Propulsion of 30,000 dwt
Handysize Bulk Carrier

Content

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Introduction

The main ship particulars of 30,000 dwt Handysize bulk carriers are normally approximately as follows: the overall ship length is 178 m, breadth 28 m and design/scantling draught 9.5 m/10.0 m, see Fig. 1.

Recent development steps have made it possible to offer solutions which will enable significantly lower transportation costs for Handysize bulk carriers (and tankers) as outlined in the following.

One of the goals in the marine industry today is to reduce the impact of CO_2 emissions from ships and, therefore, to reduce the fuel consumption for the propulsion of ships to the widest possible extent at any load.

This also means that the inherent design CO_2 index of a new ship, the so-called Energy Efficiency Design Index (EEDI), will be reduced. Based on an average reference CO_2 emission from existing bulk carriers, the CO_2 emission from new bulk carriers in gram per dwt per nautical mile must be equal to or lower than the reference emission figures valid for the specific bulk carrier.

This drive may often result in operation at lower than normal service ship speeds compared to earlier, resulting in reduced propulsion power utilisation.

The design ship speed at Normal Continuous Rating (NCR), including 15% sea margin, used to be as high as 14.0-14.5 knots. Today, the ship speed may be expected to be lower, possibly 13 knots, or even lower.

A more technically advanced development drive is to optimise the aftbody and hull lines of the ship – including bulbous bow, also considering operation in ballast condition. This makes it possible to install propellers with a larger propeller diameter and, thereby, obtaining higher propeller efficiency, but at a reduced optimum propeller speed, i.e. using less power for the same ship speed.

Fig. 1: Handysize bulk carrier

As the two-stroke main engine is directly coupled with the propeller, the introduction of the 'Green' ultra long stroke G40ME-B9.3 engine with even lower than usual shaft speed will meet this goal. The main dimensions for this engine type, and for other existing Handysize bulk carrier (and tanker) engines, are shown in Fig. 2.

On the basis of a case study of a 30,000 dwt Handysize bulk carrier in compliance with IMO Tier II emission rules, this paper shows the influence on fuel consumption when choosing the new G40ME-B engine compared with existing Handysize bulk carrier engines. The layout ranges of 6 and 7G40ME-B9.3 engines compared with 6 and 7S40ME-B9.3 are shown later in Fig. 4.

EEDI and Major Ship and Main Engine Parameters

Energy Efficiency Design Index (EEDI)

The Energy Efficiency Design Index (EEDI) is a mandatory instrument to be calculated and made as available information for new ships contracted after 1 January 2012. EEDI represents the amount of CO_2 in gram emitted when transporting one deadweight tonnage of cargo one nautical mile.

For bulk carriers, the EEDI value is essentially calculated on the basis of maximum cargo capacity, propulsion power, ship speed, SFOC (Specific Fuel Oil Consumption) and fuel type. However, certain correction factors are applicable, e.g. for installed Waste

Heat Recovery systems. To evaluate the achieved EEDI, a reference value for the specific ship type and the specified cargo capacity is used for comparison.

The main engine's SFOC incl. tolerance at 75% SMCR (Specified Maximum Continuous Rating) figure is as standard applied in the calculation of the EEDI figure, in which also the CO_2 emission from the auxiliary engines of the ship is included.

According to the rules finally decided on 15 July 2011, the EEDI of a new ship is reduced to a certain factor compared to a reference value. Thus, a ship built after 2025 is required to have a 30% lower EEDI than the reference figure.
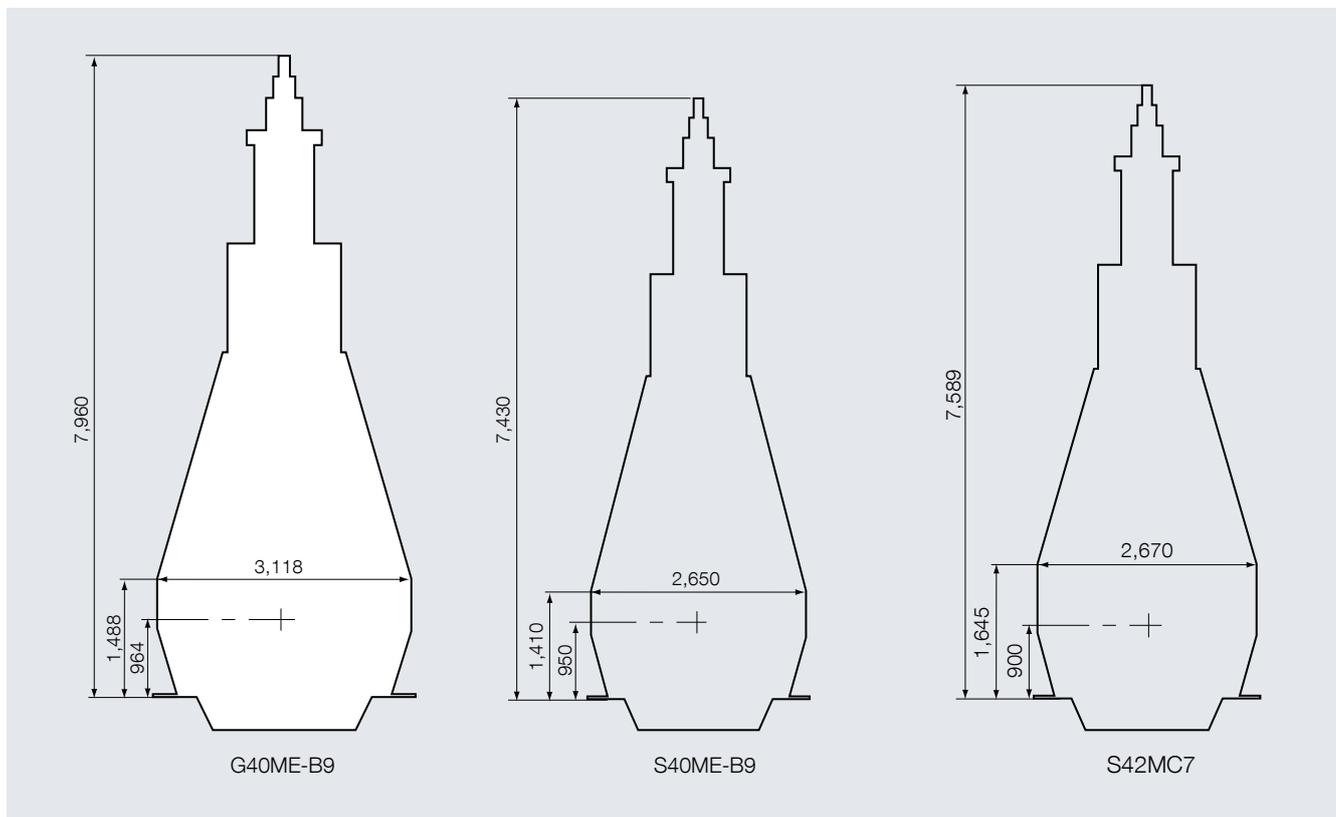

Fig. 2: Main dimensions for a G40ME-B9.3 engine and for other existing Handysize bulk carrier engines

Major propeller and engine parameters

In general, the highest possible propulsive efficiency required to provide a given ship speed is obtained with the largest possible propeller diameter d, in combination with the corresponding, optimum pitch/diameter ratio p/d.

As an example, this is illustrated for a 30,000 dwt Handysize bulk carrier with a service ship speed of 14 knots, see the black curve on Fig. 3. The needed propulsion SMCR (Specified Maximum Continuous Rating) power and speed is shown for a given optimum propeller diameter d and p/d ratio.

According to the black curve, the existing propeller diameter of 5.0 m may have the optimum pitch/diameter ratio of 0.71, and the lowest possible SMCR shaft power of about 6,700 kW at about 147 r/min.

The black curve shows that if a bigger propeller diameter of 6.0 m is possible, the necessary SMCR shaft power will be reduced to about 6,100 kW at about 105 r/min, i.e. the bigger the propeller, the lower the optimum propeller speed.

