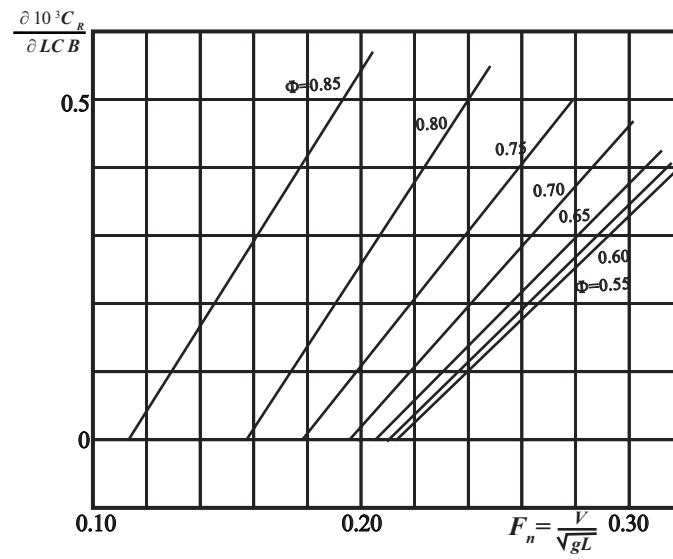


Figure 2.2 Correction Coefficient

(3) The residual resistance coefficient after LCB correction is to be calculated by the following formula:

$$10^3 C_R = 10^3 C_R (\text{standard}) + \frac{\partial 10^3 C_R}{\partial LCB} \times \Delta LCB$$

where: $10^3 C_R (\text{standard})$ — $10^3 C_R$ obtained from 2.4.

Appendix 4-6 Examples of Direct Calculation of Power Curves Determined Based on Hull-Engine-Propeller Interrelationship

1 Known conditions

(1) Ship parameters

Length between perpendiculars L_{PP}	251.50 m
Length of waterline L_{WL}	260.00 m
Draft T_F	16.5 m
Wetted area S	16400 m ²
Displacement volume ∇	142000 m ³

(2) Propeller parameters

Number	1
Number of blades, Z	5
Diameter D	8.2 m
Pitch ratio at 0.75R (P/D) _{0.75R}	0.76

(3) Open water characteristics of full-scale propeller

J	$10 \times K_T$	$100 \times K_Q$
0.200	2.841	3.235
0.250	2.641	3.045
0.300	2.436	2.855
0.350	2.226	2.665
0.400	2.011	2.465
0.450	1.791	2.265
0.500	1.566	2.055
0.550	1.336	1.825
0.600	1.101	1.575
0.650	0.861	1.295

(4) Full scale effective power, wake fraction and thrust deduction fraction

Speed V_S (kn)	Effective power P_E (kW)	Thrust deduction fraction t	Wake fraction WTS	Relative rotative efficiency η_R
14.0	6820	0.182	0.291	0.968
15.0	8360	0.211	0.304	0.980
16.0	10211	0.231	0.310	0.993
17.0	12725	0.230	0.311	1.004
18.0	16325	0.210	0.304	1.006
19.0	21005	0.209	0.304	0.999
20.0	26887	0.238	0.321	1.009

(5) Other parameters

Sea water density ρ (t/m ³)	Shafting efficiency η_s	Sea trial correction CP	Sea trial correction CN
1.025	0.98	1.010	1.020

2 Calculation of auxiliary characteristic curve of propeller ($\ln(K_T/J^2) \sim J$)

J	K_T	K_Q	K_T/J^2	$\ln(K_T/J^2)$
0.20	0.2841	0.03235	7.1025	0.960
0.25	0.2641	0.03045	4.2256	1.441
0.30	0.2436	0.02855	2.7067	0.996
0.35	0.2226	0.02665	1.8171	0.597
0.40	0.2011	0.02465	1.2569	0.229
0.45	0.1791	0.02265	0.8844	-0.123
0.50	0.1566	0.02055	0.6264	-0.468
0.55	0.1336	0.01825	0.4417	-0.817
0.60	0.1101	0.01575	0.3058	-1.185
0.65	0.0861	0.01295	0.2038	-1.591

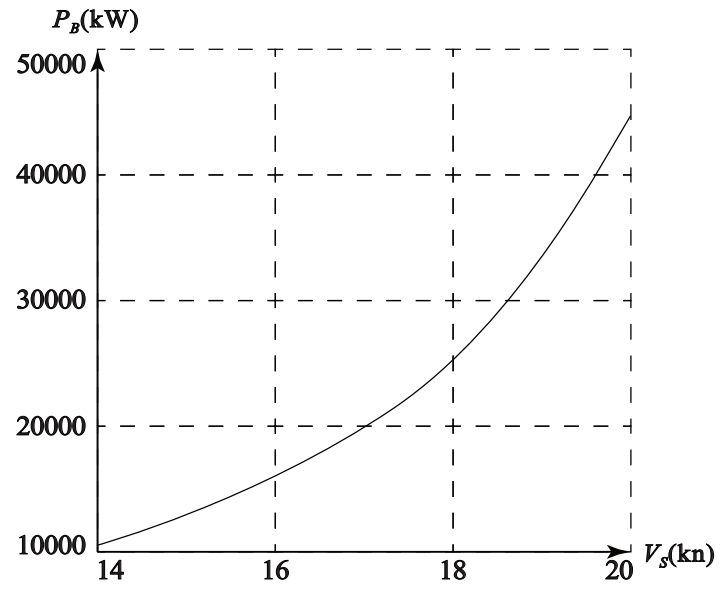
3 Calculation of power curve ($V_S - P_B$)

V_S	V	R	V_a	T	$T/(\rho V_a^2 D^2)$	$\ln(T/(\rho V_a^2 D^2))$	J
kn	m/s	kN	m/s	kN	—	—	—
①	②	③ = $P_E/2$	④ = ② × (1- WTS)	⑤ = ③/(1- t)	⑥ = ⑤/(\(\rho V_a^2 D^2\))	⑦ = $\ln(⑥)$	⑧ Obtained from $\ln(K_T/J^2)$ longitudinal coordinates on 2 curves
14.0	7.202	947.0	5.106	1157.7	0.644	-0.440	0.496
15.0	7.716	1083.5	5.370	1373.2	0.691	-0.370	0.486
16.0	8.230	1240.7	5.679	1613.4	0.726	-0.320	0.479
17.0	8.745	1455.1	6.025	1889.8	0.755	-0.281	0.474
18.0	9.259	1763.1	6.444	2231.8	0.780	-0.249	0.469
19.0	9.774	2149.1	6.803	2716.9	0.852	-0.160	0.456
20.0	10.288	2613.4	6.986	3429.7	1.020	0.019	0.430

