

ESTIMATED EEDI VERSUS CALCULATED EEDI USING S/P TRIALS FOR A CHEMICAL OIL TANKER

Bosoanca Ioan

“Dunarea de Jos” University of Galati,
Faculty of Naval Architecture, Galati, Domneasca
Street, No. 47, 800008, Romania,
E-mail: ioan.bosoanca@ugal.ro

ABSTRACT

A cleaner environment to prevent dramatic climate changes is the goal of nowadays. Efforts to achieve this goal in marine field have been made by designers, shipbuilders, stakeholders, charterers and owners. Regarding the latest requirements, in the revised edition of ISO 15016 - 2015, see [2], has been shown the Marine Environment Protection Committee by IMO Resolution MEPC 214 (63) delivered a mandatory Guideline for ships, applied for survey and certification of attained EEDI (Energy Efficiency Design Index) for every new ship. Romanian designers and shipbuilders made special efforts to update this ship to the new rules of MEPC, having the goal to reduce marine pollution even this type of ship is in disadvantage regarding container vessels, where reducing speed is very easy with slow steamer technology. The paper presents the estimation of the attained EEDI onboard a new 40500 dwt Chemical Oil Tanker versus EEDI calculated on the basis of S/P trials.

Keywords: Cleaner environment, IMO Resolution, attained EEDI

1. INTRODUCTION

The necessity of a cleaner environment by reduction of gases emissions in marine field, has been quantified by a so called attained EEDI (*Energy Efficiency Design Index*) introduced by Marine Environment Protection Committee (MEPC) by the *Resolution 212 (63)*, according to [1], [3] and [7].

EEDI index being measured in grams CO₂ can be considered as CO₂ emission (pollution) per cargo transported tone.

Even there are some disputes on the edge of this index, until now is the only tools fully accepted by classification societies, to evaluate the CO₂ emission (pollution) onboard ships.

A good thing which happened is the EEDI encouraged the researchers and designers in marine field to use innovative devices and technologies which can save power onboard ships: rudder bulbs, fins (i.e. well-known PBCF – propeller boss cap fins), ducts and combination of them (i.e. well-known Mewis Duct) in front of propeller disk, slow steaming (especially for container vessels), solar power and wind energy there are just some examples.

According to [1] all new ships being greater than 400 gross tonnage must calculate this factor beginning with 2013 and the calculated value of this index shall be under the curve corresponding to *Phase 1* (2015 - 2020), for now on (see **Fig. 1**).

Beginning with 2020 all permissive value will be reduced with a supplementary 5 - 10% which means an additional 15 - 20% related to phase 0 (2013 - 2015).

The calculation formula according to [1], is:

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

where, in accordance with [3]:

f_j : correction factor for ship specific design elements;

P_{MEi} : power of main engines;

C_F : conversion factor between fuel consumption and CO₂ emission;

SFC : specific fuel consumption;

$P_{AE_{eff}}$: auxiliary power reduction;

P_{PTI} : shaft motor power;

f_{eff} : availability factor of innovative energy efficiency technology;

$P_{AE_{eff}}$: auxiliary power reduction;

f_i : capacity factor;

f_c : cubic capacity correction factor;

Capacity: bulk carriers, tankers, gas carriers, ro-ro cargo ships and general cargo ships shall use deadweight as capacity;

f_w : weather factor;

V_{ref} ; ship's speed.

EEDI Reduction factor Phase 1 (2015-2020)

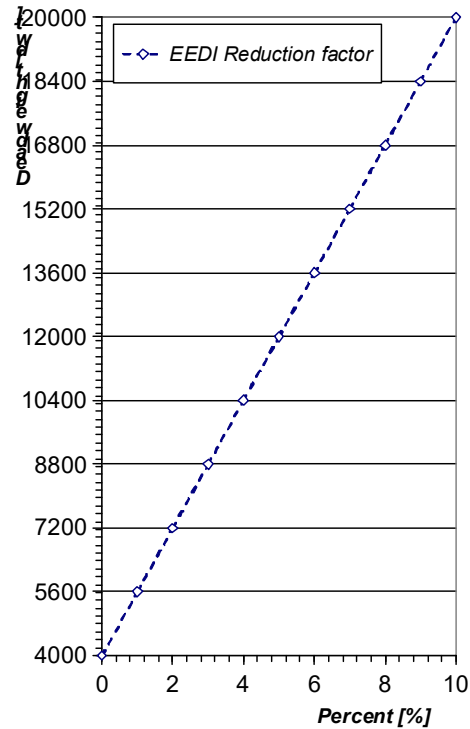


Fig. 1 EEDI Phase 1 (2015 - 2020)

2. SHIP DATA FOR EEDI CALCULUS

MAIN PARTICULARS according to [4]:

Classification: RINA, see [5], CSR (Common Structural Rules);

Hull:

- length overall approx.: **179.99** m;
- length between p.p. approx.: **173.3** m;
- breadth molded approx.: **32.26** m;
- depth approx.: **17.0** m;
- design draft: **10.6** m;
- deadweight (max.): **40500** dwt.