If the pitch for this diameter is changed, the propulsive efficiency will be reduced, i.e. the necessary SMCR shaft power will increase, see the red curve.

The red curve also shows that propulsion-wise it will always be an advantage to choose the largest possible propeller diameter, even though the optimum pitch/diameter ratio would involve a too low propeller speed (in relation to the required main engine speed). Thus, when using a somewhat lower pitch/diameter ratio, compared with the optimum ratio, the propeller/engine speed may be increased and will only cause a minor extra power increase.
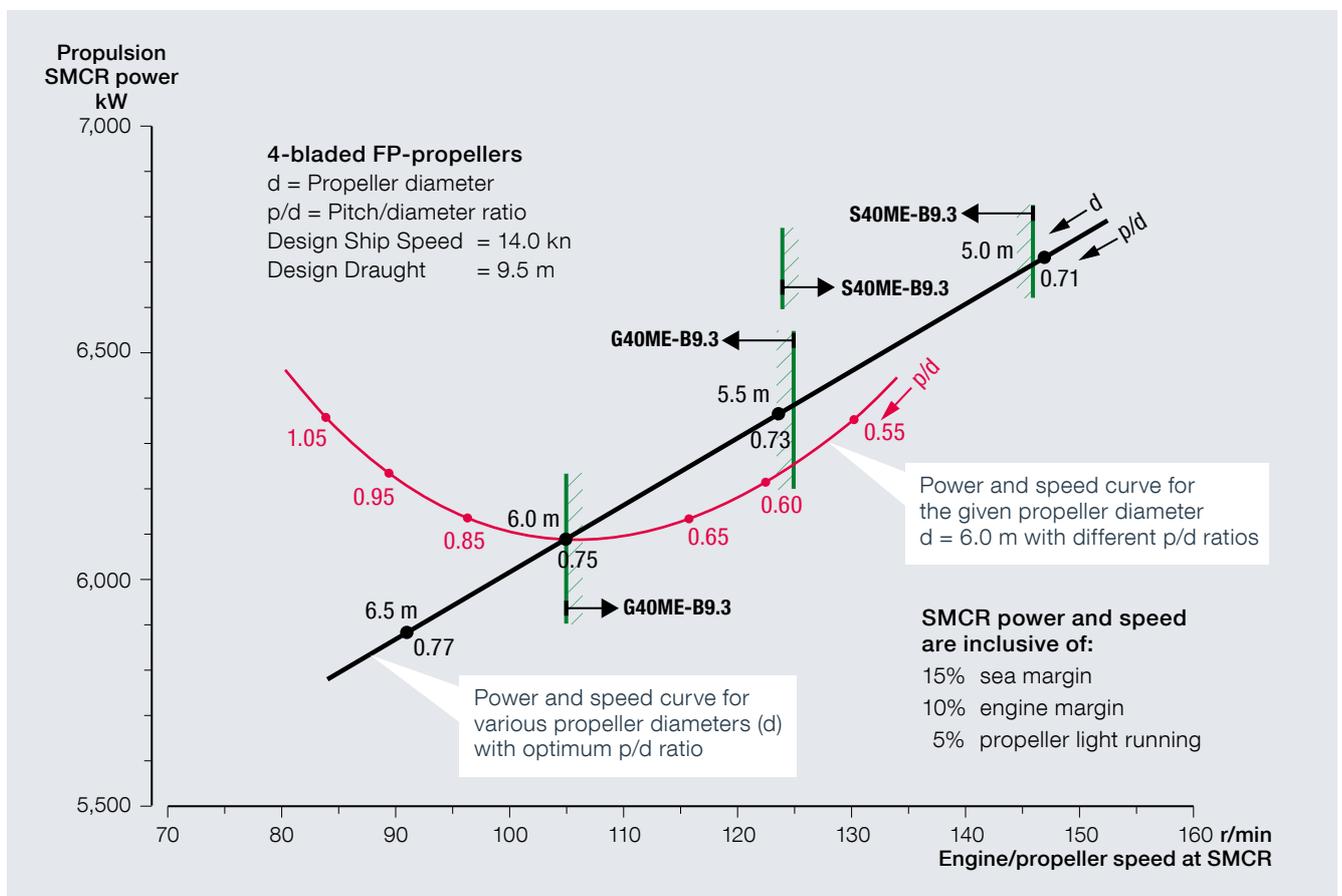

Fig. 3: Influence of propeller diameter and pitch on SMCR for a 30,000 dwt Handysize bulk carrier operating at 14.0 knots

The efficiency of a two-stroke main engine particularly depends on the ratio of the maximum (firing) pressure and the mean effective pressure. The higher the ratio, the higher the engine efficiency, i.e. the lower the Specific Fuel Oil Consumption (SFOC).

Furthermore, the higher the stroke/bore ratio of a two-stroke engine, the higher the engine efficiency. This means, for example, that an ultra long stroke en-

gine type, as the G40ME-B9.3, may have a higher efficiency compared with a shorter stroke engine type, like an S42MC-C.

The application of new propeller design technologies may also motivate use of main engines with lower rpm. Thus, for the same propeller diameter, these propeller types can demonstrate an up to 6% improved overall efficiency gain at about 10% lower propeller speed.

This is valid for propellers with Kappel technology available at MAN Diesel & Turbo, Frederikshavn, Denmark.

Hence, with such a propeller type, the advantage of the new low speed G40ME-B9.3 engine can be utilised also in case a correspondingly larger propeller cannot be accommodated.
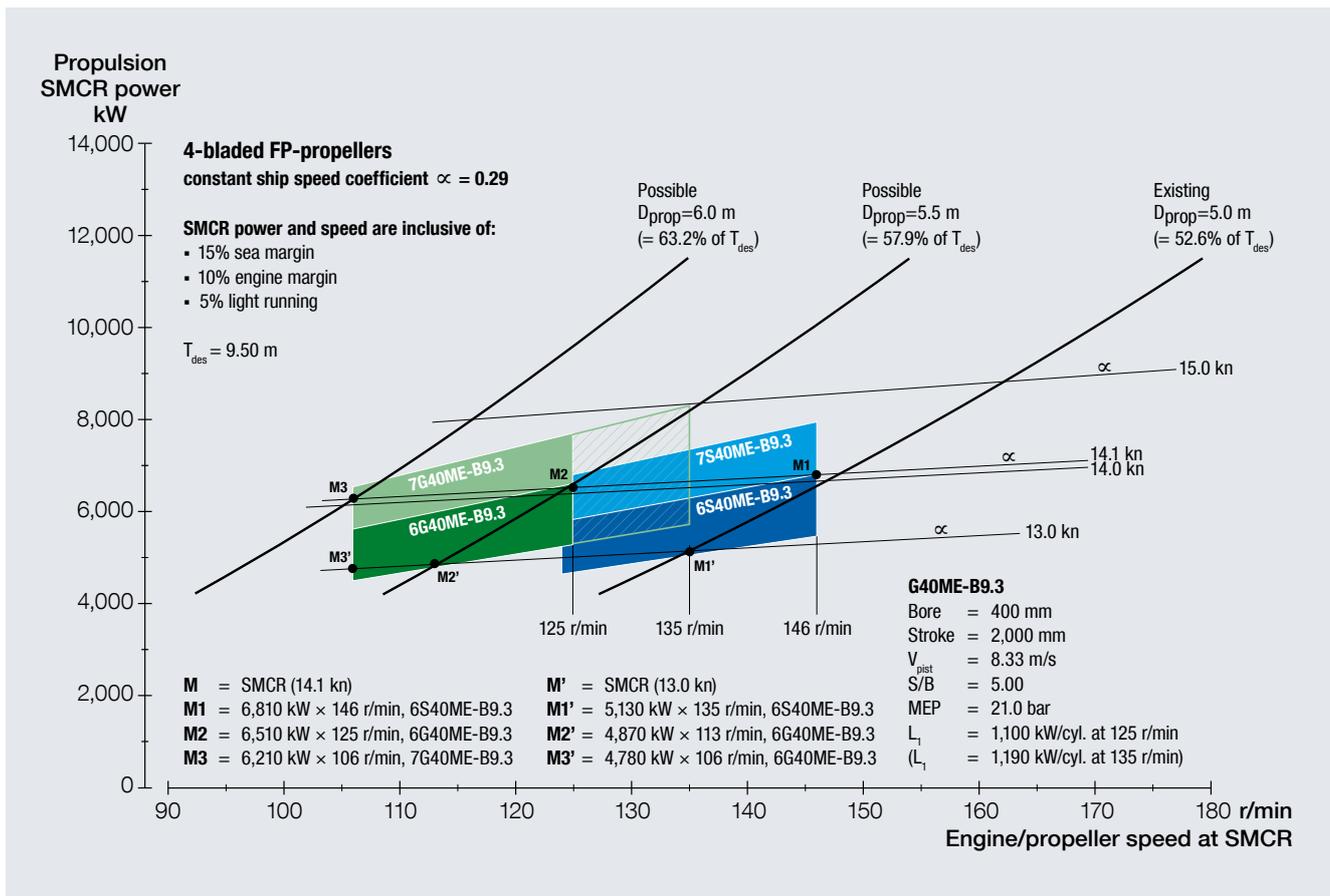