V_S	n	K_Q	P_D	$(P_D)_{CORR}$	P_B
kn	RPS	—	kW	kW	kW
①	⑨ = ④/((⑧) D)	⑩ Obtained by ⑧ from ($J-K_Q$) curve in 1(3)	⑪ = $2 \pi \rho$ ⑨ ³ D^5 ⑩	⑫ = $CP \times 11$	⑬ = $12/(\eta_s \times \eta_R)$
14.0	1.255	0.0208	9816	9914	10451
15.0	1.347	0.0212	12371	12495	13010
16.0	1.446	0.0216	15593	15749	16184
17.0	1.550	0.0218	19383	19577	19897
18.0	1.676	0.0220	24730	24977	25335
19.0	1.819	0.0225	32334	32657	33357
20.0	1.981	0.0236	43806	44244	44744

4 Power curve

According to V_s and P_B obtained from 3, the power curve is drawn as follows:



Appendix 4-7 Method of Indirect Calculation of Power Curves Determined Based on Hull-Engine-Propeller Interactions and Examples

1 Known conditions

- (1) Propeller diameter D
- (2) Characteristic curve $J - K_T/K_Q/\eta_0$ of propeller
- (3) Wake fraction w
- (4) Thrust deduction fraction t
- (5) Relative rotative efficiency η_R
- (6) Shafting efficiency η_S
- (7) Seawater density ρ
- (8) Effective power curve $V-P_E$ (full-load condition and ballast condition, deep still water, no wind and waves)

2 Calculation method

- (1) Assuming one group N of rates of revolution, as shown in Figure 2, $N = 155, 145$ and 135 r/min.
- (2) For each rate of revolution, the required main engine power P_S is calculated according to Table 2.

Calculation of Required Power at Rate of Revolution $N =$ Given Value

Table 2

Assumed speed V	V_1	V_2	V_3	
$V_A = (1 - w) V$	V_{A1}	V_{A2}	V_{A3}	
$J = V_A / nD$	J_1	J_2	J_3	
K_T (obtained from propeller characteristic curve)	K_{T1}	K_{T2}	K_{T3}	
K_Q (obtained from propeller characteristic curve)	K_{Q1}	K_{Q2}	K_{Q3}	
$T = K_T \rho n^2 D^4$	T_1	T_2	T_3	
$P_E = T (1 - t) V$	P_{E1}	P_{E2}	P_{E3}	
$Q = K_Q \rho n^2 D^5$	Q_1	Q_2	Q_3	
$P_D = 2\pi n Q$	P_{D1}	P_{D2}	P_{D3}	
$P_S = P_D / \eta_S \times \eta_R$	P_{S1}	P_{S2}	P_{S3}	

(3) $V-P_E$ curve (upper part of Figure 2) and $V-P_S$ curve (lower part of Figure 2) corresponding to speed $N =$ given value are obtained from (2), $V-P_E$ curves and $V-P_S$ curves at other given rates of revolution are obtained in this way.

(4) The curve obtained from (3) is drawn in Figure 2, together with the effective power curve $V-P_E$ under each loading condition, e.g. effective power curves under three loading conditions (full load, ballast and 110% full load) as shown in Figure 2.

(5) For each loading condition in Figure 2, a point of intersection is obtained by drawing a vertical line from the point of intersection of the $V-P_E$ curve of the same N with the effective power curve $V-P_E$ to the $V-P_S$ curve of the same N , and the curve connecting such points of intersection is the EEDI power curve under the corresponding loading condition.

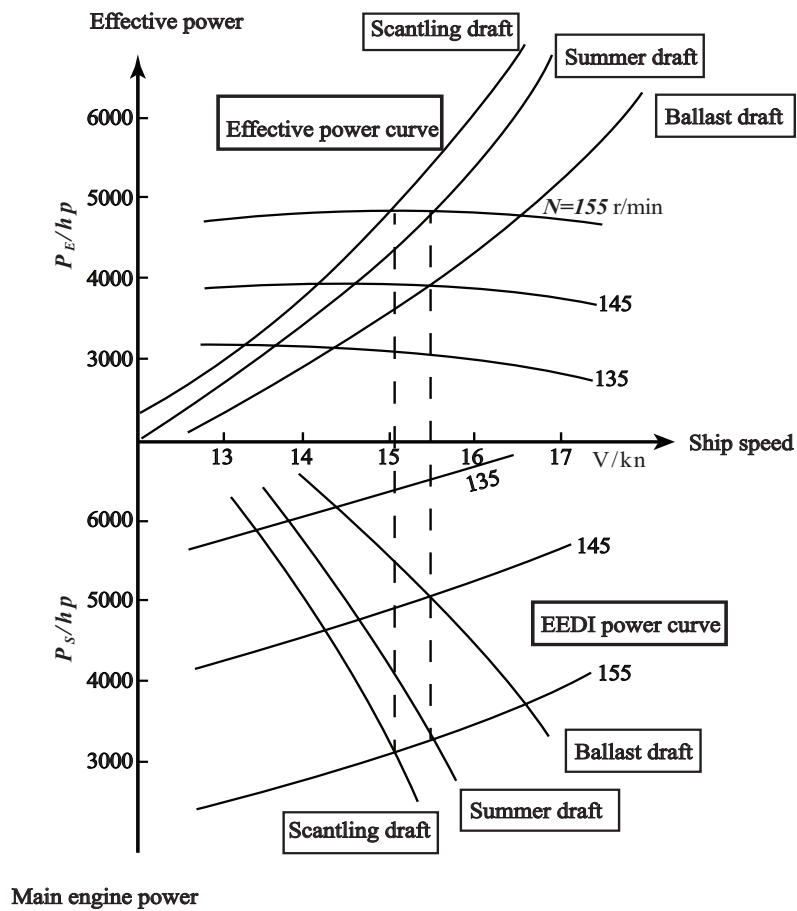


Figure 2 Example of EEDI Power Curve Determined from Characteristic Curve under Navigation

Appendix 5 Guidelines for Verification of Tank Test of EEDI Power Curves

Chapter 1 General

1.1 General provisions

1.1.1 The purpose of these Guidelines is to provide guidance for the additional information of tank test.

1.1.2 These Guidelines are developed with reference to the report of the Performance Committee of the International Towing Tank Conference (ITTC) and relevant model test information.

1.2 Basic concept of tank test

1.2.1 The tank test is used as the basis for the prediction/verification of the power (power curves) required for ship propulsion, and also for the design of propellers and the analysis of hull-engine-propeller interactions.

1.2.2 For tank tests, the forces acting on the model and full-scale ship are required to be similar. As a result, the following conditions for similarity are to be met:

- (1) geometric similarity;
- (2) kinematic similarity;
- (3) dynamic similarity.

1.2.3 The conditions for similarity are explained as follows:

(1) The geometric similarity is generally expressed as the ratio of the full-scale ship to the model — scale ratio λ :

$$\lambda = L_S / L_M$$

where: L_S, L_M — length of full-scale ship and model respectively.

As the similarity between surface features of the model and full-scale ship cannot be achieved by the geometric similarity, the model test results must be corrected (refer to 2.5 in Appendix 5-1). In addition, the similarity between tank and sea with regard to the water depth, extent and surface pressure cannot be achieved due to “wall effects” and “blockage effects”.