Machinery:

- 1 main engines MAN B&W having **6480 kW / 89 rpm** at MCR;
- 3 diesel generators **970 kW / 900 rpm** fueled with marine gas oil (MGO);
- 1 FPP with **4 blades** at **89 rpm**; propeller diameter: **6.50 m**.

Even this ship has a rudder bulb, the towing test report, delivered by HSWA Germany, concluded the power savings for the setting with the thickest rudder bulb and divergent hub cap vary from 'no-benefit' at 13 knots to 2.2 % reduced power at 15 knots. For this reason, no benefit has been taken in account in EEDI calculation. Also, no other energy saving equipment has been found onboard this ship.

The ship's profile is shown in the bellow **Fig. 2**:

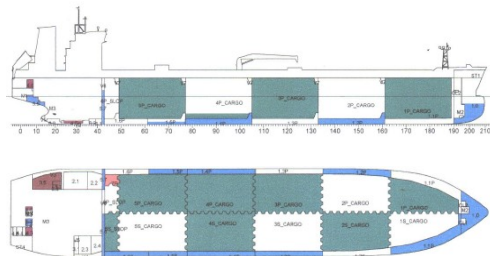


Fig. 2 Ship's profile (up: lateral view; down: upper view) at $T_F=T_A = 10.60\text{ m}$

Schematic arrangement of propulsion and electric system is shown in **Fig. 3**:

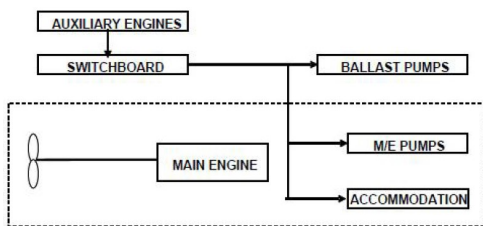


Fig. 3 Schematic figure of propulsion and electric power supply system

In **Fig. 4** is shown the location of diesel generators: Platform deck 2 (12800/13700 ABL).



Fig. 4 Platform Deck 2 (12800/13700 ABL)



Fig. 5 Side view

3. EEDI CALCULUS

With the above data, the estimated EEDI is according to Fig. 6:

MCR_{ME}	=	6480 kW
P_{ME}	=	4860 kW
i	=	1 -
MCR_{AE}	=	970 kW
MCR_{AE}	=	1125 kVA
$\eta_{kWe-kVA}$	=	0.86
i	=	3
1) P_{AE}	=	477.84 kW
Capacity	=	36784.5 dwt
V_{ref}	=	14.07 kts
C_{FME}	=	3.206
SFC_{ME}	=	168.3 g/kWh
C_{FAE}	=	3.206
SFC_{AE}	=	238 g/kWh
P_{PTO}	=	0 kW
f_j	=	1
2) f_i	=	1.022493
f_c	=	1
f_w	=	1
EstimEEDI	=	5.77 gCO ₂ /ton.mile

Fig. 6: EEDI Calculus

In this stage of calculus, the deadweight value is taken from Preliminary Stability of this ship. This value shall be compared with Required EEDI, see Fig. 1.

Required EEDI is a maximum permissive value of the attained EEDI for a certain ship's type and tonnage. The required EEDI represents a minimum energy efficiency requirement for new ships related of type and size.

For tankers, the required EEDI is calculated below, see Fig.7:

REQUIRED EEDI		
RequireEEDI = ReferenceEEDI = a*b ^{-c}		
a=	1218.8	
b=	36785	
c=	-0.488	
Required EEDI=	7.21 (gCO ₂ /ton.mile)	- phase 0 (2015 - 2015)
Required EEDI=	6.49 (gCO ₂ /ton.mile)	- phase 1 (2015 - 2020)

Fig. 7 Required EEDI

According to Fig. 6, in phase 1, regulation criteria is satisfied with of 11.05% margin.

The correspondent diagram P_B vs. V_S (Power in [kW] - ship's speed in [kts]) is shown in the below Fig. 8:

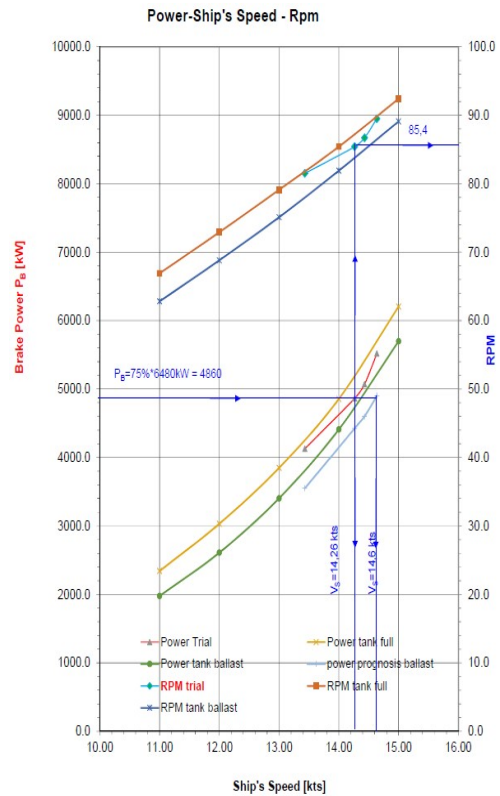


Fig. 8: The diagram P_B - V_S - Rpm recorded in S/P trials

4. S/P TRIALS

Sea trials of this ship have been conducted in the following manner, according to [4] and [7]:

- One double run, below EEDI M/E setting;
- Two double runs at EEDI M/E setting;
- One double run, at contractual M/E setting for contractual speed.