Fig. 4: Different main engine and propeller layouts and SMCR possibilities (M1, M2, M3 for 14.1 knots and M1', M2', M3' for 13.0 knots) for a 30,000 dwt Handysize bulk carrier operating at 14.1 knots and 13.0 knots, respectively

30,000 dwt Handysize bulk carrier

For a 30,000 dwt Handysize carrier, the following case study illustrates the potential for reducing fuel consumption by increasing the propeller diameter and introducing the G40ME-B9.3 as main engine. The ship particulars assumed are as follows:

Scantling draught	m	10.0
Design draught	m	9.5
Length overall	m	178.0
Length between pp	m	170.0
Breadth	m	28.0
Sea margin	%	15
Engine margin	%	10
Design ship speed	kn	14.1 and 13.0
Type of propeller		FPP
No. of propeller blades		4
Propeller diameter	m	target

Based on the above-stated average ship particulars assumed, we have made a power prediction calculation (Holtrop & Mennen's Method) for different design ship speeds and propeller diameters, and the corresponding SMCR power and speed, point M, for propulsion of the Handysize bulk carrier is found, see Fig. 4. The propeller diameter change corresponds approximately to the constant ship speed factor $\alpha = 0.29$ [ref. $P_{M2} = P_{M1} \times (n2/n1)^{\alpha}$.

Referring to the two ship speeds of 14.1 knots and 13.0 knots, respectively, three potential main engine types, 6S40ME-B9.3, 6G40ME-B9.3 and 7/6G40ME-B9.3 and pertaining layout diagrams and SMCR points have been drawn-in in Fig. 4, and the main engine operating costs have been calculated and described.

The S40ME-B9 engine type (146 r/min) has often been used in the past as prime movers in projects for Handysize bulk carriers. Therefore, a comparison between the new G40ME-B9.3 and the existing S40ME-B9.3 is of major interest in this paper.

It should be noted that the ship speed stated refers to NCR = 90% SMCR including 15% sea margin. If based on calm weather, i.e. without sea margin, the obtainable ship speed at NCR = 90% SMCR will be about 0.5 knots higher.

If based on 75% SMCR, as applied for calculation of the EEDI, the ship speed will be about 0.2 knot lower, still based on calm weather conditions, i.e. without any sea margin.
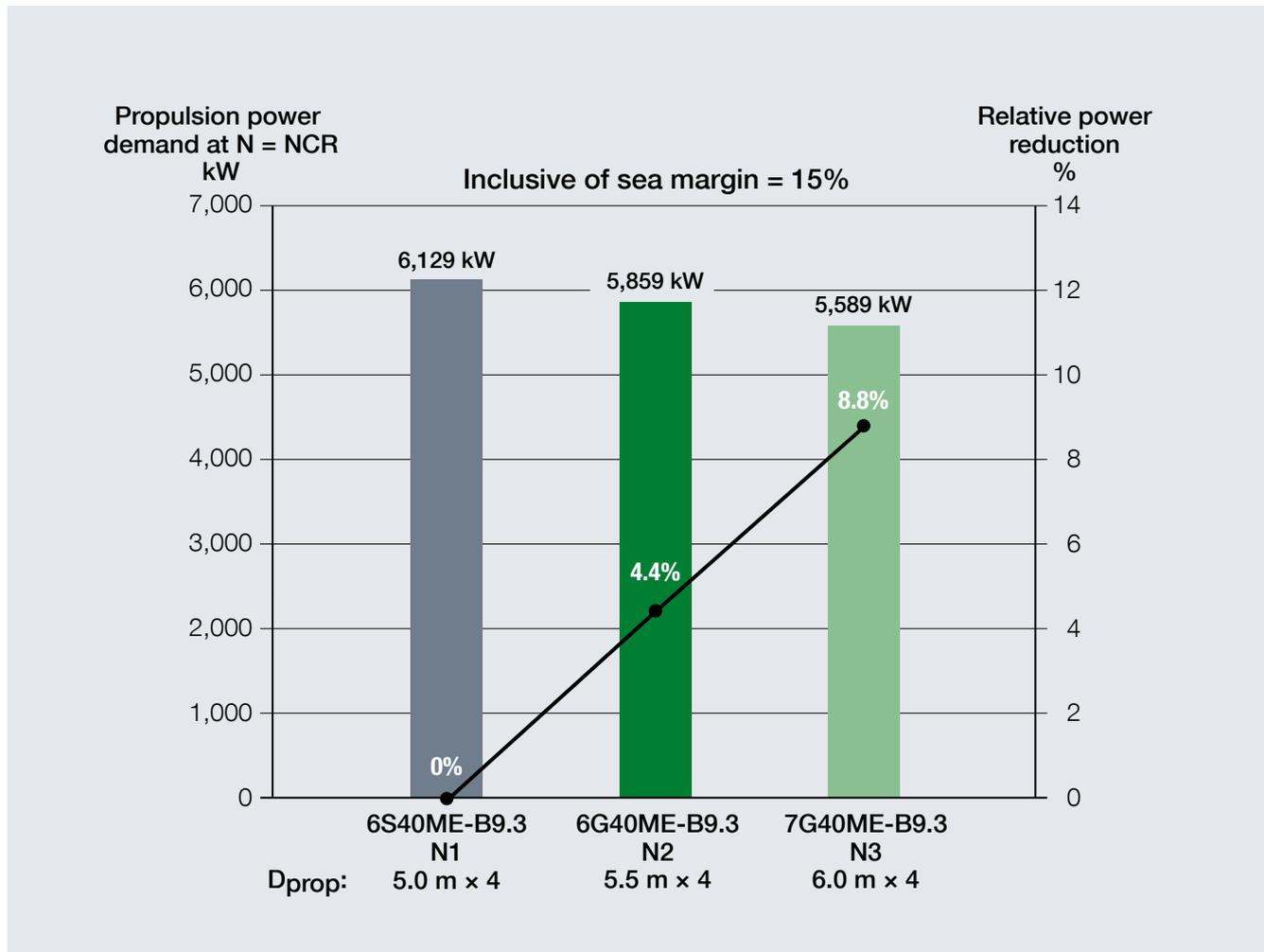
Fig. 5: Expected propulsion power demand at NCR = 90% SMCR for 14.1 knots

Main Engine Operating Costs – 14.1 knots

The calculated main engine examples are as follows:

14.1 knots

1.	6S40ME-B9.3 (D_{prop} = 5.0 m)
	M1 = 6,810 kW × 146.0 r/min
2.	6G40ME-B9.3 (D_{prop} = 5.5 m)
	M2 = 6,510 kW × 125.0 r/min.
3.	7G40ME-B9.3 (D_{prop} = 6.0 m)
	M3 = 6,210 kW × 106.0 r/min.

