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**2013 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY
TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI**

1   The Marine Environment Protection Committee, at its sixty-fifth session
(13 to 17 May 2013), agreed to circulate the *2013 Guidance on treatment of innovative
energy efficiency technologies for calculation and verification of the attained EEDI*, as set out
in the annex (MEPC 65/22, paragraph 4.134.6).

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.

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SUSTAINABLE
DEVELOPMENT:
IMO'S CONTRIBUTION
BEYOND RIO+20

ANNEX

2013 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI

TABLE OF CONTENTS

1 General

1.1 The purpose of this guidance is to assist manufacturers, shipbuilders, shipowners, verifiers and other interested parties related to Energy Efficiency Design Index (EEDI) 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.

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 system on the ground 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 "2012 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships (resolution MEPC.212(63))".

2.2 *EEDI Survey Guidelines* means "2012 guidelines on survey and certification of the energy efficiency design index (EEDI) (resolution MEPC.214(63))".

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 2.5.3 of EEDI Calculation Guidelines).

2.4 In addition to the above, definitions of the words in this guidance are 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 not generate electricity. The saved energy is counted as P_{eff}
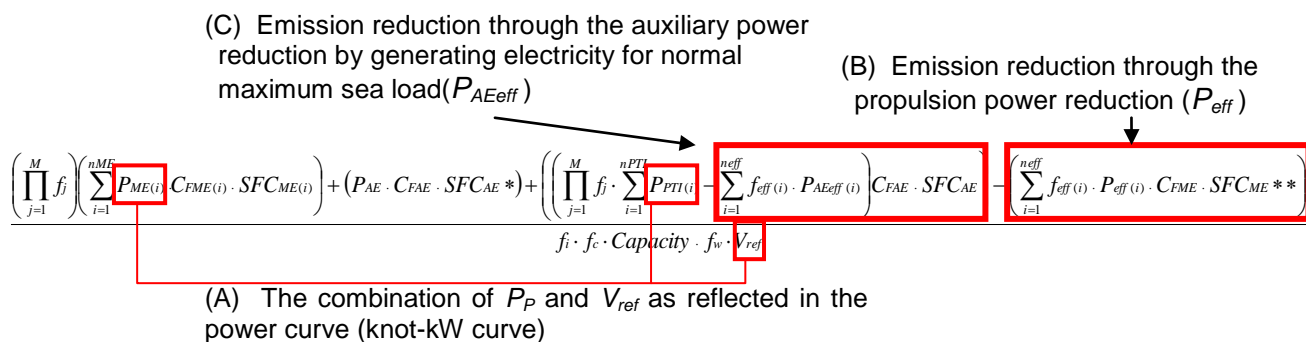
> ***Category (B-1)***: Technologies which can be used at any time during the operation and thus the availability factor (f_{eff}) should be treated as 1.00.

> ***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})

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

(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

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

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.

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

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 $\Sigma(f_{eff(i)} \cdot P_{eff(i)} \cdot C_F \cdot SFC)$ 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

Appendix 1

AIR LUBRICATION SYSTEM (CATEGORY (B-1))

