E

INTERNATIONAL
MARITIME
ORGANIZATION

4 ALBERT EMBANKMENT
LONDON SE1 7SR
Telephone: +44 (0)20 7735 7611 Fax: +44 (0)20 7587 3210

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# 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.

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# 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

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
$\Delta R_{wave}$ : Added resistance due to waves
$\Delta R_{wind}$ : Added resistance due to wind
$\eta_D$ : Propulsion efficiency
$\eta_S$ : 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.)

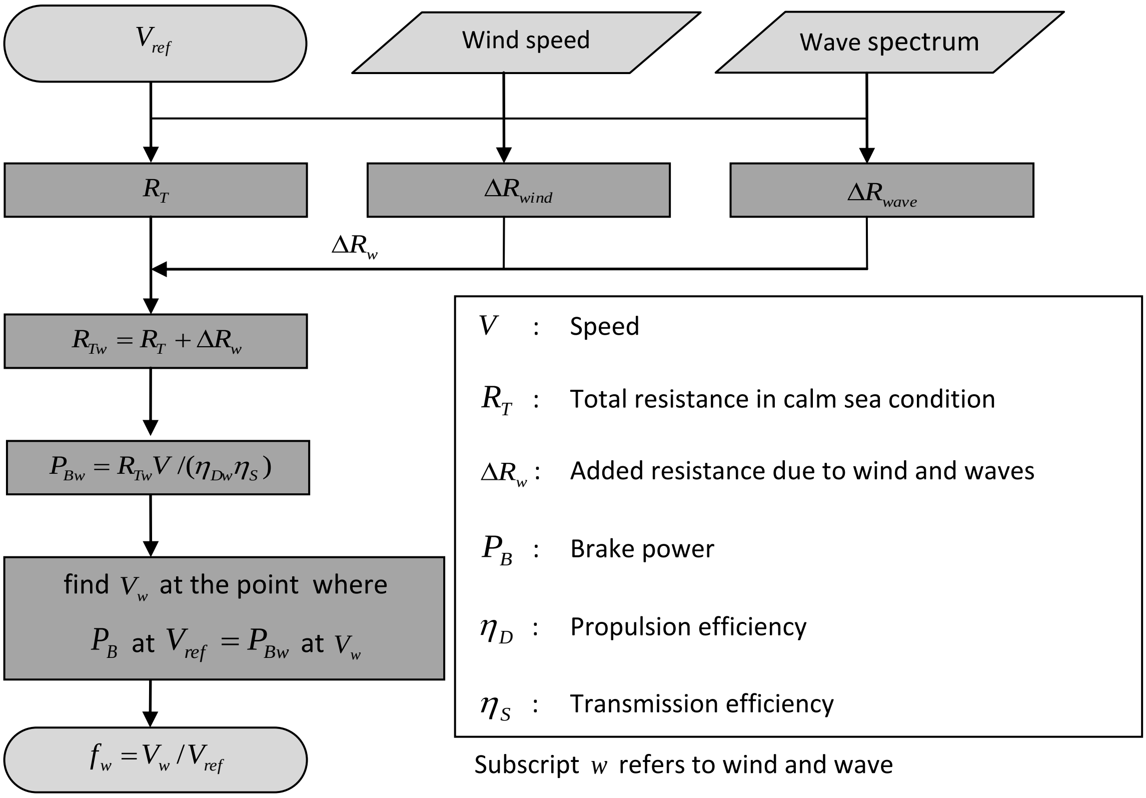


**Figure 1.1: Flow chart of calculation for the decrease in ship speed**

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

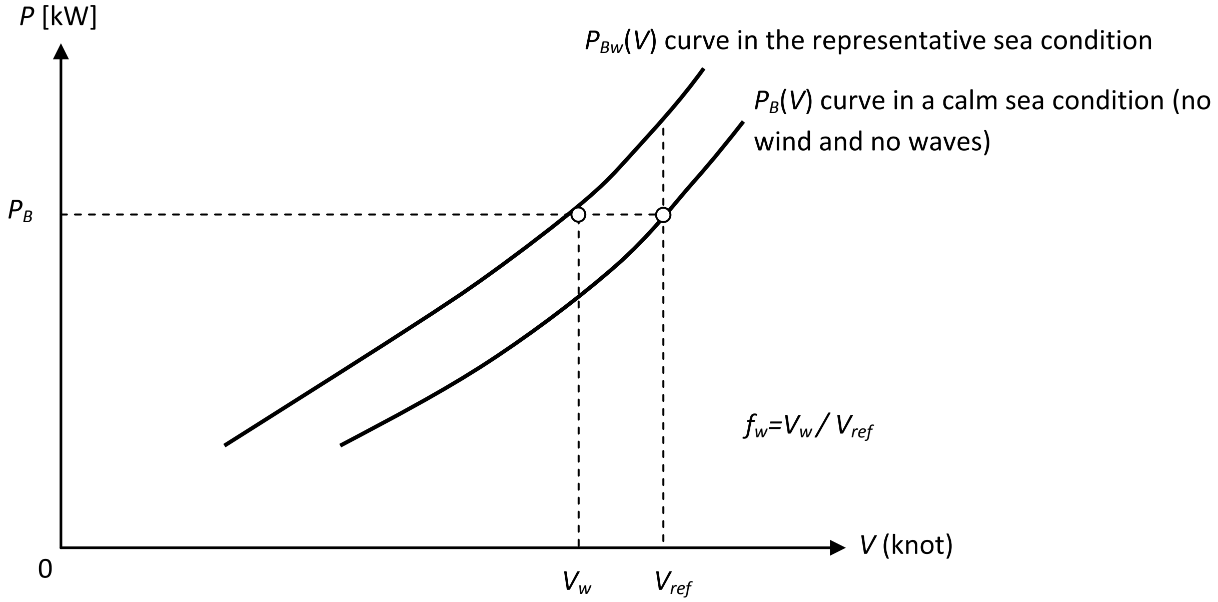


**Figure 1.2: Relation between power and the decrease in ship speed**

## 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 $\gamma$ (deg) | Significant wave height $H$ (m) | Mean wave period $T$ (s) | Mean wave direction $\theta$ (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
$\alpha$ : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
$\theta$ : Mean wave direction ($\theta$ = 0 (deg.))
$\omega$ : 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 ($D$).

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

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

where,

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

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

## 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 $\Delta R_w$, 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 ($\eta_D$) should be derived from the formulas obtained from tank tests or an alternative method equivalent in terms of accuracy, and transmission efficiency ($\eta_S$) 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:

$f_w = V_w / V_{ref}$ at the point where $P_B$ at $V_{ref} = P_{Bw}$ 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 $\Delta R_{wind}$, which is the added resistance due to wind, and $\Delta R_{wave}$, which is the added resistance due to waves, to the total resistance in a calm sea condition $R_T$.

$$\begin{aligned} R_{Tw} &= R_T + \Delta R_w \\ &= R_T + \Delta R_{wind} + \Delta R_{wave} \end{aligned}$$

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

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
