MARINE ENVIRONMENT PROTECTION COMMITTEE
60th session
Agenda item 4

MEPC 60/4/33
15 January 2010
Original: ENGLISH

PREVENTION OF AIR POLLUTION FROM SHIPS

Energy Efficiency Design Index Baseline Evaluation for Tankers, Containerships, and LNG Carriers

Submitted by the Institute of Marine Engineering, Science and Technology (IMarEST)

SUMMARY

Executive summary:	This document provides information on the development of the baseline curves for the Energy Efficiency Design Index, as it applies to tankers, containerships, and LNG carriers
Strategic direction:	7.3
High-level action:	7.3.1
Planned Output:	7.3.1.3
Action to be taken:	Paragraph 24
Related documents:	MEPC 58/4/48, MEPC 58/4/34; GHG-WG 2/2/7, GHG-WG 2/2/9, GHG-WG 2/2/22; MEPC 59/4/20, MEPC 59/4/22, MEPC 59/4/37, MEPC 59/4/44; MEPC.1/Circ.681; MEPC 59/WP.8 and MEPC 60/4/33

Introduction and Background

1 This document is submitted in accordance with MSC-MEPC.1/Circ-2, Guidelines on the Organization and Method of Work.

2 MEPC.1/Circ.681 – Interim Guidelines on the method of calculation of the Energy Efficiency Design Index for new ships have provided a core methodology for the calculation of a new vessel's attained EEDI. MEPC 59 has approved the use of the EEDI on a voluntary basis, and has invited feedback based on application of the interim Guidelines.

3 This document presents information from a study conducted for the Society of Naval Architects and Marine Engineers (SNAME) Technical & Research Program. The intent of the Study is to provide a better understanding of the robustness of the EEDI in encouraging vessel optimization, and to determine whether development of baselines based on existing vessels with limited design data accurately reflects modern design practice. This document summarizes some

of the findings of that study relative to the EEDI baseline. The other elements and findings in the Study are presented in document MEPC 60/4/33. Study reports developed by ABS and HEC on behalf of SNAME can be accessed on the SNAME website at: www.sname.org.

4 A parametric series of standard designs over a range of vessel sizes was developed for three ship types: oil tankers, containerships and LNG carriers. Principal particulars were determined based on regression analysis of recent newbuildings. Required propulsive power was estimated based on comparison to good performing modern designs, and is intended to represent the upper quartile of performance of recent newbuildings. An attained EEDI was calculated for each of these designs in accordance with the guidance provided in MEPC.1/Circ.681. By developing the series of designs based on good design practice and consistent assumptions, the analysis provided a comparative basis for assessing the relative influence of assumptions on the EEDI. The attained indices for the series of standard designs were compared to the baseline curves presented in document GHG-WG 2/2/7 (Denmark). The equations in GHG-WG 2/2/7 are selected as they are most representative of the EEDI equation in its current form. They are based on data from the LRFP database with the agreed data quality standards detailed in the report of the Working Group on GHG emissions from ships (MEPC 59/WP.8).

Assumptions for analysis of EEDI

5 An attained EEDI is calculated for each design in accordance with the guidance provided in MEPC.1/Circ.681.

6 For each Standard Design, the design speed is taken as the average design speed for recent newbuildings of that ship type and size. The required operating power is taken as that needed to attain design speed with the vessel at its design draft assuming a service margin. Service margins are taken as 15% for tankers and small containerships, and 20% for large containerships and LNG carriers. For diesel-electric plants, the propulsion motor rating is set equal to the required operating power. For diesel driven designs, the required operating power equals 90% of the installed main engine power (MCR).

Note: This typical approach for sizing the engine yields an installed power 10% above the required power to attain service speed, and therefore the EEDI is increased accordingly. This is not the case for diesel-electric propulsion systems where the propulsions are typically rated without additional margin.

7 MAN B&W MC series engines are applied for tankers, MAN B&W ME series engines are applied for containerships and LNG carriers with DRL (Diesel Engine with re-liquefaction plant) propulsion, and MAN B&W series 51/60 DF are applied for LNG carriers arranged with DFDE (Dual Fuel Diesel Electric) propulsion plants. The appropriate engine is selected, with its MCR de-rated to the required installed power as determined in paragraph 6.

