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MEPC.1/Circ.896
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2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI

1 The Marine Environment Protection Committee, at its seventy-seventh session (22 to 26 November 2021), approved the *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI*, as set out in the annex.

2 Member Governments are invited to bring the annexed Guidance to the attention of their Administrations, industry, relevant shipping organizations, shipping companies and other stakeholders concerned.

3 The Committee agreed to keep this Guidance under review in light of experience gained in its application.

4 This circular supersedes MEPC.1/Circ.815.

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ANNEX

2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI

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1 General

1.1 The purpose of this guidance is to assist manufacturers, shipbuilders, shipowners, verifiers and other interested parties relating to Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI) of ships to treat innovative energy efficiency technologies for calculation and verification of the attained EEDI, in accordance with regulations 5, 6, 7, 8, 9 and 20 of Annex VI to MARPOL. Although the term EEDI only is used through the whole guidance, it applies to both the EEDI and the EEXI calculations, as applicable.

1.2 There are EEDI Calculation Guidelines and EEDI Survey Guidelines. This guidance does not intend to supersede those guidelines but provides the methodology of calculation, survey and certification of innovative energy efficiency technologies, which are not covered by those guidelines. In the case that there are inconsistencies between this guidance and these guidelines, those guidelines should take precedence.

1.3 This guidance might not provide sufficient measures of calculation and verification for ships with diesel-electric propulsion, turbine propulsion and hybrid propulsion systems on the grounds that the attained EEDI Formula shown in EEDI Calculation Guidelines may not be able to apply to such propulsion systems.

1.4 The guidance should be reviewed for the inclusion of new innovative technologies not yet covered by the guidance.

1.5 The guidance also should be reviewed, after accumulating the experiences of each innovative technology, in order to make it more robust and effective, using the feedback from actual operating data. Therefore, it is advisable that the effect of each innovative technology in actual operating conditions should be monitored and collected for future improvement of this guidance document.

2 Definitions

2.1 *EEDI Calculation Guidelines* means *2018 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships* (resolution MEPC.308(73), as amended).

2.2 *EEDI Survey Guidelines* means *2014 guidelines on survey and certification of the energy efficiency design index (EEDI)* (resolution MEPC.254(67), as amended by resolution MEPC.261(68) and resolution MEPC.309(73)).

2.3 P_p is the propulsion power and is defined as ΣP_{ME} (In case where shaft motor(s) are installed, $\Sigma P_{ME} + \Sigma P_{PTI(i),\text{shaft}}$, as shown in paragraph 2.2.5.3 of EEDI Calculation Guidelines).

2.4 In addition to the above, definitions of the words in this guidance are the same as those of MARPOL Annex VI, EEDI Calculation Guidelines and EEDI Survey Guidelines.

3 Categorizing of Innovative Energy Efficiency Technologies

3.1 Innovative energy efficiency technologies are allocated to category (A), (B) and (C), depending on their characteristics and effects to the EEDI formula. Furthermore, innovative energy efficiency technologies of category (B) and (C) are categorized to two sub-categories (category (B-1) and (B-2), and (C-1) and (C-2), respectively).

Category (A): Technologies that shift the power curve, which results in the change of combination of P_P and V_{ref}: e.g. when V_{ref} is kept constant, P_P will be reduced and when P_P is kept constant, V_{ref} will be increased.

Category (B): Technologies that reduce the propulsion power, P_P, at V_{ref}, but do not generate electricity. The saved energy is counted as P_{eff}.

Category (B-1): Technologies which can be used at any time during the operation and thus the availability factor (f_{eff}) should be treated as 1.00.

Category (B-2): Technologies which can be used at their full output only under limited condition. The setting of availability factor (f_{eff}) should be less than 1.00.

Category (C): Technologies that generate electricity. The saved energy is counted as P_{AEeff}.

Category (C-1): Technologies which can be used at any time during the operation and thus the availability factor (f_{eff}) should be treated as 1.00.

Category (C-2): Technologies which can be used at their full output only under limited condition. The setting of availability factor (f_{eff}) should be less than 1.00.

(C) Emission reduction through the auxiliary power reduction by generating electricity for normal maximum sea load(P_{AEeff})

(B) Emission reduction through the propulsion power reduction (P_{eff})

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

(A) The combination of P_P and V_{ref} as reflected in the power curve (knot-kW curve)

Innovative Energy Efficiency Technologies				
Reduction of Main Engine Power			**Reduction of Auxiliary Power**	
Category A	***Category B-1***	***Category B-2***	***Category C-1***	***Category C-2***
Cannot be separated from overall performance of the vessel	Can be treated separately from the overall performance of the vessel		Effective at all time	Depending on ambient environment
	$f_{eff} = 1$	$f_{eff} < 1$	$f_{eff} = 1$	$f_{eff} < 1$
– low friction coating – bare optimization – rudder resistance – propeller design	– hull air lubrication system (air cavity via air injection to reduce ship resistance) (can be switched off)	– wind assistance (sails, Flettner-Rotors, kites)	– waste heat recovery system (exhaust gas heat recovery and conversion to electric power)	– photovoltaic cells

4 Calculation and Verification of effects of Innovative Energy Efficiency Technologies

4.1 General

4.1.1 The evaluation of the benefit of any innovative technology is to be carried out in conjunction with the hull form and propulsion system with which it is intended to be used. Results of model tests or sea trials of the innovative technology in conjunction with different hull forms or propulsion systems may not be applicable.

4.2 Category (A) technology

4.2.1 Innovative energy efficiency technologies in category (A) affect P_P and/or V_{ref} and their effects cannot be measured in isolation. Therefore, these effects should not be calculated nor certified in isolation in this guidance but should be treated as a part of vessel in EEDI Calculation Guidelines and EEDI Survey Guidelines.

4.3 Category (B) technology

4.3.1 The effects of innovative energy technologies in category (B) are expressed as P_{eff} which would be multiplied by C_{FME} and SFC_{ME} (in the case of $P_{PTI(i)}$ >0, the average weighted value of ($SFC_{ME} \cdot C_{FME}$) and ($SFC_{AE} \cdot C_{FAE}$)) and f_{eff}, and then be deducted from the EEDI formula. In the case of category (B-1) technology, f_{eff} is 1.00.

4.3.2 Guidance on calculation and verification of effects of Category (B) innovative technologies is given in annex 1.

4.4 Category (C) technology

4.4.1 The effects of innovative energy technologies in category (C) are expressed as P_{AEeff} which would be multiplied by C_{FAE}, SFC_{AE} and f_{eff}, and then be deducted from the EEDI formula. In the case of category (C-1) technology, f_{eff} is 1.00.

4.4.2 Guidance on calculation and verification of effects of Category (C) innovative technologies is given in annex 2.

4.5 Average weighted value in the case of $P_{PTI(i)}$ >0

4.5.1 In the case of $P_{PTI(i)}$ >0, both Category (B) and Category (C) technologies might deduct the value of $P_{PTI(i)}$. In such case, following values are to be used for average weighted value in calculating $\Sigma(f_{eff(i)} \cdot P_{eff(i)} \cdot C_{F.}\ SFC)$ in attained EEDI formula:

For shaft power(s):
$(\Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)}) \,/\, (\Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$,
where, if $(\Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ is taken negative value, the value $(\Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ should be fixed to zero; and

For main engine(s):
$\Sigma P_{ME(i)} \,/\, (\Sigma P_{ME(i)} + \Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$,
where, if $\Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)}$ is taken negative value, the value $(\Sigma P_{PTI(i),shaft} - \cdot \Sigma P_{AEeff} \cdot \eta_{GEN} \cdot \eta_{PTI(i)})$ should be fixed to zero.

ANNEX 1[1]

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (B) INNOVATIVE TECHNOLOGIES

1 AIR LUBRICATION SYSTEM (CATEGORY (B-1))

1.1 Summary of innovative energy efficient technology

1.1.1 An air lubrication system is one of the innovative energy efficiency technologies. Ship frictional resistance can be reduced by covering the ship surface with air bubbles, which is injected from the fore part of the ship bottom by using blowers, etc.