$\rho_a$ : 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: $\Delta R_{wave}$

4.3.3.1 Symbols

$H$ : Significant wave height
$T$ : Mean wave period
$V$ : Ship speed
$\alpha$ : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
$\theta$ : Mean wave direction
$\zeta_a$ : Amplitude of incident regular waves
$\omega$ : 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 $\Delta R_{wave}$ 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 $\Delta R_{wave}$ 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
$\alpha$ : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
$\rho$ : Fluid density
$\omega$ : Circular frequency of incident regular waves

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

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

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

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

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

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

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

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

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
$\alpha$ : Angle between ship course and regular waves (angle 0(deg.) is defined as the head waves direction)
$\alpha_d$ : Effect of draft and frequency
$\rho$ : Fluid density
$\zeta_a$ : Amplitude of incident regular waves
$\omega$ : Circular frequency of incident regular waves

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

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

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

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

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

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

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

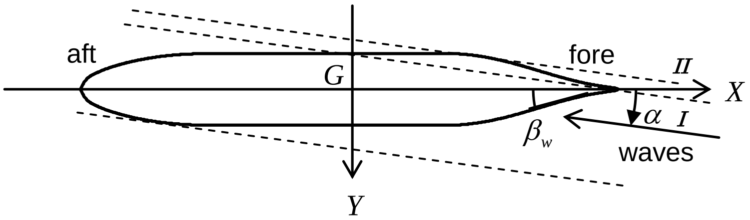


**Figure 4.1: Coordinate system for wave reflection**

(3) Effect of advance speed $\alpha_U$ 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:

$$C_U(\alpha) = \mathrm{Max}\left[F_S, F_C\right]$$

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

$$F_S = C_U(\alpha = 0) - 310\left\{B_f(\alpha) - B_f(\alpha = 0)\right\}$$
$$F_C = \mathrm{Min}\left[C_U(\alpha = 0), 10\right]$$

(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 $\alpha_U$ 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 $\alpha_U$ 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.

