IMO

INTERNATIONAL
MARITIME
ORGANIZATION

E

MEPC.1/Circ.796
12 October 2012

**INTERIM GUIDELINES FOR THE CALCULATION OF THE COEFFICIENT f_w FOR
DECREASE IN SHIP SPEED IN A REPRESENTATIVE SEA CONDITION
FOR TRIAL USE**

1   The Marine Environment Protection Committee, at its sixty-fourth session (1 to 5 October 2012), recognizing the need to develop guidelines for calculating the coefficient f_w contained in paragraph 2.9 of the *2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index for new ships* (resolution MEPC.212(63)), agreed to circulate the interim Guidelines for the calculation of the coefficient f_w for decrease in ship speed in a representative sea condition for trial use, as set out in the annex.

2   Member Governments are invited to bring the annexed interim Guidelines to the attention of their Administration, industry, relevant shipping organizations, shipping companies and other stakeholders concerned for trial use on a voluntary basis.

2   Member Governments and observer organizations are also invited to provide information of the outcome and experiences in applying the interim Guidelines to future sessions of the Committee.

***

ANNEX

INTERIM GUIDELINES FOR THE CALCULATION OF THE COEFFICIENT f_w FOR DECREASE IN SHIP SPEED IN A REPRESENTATIVE SEA CONDITION FOR TRIAL USE

CONTENTS

Introduction

INTRODUCTION

The purpose of these guidelines is to provide guidance on calculating the coefficient f_w, which is contained in the Energy Efficiency Design Index, in paragraph 2.9 in the *2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index for new ships (EEDI)*, adopted by MEPC.212(63).

f_w is a non-dimensional coefficient indicating the decrease in speed in a representative sea conditions of wave height, wave frequency and wind speed.

f_w should be determined by conducting the ship specific simulation on its performance at representative sea condition following the procedure specified in part 1: *Guidelines for the simulation for the coefficient f_w for decrease in ship speed in a representative sea condition*.

In cases where a simulation is not conducted, f_w should be determined based on the standard f_w curves following the procedure specified in part 2: *Guidelines for calculating the coefficient f_w from the standard f_w curves*.

Sample simulation and calculation of the coefficient f_w are shown in respective appendices to part 1 and part 2, and the procedures for deriving standard f_w curves are shown in appendix 2 of part 2.

PART 1: GUIDELINES FOR THE SIMULATION FOR THE COEFFICIENT F_w FOR DECREASE IN SHIP SPEED IN A REPRESENTATIVE SEA CONDITION

1   General

1.1   Application

1.1.1   The purpose of these guidelines is to provide guidance on conducting the simulation to obtain the coefficient f_w for an individual ship, which is contained in the EEDI.

1.1.2   These guidelines apply to ships of which ship resistance as well as brake power in a calm sea condition (no wind and no waves) is evaluated by tank tests, which mean model towing tests, model self-propulsion tests and model propeller open water tests. Numerical calculations may be accepted as equivalent to model propeller open water tests or used to complement the tank tests conducted (e.g. to evaluate the effect of additional hull features such as fins, etc., on ship's performance), with approval of the verifier for the EEDI.

1.1.3   The design parameters and the assumed conditions in the simulation to obtain the coefficient f_w should be consistent with those used in calculating the other components in the EEDI.

1.1.4 f_w may also be determined by the verifier's acceptance of the tank test and/or simulated data from the ship of the same type's performance in representative sea condition.

1.2   Method of calculation

1.2.1   Symbols

P_B : Brake power

R_T : Total resistance in a calm sea condition (no wind and no waves)

V_{ref} : Design ship speed when the ship is in operation in a calm sea condition (no wind and no waves)

V_w : Design ship speed when the ship is in operation under the representative sea condition

ΔR_{wave} : Added resistance due to waves

ΔR_{wind} : Added resistance due to wind

η_D : Propulsion efficiency

η_S : Transmission efficiency

Subscript w refers to wind and wave sea conditions.

1.2.2   The basic procedures in calculating decrease in ship speed is shown in figure 1.1. (See section 4 for more information.)
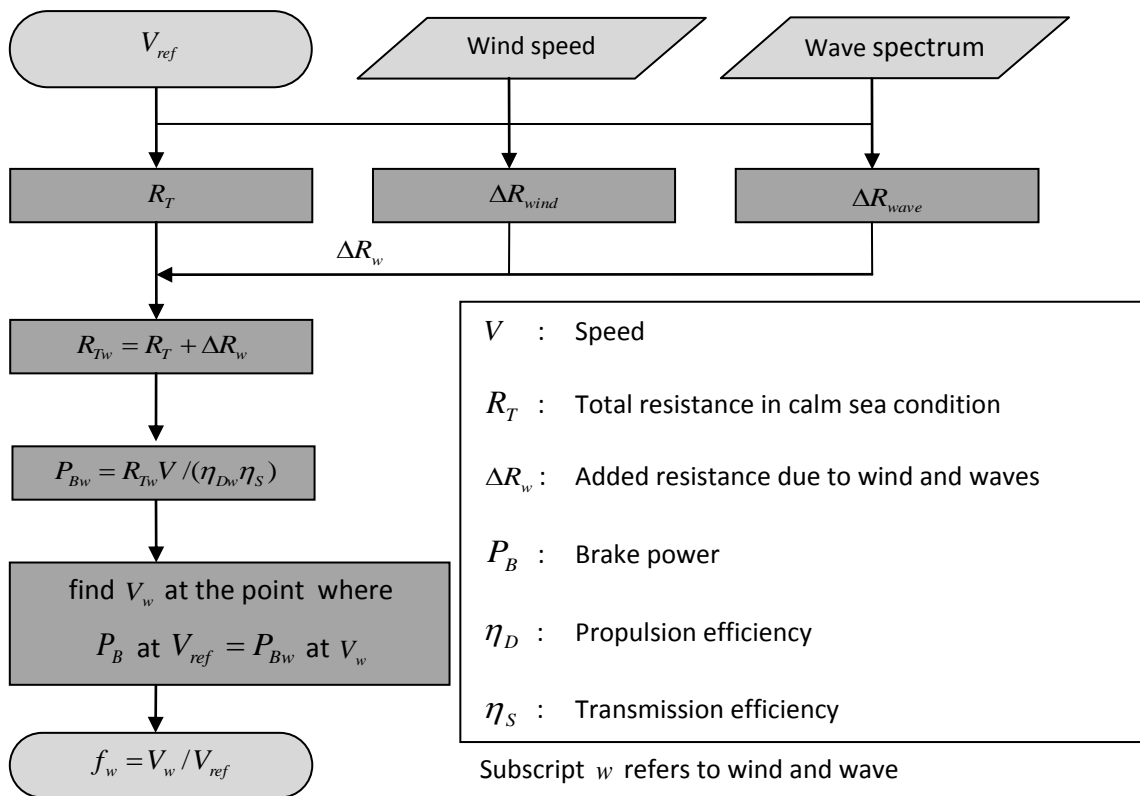
V_{ref}

