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AIR POLLUTION AND ENERGY EFFICIENCY

Consideration of the Energy Efficiency Design Index for new ships – Minimum propulsion power to maintain the manoeuvrability in adverse conditions

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SUMMARY

Executive summary:	This document presents interim guidelines to determine whether available propulsion power is sufficient to maintain the manoeuvrability in adverse conditions in the context of the EEDI framework
Strategic direction:	7.3
High-level action:	7.3.2
Planned output:	7.3.2.1
Action to be taken:	Paragraph 7
Related documents:	MEPC 62/5/19, MEPC 62/INF.21; MEPC 63/23, MEPC 63/4/11; MEPC 64/INF.7 and resolution MEPC.212(63)

Introduction

1 At MEPC 61, one of the issues relating to the Energy Efficiency Design Index (EEDI) was a ship's manoeuvrability in adverse conditions. Some delegations argued that, in order to reduce installed power, ship designers may choose to lower a ship's design speed to achieve the required EEDI. To avoid negative effects, such as under-powered ships, a provision was added to regulation 21 in chapter 4 of MARPOL Annex VI, stating:

> "For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization."

2 This matter was further considered at subsequent sessions, and MEPC 63 noted that IACS would develop a new iteration of draft guidelines for determining minimum propulsion power to enable safe manoeuvring in adverse weather conditions in time for MEPC 64 as an interim measure and would be the basis for a more permanent solution (MEPC 63/23, paragraph 4.17.5).

Proposal

3 This document provides draft interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions (the "Interim guidelines"), for those ships that are defined in resolution MEPC.212(63), as set out in the annex.

4 The draft interim guidelines are based on a three-level assessment approach. The ship is considered to have sufficient power to maintain the manoeuvrability in adverse conditions if it fulfils any of the following three assessment levels:

.1 *The minimum power lines assessment* is based on the verification that a ship has larger installed power than the power defined as a function of the ship deadweight and type.

.2 *The simplified assessment* is based on the verification that a ship has sufficient installed power to achieve the minimum required advance speed in head waves and wind conditions, defined to facilitate course-keeping in all wave and wind directions.

.3 *The comprehensive assessment* is based on the verification that a ship has sufficient installed power to maintain advance speed and course-keeping in all wave and wind directions.

5 The assessment procedures within these draft "Interim guidelines" to be applied during Phase 0 (1 January 2013–31 December 2014) of the EEDI implementation are presented in an appendix.

6 The background technical information for these draft Interim guidelines and for the assessment procedures to be applied during Phase 0 (1 January 2013–31 December 2014) of the EEDI implementation are included in document MEPC 64/INF.7, together with the work plan for the finalization of the assessment procedures for Phase 1 and later of the EEDI implementation.

Action requested of the Committee

7 The Committee is invited to consider the information provided above, the draft Interim guidelines set out in the annex, as well as the information provided in document MEPC 64/INF.7, and to take action as appropriate.

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ANNEX

INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS

0 Purpose

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

1 Definition

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

Significant wave height h_s, m	Peak wave period T_P, s	Mean wind speed V_w, m/s
6.0	8.0 to 15.0	19.0

2 Applicability

2.1 These guidelines should be applied in the case of all new ships required to comply with regulations on Energy Efficiency for Ships according to regulation 21 of MARPOL Annex VI.

2.2 These guidelines are not intended for ships in restricted navigation; for such cases, the Administration should determine appropriate guidelines, taking the operational area and relevant restrictions into account.

3 Verification procedure

3.1 The verification can be carried out at three different levels as listed below:

.1 Minimum power lines assessment;

.2 Simplified assessment; and

.3 Comprehensive assessment.

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

4 Verification level 1 – minimum power lines assessment

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

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

4.3 If the minimum power lines assessment is not fulfilled, then the simplified assessment may be applied.

5 Verification level 2 – simplified assessment

5.1 The simplified assessment is applicable only to ships whose rudder area is not less than 0.9 per cent of the submerged lateral area corrected for breadth effect.