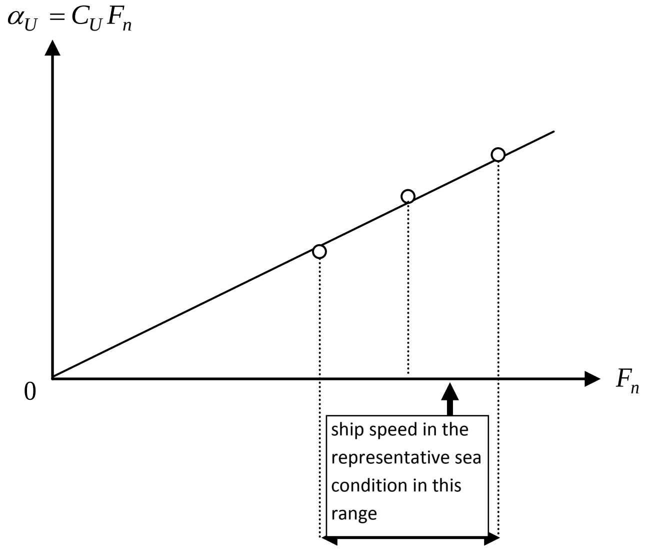


Figure 4.2: Determination of the coefficient of advance speed

* * *

## 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.

**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 |

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.

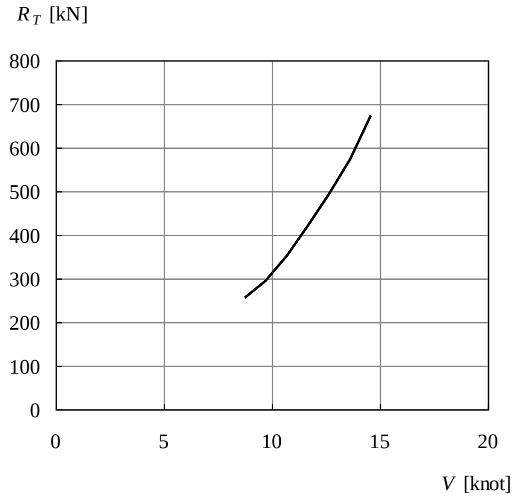


**Figure 2: Resistance in a calm sea condition**

2 The added resistance due to wind $\Delta R_{wind}$ 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 $\alpha_U$ 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.

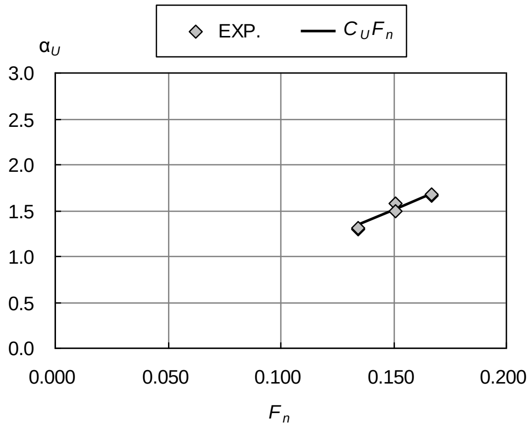
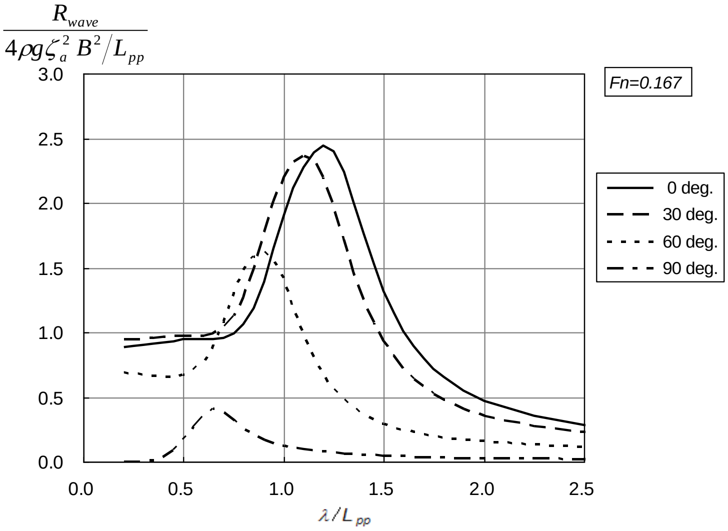