(2) The kinematic similarity requires that the ratio between speeds of the model is to be equal to that between corresponding speeds of the full-scale ship. For propeller model tests, the ratio of advance to revolution at one point on the model blade is to be equal to the corresponding ratio of the full-scale propeller (same advance ratio):

$$\frac{V_M}{n_M(2\pi R_M)} = \frac{V_S}{n_S(2\pi R_S)} \quad \text{or}$$

$$\frac{V_M}{n_M D_M} = \frac{V_S}{n_S D_S} \quad \text{or}$$

$$J_M = J_S$$

where: subscripts M and S indicates values for model and full-scale ship respectively;

R — radius in way of the point under consideration;

V — rate of advance;

n — rate of revolution;
 D — propeller diameter;
 J — advance coefficient.

(3) Only the gravitational similarity can be achieved for the required dynamic similarity (same Froude number):

$$\frac{V_M}{\sqrt{gL_M}} = \frac{V_S}{\sqrt{gL_S}} = Fn$$

where: subscripts M and S indicates values for model and full-scale ship respectively;

V — speed;
 L — length of ship;
 g — gravitational acceleration;
 Fn — Froude number.

(4) Critical Reynold's number requirements: Reynold's number of more than 5×10^6 for ship model (turbulence); Reynold's number of more than 3×10^5 for propeller model.

1.2.4 The tank test required for the verification of EEDI consists of:

- (1) manufacture of hull model and propeller model and preparations before test;
- (2) towing test (resistance test);
- (3) propeller open water test;
- (4) self-propulsion test;
- (5) streamline test (if necessary);
- (6) wake measurement (if necessary);
- (7) test in waves (if necessary).

1.3 Basic requirements for towing tank used in model test

1.3.1 The test organizations/units conducting model tests for the purpose of EEDI verification are to be registered and qualified at ITTC. The test units are also to be subject to ISO 9000 certification, and effective management and monitoring are to be carried out to the qualification of test personnel and services supplied by them.

1.3.2 The test used for the prediction of ship power is generally conducted in the model towing tank. The dimension and water depth of the towing tank are to be suitable for the length and test speed of the model used. For the maximum speed measured, the towing carriage is to be suitable for running an adequate length at constant speed. Test locations are to be provided with equipment and instrumentation for resistance test, self-propulsion test and propeller open water test. Tanks are to be at least provided with the following equipment and facilities:

- (1) wave generator and wave damper;
- (2) processing/measuring equipment of model and propeller;
- (3) instruments for measuring force and speed, capable of measuring at least:

- model speed (V_M);

- total resistance of model (R_M);
- propeller thrust (T_M);
- torque corresponding to delivered power (Q_M);
- rate of revolution of propeller (n_M);

(4) other measuring devices, e.g. trim meter, draught meter, gravimeter, wave height meter, Prandtl pitot tube and five-hole pitot tube, pressure sensor, water pressure gauge, hot-wire meter, Doppler laser velocimeter, strainmeter bridge equipment, electronic equipment (recorder, filter, analyzer, computer, printer, plotter, etc.), photographic equipment and sea trial instruments.

1.3.3 The test units are to have an effective management of monitoring, measuring and test equipment, regularly carrying out calibration and making records, to ensure the effectiveness of such equipment and guarantee the accuracy of test results. For the management and calibration of test equipment, refer to the requirements of ITTC 7.6-01-01.

1.3.4 For calibration of test instruments and evaluation of their uncertainties, refer to ITTC 7.5-01-03-01.

1.3.5 Prior to any tank test, the tank-operating unit is to have full communication with the entrusting party/designer to know the preliminary design plan, including general arrangement and main engine type/basic parameters, detailed and accurate resistance, propeller performance and wake fraction, and calculation of thrust deduction. When practicable, the hull lines plan may be developed by means of a similar parent ship or the CFD (Computational Fluid Dynamics) method. On such basis, a preliminary test scheme is to be determined with the entrusting party.

1.3.6 Test locations are to have the capability of making models of hull, propeller and appendage. The ship model is to be made according to ship lines provided. It is to ensure that the model is kept good and the displacement is correct during test. For model making, refer to ITTC 7.5-01-01-01.

1.3.7 Turbulence stimulation measures are to be clearly indicated in model making documents or test documents. For the use of wires or sand strips, refer to the relevant requirements of ITTC 7.5-01-01-01.

1.3.8 Prior to test, the model's draft is to be determined, its floating control established and the preparation of relevant information regarding the model (including hull and propeller) completed. For details, refer to ITTC 7.5-01-01-01.

1.3.9 Prior to each test, the test location is to develop a test program according to ITTC recommended procedures. The test program is to include model condition, equipment installation and required parameters in resistance/self-propulsion/propeller open water tests, as well as explanations for the use of measuring instruments and measurement accuracy, test flow and data collection and analysis. The test program is also to provide a procedure for the reliability analysis of test results and indicate the information to be included in the test report. For details, refer to the requirements of ITTC 7.5-02-02-01, 7.5-02-03-01.1 and 7.5-02-03-02.1.

1.3.10 The test unit is to have an effective management of data generated during test, which includes properly recording key data and results during test and showing test results (such as residual resistance, wake fraction, thrust deduction and power curves) in diagrams with the guidance/participation of the test unit after test. Test records, test information and prediction analysis are to be archived.

1.3.11 Test locations are to have an appropriate test data management and analysis software platform. Model tank test data are to be accumulated at least for more than 300 self-propulsion models.

1.4 Error control related to full scale ship—model

1.4.1 The errors of tank test are related to instruments and caused by test methods and conditions, generally as follows:

- | | | |
|--------------------------------|---------------|--------------------|
| • resistance | R : | $1 \sim 2\%$; |
| • power | P : | $2.0 \sim 2.5\%$; |
| • rate of revolution | n : | $0.5 \sim 0.8\%$; |
| • wake fraction | w_M : | 0.01 ; |
| • thrust deduction factor | t : | 0.007 ; |
| • relative rotative efficiency | η_{RM} : | 0.008 . |

1.4.2 Errors of a prediction method mean those errors due to the assumed incorrectness or similarity taking into account the scale effect, e.g.:

- the effect of Froude number F_n on the form factor;
- the effect of Reynolds numbers Re on the wave-making resistance, wake, thrust deduction and bilge-eddy resistance;
- the effect of the shape of wake field on the relative rotative efficiency η_R ;
- the effect of the surface roughness of hull and propeller.

1.4.3 Errors of sea trial include errors of instruments (torsigraph and velocimeter) and other errors (difference between model and full-scale propeller; trim, displacement; correction of wind, wave and current; effects of specific gravity and temperature of seawater; cavitation of propeller, etc.).

The accuracy of the available prediction method can only be inferred by comparing sea trial results with the standard deviation obtained from calculation results of the sea trial prediction program. The available study shows that:

- test errors (model test error + sea trial error) are approximately 4~5% for power P and 1~2% for rate of revolution n ;
- errors of the prediction method are approximately 4~5% for power P and 1.6~1.8% for rate of revolution n .