The main engine fuel consumption and operating costs at N = NCR = 90% SMCR have been calculated for the above three main engine/propeller cases operating on the relatively high ship speed of 14.1 knots, as often used earlier. Furthermore, the corresponding EEDI has been calculated on the basis of the 75% SMCR-related figures (without sea margin).

Fuel consumption and EEDI

Fig. 5 shows the influence of the propeller diameter with four propeller blades when going from about 5.0 m to 6.0 m. Thus, N3 for the 7G40ME-B9.3 with a 6.0 m propeller diameter has a propulsion power demand that is about 8.8% lower compared with N1 valid for the 6S40ME-B9.3 with a propeller diameter of about 5.0 m.
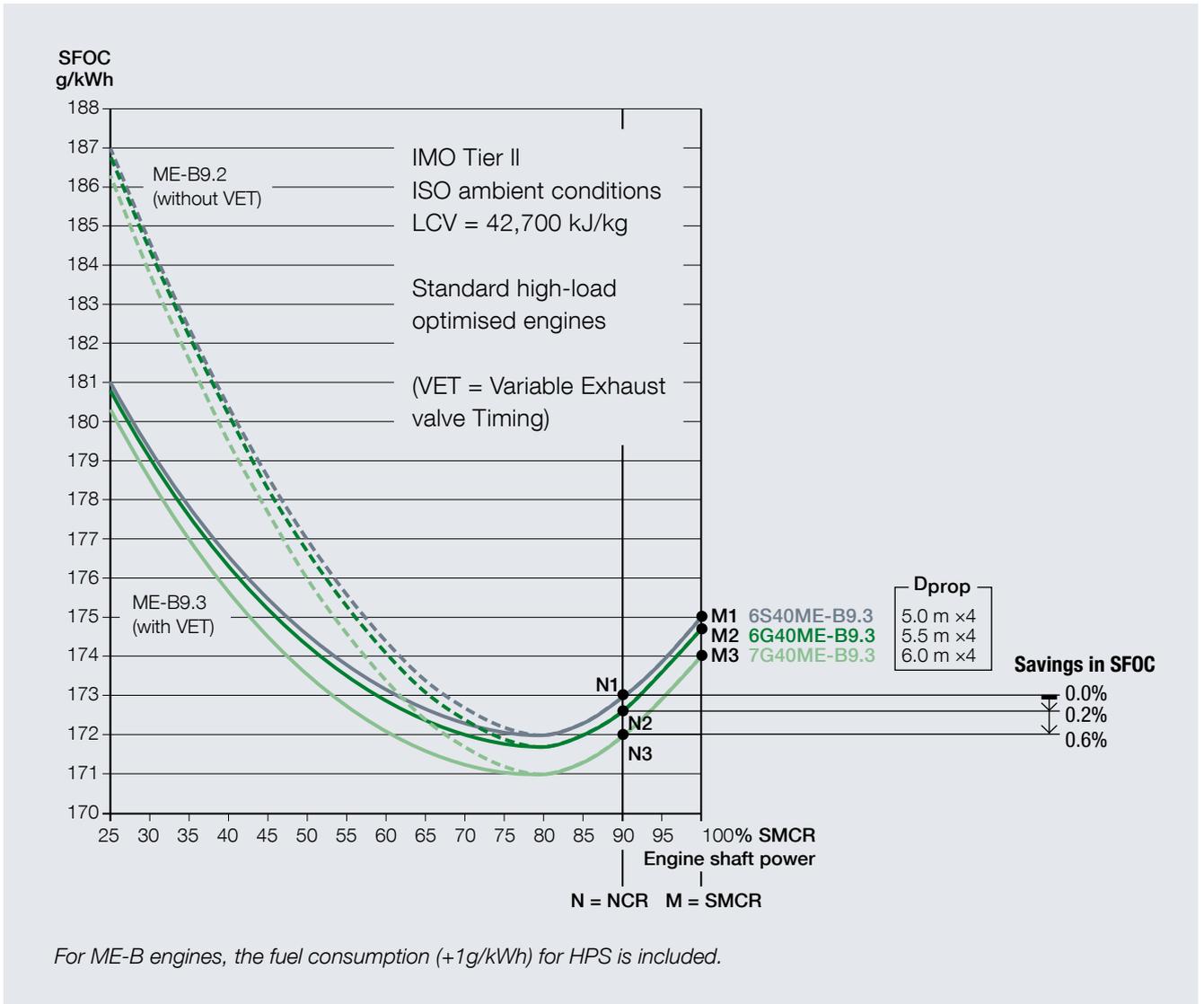
SFOC
g/kWh

IMO Tier II
ISO ambient conditions
LCV = 42,700 kJ/kg

Standard high-load
optimised engines

(VET = Variable Exhaust
valve Timing)

ME-B9.2
(without VET)

ME-B9.3
(with VET)

	Dprop	
M1 6S40ME-B9.3	5.0 m	×4
M2 6G40ME-B9.3	5.5 m	×4
M3 7G40ME-B9.3	6.0 m	×4

Savings in SFOC

0.0%
0.2%
0.6%

N1
N2
N3

Engine shaft power

N = NCR   M = SMCR

For ME-B engines, the fuel consumption (+1g/kWh) for HPS is included.

Fig. 6: Expected SFOC for 14.1 knots

Fig. 6 shows the influence on the main engine efficiency, indicated by the Specific Fuel Oil Consumption, SFOC, for the three cases. For N3 = 90% M3 with the 7G40ME-B9.3 SFOC is 172.0 g/kWh, for N2 = 90% M2 with 6G40ME-B9.3 SFOC is 172.7 g/kWh and for N1 = 90% M1 with 6S40ME-B9.3 SFOC is 173.0 g/kWh. In all cases for the ME-B engines, +1 g/kWh needed for the Hydraulic Power Supply (HPS) system is included. In N3, the SFOC is about 0.6% lower compared with N1.

All ME-B9.3 engine types are as standard fitted with VET (Variable Exhaust valve Timing) reducing the SFOC at part operation. The corresponding higher SFOC part load curves for engines without VET are also shown.

When multiplying the propulsion power demand at N (Fig. 5) with the SFOC (Fig. 6), the daily fuel consumption is found and is shown in Fig. 7. Compared with N1 for the existing 6S40ME-B9.3, the total reduction of fuel consumption of the new 6G40ME-B9.3 at N3 is about 9.4% (see also the above-mentioned savings of 8.8% and 0.6%).

The reference and the actual EEDI figures have been calculated and are shown in Fig. 8 ($EEDI_{ref}$ = 961.8 x dwt $^{-0.477}$, 15 July 2011). As can be seen for all three cases, the actual EEDI figures are relatively high with the lowest EEDI (98%) for case 3 with 7G40ME-B9.3.
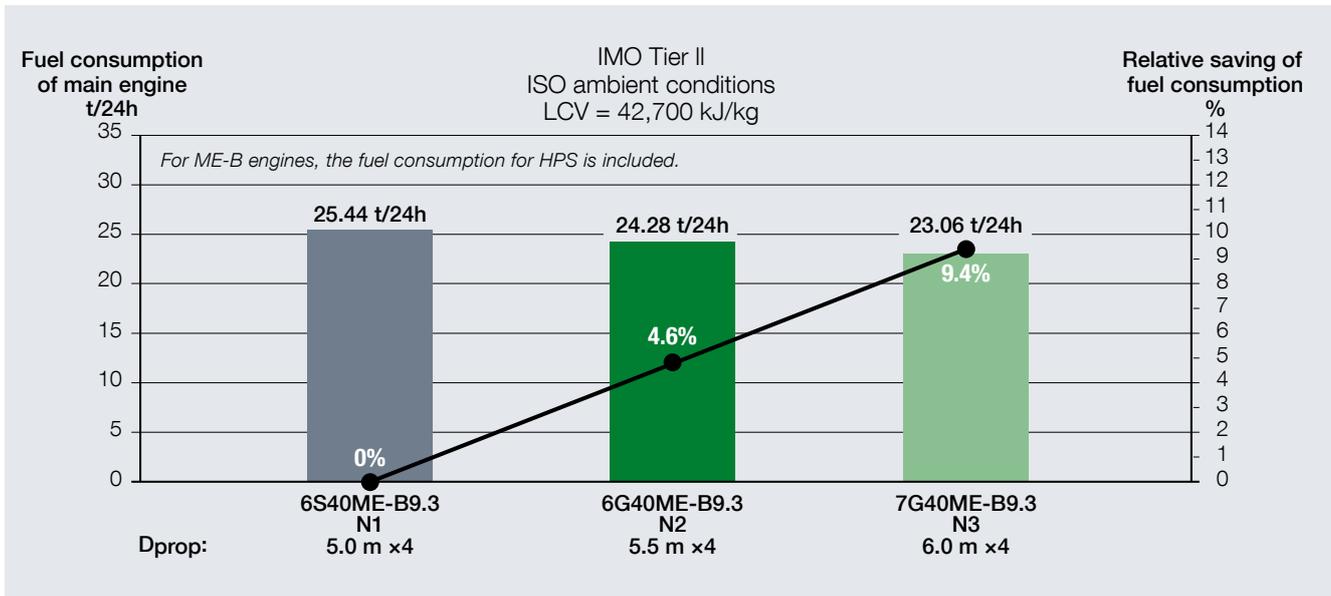