**Figure 3: Effect of advance speed**

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 $\Delta R_{wave}$ is calculated following paragraph 4.3.3.2. $\Delta R_{wave}$ in head waves at $T$ = 6.7 (s) (BF6) is expressed as shown in the following figure. For obtaining the power curve, $\Delta R_{wave}$ is expressed as a function of ship speed from the calculated $\Delta R_{wave}$ at several ship speeds. In the sample calculation, $\Delta R_{wave}$ is expressed as a quartic function of ship speed.

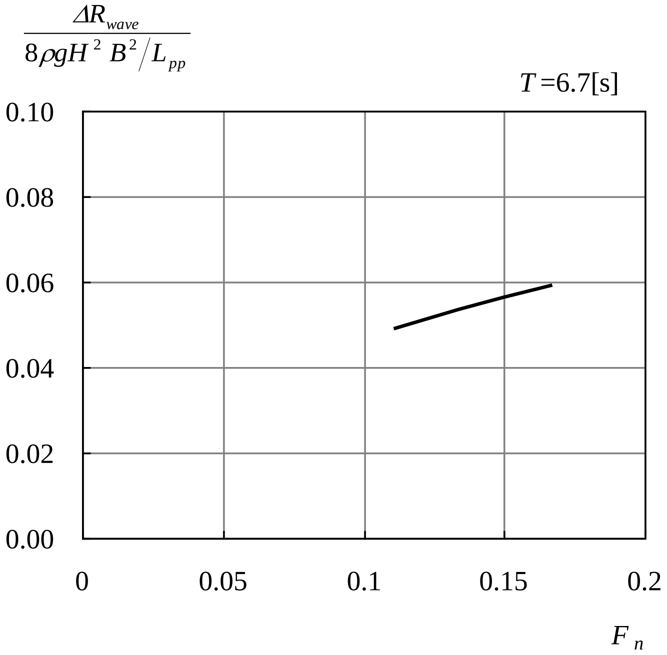


**Figure 5: Added resistance due to waves**

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 $R_T$, $\Delta R_{wind}$, and $\Delta R_{wave}$ 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 $\eta_{Dw}$ and the transmission efficiency $\eta_S$.

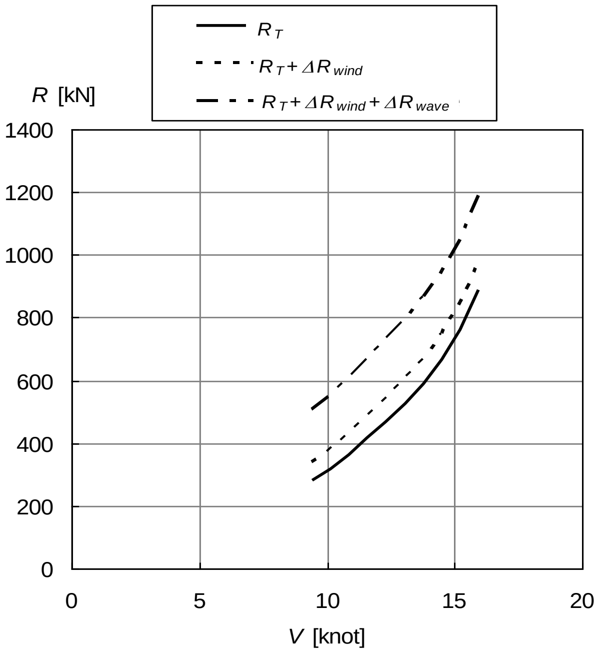


**Figure 6: Total resistance in the representative sea condition**

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, $\eta_R$ 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 $\eta_D$ is expressed as follows:

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

where $\eta_O$ is the propeller efficiency in open water obtained by the propeller characteristics.