1   Summary of innovative energy efficient technology

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.
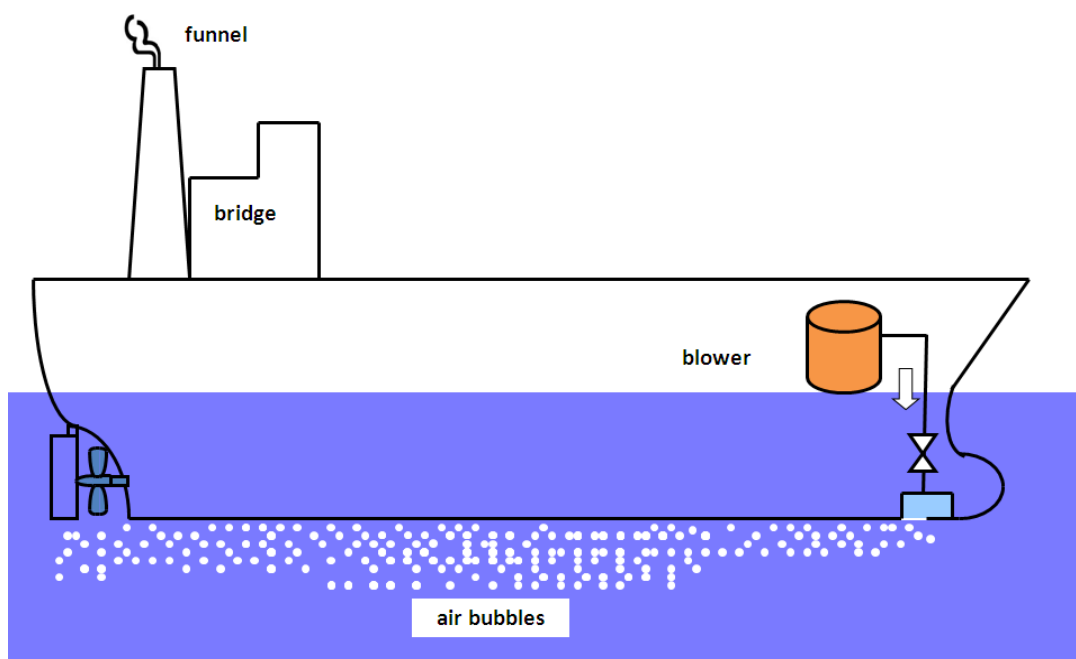

Figure 1 – Schematic illustration of an air lubrication system

2   Method of calculation

2.1   Power reduction due to air lubrication system

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.

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

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

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[1]   All examples in appendix are used solely to illustrate the proposed methods of calculation and verification.

2.1.1 P_{eff} is the effective power reduction in kW due to the air lubrication system at the 75 per cent of the rated installed power (MCR). In case that shaft generators are installed, P_{eff} should be calculated at the 75 per cent MCR having after deducted any installed shaft generators in accordance with paragraph 2.5 of EEDI Calculation Guidelines. P_{eff} should be calculated both in the fully loaded and the sea trial conditions.

2.1.2 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.

2.1.3 $P_{AEeffAL}$ 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 per cent 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.

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

2.2.1 V_{ref} in paragraph 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.

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.

3   Method of verification

3.1   General

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.

3.2   Preliminary verification at the design stage

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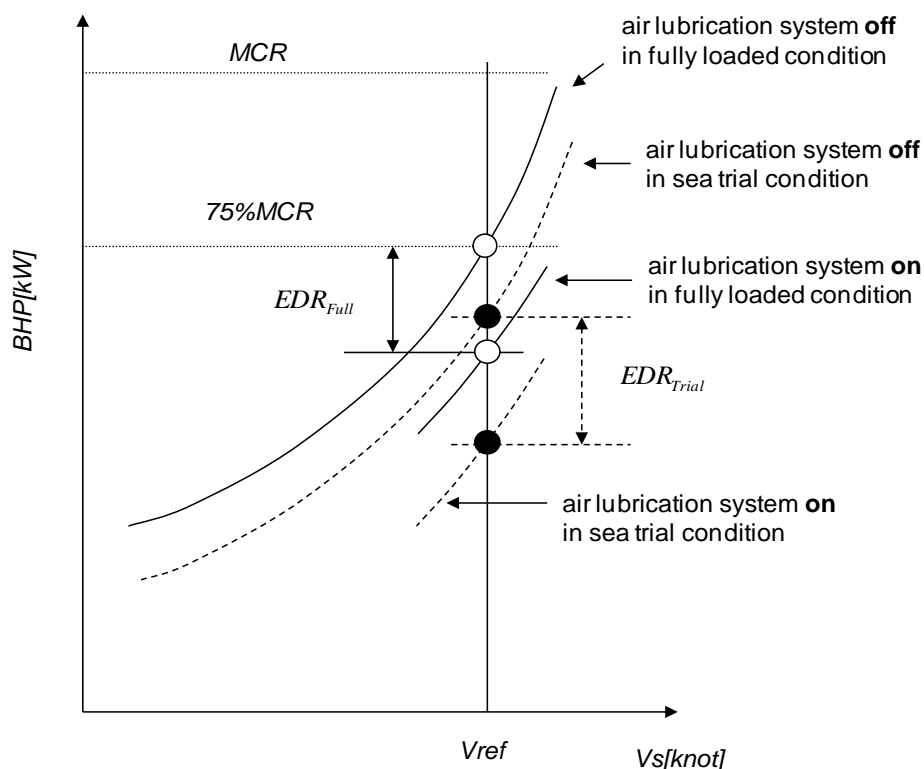
Figure 2 – Calculation of the reduction rate of propulsion power (EDR_{full} and EDR_{trial}) due to air lubrication system