5.2 The submerged lateral area corrected for breadth effect is calculated as $LppTm(1.0+25.0(Bwl/Lpp)^2)$.

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

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

5.5 If the requirements as defined in the simplified assessment are not fulfilled, then the comprehensive assessment may be applied.

6 Verification level 3 – comprehensive assessment

6.1 The methodology for the comprehensive assessment is provided in the appendix.

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

7 Documentation

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

.1 description of the ship's main particulars;

.2 description of the ship's relevant manoeuvring and propulsion systems;

.3 description of the verification level used and results; and

.4 description of the test method(s) used with references, if applicable.

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Appendix

ASSESSMENT PROCEDURES TO MAINTAIN THE MANOEUVRABILITY UNDER ADVERSE CONDITIONS, APPLICABLE DURING PHASE 0 OF THE EEDI IMPLEMENTATION (1 JANUARY 2013–31 DECEMBER 2014)

1 Scope

1.1 The procedures as described below are applicable during Phase 0 of the EEDI implementation (1 January 2013 to 31 December 2014) as defined in chapter 4 of MARPOL Annex VI.

2 Minimum power lines

2.1 The minimum power line values, in kW, for different types of ships shall be calculated as follows:

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

Where:

DWT is the deadweight of the ship in metric tons; and
a and *b* are the parameters given in Table 1.

Table 1: Parameters a and b for determination of the minimum power line values for the different ship types

No.	Ship Type	a	b
1	Bulk Carrier DWT < 275825 t	0.0606	4195.2
	Bulk Carrier DWT ≥ 275825 t	0.0273	13366.0
2	Gas Ships DWT < 129025 t	0.2300	793.6
	Gas Ships DWT ≥ 129025 t	0.0097	29224.0
3[1]	Container Ships DWT < 92186 t	0.5843	0.0
	Container Ships DWT ≥ 92186 t	0.0540	48886.0
4	Tankers	0.0603	5495.5
5	General Cargo Ships	0.1520	2399.5
6	Refrigerated Cargo Ships	0.9809	−1831.2
7	Combination Carriers	see Tankers above	

3 Simplified assessment

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

1 Minimum power lines for all ship types are derived statistically based on the same fleet data as originally employed in the derivation of EEDI reference lines (i.e. ships built during 1999 and 2009) for consistency. Therefore, specific recent trends in container ship segment may not be reflected in the minimum power lines. Subsequently, minimum power lines for container ships may need further consideration for adjustment.

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

3.3 The assessment procedure consists of two steps:

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

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

Definition of required advance speed

3.4 The required advance speed in head wind and waves is set to the maximum of:

.1 minimum navigational speed; or

.2 minimum course-keeping speed.

3.5 The minimum navigational speed facilitates leaving coastal area within a sufficient time to reduce navigational risk and risk of excessive motions in waves due to unfavourable heading with respect to wind and waves. The minimum navigational speed is set to 4.0 knots.

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

$$V_{ck} = V_{ref} - 10.0 \times (A_R\% - 0.9\%)$$

where V_{ck} is the required advance speed, knots, in head wind and waves to facilitate course-keeping in all wind and wave directions, V_{ref}, knots, is the reference advance speed, and $A_R\%$ is the actual rudder area as percentage of the submerged lateral area corrected for breadth effect.

3.7 The reference advance speed V_{ref} is defined, depending on the block coefficient C_B and the ratio A_F/A_L of the frontal windage area to the lateral windage area, as follows:

.1 for ships with the block coefficient $C_B \leq 0.74$: 16.0 and 9.0 knots for the ratio of the frontal windage area to lateral windage area, A_F/A_L=0.1 and 0.4, respectively;

.2 for ships with the block coefficient $C_B \geq 0.84$: 9.0 and 4.0 knots for the ratio of the frontal windage area to lateral windage area, A_F/A_L=0.1 and 0.40, respectively; and

.3 linearly interpolated for intermediate values of C_B and A_F/A_L.