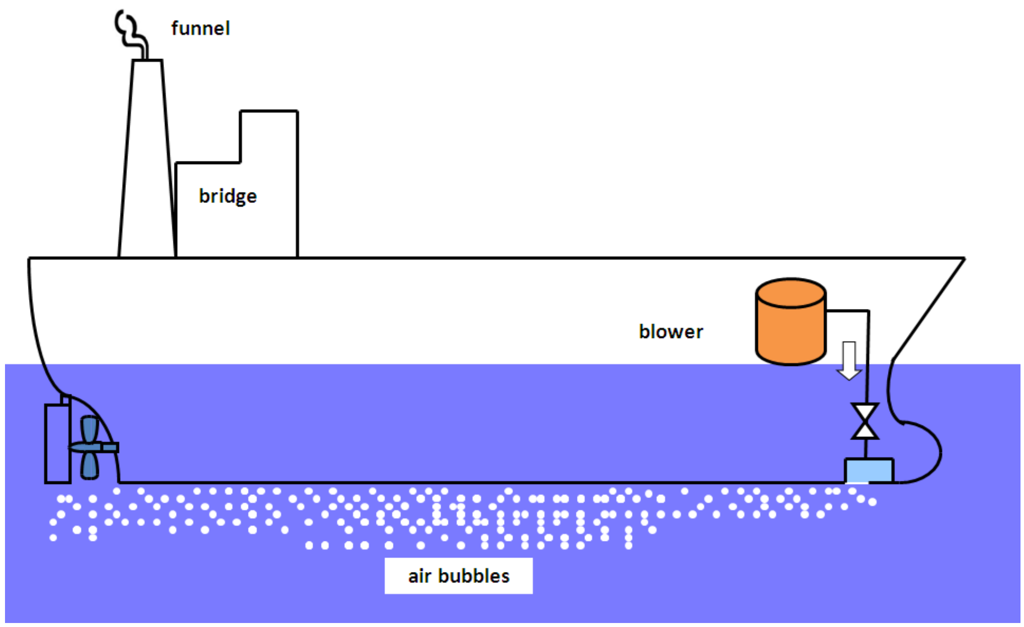

Figure 1 – Schematic illustration of an air lubrication system

1.2 Method of calculation

1.2.1 Power reduction due to air lubrication system

1.2.1.1 Power reduction factor P_{eff} due to an air lubrication system as an innovative energy efficiency technology is calculated by the following formula. The first and second terms of the right hand side represent the reduction of propulsion power by the air lubrication system and the additional power necessary for running the system, respectively. For this system, f_{eff} is 1.0 in EEDI formula.

$$P_{eff} = P_{PeffAL} - P_{AEeffAL} \frac{C_{FAE}}{C_{FME}} \frac{SFC_{AE}}{SFC_{ME} *} \quad (1)$$

* In the case of $P_{PTI(i)}$ >0, the average weighted value of ($SFC_{ME} \cdot C_{FME}$) and ($SFC_{AE} \cdot C_{FAE}$)

1 All examples in this chapter are used solely to illustrate the proposed methods of calculation and verification.

1.2.1.2 P_{eff} is the effective power reduction in kW due to the air lubrication system at the 75% t of the rated installed power (MCR). In case that shaft generators are installed, P_{eff} should be calculated at the 75% MCR having after deducted any installed shaft generators in accordance with paragraph 2.2.5 of EEDI Calculation Guidelines. P_{eff} should be calculated both in the fully loaded and the sea trial conditions.

1.2.1.3 P_{PeffAL} is the reduction of propulsion power due to the air lubrication system in kW. P_{PeffAL} should be calculated both in the condition corresponding to the *Capacity* as defined in EEDI Calculation Guidelines (hereinafter referred to as "fully loaded condition") and the sea trial condition, taking the following items into account:

.1 area of ship surface covered with air;

.2 thickness of air layer;

.3 reduction rate of frictional resistance due to the coverage of air layer;

.4 change of propulsion efficiency due to the interaction with air bubbles (self-propulsion factors and propeller open water characteristics); and

.5 change of resistance due to additional device, if equipped.

1.2.1.4 $P_{AEeffAL}$ is additional auxiliary power in kW necessary for running the air lubrication system in the fully loaded condition. $P_{AEeffAL}$ should be calculated as 75% of the rated output of blowers based on the manufacturer's test report. For a system where the calculated value above is significantly different from the output used at normal operation in the fully loaded condition, the $P_{AEeffAL}$ value may be estimated by an alternative method. In this case, the calculation process should be submitted to a verifier.

1.2.2 Points to keep in mind in calculation of attained EEDI with air lubrication system

1.2.2.1 V_{ref} in paragraph 2.2.2 of EEDI Calculation Guidelines should be calculated in the condition that the air lubrication system is OFF to avoid the double count of the effect of this system.

1.2.2.2 In accordance with EEDI Calculation Guidelines, the EEDI value for ships for the air lubrication system ON should be calculated in the fully loaded condition.

1.3 Method of verification

1.3.1 General

1.3.1.1 Attained EEDI for a ship with an innovative energy efficient technology should be verified in accordance with EEDI Survey Guidelines. Additional information on the application of air lubrication system, which is not given in the EEDI Survey Guidelines, is contained below.

1.3.2 Preliminary verification at the design stage

1.3.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File, which is to be developed by a shipowner or shipbuilder, should include:

.1 outline of the air lubrication system;

.2 P_{PeffAL} : the reduction of propulsion power due to the air lubrication system at the ship speed of V_{ref} both in the fully loaded and the sea trial conditions;

.3 EDR_{full} : the reduction rate of propulsion power in the fully loaded condition due to the air lubrication system. EDR_{full} is calculated by dividing $P_{MEeffAL}$ by P_{ME} in EEDI Calculation Guidelines in the fully loaded condition (see figure 2);

.4 EDR_{trial} : the reduction rate of propulsion power in a sea trial condition due to the air lubrication system. EDR_{trial} is calculated by dividing $P_{MEeffAL}$ by P_{ME} in EEDI Calculation Guidelines in sea trial condition (see figure 2);

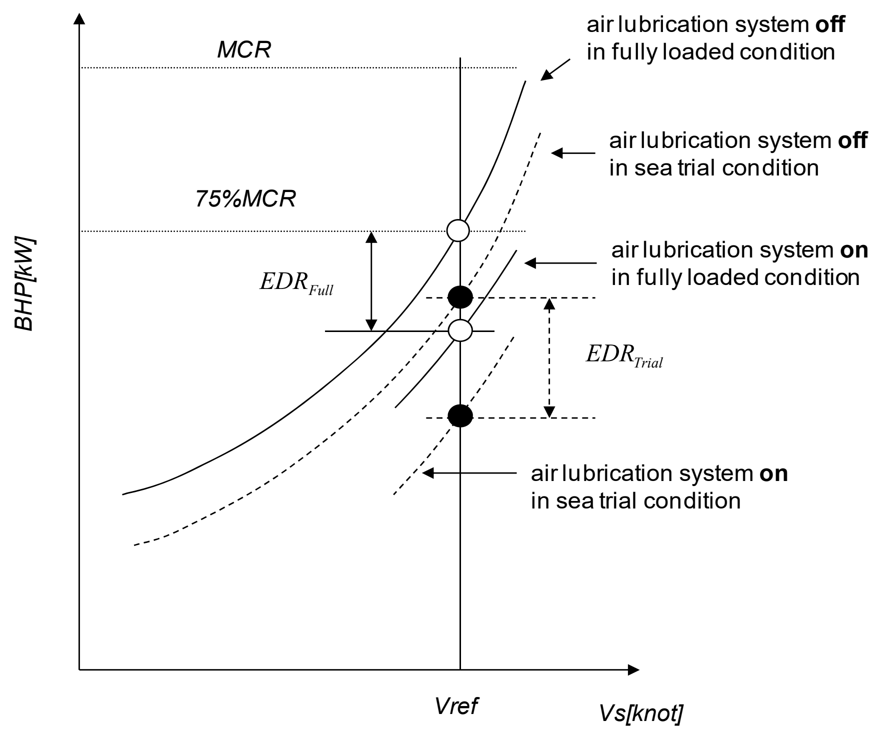

Figure 2 – Calculation of the reduction rate of propulsion power (EDR_{full} and EDR_{trial}) due to air lubrication system

.5 $P_{AEeffAL}$: additional power necessary for running the air lubrication system; and

.6 the calculated value of the EEDI for the air lubrication system ON in the fully loaded condition.