.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.

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 : $P_{AEeffAL}$.

3.3 Final verification of the attained EEDI at sea trial

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.

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.

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.

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}.

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 per cent 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 per cent MCR having after deducted any installed shaft generators in accordance with paragraph 2.5 of EEDI Calculation Guidelines.

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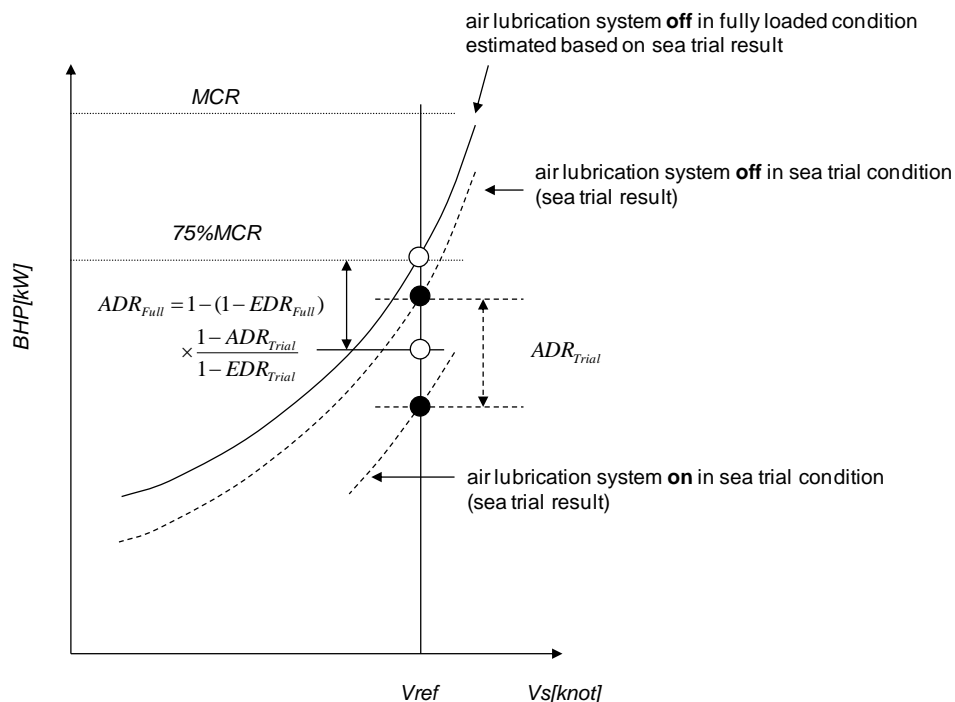
3.3.6 The shipbuilder should develop power curves for the air lubrication system ON based on the measured ship speed and output of the main engine at the sea trial. The following calculations should be conducted.

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

    .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.