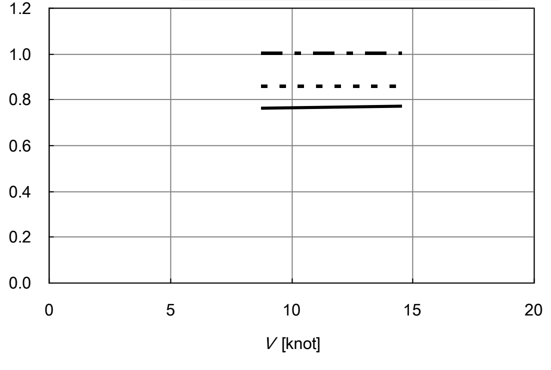


**Figure 7: Self-propulsion factors**

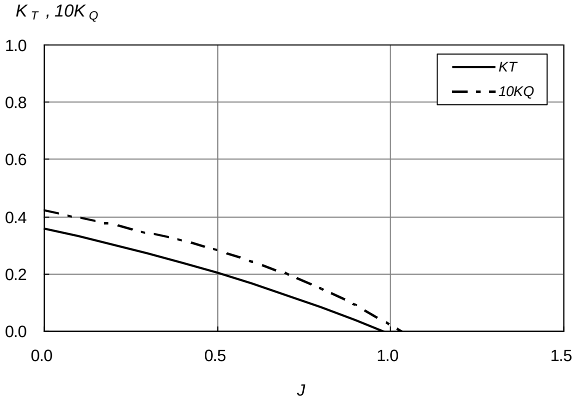


**Figure 8: Propeller characteristics**

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.

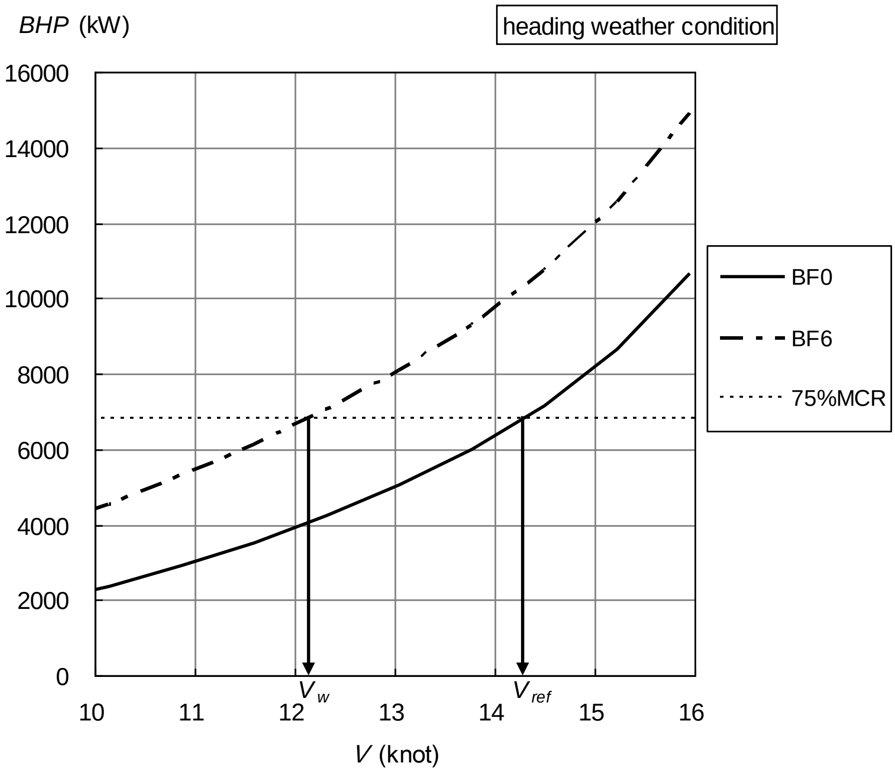


**Figure 9: Power curves**

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.)