1.3.2.2 In addition with paragraph 4.2.7 of the EEDI Survey Guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 the detailed calculation process of the reduction of propulsion power due to the air lubrication system: P_{PeffAL} ; and

.2 the detailed calculation process of the additional power necessary for running the air lubrication system: $P_{AEeffAL}$.

1.3.3 Final verification of the attained EEDI at sea trial

1.3.3.1 Final verification of the EEDI of ships due to the air lubrication system should be conducted at the sea trial. The procedure of final verification should be basically in accordance with paragraph 4.3 of the EEDI Survey Guidelines.

1.3.3.2 Prior to the sea trial, the following documents should be submitted to the verifier; a description of the test procedure that includes the measurement methods to be used at the sea trial of the ship with the air lubrication system.

1.3.3.3 The verifier should attend the sea trial and confirm the items described in paragraph 4.3.3 of the EEDI Survey Guidelines to be measured at the sea trial for the air lubrication system ON and OFF.

1.3.3.4 The main engine output at the sea trial for the air lubrication system ON and OFF should be set so that the range of the developed power curve includes the ship speed of V_{ref}.

1.3.3.5 The following procedure should be conducted based on the power curve developed for air lubrication system OFF.

.1 ship speed at 75% MCR of main engine in the fully loaded condition, V_{ref}, should be calculated. In case that shaft generators are installed, V_{ref} should be calculated at 75% MCR having after deducted any installed shaft generators in accordance with paragraph 2.2.5 of EEDI Calculation Guidelines; and

.2 in case that V_{ref} obtained above is different from that estimated at the design stage, the reduction rate of main engine should be recalculated at new V_{ref} both in the fully loaded and the sea trial conditions.

1.3.3.6 The shipbuilder should develop power curves for the air lubrication system ON based on the measured ship speed and output of the main engine at the sea trial. The following calculations should be conducted.

.1 the actual reduction rate of propulsion power ADR_{trial} at the ship speed of V_{ref} at the sea trial; and

.2 if the sea trial is not conducted in the fully loaded condition, the reduction rate of propulsion power in this condition should be calculated by the following formula:

$$1 - ADR_{Full} = (1 - EDR_{Full}) \times \frac{1 - ADR_{Trial}}{1 - EDR_{Trial}},$$

i.e.

$$ADR_{Full} = 1 - (1 - EDR_{Full}) \times \frac{1 - ADR_{Trial}}{1 - EDR_{Trial}} \qquad (2)$$

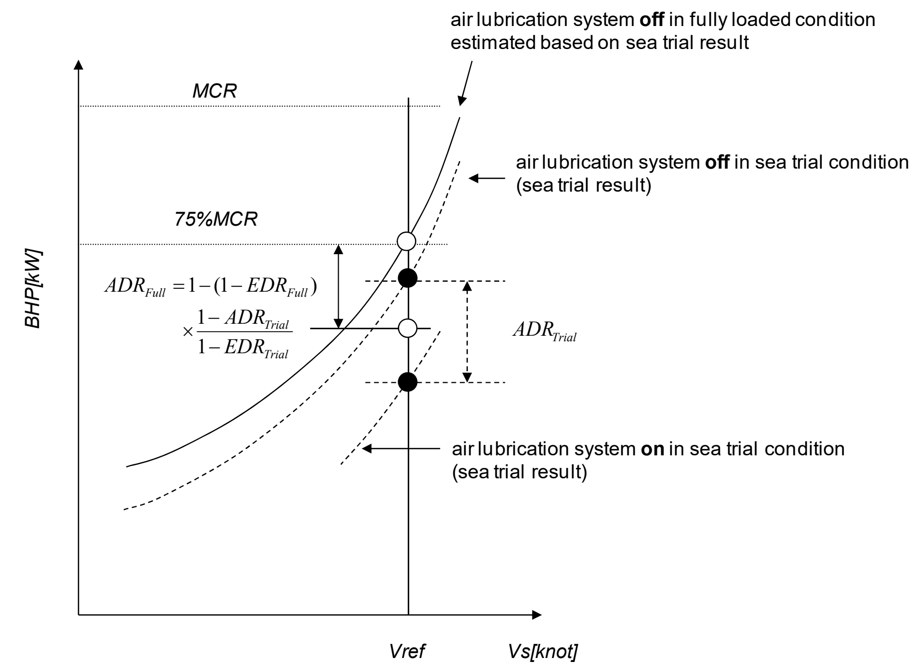

Figure 3 – Calculation of the actual reduction rate of propulsion power (ADR_{full} and ADR_{trial}) due to air lubrication system

1.3.3.7 The reduction of propulsion power due to the air lubrication system $P_{MEeffAL}$ in the fully loaded and the sea trial conditions should be calculated as follows:

$$P_{PeffAL\_Full} = ADR_{Full} \times P_P \quad (3)$$

$$P_{PeffAL\_Trial} = ADR_{Trial} \times P_P \quad (4)$$

1.3.3.8 The shipowner or the shipbuilder should revise the EEDI Technical File, as necessary, by taking the result of the sea trial into account. Such revision should include the following contents:

.1 V_{ref}, in case that it is different from that estimated at the design stage;

.2 the reduction of propulsion power P_{PeffAL} at the ship speed of V_{ref} in the fully loaded and the sea trial conditions for the air lubrication system ON;

.3 the reduction rate of propulsion power due to air lubrication system (ADR_{full} and ADR_{trial}) in the fully loaded and the sea trial conditions; and

.4 the calculated value of the EEDI for the air lubrication system ON in the fully loaded condition.

2 WIND ASSISTED PROPULSION SYSTEM (CATEGORY B-2)

2.1 Summary of innovative energy efficient technology

2.1.1 Wind assisted propulsion systems (WAPS) belong to innovative mechanical energy efficient technologies which reduce the CO_2 emissions of ships. There are different types of wind propulsion technologies (sails, wings, kites, etc.) which generate forces dependent on wind conditions. This technical guidance defines the available effective power of WAPS as the product of the reference speed and the sum of the wind assisted propulsion system force and the global wind probability distribution.

2.1.2 Secondary effects when applying the wind assisted propulsion system which might increase the ship resistance are ignored for the purpose of these guidelines. With this simplification effects as for instance additional drag due to leeway, rudder angle and heel or reduced propeller efficiency in light running condition are ignored without significant loss of accuracy. Nonetheless, the corresponding forces are considered to rule out conditions that do not allow a safe operation of the ship, for instance due to exceeding heel angles.

2.2 Definitions

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

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

.2 *wind assisted propulsion systems (WAPS)* belong to innovative mechanical energy efficient technologies which reduce the CO_2 emissions of ships. These proposed guidelines apply to wind propulsion technologies that directly transfer mechanical propulsion forces to the ship's structure (sails, wings, kites, etc.);

.3 *wind propulsion system force matrix* is a two-dimensional matrix which expresses the force characteristic of a wind assisted propulsion system dependent on ship speed, wind speed and the wind angle relative to heading;

.4 *global wind probability matrix* contains data of the global wind power on the main global shipping routes based on a statistical survey of worldwide wind data and represents the probability of wind conditions;

.5 *wind speed* is the speed of the wind in m/s measured at 10 m above sea level;

.6 *wind direction* is the North-oriented direction of the wind measured at 10 m above sea level and is subdivided into eight sectors (North, North-East, East, South-East, South, South-West, West, North-West);

.7 *wind angle* is the angle of the wind relative to the ship's heading at 10 m above sea level subdivided into 72 sectors of 5°-steps (0°, 5°,..., 355°); and

.8 the *main global shipping network* is a network of global shipping routes with the highest frequency of journeys.