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

air lubrication system **off** in fully loaded condition
estimated based on sea trial result

air lubrication system **off** in sea trial condition
(sea trial result)

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

ADR_{Trial}

air lubrication system **on** in sea trial condition
(sea trial result)

MCR

75%MCR

BHP[kW]

Vref   Vs[knot]

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

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:

$$P_{PeffAL\_Full} = ADR_{Full} \times P_P \tag{3}$$

$$P_{PeffAL\_Trial} = ADR_{Trial} \times P_P \tag{4}$$

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.

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

Appendix 2

WIND PROPULSION SYSTEM (CATEGORY B-2)

1   Summary of innovative energy efficient technology

1.1   Wind propulsion systems 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 wind propulsion systems as the product of the reference speed and the sum of the wind propulsion system force and the global wind probability distribution.

2   Definitions

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 propulsion systems* 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   *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. A detailed determination of the global wind probability matrix can be found in a separate submission (INF paper).

3   Available effective power of wind propulsion systems

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

$$\left(f_{eff} \cdot P_{eff}\right) = \left(\frac{0.5144 \cdot V_{ref}}{\eta_T} \sum_{i=1}^{m}\sum_{j=1}^{n} F(V_{ref})_{i,j} \cdot W_{i,j}\right) - \left(\sum_{i=1}^{m}\sum_{j=1}^{n} P(V_{ref})_{i,j} \cdot W_{i,j}\right)$$

Where:

.1   (f_{eff} * P_{eff}) is the available effective power in kW delivered by the specified wind 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_T is the total efficiency of the main drive(s) at 75 per cent of the rated installed power (MCR) of the main engine(s). η_T shall be set to [0.7], if no other value is specified and verified by the verifier.

.5 $F(V_{ref})_{i,j}$ is the force matrix of the respective wind propulsion system for a given ship speed V_{ref}.

.6 $W_{i,j}$ is the global wind probability matrix (see below).

.7 $P(V_{ref})_{i,j}$ is a matrix with the same dimensions as $F(V_{ref})_{i,j}$ and $W_{i,j}$ and represents the power demand in kW for the operation of the wind propulsion system.

3.2   The first 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 second term contains the power requirement for the operation of the specific wind propulsion system which has to be subtracted from the gained wind power.

4   Wind propulsion system force matrix $F(V_{ref})_{i,j}$

4.1   Every wind propulsion system has a distinctive force characteristic dependent on ship speed, wind speed and the wind angle relative to heading. The force characteristic can be expressed in a two dimensional matrix, holding elements for any combination of wind speed and wind angle relative to heading for a given ship speed V_{ref}.

4.2   Each matrix element represents the propulsion force in kilonewton (kN) for the respective wind speed and angle. The wind angle is given in relative bearings (with 0° on the bow). Table 1 gives guidance for the determination of the wind propulsion system force matrix **$F(V_{ref})_{i,j}$**. For the final determination of the CO_2 reduction of a system the force matrix must be approved by the verifier.

Table 1: Lay-out of a force matrix in kN for a wind propulsion system at V_{ref}

wind angle [°] wind speed [m/s]	0	5	…	355
<1	$f_{1,1}$	$f_{1,2}$	…	$f_{1,72}$
<2	$f_{2,1}$	$f_{2,2}$	…	$f_{2,72}$
<3	$f_{3,1}$	$f_{3,2}$	…	$f_{3,72}$
⋮	⋮	⋮	⋱	⋮
≥25	$f_{26,1}$	$f_{26,2}$	…	$f_{26,72}$

5   The global wind probability matrix $W_{i,j}$

5.1   **$W_{i,j}$** represents the probability of wind conditions. Each matrix element represents the probability of wind speed and wind angle relative to the ship coordinates. The sum over all matrix elements equals 1 and is non-dimensional. Table 2 shows the layout of the global wind probability matrix. The wind probability matrix shall be gained from the wind probability on the main global shipping routes[2].

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2   An example on a global wind probability matrix can be found in document MEPC 62/INF.34. This example should be subject to approval in a later session of MEPC.