8 In accordance with MEPC.1/Circ.681, specific fuel consumptions for the main engine and auxiliary engines (SFC_{ME} and SFC_{AE}) are to be taken from the EIAPP Certificates at 75% MCR and 50% MCR respectively. The EIAPP certificates are usually developed from tests with the engine burning distillate fuels under ISO conditions. The SFC on the EIAPP certificates is typically about 2 to 4% higher than the published values provided by the manufacturer. In this study, specific fuel consumption is taken at the manufacturer's published figures adjusted for partial load (75% or 50%) and Tier II modifications (NO_x limits under the revised MARPOL Annex VI). A 3% increase in the published SFC (out of the listed manufacturer's 5% tolerance) is applied.

9 Conversion factors for "Diesel Gas / Oil" as per MEPC.1/Circ.681 are applied for engines burning fuel oil, as manufacturer's diesel engine testing for processing the EIAPP certificates are generally performed using DMX through DMC grade distillates and then corrected to ISO conditions. For LNG carriers burning boil off gas, the conversion factor for "Liquefied Natural Gas" is applied.

10 No innovative energy efficiency technologies or application of other correction factors (f_i, f_j, and f_w) are assumed for the standard ship designs in this Study.

Assessment of EEDI baseline for tankers

11 Principal characteristics and the attained EEDI for tankers are descried in Tables 1 and 2 below.

Particulars	Size Type	Panamax Product	Aframax Crude	Suezmax Crude	VLCC Crude
100% Cargo Capacity	m^3	54,000	132,000	180,000	360,000
Length Overall	m	182.000	249.000	280.000	333.000
LBP	m	174.000	239.000	270.000	320.000
Beam	m	32.200	44.000	48.000	58.000
Depth	m	19.000	21.200	24.000	31.200
Design Draft	m	11.20	13.60	15.90	21.00
Summer Loadline Draft	m	12.62	15.06	17.41	22.05
Lightship	tonnes	10,052	19,310	25,819	43,258
Design Block Coefficient		0.800	0.825	0.825	0.820
Deadweight at Design Draft	tonnes	41,533	101,932	148,869	285,154
Deadweight at Loadline draft	tonnes	49,203	116,135	166,576	303,032
Number of Screws		1	1	1	1
Design Speed: 15% SM at 90% MCR	knots	14.90	14.90	15.20	15.80
Required Engine Power (MCR)	kW	9,222	13,822	17,185	26,736

Table 1: Principal Characteristics of Standard Tanker Designs

EEDI Calculation	Size Type	Panamax Product	Aframax Crude	Suezmax Crude	VLCC Crude
100% Cargo Capacity	m^3	54,000	132,000	180,000	360,000
Main Engine Power, 75% MCR (P_{ME})	kW	6,916	10,366	12,888	20,052
Aux. Engine Power (P_{AE})	kW	461	596	680	918
SFC, Main Engine (SFC_{ME})	g-KWhr	177.3	176.3	176.3	175.3
SFC, Diesel Generators (SFC_{AE})	g-KWhr	204.5	204.5	204.5	204.5
Fuel Conv Factors (C_{FME} and C_{FAE})	t CO_2	3.206	3.206	3.206	3.206
Deadweight at SLL (*Capacity*)	tonnes	49,203	116,135	166,576	303,032
Speed at SLL and 75% MCR (V_{ref})	knots	14.47	14.44	14.78	15.49
Attained EEDI ($EEDI_A$)		5.95	3.73	3.14	2.53
Baseline EEDI ($EEDI_{BL}$)		6.11	3.86	3.19	2.32
$\%EEDI = (EEDI_A/EEDI_{BL}) - 1$		-2.7%	-3.5%	-1.5%	9.2%

Table 2: Attained Index for Standard Tanker Designs

12 For the panamax, aframax and suezmax standard tanker designs, the attained EEDI lies 1.5% to 3.5% below the EEDI baseline curves presented in document GHG-WG 2/2/7. However, the attained EEDI for the VLCC lies 9.2% above the curve. The design speed of the standard VLCC design is 15.8 knots, which is an average value for modern VLCCs. To achieve

compliance, the design speed must be reduced to 15.1 knots, well below the typical service speed of VLCCs. One would expect that the newer standard designs developed in this Study should lie below the EEDI baseline curve, as these are well optimized designs with modern engines.