Fig. 7: Expected fuel consumption at NCR = 90% SMCR for 14.1 knots
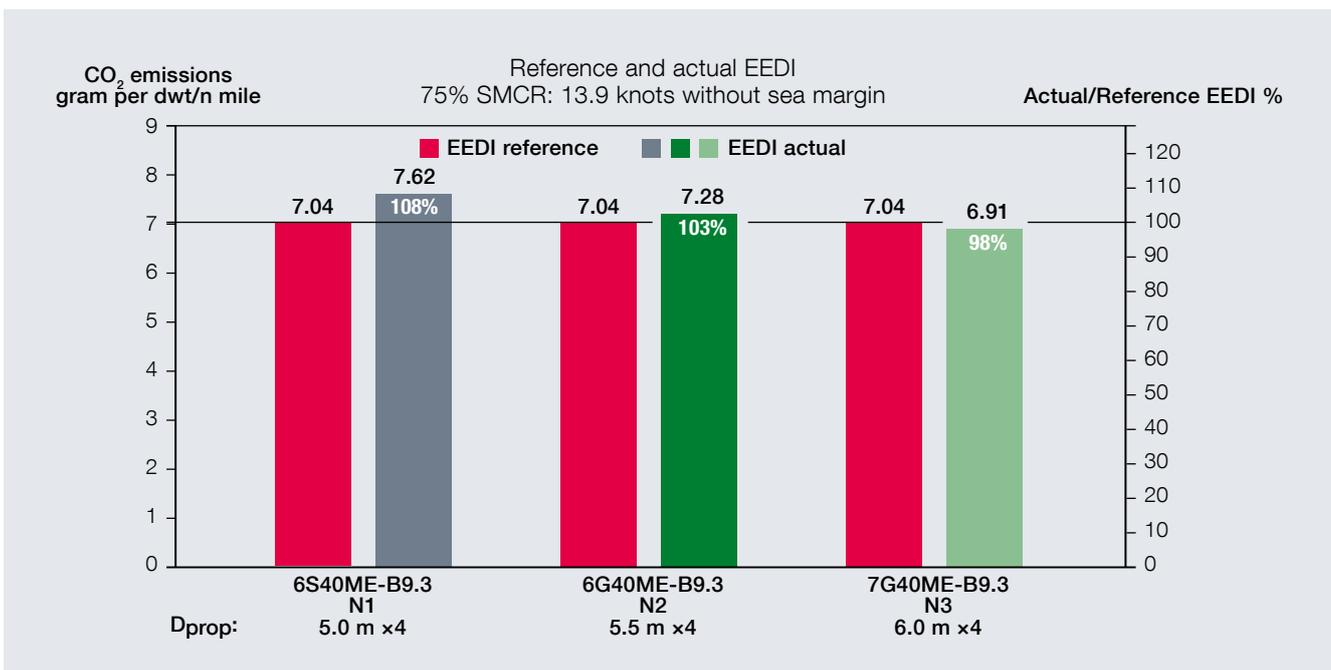

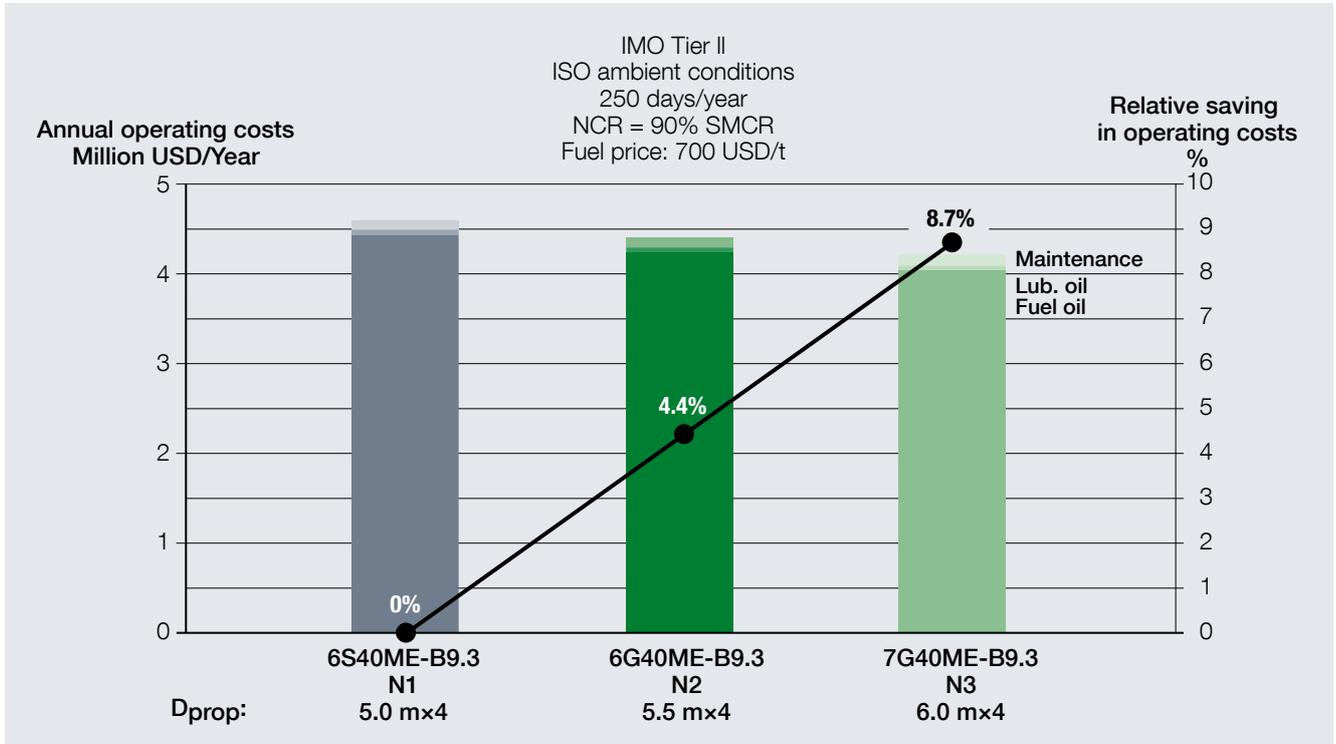Fig. 8: Reference and actual Energy Efficiency Design Index (EEDI) for 14.1 knots