2.3 Available effective power of wind assisted propulsion systems (WAPS)

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

$$(f_{eff} \cdot P_{eff}) = \left(\frac{1}{\sum_{k=1}^{q} W_k}\right) \cdot \left(\left(\frac{0.5144 \cdot V_{ref}}{\eta_D} \sum_{k=1}^{q} F(V_{ref})_k \cdot W_k\right) - \left(\sum_{k=1}^{q} P(V_{ref})_k \cdot W_k\right)\right)$$

with $F_1 - F_k \geq 0 \wedge F_{k-1} - F_k \geq 0$

(sorting all force matrix elements in descending order)

and $\sum_{k=1}^{q-1} W_k < \frac{1}{2} \wedge \sum_{k=1}^{q} W_k \geq \frac{1}{2}$
(defining q: the number of elements added in the formula)

Where:

.1 (f_{eff} * P_{eff}) is the available effective power in kW delivered by the specified wind assisted propulsion system. f_{eff} and P_{eff} are combined in the calculation because the product of availability and power is a result of a matrix operation, addressing each wind condition with a probability and a specific wind propulsion system force;

.2 the factor 0.5144 is the conversion factor from nautical miles per hour (knots) to metres per second (m/s);

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

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

.5 $F(V_{ref})_k$ is the force matrix of the respective wind assisted propulsion system for a given ship speed V_{ref}. Each matrix element represents the propulsion force in kilo newton (kN) for the respective wind speed and angle. The wind angle is given in relative bearings (with 0° on the bow);

.6 W_k is the global wind probability matrix. Each matrix element represents the probability of wind speed and wind angle relative to the ships heading. The sum over all matrix elements equals 1 and is non-dimensional; and

.7 $P(V_{ref})_k$ is a matrix with the same dimensions as $F(V_{ref})_k$ and W_k and represents the power demand in kW for the operation of the wind assisted propulsion system.

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

2.4 Wind propulsion system force matrix $F(V_{ref})_k$

2.4.1 Measurement of the wind propulsion coefficients

2.4.1.1 The wind propulsion system force matrix is a table describing the average wind propulsion coefficients corresponding to the global wind probability matrix. Therefore, the measurement of the wind propulsion coefficients has to be carried out at first in order to obtain the wind propulsion system force matrix.

2.4.1.2 Various methods can be used to determine the aerodynamic forces of a wind assisted ship, depending firstly on the type of wind assisted propulsion system, but also size limitations and successful validation for the methods already shown in literature. The methods include:

.1 wind tunnel model test;

.2 CFD/numerical calculations; and

.3 full scale test.

2.4.1.3 The forces are to be determined for the combination of wind assisted propulsion system and ship unless that is not practical due to technical or economic reasons. In the latter case the conditions of 2.4.1.4 apply.

2.4.1.4 In the case of the installation of multiple wind assisted propulsion systems, the forces may be determined for the devices in isolation and by the summing the coefficients of each units comprising the system, provided that a validated method is in place to account for interaction effects between wind propulsors and between the ship and the wind propulsors.

2.4.1.5 Wind propulsion devices are to be analysed at their operational Reynolds number, as this has been shown to affect their performance.

2.4.1.6 The wind tunnel model test is a major method for measuring the aerodynamic force of a wind assisted ship propulsion system under typical states. Appendix 1 of this annex describes the testing methods of wind tunnel model tests. If the wind propulsion coefficients are measured by the wind tunnel model test, it should be conducted in accordance with the appendix 1.

2.4.1.7 For some types of wind assisted propulsion system wind tunnel model tests are not appropriate for measuring the wind propulsion coefficients. Therefore, numerical calculations, such as CFD-computation, can be accepted for estimating the wind propulsion coefficients, but the condition and the model of the numerical calculation should be referred to experimental representative results and the numerical calculation is to be carried out in accordance with defined quality and technical standards (ITTC 7.5-03-01-02 and ITTC 7.5-03-01-04 at their latest revisions or equivalent). If both of wind tunnel model tests and numerical calculation are inappropriate to estimate the coefficient, other testing method may be acceptable with the approval of the verifier.

2.4.1.8 When a test or calculation for determining the wind propulsion coefficients is carried out, the procedure of the test or calculation should be submitted to the verifier in advance of conducting the test or calculation. In addition, the detail report of the test and calculation procedure should also be submitted to the verifier after the test. The verifier may request the submitter to provide further documents/information as necessary to verify the wind propulsion coefficients.

2.4.1.9 The test of a ship model without wind assisted propulsion system mainly measures the wind forces of the ship model pointing to the bow under different wind directions. The test of a ship model with wind assisted propulsion system mainly measures the maximum wind propulsion of the ship model pointing to the bow under different wind directions, which is then used to calculate the wind propulsion coefficient of the wind propulsion system. The coefficients of the wind assisted propulsion system should be determined at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5°.

2.4.1.10 A single wind tunnel test may be accepted for several identical wind assisted propulsion systems and identical ships. The verifier may request that supporting documentation be produced.

2.4.2 Wind tunnel test methods and data processing

Option 1: Test on a ship model fitted with the full wind assisted propulsion system

2.4.2.1 When the wind tunnel test is carried out with the ship model and the wind assisted propulsion system model, the test method should follow the specifications given in appendix 1. The wind forces acting on the ship model are normalized as:

$$C_{Fx} = F_x / (0.5\ \rho\ V^2\ A)$$

2.4.2.2 The wind propulsion coefficients[2] of the wind assisted propulsion system can be determined as:

$$\Delta C_{Fx} = C_{Fx\text{-}with\ WPS} - C_{Fx\text{-}without\ WPS}$$

Where:

.1 C_{Fx} is the wind force coefficient of the model pointing to the bow;

.2 F_x is the wind force of the model pointing to the bow;

.3 ΔC_{Fx} is the wind propulsion coefficient of the wind assisted propulsion system;

.4 ρ is the air density of the model test;

.5 V is the wind velocity of the model test;

.6 A is the total projected area of the wind assisted propulsion system; and

.7 the subscript "with WAPS" means the state with wind assisted propulsion system of the ship model, while "without WAPS" means the state without wind assisted propulsion system of the ship.

2 The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

Option 2: Test with a single wind assisted propulsion unit

2.4.2.3 When the wind tunnel test is carried out with a single wind propulsion unit, the test method should follow the specifications given in appendix 1. The wind propulsion coefficients[3] of the model can be determined as:

$C_{Fx} = F_x / (0.5\ \rho\ V^2\ A)$

Where:

.1 C_{Fx} is the wind force coefficient of the model pointing to the bow;

.2 F_x is the wind force of the model pointing to the bow;

.3 ρ is the air density of the model test;

.4 V is the wind velocity of the model test; and

.5 A is the total projected area of the wind assisted propulsion system.

2.4.2.4 The wind propulsion coefficients ΔC_{Fx} of a multi-unit wind assisted propulsion system can be calculated by summing the coefficients of the units comprising the system, weighted by the effects of interaction and masking by superstructures.

For options 1 and 2: Calculation of the average power consumption coefficients of the active wind assisted propulsion system during the wind tunnel test

2.4.2.5 The power consumption of the wind assisted propulsion system should be measured and the power consumption matrix should be filled based on the measured values and the systems control plan.

2.4.3 Calculation of the wind propulsion system force matrix

2.4.3.1 The wind propulsion coefficients[4] of the ship's wind assisted propulsion system can be used to predict the wind propulsion system force matrix. Apparent wind is defined as the combination of wind relative to the ground and wind created by the ship's velocity. The steps to calculate the wind propulsion system force matrix are as follows:

.1 determine the velocity of the ship V_{ref};

.2 select the average wind speed corresponding to terms in W_k, the global wind probability matrix at 10 m height. For example, the average wind speed corresponding to the first wind speed range (0-1 m/s) of the wind probability matrix is selected as 0.5 m/s, the average wind speed corresponding to the second wind speed range (1-2 m/s) is selected as 1.5 m/s, etc.;

.3 extrapolate the wind speed to the reference height of the wind assisted propulsion systems taken as the aerodynamic centre of effort height or half height from the waterline:

---

3 The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

4 The force coefficients are dimensionless, the units for their calculation can be freely chosen, but must be consistent with each other.

$$v_{Zref} = v_{10m}\left(\frac{z_{ref}}{10}\right)^{\alpha} \; for\ z_{ref} < 300m$$

$$v_{Zref} = v_{10m}\left(\frac{300}{10}\right)^{\alpha} \; for\ z_{ref} \geq 300m$$

Where:

.1 z_{ref} is the reference height above the water line, to be equal to the point of mid-height of each sail, Flettner, etc. in wind assisted propulsion system;

.2 v_{10m} is the wind velocity at 10 m above sea level;

.3 v_{Zref} is the resulting wind velocity at the reference height; and

.4 α is taken as 1/9 conforming to ITTC recommendations.[5]

.4 according to the corresponding average wind speed, wind direction angle and the velocity of the ship, calculate the relative wind speed V_k and the relative wind direction angle of the ship;

.5 according to the relative wind direction angle, and the corresponding relationship between the relative wind direction angle and the wind propulsion coefficient ΔC_{Fx} obtained from the test, calculate the average wind propulsion coefficients $(\Delta C_{Fx})_k$ of the wind assisted propulsion system corresponding to W_k; and

.6 according to the average wind propulsion coefficient of the wind assisted propulsion system, calculate the terms of the wind propulsion system force matrix $F(V_{ref})_k$ of the full scale ship corresponding to W_k by following formula:

$F(V_{ref})_k = (\Delta C_{Fx})_k * (0.5\ \rho\ V_k^2\ A)$

Where:

.1 $(\Delta C_{Fx})_k$ is the average wind propulsion coefficients corresponding to W_k;

.2 ρ is the average air density in shipping environment, ρ=1.225 kg/m^3;

.3 V_k is the relative wind velocity of the full-scale ship corresponding to W_k;

.4 A is the total projected area of the wind assisted propulsion system;

.5 the settings of the wind propulsor may be varied in order to find the best $(\Delta CFx)_k$; this may be done using interpolation provided that increments in settings are sufficiently small;

[5] International Towing Tank Conference (ITTC), "ITTC – Recommended Procedures and Guidelines; Preparation, Conduct and Analysis of Speed/Power Trial," International Towing Tank Conference (ITTC), 7.5-04-01-01.1, 2017.

Annotation: ITCC provides no guidance for wind speeds above an altitude above 300 m. However, it is assumed in this guideline to be constant above 300 m altitude.

.6 the settings and deployment of the wind assisted propulsion system must adhere to the operational constraints as defined for the system (e.g. a maximum operational wind speed, if lower than provided by the global wind probability matrix, > Bf 8, 19 m/s);

.7 the potential wind drag induced by the system is to be accounted for, such as in unusable wind directions close to head wind and when the systems is not operational due to exceedance of operational limits; and

.8 if $F(V_{ref})_k$ exceeds the resistance of the ship, such that the propeller thrust would be negative, $F(V_{ref})_k$ is to be limited at the resistance value.

2.4.4 Consideration of the operational limits of the wind assisted propulsion system and the lateral forces and yawing moments

2.4.4.1 Force $F(V_{ref})_k$ must be calculated only when it is within the operational domain applicable to the wind assisted propulsion system. These operational limitations can be caused at a minimum by wind conditions or by the total forces generated by the wind assisted propulsion system and applied to the ship.

2.4.4.2 $F(V_{ref})_k$ must be zero for any pair (wind direction; wind force) not in conformity with the operational domain of the wind assisted propulsion system validated by the verifier in the operations manual of the wind assisted propulsion system and the ship.

2.4.4.3 The lateral forces exerted by the wind assisted propulsion system on the ship and the resulting yawing moment can affect the performance of the system, and therefore the EEDI calculation. The lateral forces on the ship and the yawing moments applied by the wind assisted propulsion system to the ship should therefore be documented by the shipbuilder and/or propulsion system manufacturer and observed by the verifier. They can be obtained without additional effort during the tests described in paragraph 2.4.1 of the present circular.

2.4.4.4 Conformity with the operational domain requires that for any pair (wind direction; wind force), and in consideration of the total forces generated by the wind assisted propulsion system (i.e. including lateral forces to the vessel and yawing moments), the strength of the wind assisted propulsion system, the forces at the embedment and the list of the ship conform with the structural design file and the stability file of the ship, respectively. Where the lateral forces and yawing moment are particularly significant, the verifier may request course keeping and rudder angle demonstrations to validate conformity with the operational domain.

2.5 The global wind probability matrix W_k

2.5.1 Wind probabilities

2.5.1.1 Wind conditions are not constant. Winds vary their speed and direction with time. Wind expectations are unequal in different regions of the earth.

2.5.1.2 However, every wind expectation can be expressed in a distinctive wind probability pattern for every particular position on the globe. There is always a certain probability for a certain wind direction and wind speed to occur. These probabilities are documented in wind charts. With this approach each geographical region has a distinctive wind chart.

2.5.2 Wind angles relative to the ship

2.5.2.1 For a wind assisted propulsion system, it is irrelevant if the wind is coming from North or South. Only the wind angle relative to a ship's heading is of importance. As a consequence, the wind directions given in the weather data have to be recalculated for ship headings on a trading route when applied to wind assisted propulsion systems, where 0° means the ship's bow, 90° its starboard side, 180° the stern and 270° port side.

2.5.3 Main global shipping network

2.5.3.1 To determine a global wind probability chart for the wind assisted propulsion system's EEDI calculation, the average of all wind conditions along the main global shipping routes is required.

2.5.3.2 Figure 1 shows the main global shipping network used to determine the global wind conditions. Along the shown routes, 106 wind condition charts were analysed. These charts are based on 868,500 individual wind data.

2.5.3.3 The wind condition charts for each position were first recalculated in ship heading coordinates and then averaged to form a global wind condition chart. The results are visualized in figure 2, the complete chart (the global wind probability matrix) is shown as the table in appendix 2 of this annex.

2.5.3.4 Each element of the matrix W_k represents the probability of the specific wind speed and wind angle relative to the ship. The sum of all matrix elements is one (1.0), representing 100% of all wind conditions.

2.5.3.5 The results show that winds to the bow or the stern occur more often than winds to the sides. There are two possible reasons to explain this phenomenon:

.1 shipping routes and global weather systems are more East-West than North-South oriented; and

.2 shipping routes and winds are influenced by shore lines, so they tend to be parallel in some regions.

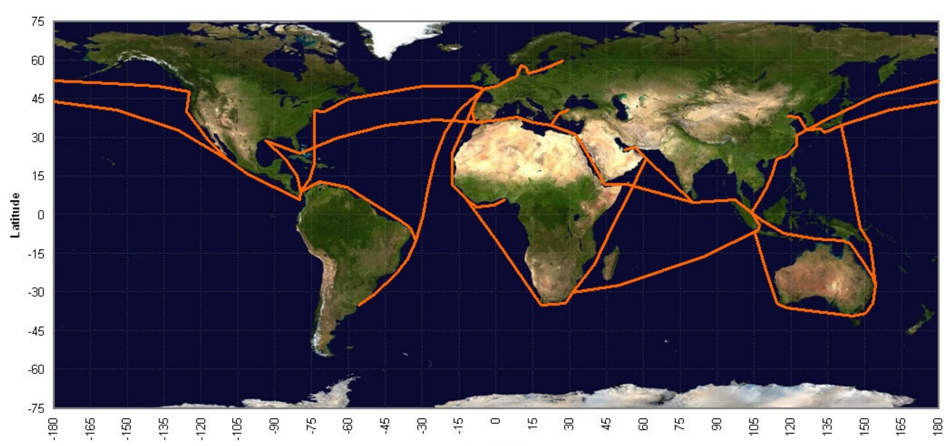

Figure 1 – The main global shipping network used for the wind chart

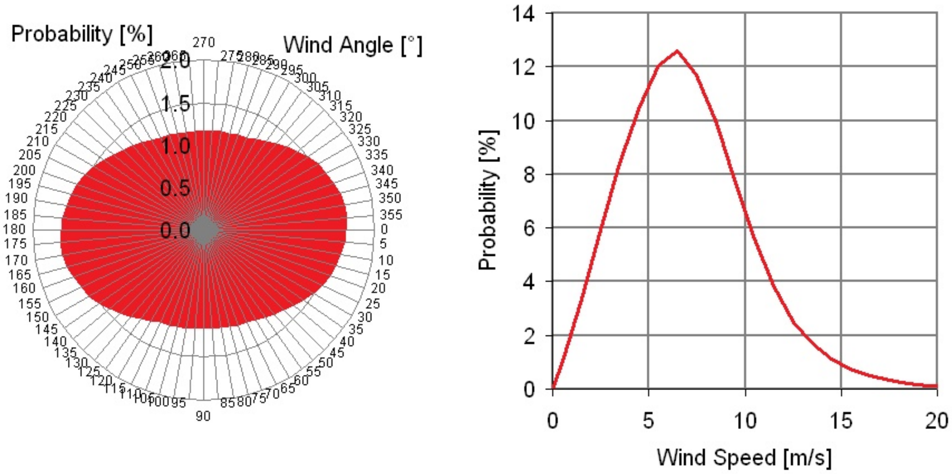

Figure 2 – Resulting wind curves on the main global shipping routes relative to the ship

2.6 Effective CO_2 reduction by wind assisted propulsion systems

2.6.1 For the calculation of the CO_2 reduction, the resulting available effective power (f_{eff} * P_{eff}) has to be multiplied with the conversion factor C_{FME} and SFC_{ME} , as contained in the original EEDI formula.