Wind speed

Wave spectrum

R_T

ΔR_{wind}

ΔR_{wave}

ΔR_w

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

$P_{Bw} = R_{Tw}V/(\eta_{Dw}\eta_S)$

find V_w at the point where

P_B at $V_{ref} = P_{Bw}$ at V_w

$f_w = V_w / V_{ref}$

V	:	Speed
R_T	:	Total resistance in calm sea condition
ΔR_w	:	Added resistance due to wind and waves
P_B	:	Brake power
η_D	:	Propulsion efficiency
η_S	:	Transmission efficiency

Subscript w refers to wind and wave

Figure 1.1: Flow chart of calculation for the decrease in ship speed

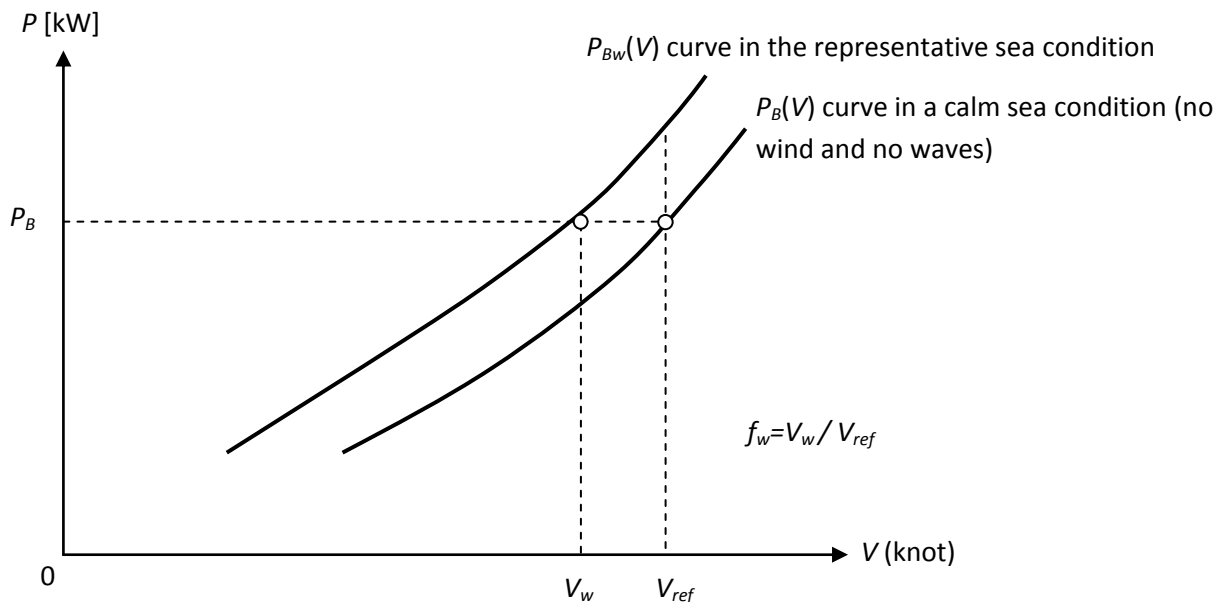1.2.3   Relation between the power and the decrease of ship speed is shown in figure 1.2

P [kW]

$P_{Bw}(V)$ curve in the representative sea condition

$P_B(V)$ curve in a calm sea condition (no wind and no waves)

P_B

$f_w = V_w / V_{ref}$

V (knot)

0

V_w V_{ref}

Figure 1.2: Relation between power and the decrease in ship speed

2   Representative sea condition

2.1   Representative sea condition

2.1.1   The representative sea condition for all ships is Beaufort 6, listed in table 2.1.

Table 2.1: Representative sea condition for all ships

	Mean wind speed U_{wind} (m/s)	Mean wind direction γ (deg)	Significant wave height H (m)	Mean wave period T (s)	Mean wave direction θ (deg)
BF6	12.6	0	3.0	6.7	0

2.1.2   The direction of wind and waves are defined as heading direction, which has the most significant effect on the speed reduction.

2.2   Wind condition

2.2.1   The mean wind speed and wind direction are given in table 2.1.

2.3   Wave condition

2.3.1   Symbols

D : Angular distribution function
E : Directional spectrum
H : Significant wave height
S : Frequency spectrum
T : Mean wave period
α : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
θ : Mean wave direction (θ = 0 (deg.))
ω : Circular frequency of incident regular waves

2.3.2   As ocean waves are characterized as irregular ones, the directional spectrum should be considered.

2.3.3   The significant wave height, mean wave period and mean wave direction are given in table 2.1. To obtain the mean wave period from the Beaufort scale, the following formula derived from a frequency spectrum for fully-developed wind waves is used.

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

where, H is the significant wave height in metres and T is the mean wave period in seconds.

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

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

$$S(\omega;H,T) = \frac{A_S}{\omega^5} e^{-\frac{B_S}{\omega^4}}$$

where,

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

$$D(\alpha,\theta) = \begin{cases} \dfrac{2}{\pi}\cos^2(\theta-\alpha) & \left(|\theta-\alpha| \le \dfrac{\pi}{2}\right) \\ 0 & (\text{others}) \end{cases}$$

3 Ship condition

3.1 The assumed ship conditions yield to the *2012 Guidelines on the method of calculation of the attained energy efficiency design index for new ships (EEDI)*, adopted by MEPC.212(63) (EEDI calculation guidelines, hereafter), constant main engine output (75 per cent of MCR, to be consistent with the one used in the EEDI calculation guidelines), and operation in steady navigating conditions on the fixed course.

3.2 The current effect is not considered.

4 Method of calculation

4.1 General

4.1.1 The total resistance in the representative sea condition, R_{Tw}, is calculated by adding ΔR_w, which is the added resistance due to wind and waves derived at 4.3, to the resistance R_T derived following the procedure specified in paragraph 1.1.2.

4.1.2 The ship speed V_w is the value of V where the brake power in the representative sea condition P_{Bw} equals to P_B, which is the brake power required for achieving the speed of V_{ref} in a calm sea condition.

4.1.3 Where P_{Bw} can be derived from the total resistance in the representative sea condition R_{Tw}, the properties for propellers and propulsion efficiency (η_D) should be derived from the formulas obtained from tank tests or an alternative method equivalent in terms of accuracy, and transmission efficiency (η_S) should be the proven value as verifiable as possible.