1.5 Main points in preparations before tank test

1.5.1 The estimation of EEDI power curves at the basic design stage is to be completed by the entrusting party.

1.5.2 For a ship contracted for construction, the range of power required for the ship is to be established by the entrusting party.

1.5.3 Detailed design is to be carried out by the entrusting party/designer for the model test, including general arrangement and main engine type /basic parameters, detailed and accurate calculation of resistance, propeller performance, wake fraction and thrust deduction. The calculation may be carried out by means of general diagrams, regression formulas or database prediction. Where practicable, the hull lines plan may be developed by means of a similar parent ship or the CFD (Computational Fluid Dynamics) method.

1.5.4 The model test task and sea trial requirements are to be developed based on the completion of the above preparations.

1.6 Exemption from tank test

1.6.1 The exemption from model test may be granted in the following cases:

- (1) sister ships or follow-on ships of the first ship;
- (2) principal parameters, e.g. length to breadth ratio L/B , block coefficient C_b and length-displacement volume coefficient $L/\nabla^{1/3}$, are the same as or similar to those of the parent ship;
- (3) numerical tests are accepted in lieu of the model test if they are performed under documented conditions agreed by the shipbuilder and shipowner;
- (4) speed trial can be completed under the EEDI condition (fully-loaded condition) for the designed ship;
- (5) the CFD method agreed by CCS is to be adopted, but the power curves and reference speed obtained accordingly are to be provided.

Chapter 2 Tank Test

2.1 General

2.1.1 This Chapter is intended to provide the shipbuilder with the main points and information in relation to model test as follows:

- (1) manufacture of model;
- (2) resistance test;
- (3) propeller open water test;
- (4) self-propulsion test;
- (5) streamline test (if necessary);
- (6) wake measurement (if necessary);
- (7) test in waves (if necessary).

And the explanations of tank test are given at the end of this Chapter.

2.1.2 In addition to complying with paragraph 1.3 above, the tank test process is to be examined according to the block diagram in Figure 2.1.2.

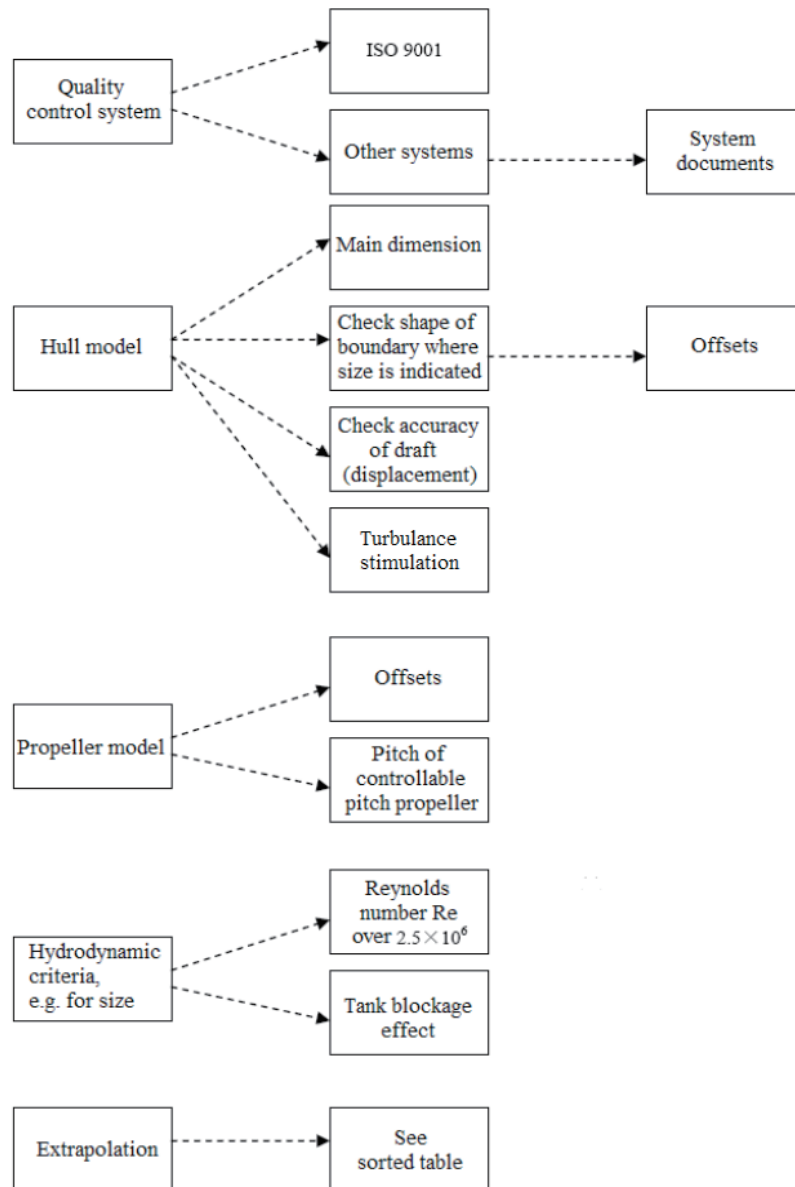


Figure 2.1.2 Examination of Tank Test Process

2.2 Manufacture of model

2.2.1 Hull model

(1) The hull model needs to be made according to the ship's lines supplied. The model itself can provide the shipbuilder with a number of useful information, e.g. fairness of lines, bow and stern shapes, and positions of rudder and propeller, etc.

(2) The use of a large-scale model is the best and most efficient method for achieving a steady condition of turbulence on the entire hull surface. The scale ratio is to be such that the model is not less than 6 m in length.

(3) The allowable error for model length is to be $\pm 0.05 L_{pp}$ or ± 1.0 mm, and the allowable errors for other dimensions are to be within ± 1 mm.

2.2.2 Propeller model: the model is generally not to be less than 200 mm in diameter and the allowable error is ± 0.1 mm.

2.3 Resistance test

2.3.1 For the purpose of EEDI verification, the objectives of the resistance test are as follows:

- (1) improving the lines of the designed ship — select lines of low resistance;
- (2) obtaining the effective power of the full-scale ship to be applied in the propeller design;
- (3) providing necessary data for the analysis of model self-propulsion test.

2.3.2 Data to be measured in test: towing speed and model resistance:

$$R_{TM} = f(V_M)$$

where: R_{TM} — model resistance;
 V_M — model speed.

2.3.3 The test requirements and conditions are as follows:

- (1) Turbulence stimulation: a metal wire of 1 mm in diameter is to be attached closely against hull surface at the 19th station so that turbulence will be formed at the boundary layer of hull surface thereafter.
- (2) The model displacement, draught and trim are to be corresponding to those of the full-scale ship.
- (3) The model is towed at speeds giving the same Froude number F_n as the full-scale ship.
- (4) The model is to be tested in the following three conditions:
 - Model hull without any appendages (naked model). This test is intended to determine the resistance coefficients of the basic form.
 - Model hull with appendages. This test is intended to determine the increase in resistance coefficients due to the appendages.
 - Model hull with appendages (excluding rudder behind propeller). This test is conducted prior to the self-propulsion test and intended to determine the resistance coefficients used for the analysis of self-propulsion test results.
 - Except for special design, the floating condition under test is to be an upright one without trim.