The above is summarized in table 2.

Table 2: Definition of reference minimum required course-keeping speed at minimum rudder area in knots

C_B	A_F/A_L=0.1	A_F/A_L=0.4
less than or equal to 0.74	16.0	9.0
more than or equal to 0.84	9.0	4.0

Procedure of assessment of installed power

3.8 The assessment is to be performed in maximum draught condition at the required advance speed defined above. The principle of the assessment is that the required propeller thrust, T, 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:

$$T = (R_{cw} + R_{air} + R_{aw} + R_{app})/(1-t) \qquad (1)$$

3.9 The calm-water resistance can be calculated neglecting the wave resistance as $R_{cw} = (1+k)C_F \frac{1}{2}\rho S V_s^2$, where k is the form factor, $C_F = \frac{0.075}{(\log_{10}\mathrm{Re}-2)^2}$ is the frictional resistance coefficient, $\mathrm{Re} = V_s L_{pp}/\nu$ is the Reynolds number, ρ is water density, kg/m^3, S is the wetted area of the bare hull, m^2, V_s is the ship speed, m/s, and ν is the kinematic viscosity of water, m^2/s.

3.10 The form factor k can be obtained either from model tests or empirical formula below:

$$k = -0.095 + 25.6 \frac{C_B}{\left(L_{pp}/B_{wl}\right)^2 \sqrt{B_{wl}/T_m}}$$

3.11 Aerodynamic resistance can be calculated as $R_{air} = C_{air} \frac{1}{2}\rho_a A_F V_w^2$, where C_{air} is the aerodynamic resistance coefficient, ρ_a is the density of air, kg/m^3, A_F is the frontal windage area of the hull, m^2, and V_w is the relative wind speed, m/s, defined by the adverse conditions in paragraph 2 of the Annex plus the ship advance speed. The coefficient C_{air} can be obtained from model tests or empirical data. If none of the above is available, the value 1.0 is to be assumed.

3.12 The added resistance in waves, defined by the adverse conditions in paragraph 2 of the annex, R_{aw}, can be derived from model test. The model test shall be added resistance test in regular waves at the required advance speed as per ITTC procedure 7.5-02 07-02.1.

3.13 The thrust deduction factor t can be obtained either from model tests or empirical formula. Default conservative estimate is t=0.7w, where w is the wake fraction defined below.

3.14 In order to check whether the required thrust can be provided by the engine, the required advance ratio of the propeller J is found from the equation:

$$T = \rho u_a^2 D_P^2 K_T(J)/J^2 \quad (2)$$

where $K_T(J)$ is the thrust coefficient curve, and $u_a = V_s(1-w)$. Wake fraction w can be obtained from model tests or empirical formula; default conservative estimates are given in table 3.

Table 3: Recommended values for wake fraction *w*

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	0.35	0.23

3.15 The required rotation speed of the propeller is found from the relation:

$$n = u_a/(JD_P) \quad (3)$$

3.16 The required power is then defined from the relation

$$P_D = 2\pi\rho n^3 D_P^5 K_Q(J) \quad (4)$$

3.17 For diesel engines, the available power is limited because of the torque-speed limitation of the engine $Q \le Q_{max}(n)$. Therefore, an additional requirement shell be evaluated as:

$$Q = P_D/(2\pi n) \le Q_{max}(n). \quad (5)$$

4 Comprehensive assessment

4.1 The aim of the comprehensive assessment is to demonstrate that, in adverse conditions, the ship is able to maintain the minimum advance speed of 4.0 knots and keep the required course within a maximum deviation of 10°, in waves and wind from any direction with respect to the required course.

Procedure

4.2 The assessment procedure is based on the solution of equilibrium equations for longitudinal and transverse forces, as well as for the yaw moment, neglecting all time-dependent effects. The forces and moments due to wind, wave, drift, propeller and rudder are taken into account.