13 Some differences in the attained EEDI and the baseline curve are to be expected, due to simplifying assumptions applied in document GHG-WG 2/2/7. GHG-WG 2/2/7 assumes constant values for specific fuel consumption (SFC_{ME} = 190 g/kWh and SFC_{AE} = 210 g/kWh) and C_{FME} and C_{FAE} factors for HFO rather than lighter fuel oils. The quoted speeds in the LRFP database are applied, which are generally speeds at the design draft rather than the summer load line draft. Also, the most common practice is to quote service speeds with 15% service margin and the main engine operating at 90% MCR, which equals 0.90/1.15 = 78.3% MCR rather than 75% MCR.

14 For illustration purposes, Table 3 shows the attained EEDI for the standard designs calculated using the same assumptions as in document GHG-WG 2/2/7. This analysis fails to explain why the standard VLCC shown in Table 2 as +9.2%, falls so far out of compliance. In fact, one finds that for tankers the overall impact of the simplifying assumptions is slightly conservative (tending to produce a higher attained EEDI value).

EEDI with GHG 2/2/7 Assumptions	Size Type	Panamax Product	Aframax Crude	Suezmax Crude	VLCC Crude
100% Cargo Capacity	m^3	54,000	132,000	180,000	360,000
Main Engine Power, 75% MCR (P_{ME})	kW	6,916	10,366	12,888	20,052
Aux. Engine Power (P_{AE})	kW	461	596	680	918
SFC, Main Engine (SFC_{ME})	g-KWhr	**190.0**	**190.0**	**190.0**	**190.0**
SFC, Diesel Generators (SFC_{AE})	g-KWhr	**210.0**	**210.0**	**210.0**	**210.0**
Fuel Type		**HFO**	**HFO**	**HFO**	**HFO**
Fuel Conv Factors (C_{FME} and C_{FAE})	t CO_2	**3.114**	**3.114**	**3.114**	**3.114**
Deadweight at SLL (*Capacity*)	MT	49,203	116,135	166,576	303,032
Service Speed at Design Draft (V_{ref})	knots	**14.90**	**14.90**	**15.20**	**15.80**
Attained EEDI ($EEDI_A$)		**5.99**	**3.77**	**3.19**	**2.60**
Baseline EEDI ($EEDI_{BL}$)		6.11	3.86	3.19	2.32
Influence of Simplifying Assumptions -- Comparison to Calculated EEDI in Table 2					
GHG 2/2/7 applies constant SFC values		+7.1%	+7.8%	+7.8%	+8.4%
GHG 2/2/7 applies HFO rather than MDO		-2.9%	-2.9%	-2.9%	-2.9%
Impact: Combination of SFC & Fuel Type		+3.6%	+4.2%	+4.2%	+4.8%
GHG 2/2/7 applies speed at design draft		-3.0%	-3.2%	-2.8%	-2.0%
Overall influence of simplifying assumptions		+0.8%	+1.2%	+1.5%	+3.0%

Table 3: Attained Index for Standard Tanker Designs applying WG-GHG 2/2/7 assumptions

15 The likely source for the discrepancy in the VLCC EEDI calculation is the application in document GHG-WG 2/2/7 of a single, exponential regression curve to represent all ships ranging from GT>400 to the largest vessels. At the tail of the curve representing the larger vessels, a majority of the data points lie above the curve. It is important that the baseline be a proper representation over the entire range of sizes, so that one particular size of vessel is not unduly impacted.