2.3.4 The main points during test are as follows:

- (1) The wave system generated by the model during towing is to be observed. If necessary, wave-making characteristics may be evaluated by means of analysis of the wave system, e.g. by modifying the characteristic dimension of the bulbous bow to reduce resistance.
- (2) During the resistance test, the towing at each speed is to be completed at one run. There is to be a certain time interval between two runs. In addition, a complete resistance curve is to be developed within one day in order to avoid the effects of water temperature and different turbulence conditions in the tank.
- (3) The power prediction and faired resistance and power curves are preferably to be given together with original test data for the purpose of test analysis. It is important for the shipbuilder/designer to carry out an analysis of the towing test.
- (4) It is to be noted that the original test data of one tank are not to be compared with those of another tank.

2.3.5 The conversion from data of model resistance test to full-scale resistance is given in Appendix 5-1.

2.4 Propeller open water test

2.4.1 For the purpose of EEDI verification, the objectives of the propeller open water test are as follows:

(1) testing and developing the open water characteristic curve ($J \sim K_T, K_Q, \eta$) of the designed propeller in a uniform flow field;

(2) providing necessary data for the analysis of model self-propulsion test.

2.4.2 Data to be measured in test: constant rate of revolution n_M , changed rate of advance V_{AM} , thrust T_M and torque Q_M of model propeller measured at V_{AM} .

2.4.3 The test requirements and conditions are as follows:

(1) The advance coefficients of model and full-scale propellers are to be equal.

(2) The water depth l of shaft line is to be greater than (0.8-1.0) model propeller diameter D_M .

(3) Reynolds number $Re_{0.7R}$ of model propeller based on chord length $0.7 R$ is to be greater than 3×10^5 .

2.4.4 Where a substitute propeller is used in the self-propulsion test (a model propeller available in the laboratory and of which open water data are known), a special model need not be made for the open water test.

2.5 Self-propulsion test

2.5.1 For the purpose of EEDI verification, the objectives of self-propulsion test are as follows:

(1) confirming satisfactory matching between propeller, main engine and hull;

(2) obtaining information on wake fraction, thrust deduction and relative rotative efficiency;

(3) obtaining predicted power for reference and corresponding full-scale ship speed and rate of propeller revolutions.

2.5.2 The test requirements and conditions are as follows:

(1) the same as 2.3.3;

(2) model hull with appendages;

(3) the diameter D_M of the model propeller is in general not to be less than 200 mm so as to minimize the scale effect. Where D_M is less than 150 mm, the test results must be corrected;

(4) unless it is confirmed that the sea trial of the full-scale ship will be carried out under the full load condition, the model self-propulsion test is to be carried out under ballast and full load conditions.

2.5.3 Data to be measured in test:

(1) model speed V_M ;

(2) rate of revolution n_M , thrust T_M and torque Q_M of model propeller;

(3) model towing force Z (for forced self-propulsion).

2.5.4 The main points are as follows:

- (1) The self-propulsion test is generally to be carried out only after confirmation by the shipbuilder / designer that hull lines have been optimized.
- (2) In order to compensate for various scale effects, the thrust deduction and wake fraction obtained from the self-propulsion test must be corrected by a certain method (see Appendix 5-1) so as to be applied to the full-scale ship. During the analysis, check against the values obtained from diagrams or formulas is necessary for evaluating whether the calculated thrust deduction and wake fraction are appropriate.
- (3) Where propeller arrangements are non-conventional, it is still necessary to use a specially manufactured model rather than the substitute propeller to carry out the test. In addition, the substitute propeller may be used where only the thrust deduction and wake fraction are obtained from the test. However, in order to ensure consistency between model and full-scale ship, the diameter of the substitute propeller (propeller model) is to be the same as that of the full scale propeller (propeller model).
- (4) Except as specially required, the test condition is generally to be an upright one without trim.

2.6 Streamline test

2.6.1 For the purpose of EEDI verification, this test is not necessary but it is useful in minimizing the resistance of local appendages, e.g. bilge keel, shaft bracket.

2.6.2 The streamline test is in generally carried out by wet printing.

2.6.3 It is possible for the shipbuilder/designer to determine, based on their experience, the arrangement of such appendages without conducting a streamline test.

2.7 Wake measurement

2.7.1 For the purpose of EEDI verification, this test is not necessary but it provides important original data for optimizing propeller design and important information necessary for the calculation of surface pressure variation of propeller blade and hull to avoid noise and vibration in so far as practicable.

2.7.2 Normally, only the wake distribution along the radial direction of the blade is to be known for propeller design. In general, this information may be easily obtained by resistance ring and vane wheel, from which the concept of non-uniform distribution of wake may be obtained.

2.7.3 It is to be noted that full-scale data can be obtained from the wake measured from model only by means of appropriate conversion of the wake fraction isoline.

2.8 Test of speed loss in waves (resistance increase due to waves)

2.8.1 The purpose of the test is to determine the speed decrease/resistance increase in representative sea states regarding wave height, wave frequency and wind speed etc., thereby determining the non-dimensional coefficient f_w in the calculation formula of Attained EEDI.

2.8.2 Only the speed loss (resistance increase) for navigation in head sea is considered.

2.8.3 The model test is to be carried out in accordance with the relevant ITTC standard (ITTC 7.5-02-07-02.2)/recommendations/methods agreed or accepted by the Administration.

2.9 Explanations of model tests

2.9.1 The following measures are recommended for model tests at the early stage of design:

(1) Models are to be manufactured of materials whose surface shape is susceptible to deformation, but it is to be ensured that the model deformation is controlled within an allowable range during test.

(2) Models of large scale are to be manufactured in so far as practicable.

(3) For optimization of lines, only the resistance test may be carried out but the wave system needs to be observed to judge the resistance performance.

(4) The prediction of the full-scale ship is to be carried out.

2.9.2 Where the lines need to be finalized, the following procedure is recommended:

(1) A model with a required length is to be manufactured.

(2) Resistance test is to be carried out to estimate the resistance performance.

(3) The model is to be modified if necessary.

(4) Where the resistance performance is satisfactory, self-propulsion test is to be carried out with the substitute propeller to measure the wake fraction and thrust deduction and predict power.

(5) The resistance and self-propulsion tests are to be repeated in one or two other conditions, e.g. ballast or sea trial condition.

(6) Where the wake is predicted to be not uniform, a test is to be carried out by using a pitot tube in wake measurement, thereby analyzing propulsion, noise and vibration.

2.9.3 Where the test results are intended to be effectively applied by the shipbuilder/designer in design, copies of original test records must be requested.

2.9.4 Representatives of the shipbuilder/designer are to supervise all the tests and know how they are carried out, paying particular attention to:

(1) confirming the accuracy of model manufacture;

(2) confirming satisfactory condition and correct displacement of model;

(3) keeping proper records of test results;

(4) archiving test records, test information and predictive analysis;

(5) developing diagrams and curves for test results, e.g. residual resistance, wake fraction, thrust deduction and power curves, with the guidance/participation of the test unit.