The brake power can also be obtained from the reliable self-propulsion tests.

$$P_B = R_T V / (\eta_D \eta_S)$$

4.1.4 The coefficient for decrease of ship speed f_w is calculated by dividing V_w by V_{ref} as follows:

$$f_w = V_w / V_{ref} \quad \text{at the point where } P_B \text{ at } V_{ref} = P_{Bw} \text{ at } V_w$$

4.2   Total resistance in a calm sea condition: R_T

4.2.1   The total resistance in a calm sea condition is derived following the procedure specified in paragraph 1.1.2 as the function of speed.

4.3   Total resistance in the representative sea condition: R_{Tw}

4.3.1   The total resistance in the representative sea condition, R_{Tw}, is calculated by adding $\varDelta R_{wind}$, which is the added resistance due to wind, and $\varDelta R_{wave}$, which is the added resistance due to waves, to the total resistance in a calm sea condition R_T.

$$R_{Tw} = R_T + \Delta R_w$$
$$\phantom{R_{Tw}} = R_T + \Delta R_{wind} + \Delta R_{wave}$$

4.3.2   Added resistance due to wind: $\varDelta R_{wind}$

4.3.2.1   Symbols

A_L	: Projected lateral area above the designated load condition
A_T	: Projected transverse area above the designated load condition
B	: Ship breadth
C	: Distance from the midship section to the centre of the projected lateral area (A_L); a positive value of C means that the centre of the projected lateral area is located ahead of the midship section
C_{Dwind}	: Drag coefficient due to wind
L_{OA}	: Length overall
U_{wind}	: Mean wind speed
ρ_a	: Air density (1.226(kg/m^3))

4.3.2.2   Added resistance due to wind is calculated by the following formula on the basis of the mean wind speed and wind direction given in table 2.1.

$$\Delta R_{wind} = \frac{1}{2} \rho_a A_T C_{Dwind} \left\{ \left(U_{wind} + V_w \right)^2 - V_{ref}^{\ 2} \right\}$$

4.3.2.3 C_{Dwind} should be calculated by a formula with considerable accuracy, which has been confirmed by model tests in a wind tunnel. The following formula is known for the expression of C_{Dwind}, for example:

$$C_{Dwind} = 0.922 - 0.507 \frac{A_L}{L_{OA}B} - 1.162 \frac{C}{L_{OA}}$$

4.3.3   Added resistance due to waves: $\varDelta R_{wave}$

4.3.3.1 Symbols

H : Significant wave height
T : Mean wave period
V : Ship speed
α : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
θ : Mean wave direction
ζ_a : Amplitude of incident regular waves
ω : Circular frequency of incident regular waves

4.3.3.2 Irregular waves can be represented as linear superposition of the components of regular waves. Therefore added resistance due to waves ΔR_{wave} is also calculated by linear superposition of the directional spectrum (E) and added resistance in regular waves (R_{wave}).

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

4.3.3.3 Added resistance in irregular waves ΔR_{wave} should be determined by tank tests or a formula equivalent in terms of accuracy. In cases of applying the theoretical formula, added resistance in regular waves R_{wave} is calculated from the components of added resistance primary induced by ship motion in regular waves, R_{wm} and added resistance due to wave reflection in regular waves R_{wr} as an example.

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

As an example, R_{wm} and R_{wr} are calculated by the method in 4.3.3.4 and 4.3.3.5.

4.3.3.4 Added resistance primary induced by ship motion in regular waves

(1) Symbols

g : Gravitational acceleration
$H(m)$: Function to be determined by the distribution of singularities which represent periodical disturbance by the ship
V : Ship speed
α : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
ρ : Fluid density
ω : Circular frequency of incident regular waves

(2)   Added resistance primary induced by ship motion in regular waves R_{wm} is calculated as follows:

$$R_{wm} = \begin{cases} 4\pi\rho\left(-\int_{-\infty}^{m_3} + \int_{m_4}^{\infty}\right)|H_1(m)|^2 \dfrac{(m+K_0\Omega_e)^2(m+K\cos\alpha)}{\sqrt{(m+K_0\Omega_e)^4 - m^2K_0^{\,2}}}\,dm & \left(\Omega_e \le \dfrac{1}{4}\right) \\[4mm] 4\pi\rho\left(-\int_{-\infty}^{m_3} + \int_{m_4}^{m_2} + \int_{m_1}^{\infty}\right)|H_1(m)|^2 \dfrac{(m+K_0\Omega_e)^2(m+K\cos\alpha)}{\sqrt{(m+K_0\Omega_e)^4 - m^2K_0^{\,2}}}\,dm & \left(\Omega_e > \dfrac{1}{4}\right) \end{cases}$$

$$\Omega_e = \frac{\omega_e V}{g} \quad , \quad K = \frac{\omega^2}{g} \quad , \quad K_0 = \frac{g}{V^2}$$

$$\omega_e = \omega + KV\cos\alpha$$

$$m_1 = \frac{K_0\left(1 - 2\Omega_e + \sqrt{1 - 4\Omega_e}\right)}{2}$$

$$m_2 = \frac{K_0\left(1 - 2\Omega_e - \sqrt{1 - 4\Omega_e}\right)}{2}$$

$$m_3 = -\frac{K_0\left(1 + 2\Omega_e + \sqrt{1 + 4\Omega_e}\right)}{2}$$

$$m_4 = -\frac{K_0\left(1 + 2\Omega_e - \sqrt{1 + 4\Omega_e}\right)}{2}$$

4.3.3.5 Added resistance due to wave reflection in regular waves

(1)   Symbols

B : Ship breadth

B_f : Bluntness coefficient, which is derived from the shape of water plane and wave direction

C_U : Coefficient of advance speed, which is determined on the basis of the guidance for tank tests

d : Ship draft

$F_n = V\big/\sqrt{L_{pp}g}$: Froude number (non-dimensional number in relation to ship speed)

g : Gravitational acceleration

I_1 : Modified Bessel function of the first kind of order 1

K : Wave number of regular waves

K_1 : Modified Bessel function of the second kind of order 1

L_{pp} : Ship length between perpendiculars

V : Ship speed

α : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)

α_d : Effect of draft and frequency

ρ : Fluid density

ζ_a : Amplitude of incident regular waves

ω : Circular frequency of incident regular waves

(2)   Added resistance due to wave reflection in regular waves is calculated as follows:

$$R_{wr} = \frac{1}{2}\rho g \zeta_a{}^2 B B_f (1 + C_U F_n)\alpha_d$$

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

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

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

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

where, dl is a line element along the water plane, β_w is the slope of line element along the waterline, and domains of integration are shown in the following figure.