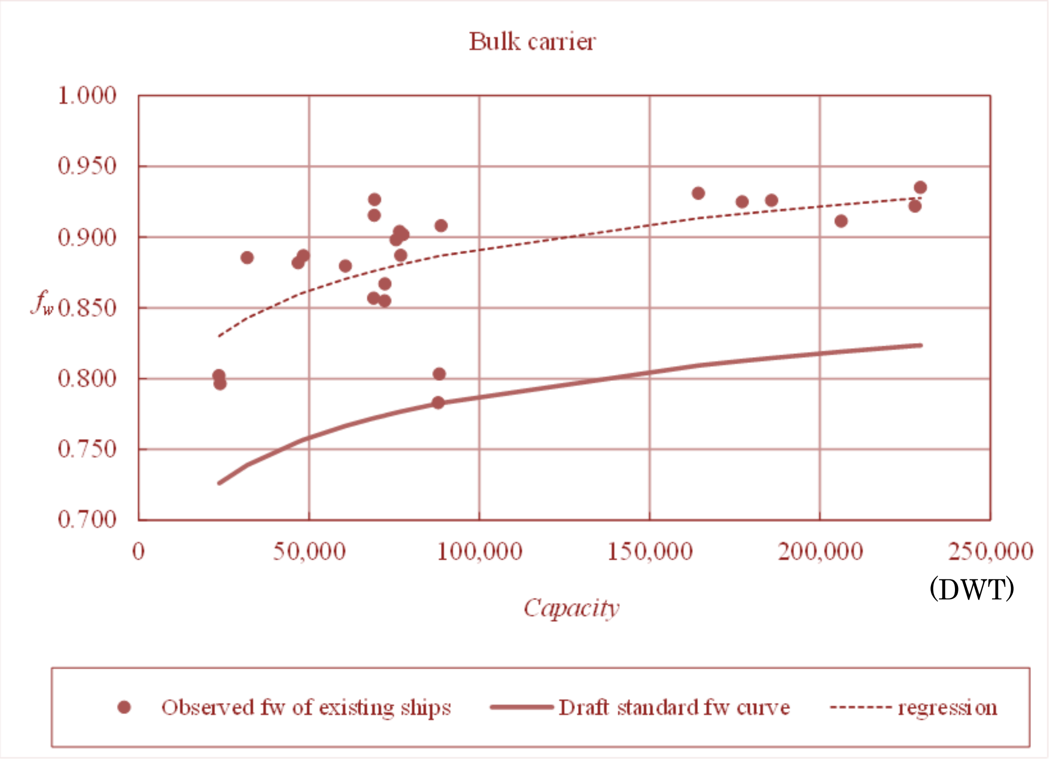
2.3 Each standard $f_w$ curve is shown from figure 1 to figure 3, and the standard $f_w$ value is expressed as follows:

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

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

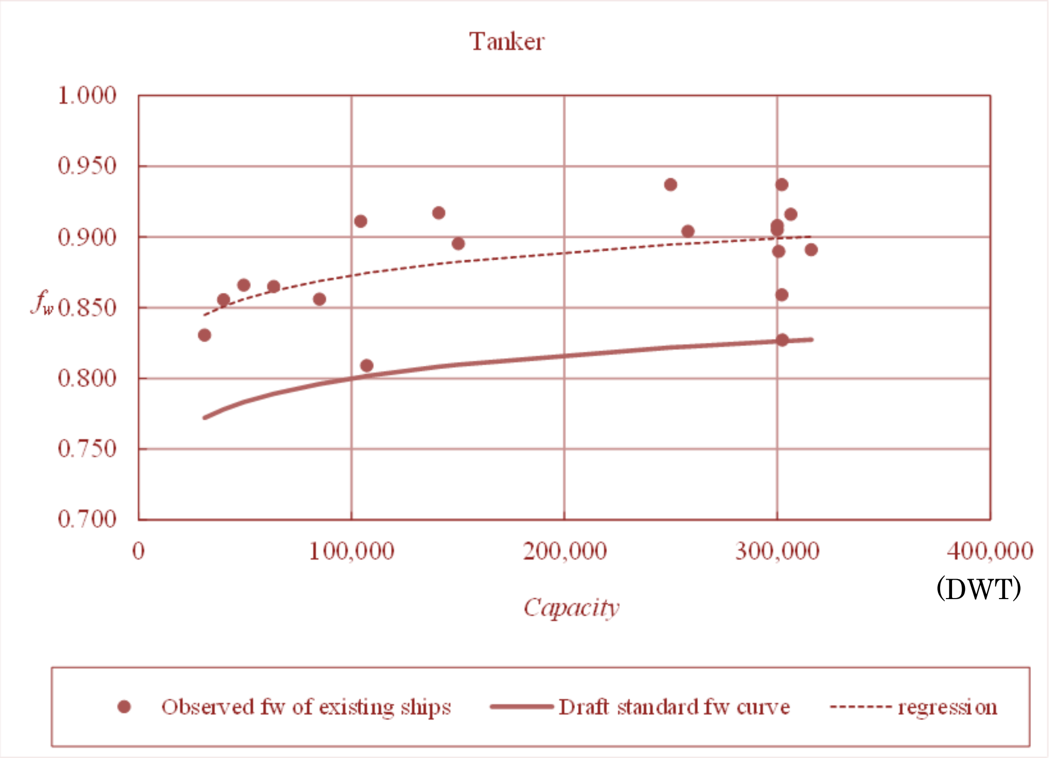
**Table 1: Parameters for determination of standard $f_w$ value**