Table 2: Lay-out of the global wind probability matrix

wind angle [°] wind speed [m/s]	0	5	…	355
<1	$w_{1,1}$	$w_{1,2}$	…	$w_{1,72}$
<2	$w_{2,1}$	$w_{2,2}$	…	$w_{2,72}$
<3	$w_{3,1}$	$w_{3,2}$	…	$w_{3,72}$
⋮	⋮	⋮	⋱	⋮
≥25	$w_{26,1}$	$w_{26,2}$	…	$w_{26,72}$

6 Effective CO_2 reduction by wind propulsion systems

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.

7 Verification of wind propulsion systems in the EEDI certification process

7.1 General

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.

7.2 Preliminary verification at the design stage

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 propulsion systems; and

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

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 $F(V_{ref})_{i,j}$ and results of performance tests[3].

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[4].

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[3] Performance test for the specific type of wind propulsion system are required to determine the wind propulsion system force matrix. Technical guidance for the conduction of performance tests should be subject to approval in a later session of MEPC.

[4] Technical guidance for the conduction of performance tests should be subject to approval in a later session of MEPC.

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.

7.3   Final verification of the attained EEDI at sea trial

The total net power generated by wind propulsion systems should be confirmed based on the EEDI Technical File. In addition to the confirmation, it should be confirmed prior to the final verification, whether the configuration of the wind propulsion systems on the ship is the same as applied in the pre-verification.

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ANNEX 2[5]

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

Appendix 1

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

1   Summary of innovative energy efficient technology

This Appendix 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 $V_{ref.}$.

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.

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

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

(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.

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[5]   All examples in appendix are used solely to illustrate the proposed methods of calculation and verification.
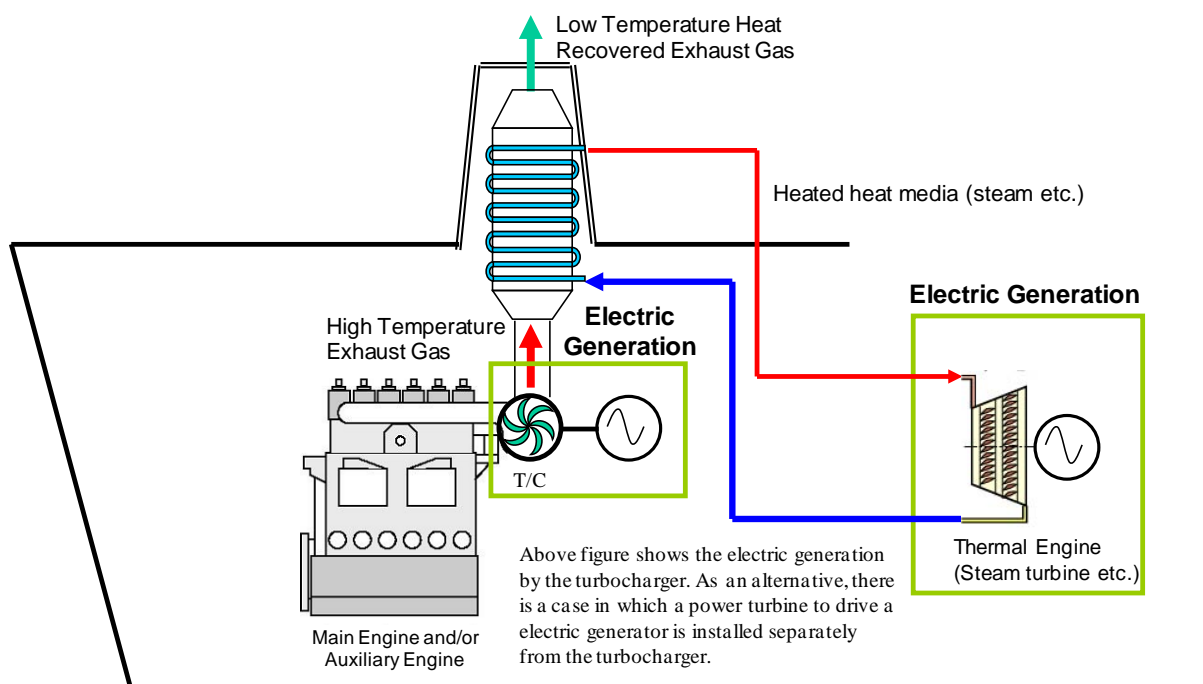
Figure 1 – Schematic illustration of Exhaust Heat Recovery