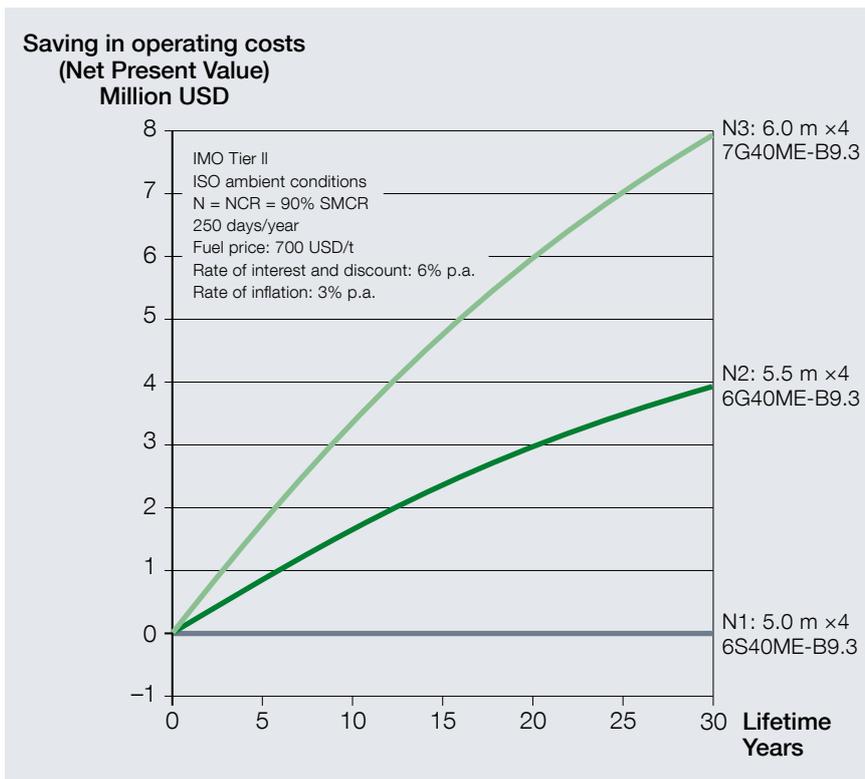Fig. 9: Total annual main engine operating costs for 14.1 knots

Fig. 10: Relative saving in main engine operating costs (NPV) for 14.1 knots

Operating costs

The total main engine operating costs per year, 250 days/year, and fuel price of 700 USD/t, are shown in Fig. 9. The lube oil and maintenance costs are shown too. As can be seen, the major operating costs originate from the fuel costs – about 96%.

After some years in service, the relative savings in operating costs in Net Present Value (NPV), see Fig. 10, with the existing 6S40ME-B9.3 used as basis with the propeller diameter of about 5.0 m, indicates an NPV saving for the new 6 and 7G40ME-B9.3 engines. After 25 years in operation, the saving is about 7.1 million USD for N3 with 7G40ME-B9.3 with the SMCR speed of 106.0 r/min and propeller diameter of about 6.0 m.
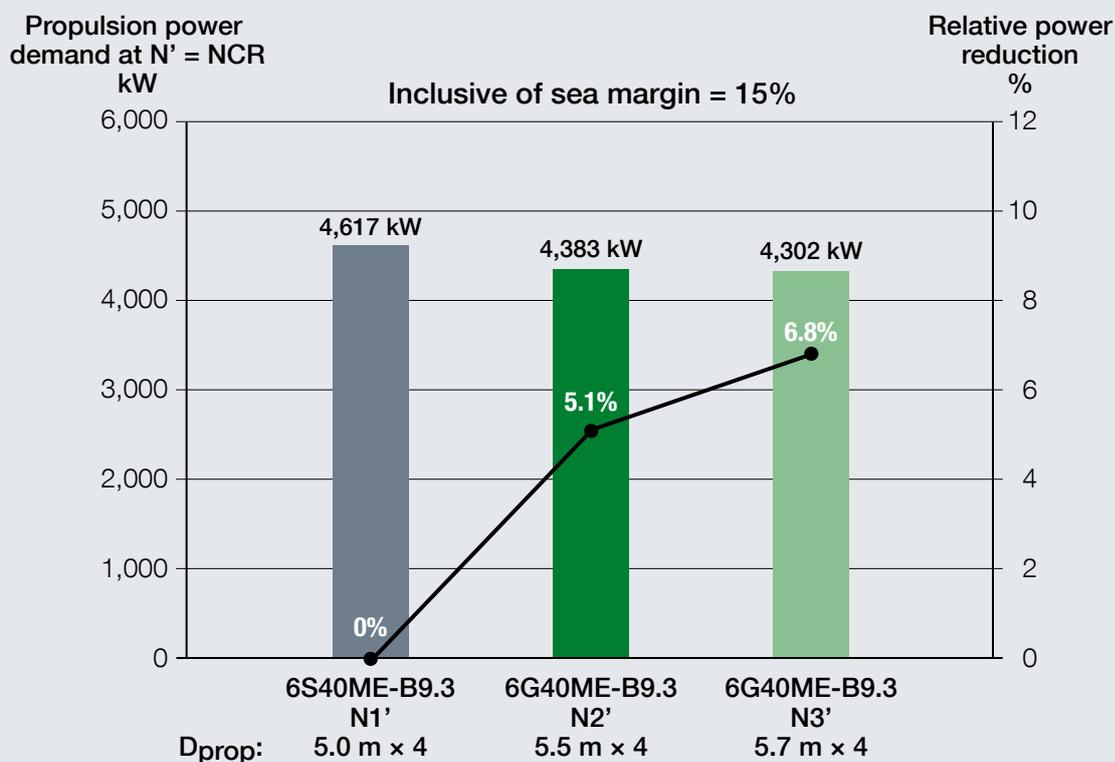
Fig. 11: Expected propulsion power demand at NCR = 90% SMCR for 13.0 knots

Main Engine Operating Costs – 13.0 knots

The calculated main engine examples are as follows:

13.0 knots

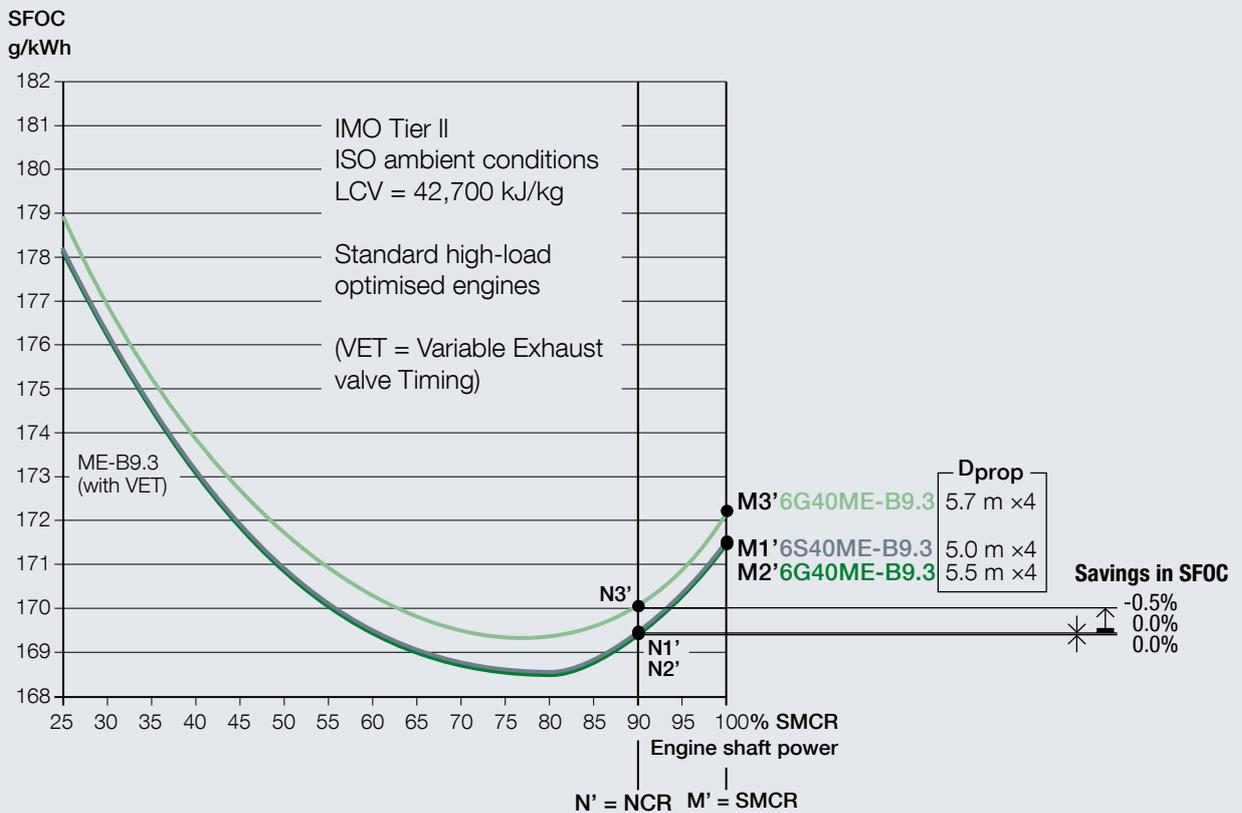|	
1'.	6S40ME-B9.3 (D_{prop} = 5.0 m)
	M1' = 5,130 kW × 135.0 r/min
2'.	6G40ME-B9.3 (D_{prop} = 5.5 m)
	M2' = 4,870 kW × 113.0 r/min.
3'.	6G40ME-B9.3 (D_{prop} = 5.7 m)
	M3' = 4,780 kW × 106.0 r/min.