16 Principal characteristics and the attained EEDI for containerships are as set out in Table 4 below:

Particulars		Feedership	Panamax	Baby Neo-Panamax	Post-Panamax	Ultra Large
Slot Capacity	TEU	1,000	4,500	4,500	8,000	12,500
Length Overall	m	145.248	295.625	280.145	333.256	388.396
LBP	m	136.000	275.000	260.600	308.000	356.000
Beam	m	23.400	32.200	34.800	42.800	48.200
Depth	m	11.750	21.000	19.300	24.500	29.850
Design Draft	m	7.60	11.80	11.80	13.00	14.20
Summer Loadline Draft	m	8.51	13.22	13.22	14.56	15.90
Lightship	tonnes	5,022	19,119	19,071	31,752	47,063
Design Block Coefficient		0.655	0.630	0.630	0.630	0.665
Deadweight at Design Draft	tonnes	11,257	48,524	50,206	79,187	119,437
Deadweight at Loadline draft	tonnes	13,669	58,817	60,747	96,068	143,865
Number of Screws		1	1	1	1	1
Sea Margin		15%	15%	15%	15%	20%
Design Speed: with SM at 90% MCR	knots	18.50	24.50	24.50	25.00	25.00
Required Engine Power (MCR)	kW	9,337	38,532	41,330	57,843	75,920

Table 4: Principal Characteristics of Standard Containership Designs

EEDI Calculation		Feedership	Panamax	Baby Neo-Panamax	Post-Panamax	Ultra Large
Slot Capacity	TEU	1,000	4,500	4,500	8,000	12,500
Main Engine Power, 75% MCR (P_{ME})	kW	7,003	28,899	30,998	43,382	56,940
Aux. Engine Power (P_{AE})	kW	467	1,213	1,283	1,696	2,148
SFC, Main Engine (SFC_{ME})	g-KWhr	173.3	175.3	175.3	175.3	175.3
SFC, Diesel Generators (SFC_{AE})	g-KWhr	196.9	196.9	196.9	196.9	196.9
Fuel Conv Factors (C_{FME} and C_{FAE})	t CO_2	3.206	3.206	3.206	3.206	3.206
Deadweight at SLL (*Capacity*)	tonnes	13,669	58,817	60,747	96,068	143,865
Speed at SLL and 75% MCR (V_{ref})	knots	18.71	24.73	24.78	25.22	25.46
Attained EEDI ($EEDI_A$)		25.18	17.99	18.64	16.17	14.01
Baseline EEDI ($EEDI_{BL}$)		17.72	12.92	12.83	11.61	10.64
$\%EEDI = (EEDI_A/EEDI_{BL}) - 1$		42.1%	39.3%	45.3%	39.2%	31.7%

Table 5: Attained Index for Standard Containership Designs

17 It should be recognized that the GHG-WG 2/2/7 baseline curve was developed before the capacity for containerships was re-defined to 65% of the summer deadweight. This explains the large discrepancies between the attained EEDI for standard containerships and the baseline. However, it should be noted that the relative differences between the values suggests that, similar to tankers, the baseline may not be properly representing the larger ships.

18 Principal characteristics and the attained EEDI for LNG Carriers are shown below. All designs assume a membrane-type containment system. Single screw designs with dual fuel diesel-electric (DFDE) propulsion are evaluated for 150,000 to 215,000 m^3 LNG carriers. Twin skeg, twin screw designs fitted with direct drive slow speed diesel engines and reliquefaction plants (generally referred to as DRL propulsion) are evaluated for 180,000 to 265,000 m^3 LNG carriers. These assumptions are consistent with current practice. Whereas the majority of LNG carriers in service have steam propulsion plants, the preponderance of recent deliveries and ships on order are arranged with either DFDE or DRL propulsion plants.

Propulsion Plant Shafting Configuration		DFDE Single	DFDE Single	DFDE Single	DRL Twin	DRL Twin	DRL Twin
100% Cargo Capacity	m3	150,000	180,000	215,000	180,000	215,000	265,000
Length Overall	m	289.000	302.000	315.000	302.000	315.000	345.000
LBP	m	276.000	289.500	303.000	289.500	303.000	332.000
Beam	m	44.000	46.500	50.000	46.500	50.000	53.800
Depth	m	26.000	26.500	27.000	26.500	27.000	27.000
Design Draft	m	11.50	11.75	12.00	11.75	12.00	12.00
Summer Loadline Draft	m	12.45	12.70	13.00	12.70	13.00	13.00
Lightship	tonnes	31,349	35,064	39,858	36,168	41,029	48,159
Design Block Coefficient		0.746	0.757	0.770	0.757	0.770	0.788
Deadweight at Design Draft	tonnes	75,634	87,910	103,903	86,806	102,731	125,407
Deadweight at Load Line draft	tonnes	85,837	99,309	117,537	98,205	116,366	141,710
Design Speed: 20% SM at 90% MCR	knots	19.80	19.80	19.80	19.80	19.80	19.80
Required Brake Power	kW	25,930	28,317	31,696	26,417	29,374	33,665
Required for Main Propulsion (MCR)	kW	31,559	34,464	38,577	29,353	32,637	37,406