Figure 4.1: Coordinate system for wave reflection

(3)   Effect of advance speed α_U is determined as follows:

$$\alpha_U = C_U(\alpha)F_n$$

(4)   The coefficient of advance speed in oblique waves $C_U(\alpha)$ is calculated as follows:

$$C_U(\alpha) = \text{Max}[F_S, F_C]$$

(i) $B_f(\alpha = 0) < B_{fc}$ or $B_f(\alpha = 0) < B_{fs}$
$$F_S = C_U(\alpha = 0) - 310\{B_f(\alpha) - B_f(\alpha = 0)\}$$
$$F_C = \text{Min}[C_U(\alpha = 0), 10]$$

(ii) $B_f(\alpha = 0) \geq B_{fc}$ and $B_f(\alpha = 0) \geq B_{fs}$
$$F_S = 68 - 310 B_f(\alpha)$$
$$F_C = C_U(\alpha = 0)$$

where, $B_{fc} = \dfrac{58}{310}$, $B_{fs} = \dfrac{68 - C_U(\alpha = 0)}{310}$.

(5)   The aforementioned coefficient $C_U(\alpha = 0)$ is determined by tank tests. The tank tests should be carried out in short waves since R_{wr} mainly works in short waves. The length of short waves should be $0.5 L_{pp}$ or less.

(6)   Effect of advance speed in regular head waves α_U is calculated by the following equation where R_{wave}^{EXP} is added resistance obtained by the tank tests in regular head waves, and R_{wm} is added resistance due to ship motion in regular waves calculated by 4.3.3.4.

$$\alpha_U(F_n) = C_U F_n = \frac{R_{wave}^{EXP}(F_n) - R_{wm}(F_n)}{\frac{1}{2}\rho g \zeta_a^{\ 2} B B_f \alpha_d} - 1$$

(7)   Effect of advance speed α_U is obtained for each speed of the experiment by the aforementioned equation. Thereafter the coefficient of advance speed $C_U(\alpha = 0)$ is determined by the least square method against F_n; see figure below. The tank tests should be conducted under at least three different points of F_n. The range of F_n should include the F_n corresponding to the speed in a representative sea condition.
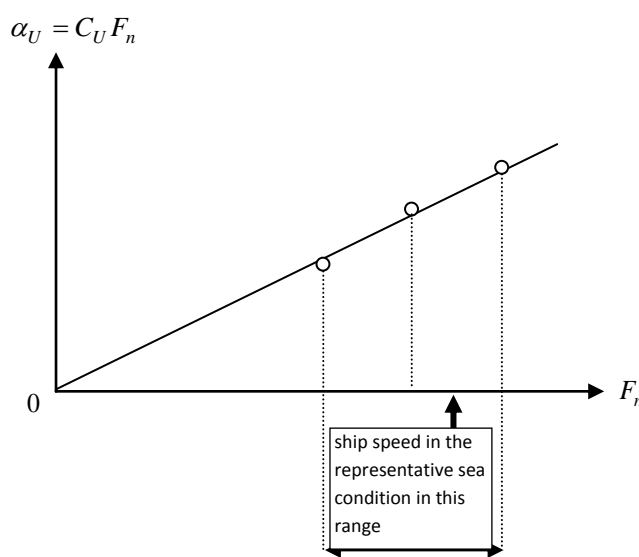

Figure 4.2: Determination of the coefficient of advance speed

* * *

APPENDIX

SAMPLE SIMULATION OF THE COEFFICIENT f_w

Sample: Bulk carrier

The subject ship is a bulk carrier shown in the following figure and the following table.

Table 1: Dimensions of the subject ship

Dimensions	Value	
Length between perpendiculars	217	m
Breadth	32.26	m
Draft	14	m
Ship speed	14.5	knot
Output power at MCR	9,070	kW
Deadweight	73,000	ton

Figure 1: Subject ship

Calculation of f_w from the ship specific simulation

The definition of symbols and paragraph number are followed by the *Guidelines for the simulation for the coefficient f_w for decrease in ship speed in a representative sea condition*.

1   The total resistance in a calm sea condition R_T is derived from tank tests[*] in a calm sea condition as the function of speed following paragraph 4.2 as shown in the following figure.

> *   The tank tests are conducted in the conventional ship design process for the evaluation of ship performance in a calm sea condition.
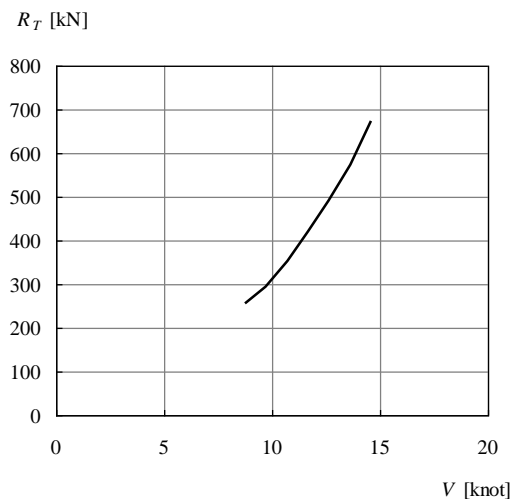

Figure 2: Resistance in a calm sea condition

2   The added resistance due to wind ΔR_{wind} is calculated following paragraph 4.3.2. For the subject ship, the drag coefficient due to wind C_{Dwind} is calculated as 0.853.

3   In the guidelines, the added resistance in regular waves R_{wave} is calculated from the components of added resistance primary induced by ship motion in regular waves R_{wm} and the added resistance due to wave reflection in regular waves R_{wr}.

R_{wm} and R_{wr} are calculated in accordance with paragraphs 4.3.3.4 and 4.3.3.5, respectively.

Here C_U in head waves is determined following the paragraphs from 4.3.3.5 (5) to (7).[*] For the subject ship, effect of advance speed α_U in head waves is obtained as shown in the following figure, and C_U is determined as 10.0.

>   [*] C_U is determined by tank tests in short waves. Since the ship motion is very small in short waves, the tests can be simply conducted with the same setting as the conventional resistance test, and the required time is about four hours.
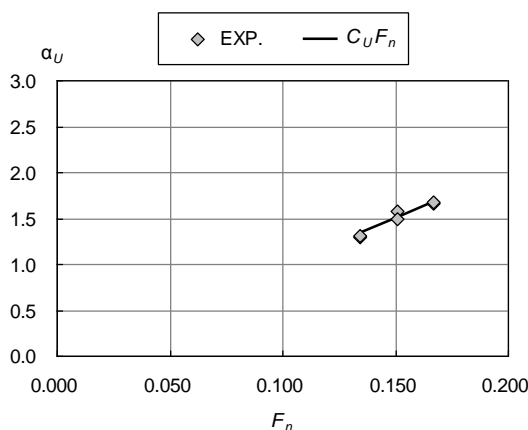
Figure 3: Effect of advance speed