The calculated value on basis of S/P trials is shown in the below **Fig. 9**:

P_{ME}	=	5210	KW	M/E Power at Full Speed measured in sea trials in 24.08.2020
P_{ME}	=	3907.5	KW	75% P_{ME}
i	=	1	-	no. of M/Es
MCR_{AE}	=	970	KW	DG rated Power in KW
MCR_{AE}	=	1125	KVA	DG rated Power in KVA (kWe)
$\eta_{kwe-kva}$	=	0.86	-	The weighted average efficiency of generators
i	=	1	-	no. of A/Es running during trials
P_{AE}	=	416.00	KW	recorded from ECR (switchboard): DG1 set=416 kW; DG2 set=0 kW; DG3 set=0 kW
Capacity	=	37364	dwt	Deadweight at 10.6 m, acc. to FINAL INTACT STABILITY NB589 page - 52
V_{ref}	=	13.98	kts	Ship's speed at 75% load, ship's speed (uncorrected), acc. to DMG PROGRESSIVE S/P Trials, doc.no. 19.02 / 171.101.002
C_{FMEI}	=	3.206	-	
SFC_{MEI}	=	168.3	g/kWh	at 75% MCR acc. to Ship Test Report, ISO corrected, page 4-3
C_{FAE}	=	3.206	-	
SFC_{AE}	=	234	g/kWh	acc. to manufacturer specification (diagram)MEPC/Circ.855/Rev 2 page 3, 4.2.2.1
P_{PTO}	=	0	KW	
f_j	=	1	-	
f_i	=	1.022499	-	for CSR class notations, acc. to PR38 page 42 $f_{CSR} = 1 + 0.08 \cdot LWTC_{SR} / DWTC_{SR} = 1.0225$
f_c	=	1	-	
f_w	=	1	-	
EstimEEDI	=	4.63	gCO ₂ /ton.nm	

Fig. 9: Calculated EEDI on basis of the results measured in S/P trials acc. to [6]

Calculated EEDI on basis of S/P trials according to **Fig. 9**, is **5.17 gCO₂/ton.nm**, better than EEDI calculated in **Fig. 6**, **5.77 gCO₂/ton.nm**.

5. CONCLUDING REMARKS

Day by day the legislation on sea and ports related to pollution, is continuously updated having the goal to reduce the emissions, and to avoid climate changes.

A ship with a small pollution degree (small EEDI) can has access in any harbor, even in the harbors which are inside an ECA (Emission Control Area) with a very small accepted degree of pollution; for a certain ship this means better opportunities to find cargo, so to be more profitable.

The EEDI calculus is an important stage when the ship is delivered to owner, with a special attention not only of owner but class surveyors also. A clear procedure to perform this task onboard during S/P trials of ship assures accuracy results and reliable data necessary in the later analysis and syntheses. Based on them, the legislation in marine field can be updated and improved which finally means a cleaner environment.

For this ship, the S/P trials demonstrated a better EEDI index which means an important advantage not only for shipbuilder but also for ship's owner and, with a 11.9 % margin, satisfying the regulation criteria for the next phase 2 (between 2020 – 2025).

Even so, what is the next step to obtain a smaller EEDI in the years to come? One way to decrease the EEDI in order to fulfill the pollution limits is to apply innovative technologies:

Passive devices, regularly in front of propeller disk: PBCF (Propeller Boss Cap Fin), SILD (Sumitomo Integrated Lammeren Duct), PSS (DSME - Pre Swirl System), Mewis Duct etc... These devices use:

- a) fins to generate of a pre-rotation before propeller disk,
- b) have a duct ahead the propeller disk for direct flow to the inner radii,
- c) generate pre-swirl mainly inwards: reduction of hub vortex losses.

Regarding the efficiency of the Mewis Duct, investigations performed by author, see [8], onboard crude oil tanker of 165000 dwt, proved in sea trials a reduction of consumed power at shaft, in ballast conditions, of 3%.

- PTI/PTO generators: N/A for this configuration of the actual shaft line

due to variable revolution speed of M/E;

- Low steam engine;
- Dual fuel technologies;
- Fuel cell technologies etc...

These will be a challenge for marine designers in the next 10-20 years which will have the difficult task to updating and implementing these innovative technologies in shipbuilding.

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