2.7 Verification of wind assisted propulsion systems in the EEDI certification process

2.7.1 General

2.7.1.1 Verification of EEDI with innovative energy efficient technologies should be conducted according to the EEDI Survey Guidelines. Additional items concerning innovative energy efficient technologies not contained in EEDI Survey Guidelines are described below.

2.7.2 Preliminary verification at the design stage

2.7.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 Outline of wind assisted propulsion systems; and

.2 Calculated value of EEDI due to the wind assisted propulsion system.

2.7.2.2 In addition to paragraph 4.2.7 of the EEDI Survey Guidelines, additional information from the shipbuilder may be requested by the verifier. It includes:

.1 Detailed calculation process of the wind propulsion system force matrix $F(V_{ref})_k$ and results of performance tests.

2.7.2.3 In order to prevent undesirable effects on the ship's structure or main drive, the influences of added forces on the ship should be determined during the EEDI certification process. Elements in the wind propulsion system force matrix may be limited to ship specific restrictions, if necessary. The technical means to restrict the wind propulsion system's force should be verified as part of the performance test.

2.7.2.4 If more than one innovative energy efficient technology is subject to approval in the EEDI certification, interactions between these technologies should be considered. The appropriate technical papers should be included in the additional information submitted to the verifier in the certification process.

2.7.3 Final verification of the attained EEDI

2.7.3.1 The total net power generated by wind assisted propulsion systems should be confirmed based on the documentation in the EEDI Technical File. For final verification, EEDI verifier should check that the configuration of the installed wind assisted propulsion system agrees with the system as described in the EEDI Technical File.

APPENDIX 1

METHOD OF WIND TUNNEL MODEL TEST

In accordance with section 2.4.1 of the present circular, two test methods are defined:

.1 option 1: test on a ship model fitted with the full wind assisted propulsion system; and

.2 option 2: test on a complete model of a single wind propulsion unit.

Option 1: Test on a ship model fitted with the full wind assisted propulsion system

1 Model

1.1 The wind assisted propulsion system model and the hull model should be made similarly to the real form, but appendages which do not affect the aerodynamic characteristics can be omitted from the model (e.g. handrails, windlass, etc.).

1.2 The draught condition of the hull model should be corresponding to the *Capacity* as defined in EEDI Calculation Guidelines.

1.3 The hull model is connected with the turntable by force balance, and the wind direction angle of the ship model is changed by changing the angle of the turntable.

2 Test condition

2.1 In addition to geometric similarity, the dynamic similarity criterion must be satisfied in the wind matrix wind tunnel model test of a ship's wind assisted propulsion system. That is, when the test wind speed is higher than a certain critical wind speed, the dimensionless wind coefficient tends to be stable, and the flow around the model is similar to the real ship. The measured wind coefficient can be directly extrapolated to the real ship. During the test, the critical wind speed is determined by a variable wind speed test.

2.2 In the wind tunnel model test, spires and roughness elements are arranged at the front of the test section, and the wind field of the atmospheric boundary layer on the ocean surface at the model scale for wind matrix test is obtained. Reynolds number of the test should be more than 1.0 x 10^6. The Reynolds number, *Re*, is expressed by the following formula:

$$\mu$$

where ρ and μ are the density and viscosity of the air, respectively, U is the wind speed, L_{pp} is the length between perpendiculars of the model ship.

2.3 The blockage ratio should not be more than 5%. The ratio is calculated by the transverse projected area of the model divided by the cross-sectional area of wind tunnel.

3 Test method

3.1 At the same hull wind direction, the wind propulsion coefficients of the wind assisted propulsion system are different at different angles of attack. In order to obtain the maximum wind propulsion coefficients of the wind assisted propulsion system at each hull wind direction angle, the test scheme should include:

.1 measurements of the aerodynamic force characteristics of the ship model without wind assisted propulsion system at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5°, potentially extended to 10° only for beam to stern;

.2 measurements of the aerodynamic force characteristics of the ship model with wind assisted propulsion system at a series of wind angles ranging from 0° to 360°, spaced by an interval of 5° or 10°, attack angles of the wind assisted propulsion system range from 0° to 180°, spaced by an interval of 5° or 10° in every wind angle of the ship model. Smaller intervals of attack angles should be needed around the maximum wind propulsion coefficients; and

.3 in the case where the measurements are carried out with spaced by an interval of 10°, each intermediate force characteristic (i.e. F_X at 5°, 15°, 25°…) should be interpolated by using the measurement results.

3.2 In the case where the shape of the ship and wind assisted propulsion system are symmetrical on starboard side and port side, the wind propulsion coefficients are also symmetrical and thus, the measurements at a series of wind angles ranging from 0° to 180° or 180° to 360° can be omitted.

3.3 If the wind assisted propulsion system has a changeable and controllable structure, such as sails and rotors, the model of the wind assisted propulsion system can be arranged as the wind angle, the rotor speed, or other controllable structure to maximize the gained wind force or to minimize the wind resistance.

Option 2: Test on a complete model of a single wind propulsion unit

4 Model

4.1 The effects of the hull and superstructures should be taken into account by corrective actions taking into account the masked area and distance. If several wind propulsion units are installed on board the ship, the aerodynamic interactions between them should be taken into account by corrective actions. The verifier may request documentation from the test author to verify that these effects have been taken into account.

4.2 The wind propulsion unit model is connected to the turntable by means of a force balance, and the wind direction angle of the ship model is changed by changing the angle of the turntable.

5 Test conditions

5.1 In addition to geometric similarity, the dynamic similarity criterion must be satisfied in the wind matrix wind tunnel model test of a ship's wind assisted propulsion system. That is, when the test wind speed is higher than a certain critical wind speed, the dimensionless wind coefficient tends to be stable, and the flow around the model is similar to the real ship. The measured wind coefficient can be directly extrapolated to the real ship. During the test, the critical wind speed is determined by a variable wind speed test.

5.2 The maximum Reynolds number of the test should be more than 5.0×10^5. The Reynolds number, Re, is expressed by the following formula:

$$Re = \rho \, . \, U \, . \, C / \mu$$

where ρ and μ are the density and viscosity of the air, respectively, U is the wind speed, C is the mean chord length of the wind propulsion unit.

5.3 The blockage ratio should not be more than 5%. The ratio is calculated by the transverse projected area of the model divided by the cross-sectional area of wind tunnel.

6 Test method

6.1 In order to obtain the maximum wind propulsion coefficients of the wind assisted propulsion system at each ship wind direction angle, the test scheme should include measurements of the aerodynamic force characteristics for:

.1 a range of permissible angles of attack on the wind propulsion unit; and

.2 a range of permissible settings (profile camber, rotation speed, suction rate, reduced area, etc.).