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



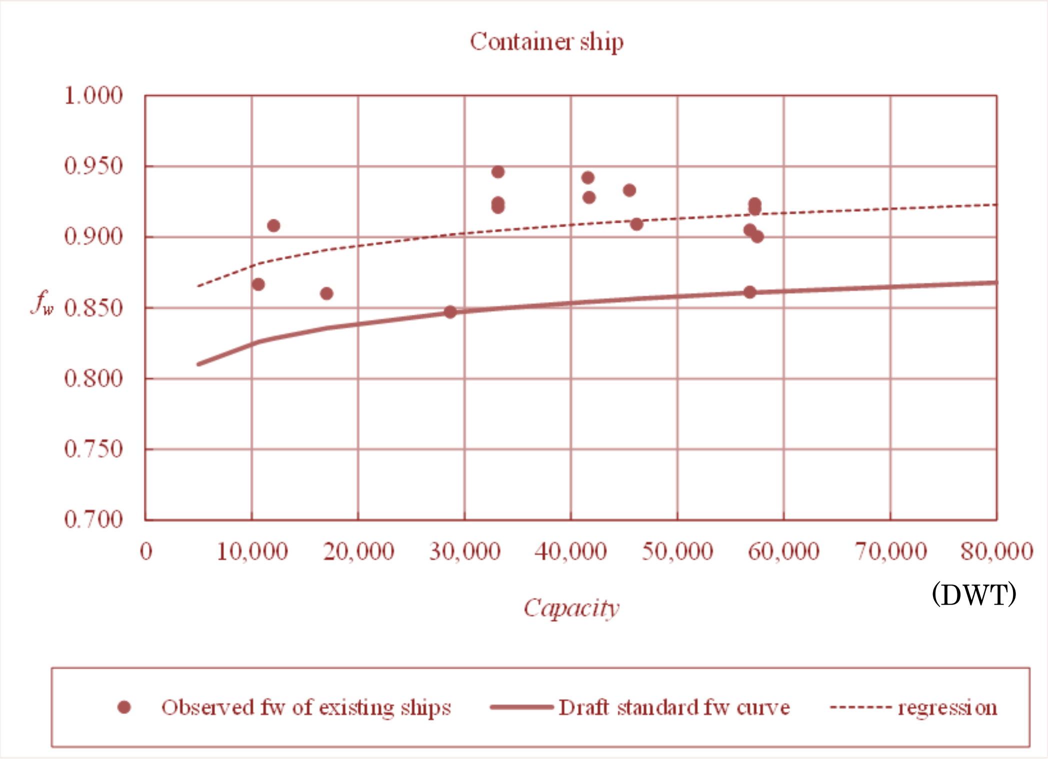
$f_w$ = 0.0429ln(*Capacity*)+0.294

**Figure 1: Standard $f_w$ curve for bulk carrier**



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

**Figure 2: Standard $f_w$ curve for tanker**



$$f_w = 0.0208\ln(\mathit{Capacity})+0.633$$

**Figure 3: Standard $f_w$ curve for containership**

* * *

## APPENDIX 1

## SAMPLE CALCULATION OF THE COEFFICIENT $f_w$ FROM THE STANDARD $f_w$ CURVES

### Sample: Bulk carrier

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

**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 |

Calculation of $f_w$ from the standard $f_w$ curves

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.

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

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]

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[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,
$\nabla_0$ : 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.

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[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.