4   With the obtained C_U, the added resistance in regular waves R_{wave} is calculated following the paragraph 4.3.3.3. For example, in the case of F_n =0.167, the non-dimensional value of the added resistance in regular waves is expressed as shown in the following figure.
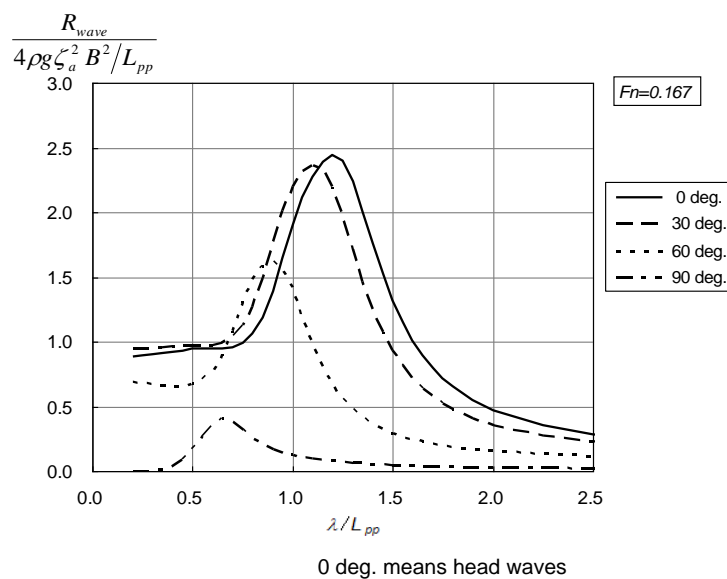
0 deg. means head waves

Figure 4: Added resistance in regular waves

5   The added resistance due to waves in head waves ΔR_{wave} is calculated following paragraph 4.3.3.2. ΔR_{wave} in head waves at T = 6.7 (s) (BF6) is expressed as shown in the following figure. For obtaining the power curve, ΔR_{wave} is expressed as a function of ship speed from the calculated ΔR_{wave} at several ship speeds. In the sample calculation, ΔR_{wave} is expressed as a quartic function of ship speed.
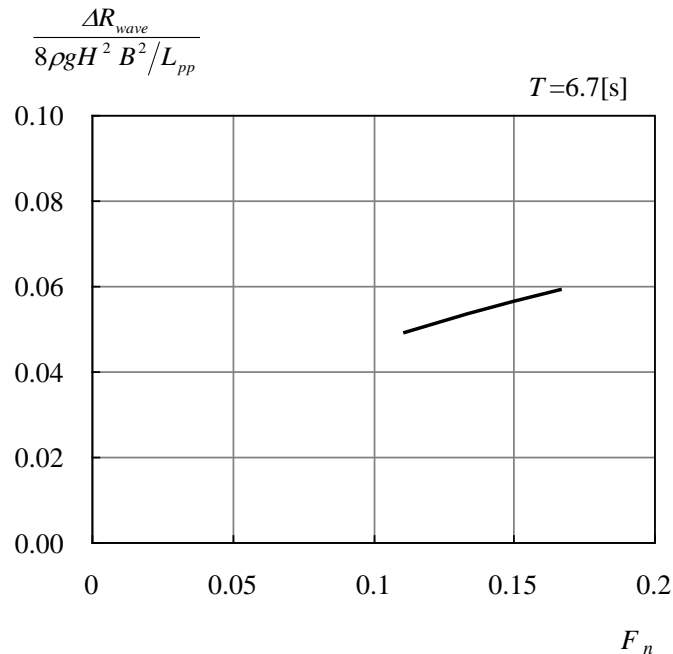
$$\frac{\Delta R_{wave}}{8\rho g H^2 B^2 / L_{pp}}$$

$T = 6.7[s]$

Figure 5: Added resistance due to waves

6   The total resistance in the representative sea condition R_{TW} is calculated following paragraph 4.3, and the brake power in the representative sea condition P_{BW} is calculated following paragraph 4.1.3. That is, R_{TW} is calculated as a sum of R_T, ΔR_{wind}, and ΔR_{wave} as shown in the following figure and P_{BW} is calculated by dividing $R_{TW}V$ by the propulsion efficiency in the representative sea condition η_{Dw} and the transmission efficiency η_S.

R [kN]

Legend:
— R_T
···· $R_T + \Delta R_{wind}$
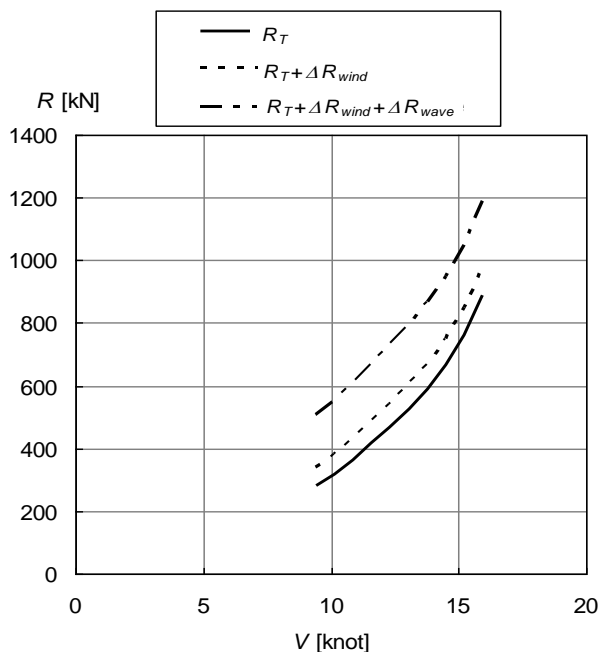—·— $R_T + \Delta R_{wind} + \Delta R_{wave}$

Figure 6: Total resistance in the representative sea condition

7   The self-propulsion factors and the propeller characteristics for the subject ship are shown in the following figures. Here $(1-w)$ is the wake coefficient in full scale, $(1-t)$ is the thrust deduction fraction, η_R is the propeller rotative efficiency, $J = V_a/(nD)$ is the advance coefficient, V_a is the advance speed of the propeller, n is the propeller revolutions, D is the propeller diameter, K_T is the propeller thrust coefficient, and K_Q is the propeller torque coefficient.