6.2 The propulsive force on the ship is the aerodynamic force measured on the wind propulsion unit pointing to the bow.

APPENDIX 2

GLOBAL WIND PROBABILITY MATRIX W_k

Table 1 – Normalized global wind chart showing the probability of wind conditions relative to the ship's heading along the main global trading routes

Wind Angle [°] / Wind Speed [m/s]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
<1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
<3	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
<4	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0011	0.0011
<5	0.0017	0.0017	0.0017	0.0016	0.0016	0.0015	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
<6	0.0021	0.0020	0.0020	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014	0.0014	0.0014	0.0013	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015
<7	0.0022	0.0022	0.0021	0.0020	0.0020	0.0019	0.0018	0.0017	0.0017	0.0016	0.0015	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0015
<8	0.0020	0.0020	0.0020	0.0019	0.0019	0.0018	0.0017	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0014	0.0014	0.0014
<9	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012
<10	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0009	0.0009
<11	0.0010	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
<12	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
<13	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
<14	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<15	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Wind Angle [°] / Wind Speed [m/s]	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235
<1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
<3	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
<4	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0011	0.0011	0.0011	0.0011
<5	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016	0.0015	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013
<6	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021	0.0021	0.0021	0.0020	0.0020	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014
<7	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0022	0.0022	0.0022	0.0021	0.0020	0.0020	0.0019	0.0018	0.0017	0.0017	0.0016	0.0015	0.0014
<8	0.0015	0.0015	0.0016	0.0017	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0021	0.0021	0.0020	0.0020	0.0020	0.0019	0.0019	0.0018	0.0017	0.0016	0.0016	0.0015	0.0014	0.0014
<9	0.0012	0.0012	0.0013	0.0014	0.0014	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012
<10	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0010	0.0010
<11	0.0006	0.0006	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008
<12	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005
<13	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
<14	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
<15	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Wind Angle [°] / Wind Speed [m/s]	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	355
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<2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
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<4	0.0011	0.0011	0.0011	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
<5	0.0013	0.0012	0.0012	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
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<7	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0015	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0022
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<9	0.0012	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0012	0.0013	0.0014	0.0014	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	0.0017
<10	0.0010	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013
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<13	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
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<15	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
<16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<17	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
<19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<24	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>=25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

ANNEX 2[6]

GUIDANCE ON CALCULATION AND VERIFICATION OF EFFECTS OF CATEGORY (C) INNOVATIVE TECHNOLOGIES

1 WASTE HEAT RECOVERY SYSTEM FOR GENERATION OF ELECTRICITY (CATEGORY (C-1))

1.1 Summary of innovative energy efficient technology

1.1.1 This chapter provides the guidance on the treatment of high temperature waste heat recovery systems (electric generation type) as innovative energy efficiency technologies related to the reduction of the auxiliary power (concerning $P_{AEeff(i)}$). Mechanical recovered waste energy directly coupled to shafts need not be measured in this category, since the effect of the technology is directly reflected in the V_{ref}.

1.1.2 Waste heat energy technologies increase the efficiency utilization of the energy generated from fuel combustion in the engine through recovery of the thermal energy of exhaust gas, cooling water, etc. thereby generating electricity.

1.1.3 There are the following two methods of generating electricity by the waste heat energy technologies (electric generation type):

.1 (A) method to recover thermal energy by a heat exchanger and to drive the thermal engine which drives an electric generator; and

.2 (B) method to drive directly an electric generator using power turbine, etc. Furthermore, there is a waste heat recovery system which combines both of the above methods.

[6] All examples in this chapter are used solely to illustrate the proposed methods of calculation and verification.

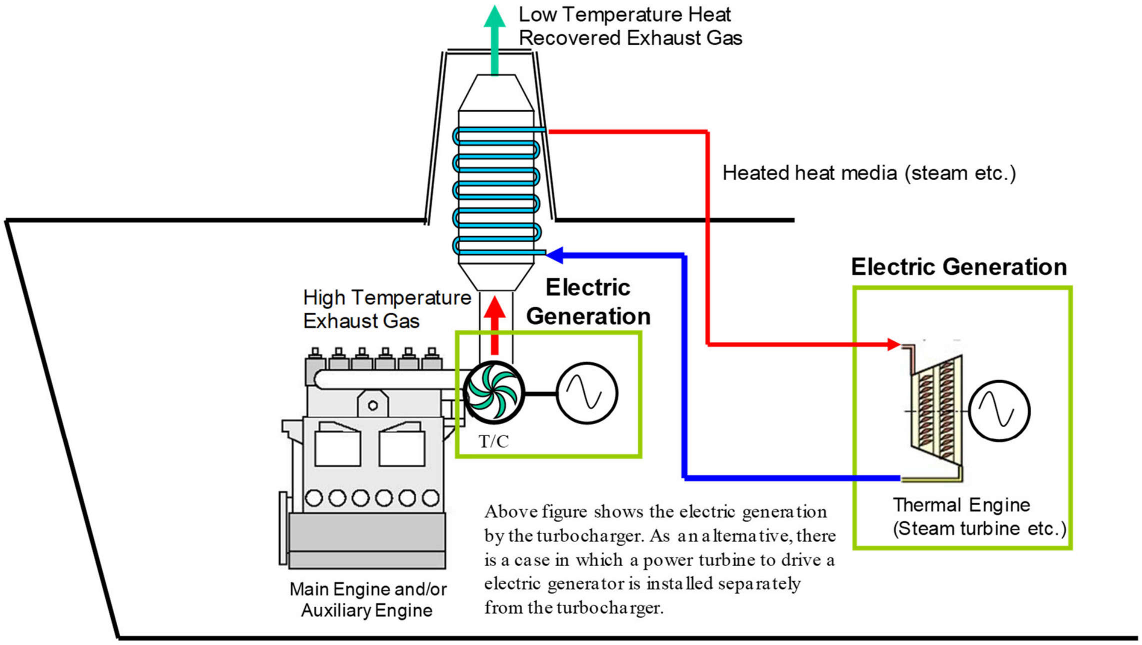

Figure 1 – Schematic illustration of Exhaust Heat Recovery

1.2 Method of calculation

1.2.1 Power reduction due to waste heating recovery system

1.2.1.1 The reduction of power by the waste heat recovery system is calculated by the following equation. For this system, f_{eff} is 1.00 in EEDI formula.

$$P_{AEeff} = P'_{AEeff} - P_{AEeff\_loss} \qquad (1)$$

In the above equation, P'_{AEeff} is power produced by the waste heat recovery system. P_{AEeff_Loss} is the necessary power to drive the waste heat recovery system.

1.2.1.2 P_{AEeff} is the reduction of the ship's total auxiliary power (kW) by the waste heat recovery system under the ship performance condition applied for EEDI calculation. The power generated by the system under this condition and fed into the main switch board is to be taken into account, regardless of its application on board the vessel (except for power consumed by machinery as described in paragraph 1.2.1.4 of this chapter).

1.2.1.3 P'_{AEeff} is defined by the following equation.

$$P'_{AEeff} = \frac{W_e}{\eta_g}, \qquad (2)$$

where:

W_e : Calculated production of electricity by the waste heat recovery system
η_g : Weighted average generator efficiency

1.2.1.4 P_{AEeff} is determined by the following factors:

.1 temperature and mass flow of exhaust gas of the engines, etc.;

.2 constitution of the waste heat recovery system; and

.3 efficiency and performances of the components of the waste heat recovery system.

1.2.1.5 P_{AEeff_Loss} is the power (kW) for the pump, etc. necessary to drive the waste heat recovery system.

1.3 Method of verification

1.3.1 General

1.3.1.1 Verification of EEDI with innovative energy efficient technologies should be conducted according to the EEDI Survey Guidelines. Additional items concerning innovative energy efficient technologies not contained in EEDI Survey Guidelines are described below.

1.3.2 Preliminary verification at the design stage

1.3.2.1 In addition to paragraph 4.2.2 of EEDI Survey Guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 diagrams, such as a plant diagram, a process flow diagram, or a piping and instrumentation diagram outlining the waste heat recovery system, and its related information such as specifications of the system components;

.2 deduction of the saved energy from the auxiliary engine power by the waste heat recovery system; and

.3 calculation result of EEDI.

1.3.2.2 In addition to paragraph 4.2.7 of the EEDI Survey Guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 exhaust gas data for the main engine at 75% MCR (and/or the auxiliary engine at the measurement condition of SFC) at different ambient air inlet temperatures, e.g. 5°C, 25°C and 35°C; which consist of:

.1 exhaust gas mass flow for turbo charger (kg/h);

.2 exhaust gas temperatures after turbo charger (C°);

.3 exhaust gas bypass mass flow available for power turbine, if any (kg/h);

.4 exhaust gas temperature for bypass flow (C°); and

.5 exhaust gas pressure for bypass flow (bar).