2.9.5 The shipbuilder/designer often has to carry out design first and then conduct model test, the purpose of which is only to understand the pros and cons of design and the performance criteria the ship might achieve in future trials. It is important for the shipbuilder/designer to carry out flexible design based on early estimation and experience and in conjunction with model test.

2.9.6 Where the shipbuilder/designer has established a database of designed products and input the test and sea trial results of each product into the database, more and more valuable information will be accumulated for future designs.

2.9.7 For single screw ships, the analysis procedures in 1978 ITTC Performance Prediction Method for Single Screw Ships (appendix to the proceedings of 15th International Towing Tank Conference (ITTC, 1978)) are recommend for prediction of power performance of full-scale ships by means of model test. An introduction to the analysis procedures of this method for resistance test, propeller open water test and self-propulsion test is given in Appendix 5-1 of these Guidelines.

2.10 Prediction flow

2.10.1 The full-scale prediction flow for tank test is shown in Figure 2.10.1:

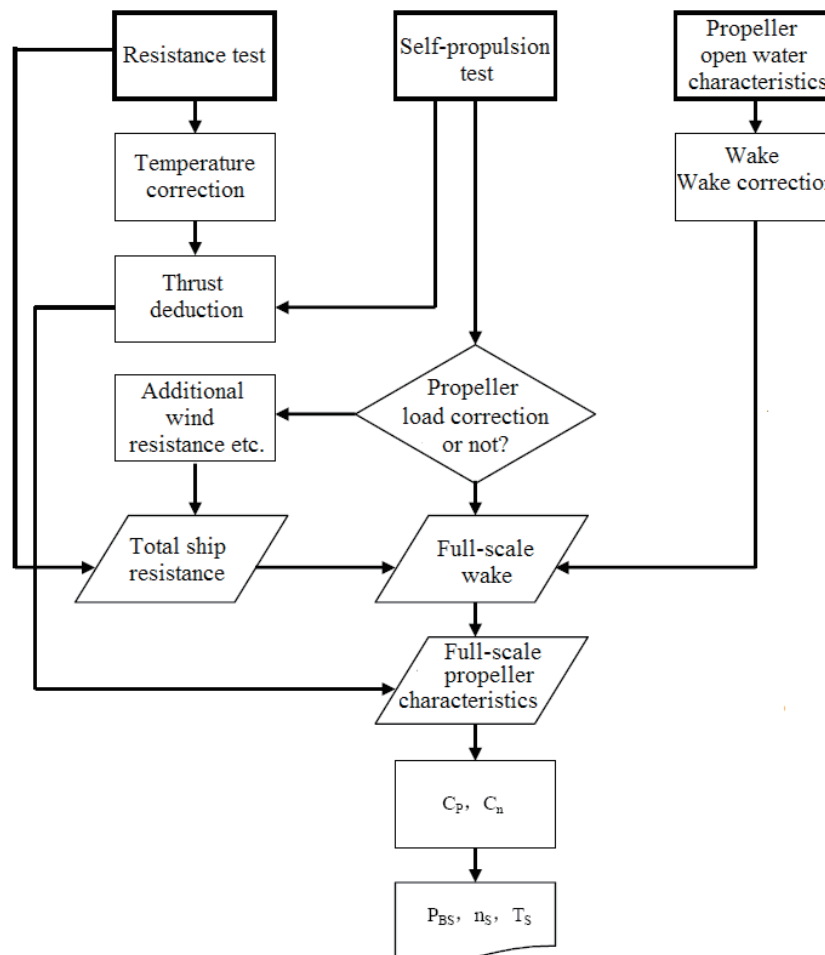


Figure 2.10.1 Sea Trial Prediction Flow of Speed in Tank Test

Chapter 3 Tank Test Information in the Technical File Submitted for EEDI Verification

3.1 General

3.1.1 The purpose of this Chapter is to implement the requirements of paragraph 4.2.7 of the Annex to MEPC.1/Circ.682 Interim Guidelines for Voluntary Verification of the Energy Efficiency Design Index in relation to the information on tank test in the technical file submitted by the shipbuilder/designer to CCS for EEDI verification.

3.2 Description of a tank test facility

3.2.1 Name of tank test unit/laboratory.

3.2.2 The description of the tank test facility is to include, but not limited to, the contents of this section.

(1) Arrangement of model test tank (plain view and transverse section), indicating the following:

- principal length L , breadth B and water depth h of tank;
- length of towing carriage, accelerating section, adjusting section, measuring section, decelerating section and spare brake section;
- maximum test speed and minimum steady speed in tank;
- type of wave generator (for test in waves);
- type of wave damper and arrangement.

(2) Processing/measuring equipment for ship and propeller model.

3.2.3 Equipment, but not limited to:

- resistance dynamometer;
- trim meter;
- speed recorder;
- recorder of rate of propeller revolutions;
- propeller dynamometer;
- major auxiliary equipment and monitoring equipment;

and calibration records during test.

3.3 Description of hull model and propeller model for test

3.3.1 Materials used for model manufacture.

3.3.2 Scale ratio and principal dimensions of model:

- length, breadth and lines of hull model (side view, transverse section and half-breadth plan);
- diameter of propeller model;
- similarity on which model test is based.

3.3.3 Lightweight and displacement—draught table for the verification of deadweight.

3.4 Test methods and reports

3.4.1 With regard to single screw ships, the model test and data analysis method of 1978 ITTC Performance Prediction Method for Single Screw Ships are recommended, e.g. roughness allowance, thrust deduction and wake fraction.

3.4.2 The submitted model test report is to include, but not limited to, the following items as required by paragraph 4.2.7 of the Annex to MEPC.1/Circ.682 Interim Guidelines for Voluntary Verification of the Energy Efficiency Design Index:

- contents of 3.2 and 3.3;
- analysis procedures for resistance test, propeller open water test and self-propulsion test;
- the model resistance curves obtained from the model resistance test of the designed ship and the effective power converted to the full-scale ship;
- the propeller performance curves obtained from the propeller model open water test for the designed ship;
- thrust deduction and wake fraction at different speeds obtained from self-propulsion tests of the designed ship and propeller model;
- the following power prediction data of the designed ship before sea trial:
 - power curves (P_B (kW) — V_S (kn) curve) under the fully-loaded condition and sea trial condition;
 - ship speed on deep water at 75% of the maximum continuous rating (*MCR*) for the main engine under the fully-loaded condition (maximum design loading condition).

Appendix 5-1 Analysis Procedures for Model Test in 1978 ITTC Performance Prediction Method for Single Screw Ships

1 General

1.1 On the basis of the analysis of the sea trial results of nearly 400 full-scale ships, the report “1978 ITTC Performance Prediction Method for Single Screw Ships” was submitted by the ITTC Performance Committee. The member organizations were required by ITTC to use the 1978 ITTC Performance Prediction Method for Single Screw Ships as tentative standards in 1978, with attention paid to revisions and updates by ITTC.