4.3 The assessment shell be carried out for co-aligned wind and waves from directions 0º (head sea) to 180º (following sea) every 30º.

Coordinate systems and motion equations

4.4 The ship is assumed to sail in the direction north with the speed V_s; her heading deviates from the course by the drift angle β (positive clockwise). The main wave direction β_e

is assumed to be aligned with the wind direction β_W (0º for the waves and wind from the north, 90º from the east and 180º from the south).

4.5 The coordinate system is fixed to the ship with the origin O in the main section at the water plane and the *x*-, *y*- and *z*-axes pointing towards bow, starboard and downwards, respectively (positive rotations and moments around the *z*-axis are clockwise). Rudder angle δ is positive to port.

4.6 Force equilibrium in the *x*- and *y*-directions and moment equilibrium with respect to the *z*-axis are considered in the form of the following equations:

$$X_s + X_w + X_e + X_d + X_R + T(1-t) = 0, \tag{6}$$
$$Y_s + Y_w + Y_e + Y_d + Y_R = 0, \tag{7}$$
$$N_s + N_w + N_e + N_d + N_R = 0; \tag{8}$$

Where *X* denotes longitudinal forces, *Y* transversal forces, *N* yaw moments and *T* the propeller thrust. Indices s, w, d and R denote steady still-water hydrodynamic reactions, wind forces, drift forces due to waves, and forces and moment on the rudder, respectively.

Solution of motion equations

4.7 Equations (6) to (8) are solved with respect to propeller thrust *T*, ship drift angle β and rudder angle δ. Once the propeller thrust is found, the required delivered power to the propeller may be derived following the procedure described in the Simplified Assessment. The procedure should take into account propeller characteristics in the form of the open-water propeller curves, which can be derived from model tests, available data for similar propellers or numerical computations.

4.8 The required installed power on the ship is calculated from the required delivered power to the propeller taking into account engine dynamics. The model of engine dynamics should consider, at least, the following parameters and effects: maximum continuous rating of the engine and the corresponding rotation rate, minimum rotation rate of the engine, and torque-speed limitation curve for diesel engines.

Determination of forces

4.9 The following forces and moments are to be obtained from model tests:

.1 Forces and moment due to steady still-water hydrodynamic reactions, in the form of non-dimensional coefficients $X'_s(\beta) = X_s / (0.5\rho V_s^2 L_{pp} T_m)$, $Y'_s(\beta) = Y_s / (0.5\rho V_s^2 L_{pp} T_m)$ and $N'_s(\beta) = N_s / (0.5\rho V_s^2 L_{pp}^2 T_m)$, depending on the ship drift angle. Standard steady-drift or planar motion model tests can be employed.

.2 Drift forces and moment due to waves, in the form of quadratic transfer functions $X_d(u_s, \mu, \omega)/\zeta_a^2$, $Y_d(u_s, \mu, \omega)/\zeta_a^2$ and $N_d(u_s, \mu, \omega)/\zeta_a^2$, depending on the longitudinal ship speed u_s, mean wave direction with respect to the ship centre plane $\mu = \beta_e - \beta$ and wave frequency ω (ζ_a is the wave amplitude). Tests in regular waves following ITTC procedure 7.5-02 07-02.1 can be employed.

.3 Forces and moment on the rudder in the propeller race in the form of non-dimensional lift and drag coefficients of the rudder, depending on the rudder angle, its angle of attack with respect to the surrounding flow, ship speed and the thrust loading coefficient of the propeller.

The forces and moments due to wind can be obtained from wind channel tests or empirical data in the form of non-dimensional coefficients $X'_w(\varepsilon) = X_w / (0.5\rho_a V_w^2 A_F)$, $Y'_w(\varepsilon) = Y_w / (0.5\rho_a V_w^2 A_L)$ and $N'_w(\varepsilon) = N_w / (0.5\rho_a V_w^2 A_L L_{oa})$, depending on the wind incidence angle ε.