.2 in the case of system using heat exchanger, expected output steam flows and steam temperatures for the exchanger, based on the exhaust gas data from the main engine;

.3 estimation process of the heat energy recovered by the waste heat recovery system; and

.4 further details of the calculation method of P_{AEeff} defined in paragraph 1.2.1 of this chapter.

1.3.3 Final verification of the attained EEDI at sea trial

1.3.3.1 Deduction of the saved energy from the auxiliary engine power by the waste heat recovery system should be verified by the results of shop tests of the waste heat recovery system's principal components and, where possible, at sea trials.

1.3.3.2 In the case of systems for which shop tests are difficult to be conducted, e.g. in case of the exhaust gas economizer, the performance of the waste heat recovery system should be verified by measuring the amount of the generated steam, its temperature, etc. at the sea trial. In that case, the measured vapour amount, temperature, etc. should be corrected to the value under the exhaust gas condition when they were designed, and at the measurement conditions of *SFC* of the main/auxiliary engine(s). The exhaust gas condition should be corrected based on the atmospheric temperature in the engine-room (Measurement condition of *SFC* of main/auxiliary engine(s); i.e. 25°C), etc.

2 PHOTOVOLTAIC POWER GENERATION SYSTEM (CATEGORY (C-2))

2.1 Summary of innovative energy efficient technology

2.1.1 Photovoltaic (PV) power generation system set on a ship will provide part of the electric power either for propelling the ship or for use inboard. PV power generation system consists of PV modules and other electric equipment. Figure 1 shows a schematic diagram of PV power generation system. The PV module consists of combining solar cells and there are some types of solar cell such as "Crystalline silicon terrestrial photovoltaic" and "Thin-film terrestrial photovoltaic", etc.

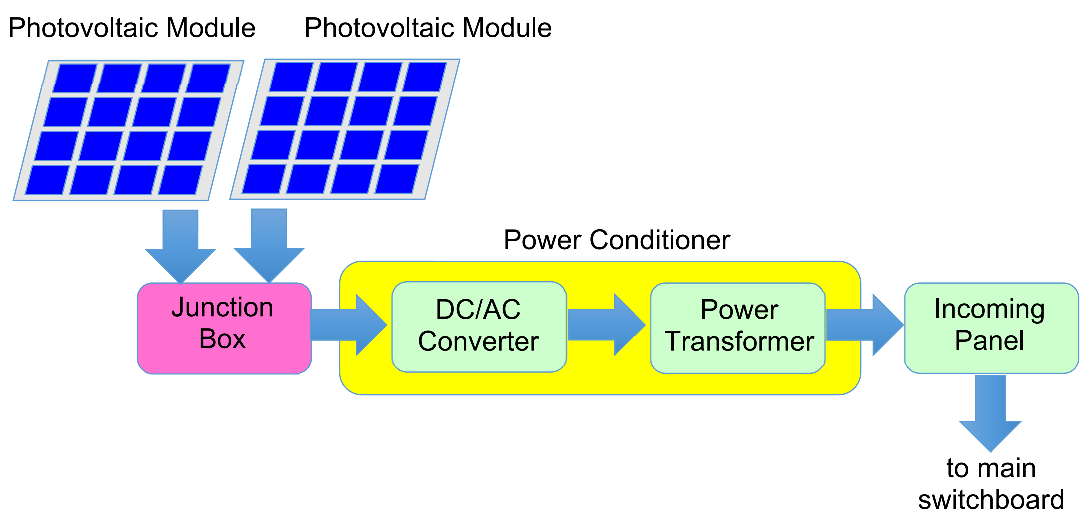

Figure 1 – Schematic diagram of photovoltaic power generation system

2.2 Method of calculation

2.2.1 Electric power due to photovoltaic power generation system

2.2.1.1 The auxiliary power reduction due to the PV power generation system can be calculated as follows:

$$f_{eff} \cdot P_{AEeff} = \{f_{rad} \times (1 + L_{temp} / 100)\} \times \{P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}\} \quad (1)$$

where $f_{eff} \cdot P_{AEeff}$ is the total net electric power (kW) generated by the PV power generation system.

2.2.1.2 Effective coefficient f_{eff} is the ratio of average PV power generation in main global shipping routes to the nominal PV power generation specified by the manufacturer. Effective coefficient can be calculated by the following formula using the solar irradiance and air temperature of main global shipping routes:

$$f_{eff} = f_{rad} \times (1 + L_{temp} / 100) \quad (2)$$

2.2.1.3 f_{rad} is the ratio of the average solar irradiance on main global shipping route to the nominal solar irradiance specified by the manufacturer. Nominal maximum generating power P_{max} is measured under the Standard Test Condition (STC) of IEC standard.[7] STC specified by manufacturer is that: Air Mass (AM) 1.5, the module's temperature is 25°C, and the solar irradiance is 1000 W/m^2. The average solar irradiance on main global shipping route is 200 W/m^2. Therefore, f_{rad} is calculated by the following formula:

$$f_{rad} = 200 \text{ W/m}^2 \div 1000 \text{ W/m}^2 = 0.2 \quad (3)$$

2.2.1.4 L_{temp} is the correction factor, which is usually in minus, and derived from the temperature of PV modules, and the value is expressed in per cent. The average temperature of the modules is deemed 40°C, based on the average air temperature on main global shipping routes. Therefore, L_{temp} is derived from the temperature coefficient f_{temp} (percent/K) specified by the manufacturer (see IEC standard[7]) as follows:

$$L_{temp} = f_{temp} \times (40°\text{C} - 25°\text{C}) \quad (4)$$

2.2.1.5 P_{AEeff} is the generated PV power divided by the weighted average efficiency of the generator(s) under the condition specified by the manufacturer and expressed as follows:

$$P_{AEeff} = P_{max} \times (1 - L_{others} / 100) \times N / \eta_{GEN}, \quad (5)$$

where η_{GEN} is the weighted average efficiency of the generator(s).

2.2.1.6 P_{max} is the nominal maximum generated PV power generation of a module expressed in kilowatt, specified based on IEC Standards.[7]

[7] Refer to IEC 61215 "Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval" for Crystalline silicon terrestrial PV modules, and to IEC 61646 "Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval" for Thin-film terrestrial PV modules.

2.2.1.7 L_{others} is the summation of other losses expressed by percent and includes the losses in a power conditioner, at contact, by electrical resistance, etc. Based on experiences, it is estimated that L_{others} is 10% (the loss in the power conditioner: 5% and the sum of other losses: 5%). However, for the loss in the power conditioner, it is practical to apply the value specified based on IEC Standards.[8]

2.2.1.8 *N* is the numbers of modules used in a PV power generation system.

2.3 Method of verification

2.3.1 General

2.3.1.1 Verification of EEDI with innovative energy efficient technologies is conducted according to EEDI Survey Guidelines**.** This section provides additional requirements related to innovative technologies.

2.3.2 Preliminary verification at the design stage

2.3.2.1 In addition to paragraph 4.2.2 of EEDI Survey guidelines, the EEDI Technical File which is to be developed by the shipowner or shipbuilder should include:

.1 outline of the PV power generation system;

.2 power generated by the PV power generation system; and

.3 calculated value of EEDI due to the PV power generation system.

2.3.2.2 In addition to paragraph 4.2.7 of the EEDI survey guidelines, additional information that the verifier may request the shipbuilder to provide directly to it includes:

.1 detailed calculation process of the auxiliary power reduction by the PV power generation system; and

.2 detailed calculation process of the total net electric power ($f_{eff} \cdot P_{AEeff}$) specified in section 2.2 in this guidance.

2.3.3 Final verification of the attained EEDI at sea trial

2.3.3.1 The total net electric power generated by PV power generation system should be confirmed based on the EEDI Technical File. In addition to the confirmation, it should be confirmed whether the configuration of the PV power generation systems on ship is as applied, prior to the final verification.

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8 IEC 61683 "Photovoltaic systems – Power conditioners – Procedure for measuring efficiency".