The main engine fuel consumption and operating costs at N' = NCR = 90% SMCR have been calculated for the above three main engine/propeller cases operating on the relatively lower ship speed of 13.0 knots, which is probably going to be a more normal choice in the future. Furthermore, the EEDI has been calculated on the basis of the 75% SMCR-related figures (without sea margin).

Fuel consumption and EEDI

Fig. 11 shows the influence of the propeller diameter with four propeller blades when going from about 5.0 m to 5.7 m. Thus, N3' for the 6G40ME-B9.3 with an about 5.7 m propeller diameter has a propulsion power demand that is about 6.8% lower compared with the N1' for the 6S40ME-B9.3 with an about 5.0 m propeller diameter. For the three ME-B engine cases, an extra SFOC of +1 g/kWh has been added corresponding to the power demand needed for the Hydraulic Power Supply (HPS) system.

SFOC
g/kWh

IMO Tier ll
ISO ambient conditions
LCV = 42,700 kJ/kg

Standard high-load
optimised engines

(VET = Variable Exhaust
valve Timing)

ME-B9.3
(with VET)

	D_{prop}	
M3' 6G40ME-B9.3	5.7 m ×4	
M1' 6S40ME-B9.3	5.0 m ×4	
M2' 6G40ME-B9.3	5.5 m ×4	

Savings in SFOC
-0.5%
0.0%
0.0%

N3'

N1'
N2'

% SMCR
Engine shaft power

N' = NCR   M' = SMCR

For ME-B engines, the fuel consumption (+1g/kWh) for HPS is included.

Fig. 12: Expected SFOC for 13.0 knots

Fig. 12 shows the influence on the main engine efficiency, indicated by the Specific Fuel Oil Consumption, SFOC, for the three cases. N3' = 90% M3' with the 6G40ME-B9.3 has a relatively high SFOC of 170.1 g/kWh compared with the 169.3 g/kWh for N1' = 90% M1' for the 6S40ME-B9.3, i.e. an SFOC increase of about 0.5%, mainly caused by the greater speed derating potential giving higher mep of the G-engine type, but involving a higher potential propeller efficiency.

The daily fuel consumption is found by multiplying the propulsion power demand at N' (Fig. 11) with the SFOC (Fig. 12), see Fig. 13. The total reduction of fuel consumption of the new 6G40ME-B9.3, N3' with propeller diameter 5.7 m, is about 6.3% compared with the existing 6S40ME-B9.3 (see also the above-mentioned savings of 6.8% and –0.5%).

The reference and the actual EEDI figures have been calculated and are shown in Fig. 14 (EEDI$_{ref}$ = 961.8 × dwt $^{-0.477}$, 15 July 2011). As can be seen for all three cases, the actual EEDI figures are now somewhat lower than the reference figure because of the relatively low ship speed of 13.0 knots. Particularly, case 3' with 6G40ME-B9.3 has a low EEDI – about 81% of the reference figure.
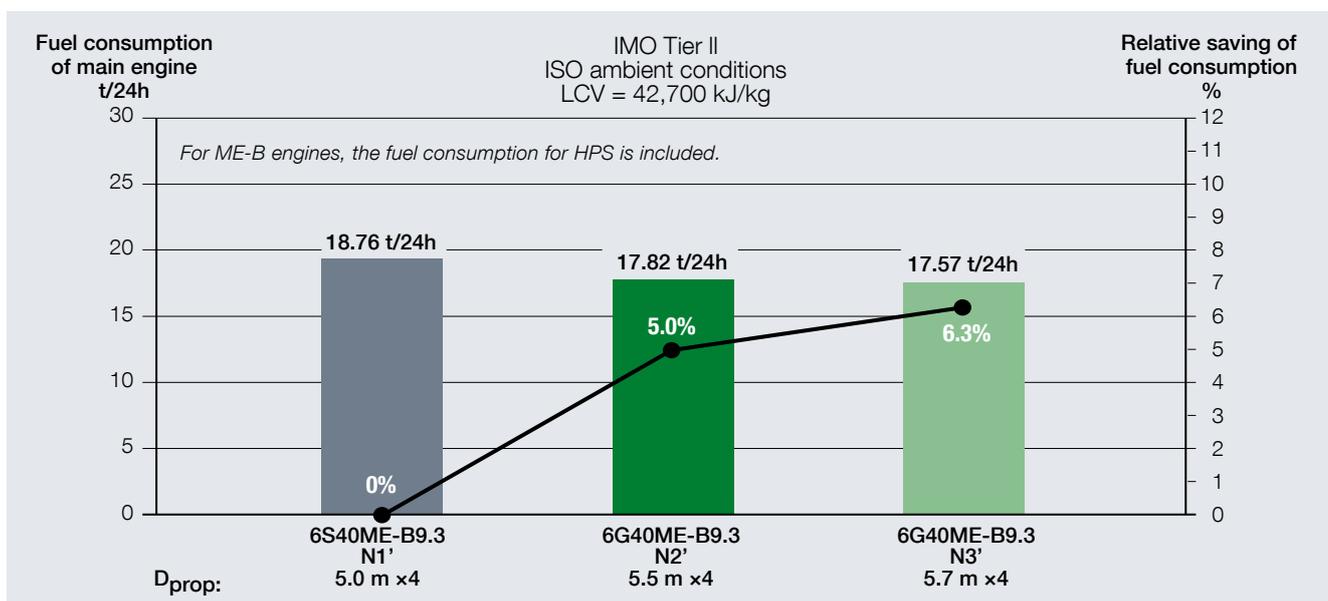