1.2 The analysis procedures for model resistance test, propeller model open water test and model self-propulsion test covered in the 1978 ITTC Performance Prediction Method for Single Screw Ships are introduced in this Appendix.

1.3 According to 1978 ITTC Performance Prediction Method for Single Screw Ships, the results of model resistance test, propeller model open water test and model self-propulsion test are converted for full-scale ships, scale effect corrections are made to the resistance coefficient and wake fraction, as well as to the thrust and torque coefficient for propeller open water test and it is considered that there is no scale effect for the relative rotative efficiency η_R and thrust deduction fraction.

1.4 According to the computer program in 1978 ITTC Performance Prediction Method for Single Screw Ships, generally the standard error is approximately 6%~7% for power P and 2%~2.5% for rate of revolution N .

1.5 For details of 1978 ITTC Performance Prediction Method for Single Screw Ships, see the appendix to the proceedings of 15th International Towing Tank Conference (ITTC, 1978).

1.6 Following analysis procedures are prepared according to ITTC 7.5-02-03-01.4.

2 Analysis procedure for resistance test

2.1 Resistance test (see 2.3 of Chapter 2)

2.2 Determination of form factor k_M : the parameter c is to be determined from resistance test data by the following formula using the least square method:

$$\frac{C_{TM}}{C_{FM}} = (1 + k_M) + c \frac{F_n^4}{C_{FM}}$$

where: C_{TM} —total resistance coefficient of model;

C_{FM} —frictional resistance coefficient of model, to be calculated in accordance with ITTC 1957 model—ship correlation line:

$$C_{FM} = \frac{0.075}{(\log_{10} R_{eM} - 2)^2}$$

R_{eM} —Reynolds number of model;

F_n —Froude number of model.

2.3 The residual resistance coefficient C_{RM} is to be calculated by the following formula:

$$C_{RM} = C_{TM} - (1 + k_M) C_{FM}$$

2.4 Assuming:

$$k_S = k_M$$

$$C_{RS} = C_{RM}$$

where: C_{RS} — residual resistance coefficient of full-scale ship;
 C_{RM} — residual resistance coefficient of model.

2.5 The roughness allowance C_A of the full-scale ship is to be estimated by the following formula:

$$C_A = \left[105 \left(\frac{k_S}{L_{WL}} \right)^{1/3} - 0.64 \right] \times 10^{-3}$$

where: k_S — the average value 150×10^{-6} may be taken;
 L_{WL} — waterline length of full-scale ship, to be taken not greater than 400 m.

2.6 The air resistance C_{AA} is to be estimated by the following formula:

$$C_{AA} = 0.001 \left(\frac{A_T}{S} \right)$$

where: A_T — transverse projected area of full-scale ship above waterplane;
 S — wetted surface area of full-scale ship.

2.7 The frictional resistance coefficient C_{FS} of the full-scale ship is to be calculated by the following formula:

$$C_{FS} = \frac{0.075}{(\log_{10} R_{eS} - 2)^2}$$

where: R_{eS} — Reynolds number of full scale-ship.

2.8 Resistance data of full scale ship:

(1) The total resistance coefficient C_{TS} of a full-scale ship without bilge keels is to be calculated as follows:

$$C_{TS} = C_{FS} (1 + k) + C_{RS} + C_A + C_{AA}$$

(2) The total resistance C_{TS} of a full-scale ship with bilge keels is to be calculated as follows:

$$C_{TS} = \frac{S + S_{BK}}{S} [(1 + k) C_{FS} + C_A] + C_{RS} + C_{AA}$$

where: S_{BK} — wetted surface area of bilge keels.

(3) The total resistance R_{TS} of full scale ship is to be calculated as follows:

$$R_{TS} = C_{TS} \left(\frac{1}{2} \rho V_S^2 \right) S$$

where: ρ — seawater density;
 V_S — full-scale ship speed.

3 Analysis procedure for propeller open-water test

3.1 Propeller open-water test (see 2.4 of Chapter 2)

3.2 The propeller thrust coefficient K_{TM} and torque coefficient K_{QM} of model propeller are to be calculated as follows:

$$K_{TM} = f_1(J)$$

$$K_{QM} = f_2(J)$$

where: J — advance coefficient, to be calculated by the following formula:

$$J = \frac{V_A}{nD}$$

where: V_A — advance rate of propeller;
 n — rate of revolution of propeller;
 D — diameter of propeller.

3.3 The difference in the drag coefficient ΔC_D of blades is assumed as follows:

$$\Delta C_D = C_{DM} - C_{DS}$$

where:

$$C_{DM} = 2\left(1 + 2\frac{t}{c}\right) \left[\frac{0.044}{R_{eco}^{1/6}} - \frac{5}{R_{eco}^{2/3}} \right]$$

$$C_{DS} = 2\left(1 + 2\frac{t}{c}\right) \left[1.89 + 1.62 \log_{10} \frac{C}{k_p} \right]^{2.5}$$

where: C — chord length of blade;
 t — maximum thickness of blade;
 R_{eco} — local Reynolds number at $r/R = 0.75$, not to be lower than 2×10^5 at the open-water test;
 k_p — blade roughness, to be taken as 30×10^{-6} m.

3.4 The correction ΔK_T and ΔK_Q of propeller characteristics are to be calculated as follows:

$$\Delta K_T = -0.30Z\left(\frac{C}{D}\right)^{0.75} P / D \Delta C_D$$

$$\Delta K_Q = 0.25Z\left(\frac{C}{D}\right)^{0.75} \Delta C_D$$

where: Z — number of propeller blades;
 P/D — pitch ratio.

3.5 The full-scale propeller thrust coefficient K_{TS} and torque coefficient K_{QS} are to be calculated as follows:

$$K_{TS} = K_{TM} - \Delta K_T$$

$$K_{QS} = K_{QM} - \Delta K_Q$$

4 Analysis procedure for self-propulsion test

4.1 V_M

Model speed at self-propulsion test.

4.2 R_M

The resistance at the self-propulsion test (corrected for differences in temperature between resistance and self-propulsion tests) are to be calculated as follows:

$$R_M = \frac{(1+k)C_{FMC} + C_R}{(1+k)C_{FM} + C_R} R_{TM}$$

where: C_{FMC} — friction coefficient at the temperature of the self-propulsion test;
 R_{TM} — resistance at resistance test;
 C_{FM} — friction coefficient at the water temperature in the resistance test;
 C_R — residual resistance coefficient, to be obtained from 2.

4.3 V_S

Full-scale ship speed:

$$V_S = \sqrt{\lambda} V_M / 0.5144$$

where: λ — scale ratio of model.

4.4 C_{TM}

Resistance coefficient in the self-propulsion test:

$$C_{TM} = R_M / \frac{1}{2} \rho_M V_M^2 S_M$$

where: ρ_M — mass density at the water temperature in the self-propulsion test.

4.5 k

Form factor, to be obtained from 2.

4.6 C_{TS}

Total resistance coefficient of full-scale ship, to be obtained from 2.8(2).