2 Method of calculation

2.1 Power reduction due to waste heating recovery system

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.

$$P_{AEeff} = P'_{AEeff} - P_{AEeff_{loss}}$$ (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.

2.1.1 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 2.1.4).

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

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

where:

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

2.1.3 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.

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

3   Method of verification

3.1   General

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.

3.2   Preliminary verification at the design stage

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.

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 per cent 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:

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

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

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

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

.1.5   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 2.1 of this appendix.

3.3 Final verification of the attained EEDI at sea trial

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.

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.

Appendix 2

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

1   Summary of innovative energy efficient technology

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.
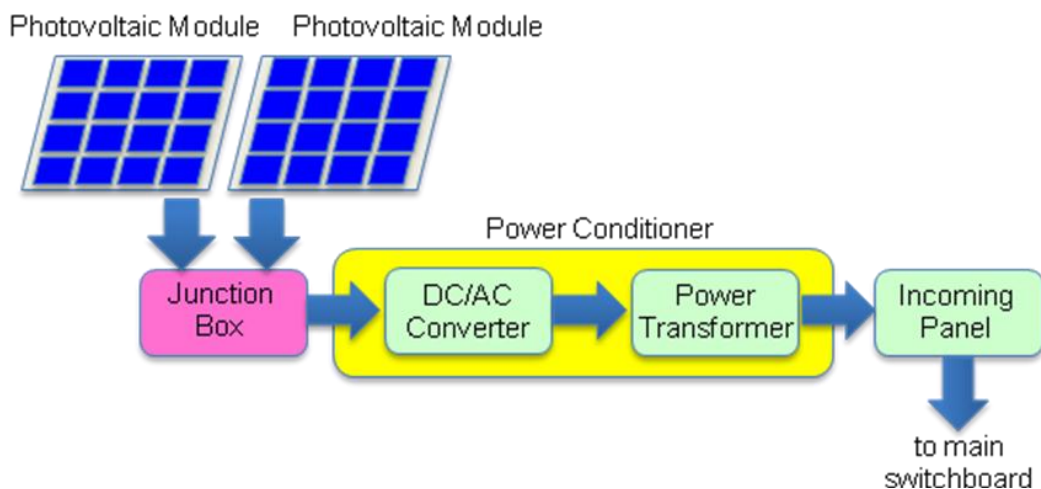

Figure 1 – Schematic diagram of photovoltaic power generation system

2   Method of calculation

2.1   Electric power due to photovoltaic power generation system

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

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

2.1.1 $f_{eff} \cdot P_{AEeff}$ is the total net electric power (kW) generated by the PV power generation system.

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:

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

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[6]. 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/m². The average solar irradiance on main global shipping route is 200 W/m². Therefore, f_{rad} is calculated by the following formula:

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

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[6]) as follows:

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

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:

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

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

2.1.6 P_{max} is the nominal maximum generated PV power generation of a module expressed in kilowatt, specified based on IEC Standards[6].

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 per cent (the loss in the power conditioner: 5 per cent 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[7].

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

3   Method of verification

3.1   General

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

3.2   Preliminary verification at the design stage

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:

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[6]   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.

[7]   IEC 61683 "Photovoltaic systems – Power conditioners – Procedure for measuring efficiency".

.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.

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 paragraph 2 in this guidance.

3.3 Final verification of the attained EEDI at sea trial

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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