8   The propulsion efficiency η_D is expressed as follows:

$$\eta_D = \frac{1-t}{1-w}\eta_R\eta_o$$

where η_O is the propeller efficiency in open water obtained by the propeller characteristics.
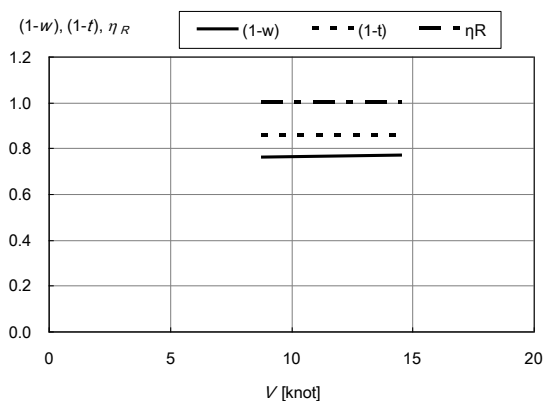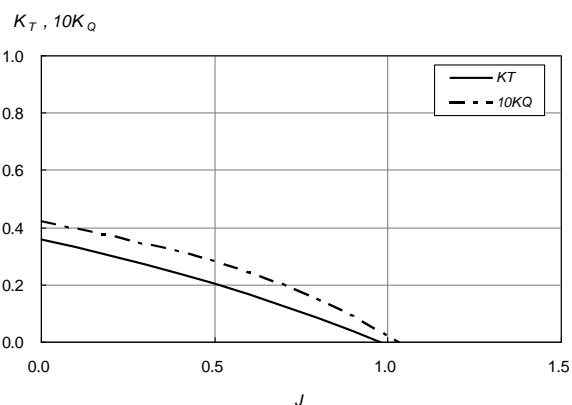
Figure 7: Self-propulsion factors

Figure 8: Propeller characteristics

9   The power curve in the representative sea condition is obtained by solving the equilibrium equation on a force in the longitudinal direction numerically.

The representative sea condition is BF6. The brake power in a calm sea condition (BF0) and that in the representative sea condition (BF6) are calculated as shown in the following figure.
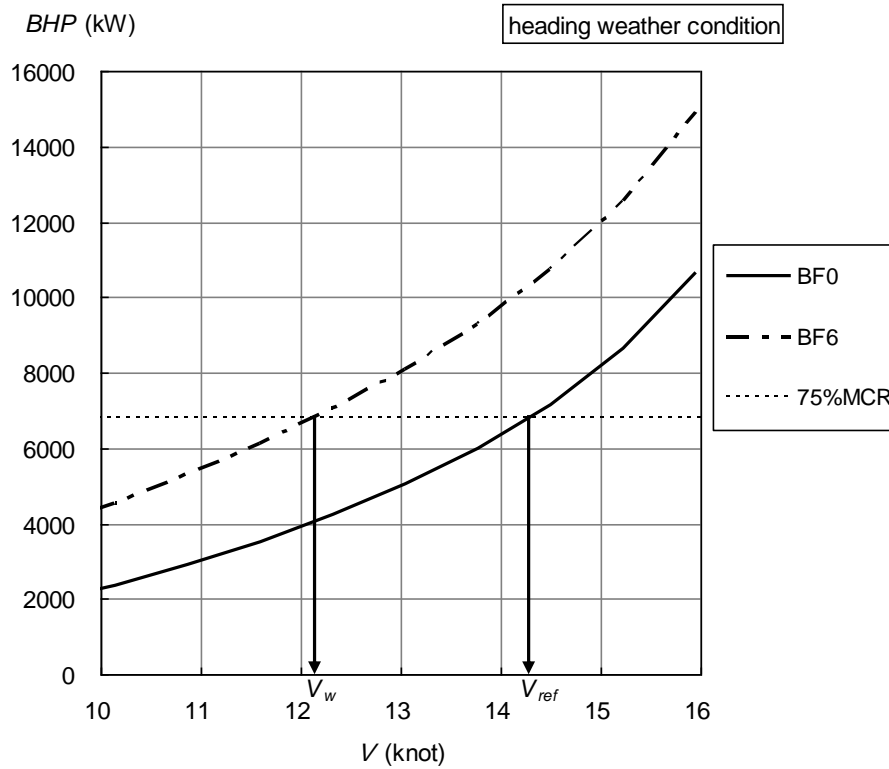

Figure 9: Power curves

10   Following paragraph 4.1.4, the coefficient of the decrease of ship speed f_w is calculated as 0.846 from V_w = 12.10(knot) and V_{ref} = 14.31(knot) at the output power of 75 per cent MCR: 6802.5(kW).

In the EEDI Technical File, f_w is listed as follows:

7.2 Calculated weather factor, f_w	
f_w	0.846

PART 2: GUIDELINES FOR CALCULATING THE COEFFICIENT F_w FROM THE STANDARD F_w CURVES

1 Application

1.1 The purpose of these guidelines is to provide guidance on calculating the coefficient f_w from the standard f_w curves, which is contained in the EEDI.

1.2 These guidelines apply to ships for which a simulation is not conducted to obtain the coefficient f_w following *Guidelines for the simulation for the coefficient f_w for decrease in ship speed in a representative sea condition*.

1.3 The representative sea condition for each ship is defined in paragraph 2.1 in the *Guidelines for the simulation for the coefficient f_w for decrease in ship speed in a representative sea condition*.

1.4 The design parameters in the calculation of f_w from the standard f_w curves should be consistent with those used in the calculation of the other components in the EEDI.

2 Method of calculation

2.1 Three kinds of standard f_w curves are provided for bulk carriers, tankers and containerships, and expressed as a function of *Capacity* defined in the *2012 Guidelines on the method of calculation of the attained Energy Efficiency Design Index for new ships (EEDI)*, adopted by MEPC.212(63). Ship types are defined in regulation 2 in Annex VI to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended by resolution MEPC.203(62).

2.2 Each standard f_w curve has been obtained on the basis of data of actual speed reduction of existing ships under the representative sea condition in accordance with procedure for deriving standard f_w curves. (see appendix 2.)
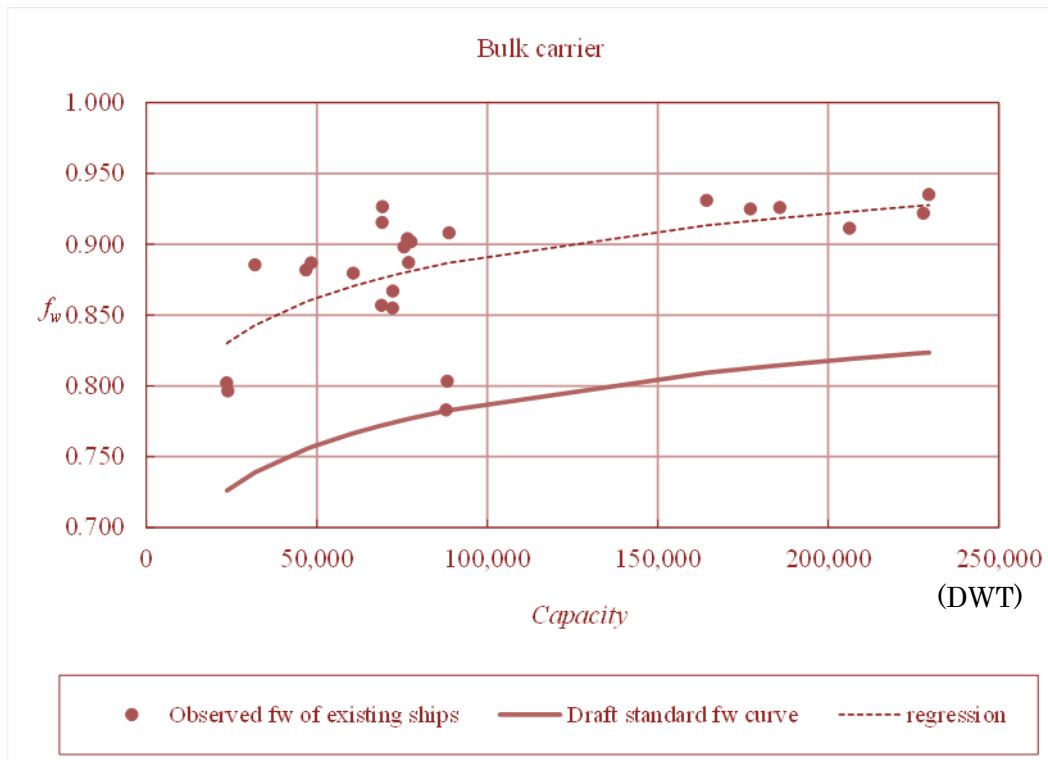
2.3 Each standard f_w curve is shown from figure 1 to figure 3, and the standard f_w value is expressed as follows:

standard f_w value = $a \times \ln(Capacity) + b$

where *a* and *b* are the parameters given in table 1.

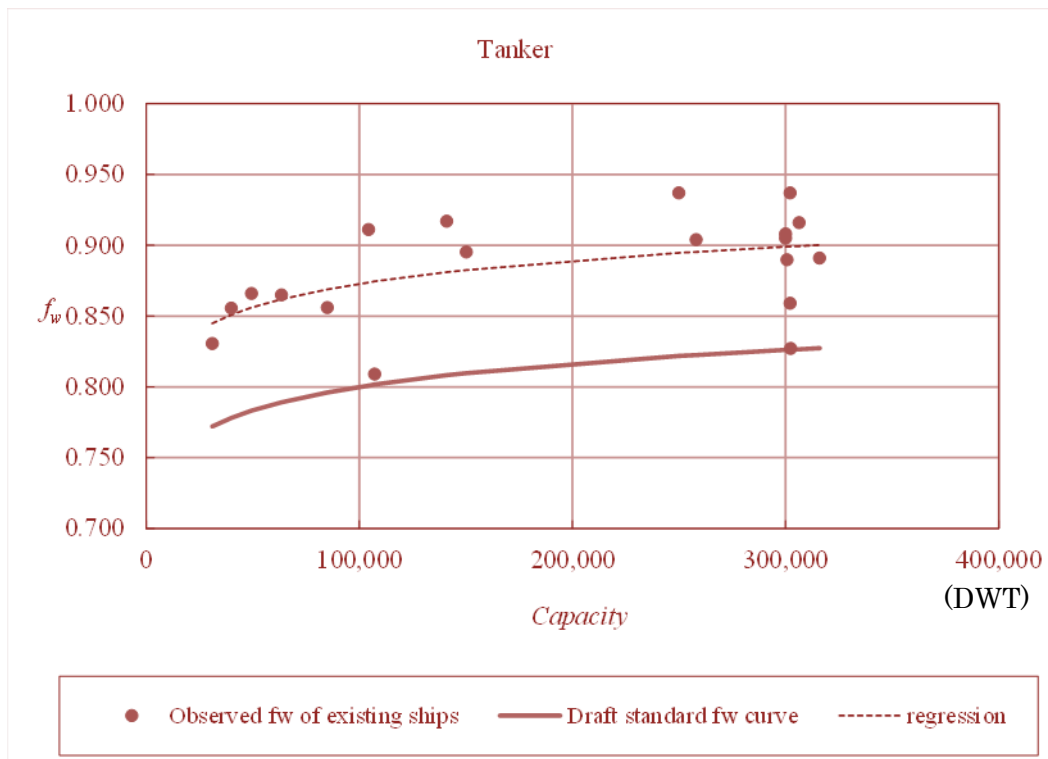**Table 1: Parameters for determination of standard f_w value**

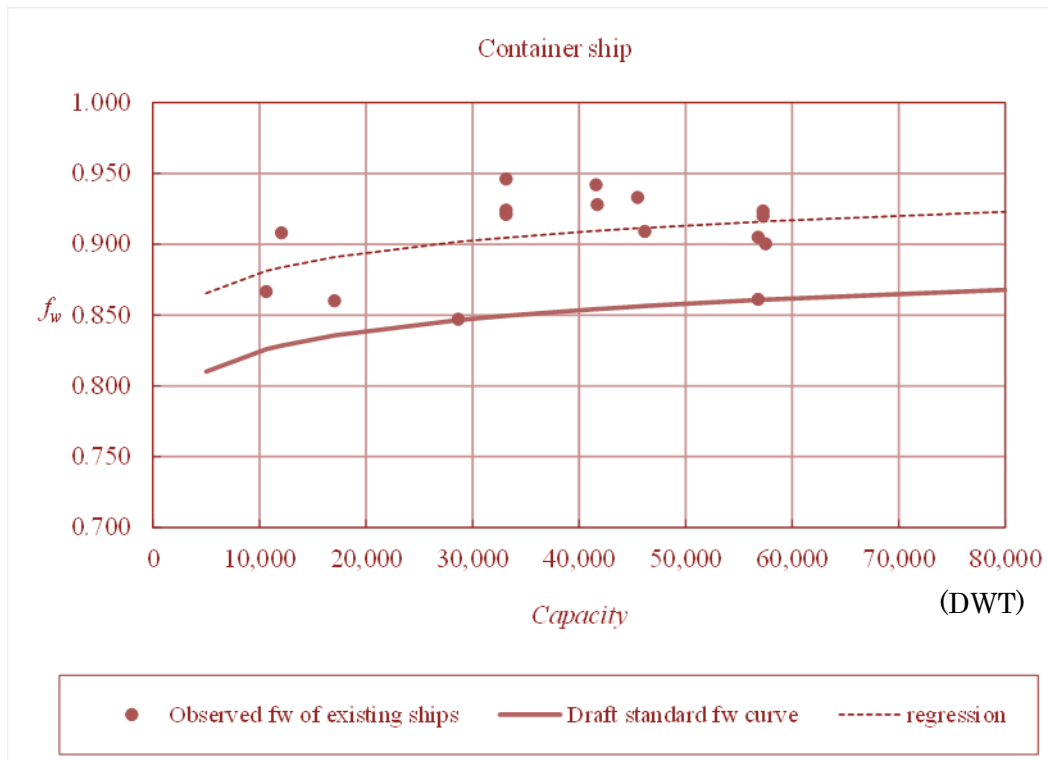| Ship type	*a*	*b*
Bulk carrier	0.0429	0.294
Tanker	0.0238	0.526
Containership	0.0208	0.633

$$f_w = 0.0429\ln(Capacity)+0.294$$

Figure 1: Standard f_w curve for bulk carrier

$$f_w = 0.0238\ln(Capacity)+0.526$$

Figure 2: Standard f_w curve for tanker

$$f_w = 0.0208\ln(Capacity)+0.633$$

Figure 3: Standard f_w curve for containership

* * *

APPENDIX 1

SAMPLE CALCULATION OF THE COEFFICIENT f_w FROM THE STANDARD f_w CURVES

<u>**Sample: Bulk carrier**</u>

<u>The subject ship is a bulk carrier shown in the following figure and the following table.</u>