4.7 F_D

Surface friction correction:

$$F_D = \frac{1}{2} \rho_M S_M V_M [C_{FM} - (C_{FS} - C_A)]$$

4.8 n_M, Q_M, T_M

They are read off from the self-propulsion test diagram using F_D .

4.9 K_{TM}

Thrust coefficient:

$$K_{TM} = \frac{T_M}{\rho_M D_M^4 n_M^2}$$

4.10 K_{QM}

Torque coefficient:

$$K_{QM} = \frac{Q_M}{\rho_M D_M^5 n_M^2}$$

4.11 J_O, K_{QO}

J_O and K_{QO} are read off from the propeller open water diagram, according to thrust identity $K_{TM} = K_0$.

4.12 w_M

Wake fraction of model:

$$w_M = 1 - J_0 n_M D_M / V_M$$

4.13 t_M

Thrust deduction of model:

$$t_M = 1 - (R_M - F_D) / T_M$$

4.14 η_R

Relative rotative efficiency:

$$\eta_R = K_{QO} / K_{QM}$$

4.15 P_{ES}

Effective power of full-scale ship:

$$P_{ES} = \frac{1}{2} \rho_s S_s V_s^2 C_{TS}$$

4.16 $\Delta K_T, \Delta K_Q$

Scale effect corrections for propeller characteristics, to be obtained from 3.4.

4.17 K_{TS}, K_{QS}

Thrust coefficient of full-scale propeller:

$$K_{TS} = K_{TM} - \Delta K_T$$

Torque coefficient of full-scale propeller:

$$K_{QS} = K_{QM} - \Delta K_Q$$

4.18 Full-scale propeller characteristics

$$K_{TS} - J_s \text{ and } K_{QS} - J_s \text{ diagram}$$

4.19 w_s

Full-scale ship wake fraction:

$$w_{TS} = (t_M + 0.04) + (w_{TM} - t_M - 0.04) \frac{(1+k)C_{FS} + C_A}{(1+k)C_{FM}}$$

4.20 K_T / J_S^2

Load coefficient of the full-scale propeller:

$$\frac{K_T}{J_S^2} = \frac{S}{2D_S^2} \frac{C_{TS}}{(1-t_M)(1-w_{TS})^2}$$

4.21 n_S

Rate of full-scale propeller revolutions:

$$n_S = \frac{(1-w_{TS})V_S}{J_{TS}D_S}$$

4.22 $K_{TS} - J_S$ diagram

The $K_T / J_S^2 - J_S$ curve is developed on the $K_{TS} - J_S$ diagram for calculation regarding the right side of 4.20.

4.23 J_{TS}, K_{QTS}

Full-scale advance coefficient and torque coefficient, J_{TS} , K_{QTS} and K_{TTS} are obtained from the intersection point of $K_T / J_S^2 - J_S$ and $K_{TS} - J_S$ curves.

4.24 η_H

Hull efficiency:

$$\eta_H = \frac{1-t_M}{1-w_{TS}}$$

4.25 P_{DS}

Delivered power at full-scale ship:

$$P_{DS} = 2\pi\rho_S D_S^5 n_S^3 K_{QTS} \times 10^{-3} / \eta_R$$

4.26 T_S

Thrust of full-scale ship:

$$T_S = \rho_S D_S^4 n_S^2 K_{TTS}$$

4.27 Q_S

Torque of full-scale ship:

$$Q_S = \rho_S D_S^5 n_S^2 K_{TQS} / \eta_R$$

4.28 η_D

Propulsive efficiency:

$$\eta_D = P_{ES} / P_{DS}$$

4.29 Relevant analysis of full-scale ship-ship model

(1) ΔC_{FS} , Δw_C method

When calculating the total resistance coefficient C_{TS} in 4.6, the following formula is to be used:

$$C_A = \left[105 \left(\frac{k_S}{L_{WL}} \right)^{1/3} - 0.64 \right] \times 10^{-3} + \Delta C_{FC}$$

When calculating w_S in 4.19, the following formula is to be used:

$$w_{TS} = (t_M + 0.04) + (w_{TM} - t_M - 0.04) \frac{(1+k)C_{FS} + C_A}{(1+k)C_{FM}} - \Delta w_C$$

where: ΔC_{FS} , Δw_C — determined from testing tank in accordance with relevant analysis.

(2) C_P , C_N method

When calculating the delivered power P_{DS} at the full-scale ship in 4.25, the following formula is to be used:

$$P_{DS} = [2\pi\rho_S D_S^5 n_S^3 K_{QTS} \times 10^{-3} / \eta_R] \times C_P$$

When calculating the rate n_S of full-scale propeller revolutions in 4.21, the following formula is to be used:

$$n_S = [(1 - w_S) V_S / J_{TS} D_S] \times C_N$$

where: C_P , C_N — determined from testing tank in accordance with relevant analysis.

4.30 Tank test prediction

(1) Tank test prediction contents

- full-scale ship wake fraction w , thrust deduction fraction t and relative rotative efficiency η_R ;
- effective power curves and data of full-scale ship under full load condition and ballast condition (if applicable);
- delivered power curves and data having been subject to relevant analysis and those having not been subject to relevant analysis, for full-scale ship under full load condition and ballast condition (if applicable), as shown in Figure 4.30:

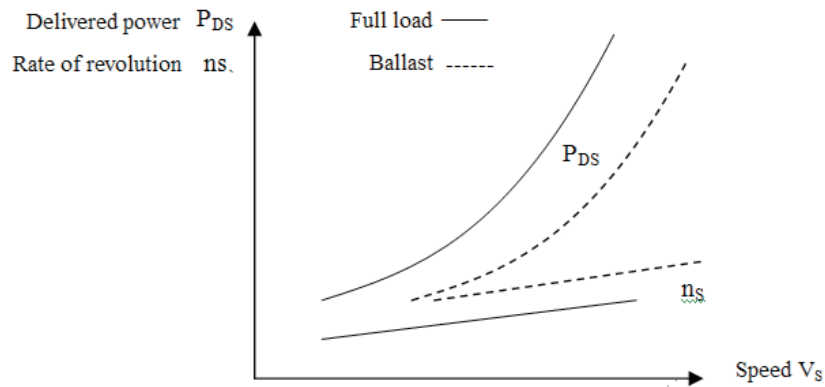


Figure 4.30 Full Scale Ship Performance Prediction Curve (not subject to relevant analysis)

— power curves and data of full-scale ship under full load condition and ballast condition (if applicable).

(2) Redesign of propeller

- If the model self-propulsion test is carried out not using a newly designed propeller (substitute propeller in tank), the propeller parameters of the designed ship are to be revised based on the parameters of the test propeller. Propellers may also be redesigned according to the full-scale resistance R_T , thrust deduction t , wake fraction w and relative rotative efficiency η_R obtained from model tests.
- If the propeller is redesigned by the test unit after the self-propulsion test, EEDI power curves under full load and ballast conditions are to be determined according to Appendix 4/3.3 or Appendix 4-7.