Table 6: Principal Characteristics of Standard LNG Carrier Designs

Propulsion Plant Shafting Configuration		DFDE Single	DFDE Single	DFDE Single	DRL Twin	DRL Twin	DRL Twin
100% Cargo Capacity	m^3	150,000	180,000	215,000	180,000	215,000	265,000
Rated Power of Propulsion Motors	KW	25,930	28,317	31,696			
Main Engine Electrical Efficiency		91.3%	91.3%	91.3%			
Installed Main Engine Power (MCR)	kW				29,352	32,638	37,406
Main Engine Power (P_{ME})	kW	21,303	23,264	26,040	22,014	24,478	28,054
Aux. Engine Power (P_{AE})	kW	898	958	1,042	984	1,066	1,185
Deadweight at SLL (Capacity)	tonnes	85,837	99,309	117,537	98,205	116,366	141,710
Speed at SLL and 75% MCR (V_{ref})	knots	19.10	19.11	19.12	19.58	19.59	19.64
Fuel Type (LNG)							
SFC, Main Engine (SFC_{ME})	g-KWhr	159.3	159.3	159.3			
SFC, Diesel Generators (SFC_{AE})	g-KWhr	159.3	159.3	159.3			
Fuel Conv Factors (C_{FME} and C_{FAE})	t CO_2	2.750	2.750	2.750	2.750	2.750	2.750
Attained EEDI ($EEDI_A$)		5.93	5.59	5.28			
Baseline EEDI ($EEDI_{BL}$)		6.76	6.32	5.85			
%EEDI = ($EEDI_A$/$EEDI_{BL}$) - 1		-12.2%	-11.5%	-9.7%			
Fuel Type (MDO)							
SFC, Main Engine (SFC_{ME})	g-KWhr	204.2	204.2	204.2	173.3	172.3	173.3
SFC, Diesel Generators (SFC_{AE})	g-KWhr	204.2	204.2	204.2	196.9	196.9	196.9
Fuel Conv Factors (C_{FME} and C_{FAE})	t CO_2	3.206	3.206	3.206	3.206	3.206	3.206
Attained EEDI ($EEDI_A$)		8.87	8.36	7.89	6.68	6.23	5.87
Baseline EEDI ($EEDI_{BL}$)		6.76	6.32	5.85	6.35	5.88	5.37
%EEDI = ($EEDI_A$/$EEDI_{BL}$) - 1		31.2%	32.2%	34.9%	5.2%	5.9%	9.4%

Table 7: Attained Index for Standard LNG Carrier Designs

19 The attained EEDI values for the DRL vessels burning MDO as typically applied for in the EIAPP certificate lie 5.2% to 9.4% above the baseline. The conformity between the attained EEDI and the baseline diverge for the larger vessels.

20 For the LNG carriers with DFDE propulsion plants, the attained EEDI falls significantly below the baseline curve when burning boil-off gas, and significantly above the curve when burning fuel oil.

Conclusions

21 The simplifying assumptions applied in document GHG-WG 2/2/7 deviate significantly from actual performance data, but appear to largely offset one another. This was verified for tankers, but should be confirmed also for other ship types.

22 The EEDI baselines are overly onerous for larger vessels. This appears to be true for all three ship types analyzed in this Study. Fitting of the regression curves should be reconsidered, to ensure that all sizes of ships are properly represented.

23 Use of historical data does not necessarily reflect modern practice. This is particularly true for LNG carriers, which in recent years have increased in size by more than 60% and transitioned from steam propulsion to DFDE and DRL propulsion.

Action requested of the Committee

24 The Committee is invited to take note of the information provided, consider the technical analysis described herein, and take action as appropriate.

___