Figure 1: Subject ship

Table 1: Dimensions of the subject ship

Dimensions	Value	
Length between perpendiculars	217	m
Breadth	32.26	m
Draft	14	m
Ship speed	14.5	knot
Output power at MCR	9,070	kW
Deadweight	73,000	ton

<u>Calculation of f_w from the standard f_w curves</u>

The paragraph numbers are followed by guidelines for calculating the coefficient f_w from the standard f_w curves.

1   The standard f_w value is calculated following paragraph 2.3. Since the subject ship is a bulk carrier, the standard f_w value is obtained from the following equation.

Standard f_w value = $0.0429 \times \ln(Capacity) + 0.294$

2   Since the *Capacity* for the bulk carriers is deadweight, the *Capacity* for the subject ship is determined as 73,000 (ton). By substitution of 73,000 to the above equation, the standard f_w value is obtained as 0.774.

In the EEDI Technical File, f_w is listed as follows:

7.2	Calculated weather factor, f_w	
	f_w	0.774

APPENDIX 2

PROCEDURES FOR DERIVING STANDARD f_w CURVES

1.   This document provides the procedures for deriving the standard f_w curves on the basis of main ship particulars and operation data of approximately 180 existing ships in operation.
2.   The coefficient f_w has been obtained for individual existing ships, by selecting the data that meet certain conditions as explained below.
3.   The derivation resulted in three standard f_w curves for bulk carriers, tankers and containerships.

The procedures for calculating the standard f_w curves comprise the following five steps:

Step 1: To extract data from the ship's particulars

The data needed for calculation are Displacement, Speed, Main Engine Output as well as RPM at *NOR*(normal rating). In case the necessary data for f_w are not obtained, the data of the ship is not used for deriving the standard f_w curves.

Step 2: To extract data from the abstract log

The data required are Displacement, Wind Direction (WDIR), Observed Beaufort Scale (WFOR), Measuring duration of Distlog and DistOG (HP (hours)), Distance Log (Distlog), Distance over the Ground (DistOG), Rotational Speed per minute (RPM) and Shaft Horse Power (SHP) for every 24 hours.

The data for calculation of f_w of individual ships are subject to screening, by following the procedures provided from (i) to (vi). The data meeting all the criteria provided from (i) to (vi) are to be used. In case the data are not extracted in the following process, the data of the ship is not used for deriving the standard f_w curves.

(i)   Displacement should be within ±15 per cent of average displacement of the voyages which have been reported to be close to the fully loaded condition or to the 70 per cent DWT condition in the case of a containership.[1] In cases where displacement is not available, the average of draft may be used instead of the displacement.

(ii)   Wind direction (WDIR): Heading (relative wind direction not exceeding ±67.5 degree).

(iii)   Beaufort Scale (WFOR) for the selected data should be 2, 3 or 6.
The data under WFOR 2 and 3 are used to represent the calm sea condition (no wind and no waves), and the data under WFOR 6 are used to represent the representative sea condition.

(iv)   The RPM (Rotational speed per minute) should be within ±5 per cent of the average RPM on the voyage.[2]

---

[1]   In reality, it is impossible to collect only the data which are under completely full load conditions. Data deviated too much from the object displacement cannot be calibrated by the method described in step 3-1.

[2]   Data with RPM deviated from the average RPM may not be on the normal operational condition.

(v)   SHP should be within ±20 per cent of the 75 per cent of the rated installed power (*MCR*). In case where SHP is not available, the fuel oil consumption may be used instead of the SHP.[3]

(vi)   Distlog should be used under the conditions that the difference between DistOG and Distlog is within ±10 per cent of whichever is smaller.[4]

Step 3: Data correction

3.1   Calibration of the data to reflect the difference between the object condition specified in EEDI calculation guidelines and the actual operation.

Distlog data selected in step 2 are calibrated by the following equation, in order to take into account the difference between the object condition and the actual operation in terms of displacement and *SHP* [5]:

$$V_1 = V_0 \left[\left(\frac{\nabla_0}{\nabla_{average}} \right)^{\frac{2}{3}} \right]^{\frac{1}{3}}, \quad V_2 = V_1 \left(\frac{75\% MCR}{SHP_0} \right)^{\frac{1}{3}}$$

where:

$75\% MCR$: 75 per cent of the rated installed power (*MCR*)

$\nabla_{average}$: Average displacement on the reported voyages,

∇_0 : Displacement in measurement

HP : Running time (Hours propelling)

SHP_0 : Output in measurement

V_0 : Measured ship speed relative to water (Distlog/HP)

V_1 : Calibrated velocity based on displacement

V_2 : Calibrated velocity based on output

3.2   Calculation of V_2 corresponding to calm sea:

30 per cent largest values of V_2 under Beaufort 2 and 3 are extracted to represent the calm sea condition.

---

[3]   Data deviated too much from 75 per cent MCR cannot be calibrated by the method described in step 3.1.

[4]   Data with a large difference between Distlog and DistOG may be affected by the tidal current and the ocean current.

[5]   Since *SHP* is approximately proportional to the wetted surface and the cube of ship speed, ship speed is calibrated with two thirds of the displacement, which has the same dimension as the wetted surface, and one third of the *SHP*.

Step 4: Calculation of *f_w* for individual existing ships

f_w = average of V_2 corresponding to BF6 / average of V_2 corresponding to calm sea for all ships.

In cases calculated f_w is larger than 1.0, the data shall be removed for the averaging.

Step 5: Development of "standard *f_w*" curves

Run the regression, based on the natural logarithmic function, on those f_w values obtained by Step 4.

Regression line, in the form of natural logarithmic line, is obtained from the observed f_w values calculated in the above steps and the *Capacity* of each ship. The standard f_w curves should be determined so that we can avoid f_w by the standard curves would be much higher than the actual f_w value. Then the standard f_w curves are set to pass the lower limit of the observed f_w values by changing the intercept of the regression line in the form of natural logarithmic line.

_____