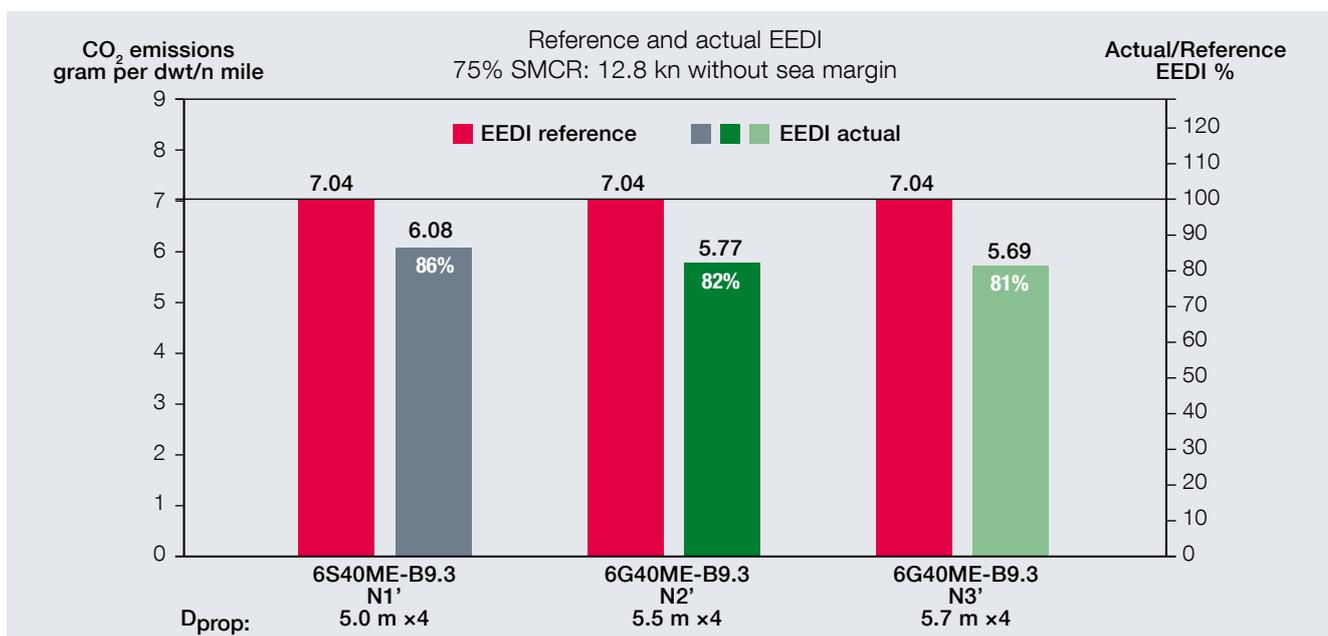Fig. 13: Expected fuel consumption at NCR = 90% SMCR for 13.0 knots

Fig. 14: Reference and actual Energy Efficiency Design Index (EEDI) for 13.0 knots
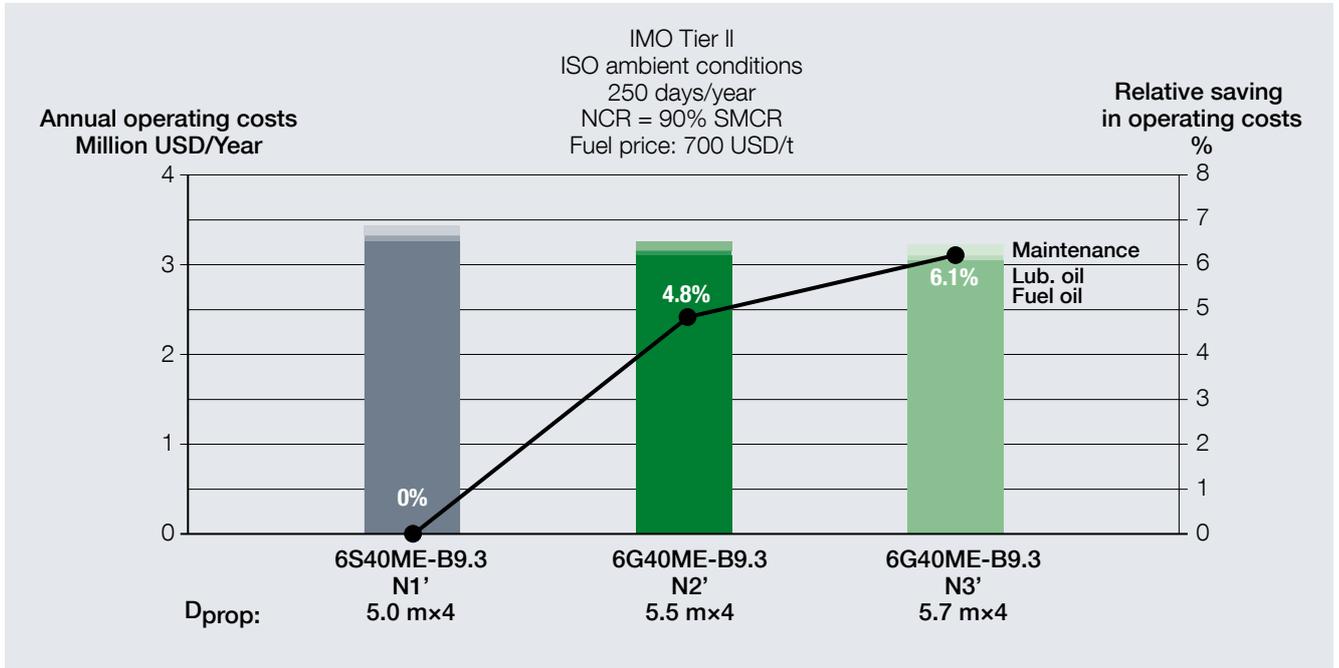
IMO Tier II
ISO ambient conditions
250 days/year
NCR = 90% SMCR
Fuel price: 700 USD/t

**Annual operating costs
Million USD/Year**

**Relative saving
in operating costs
%**

Maintenance
Lub. oil
Fuel oil

0%   4.8%   6.1%

	6S40ME-B9.3	6G40ME-B9.3	6G40ME-B9.3
	N1'	N2'	N3'
D_{prop}:	5.0 m×4	5.5 m×4	5.7 m×4

Fig. 15: Total annual main engine operating costs for 13.0 knots

**Saving in operating costs
(Net Present Value)
Million USD**

IMO Tier II
ISO ambient conditions
N' = NCR = 90% SMCR
250 days/year
Fuel price: 700 USD/t
Rate of interest and discount: 6% p.a.
Rate of inflation: 3% p.a.

N3': 5.7 m ×4
6G40ME-B9.3

N2': 5.5 m ×4
6G40ME-B9.3

N1': 5.0 m ×4
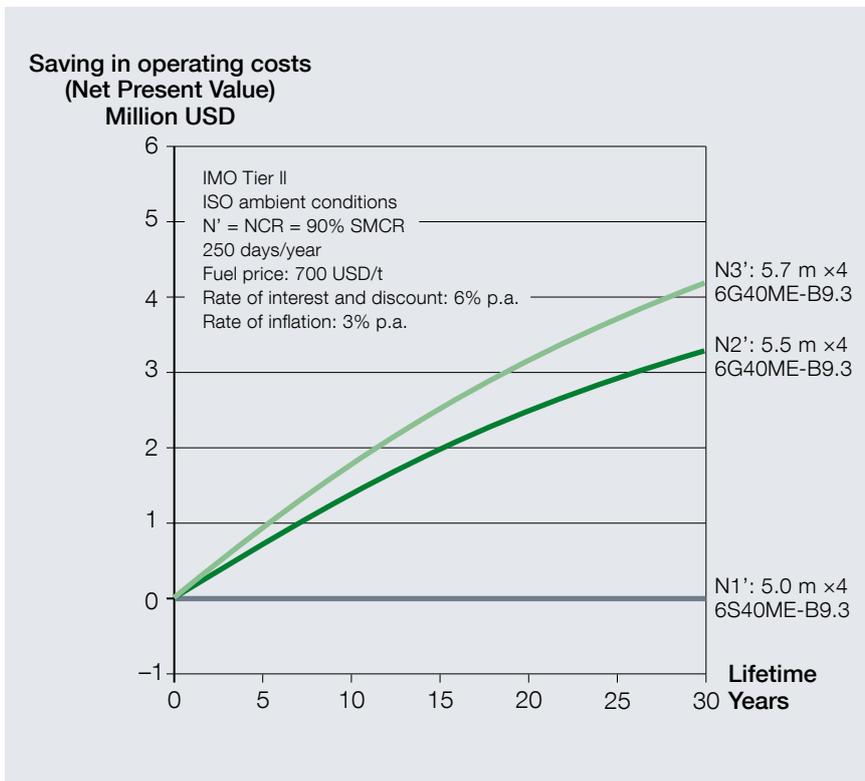6S40ME-B9.3

**Lifetime
Years**

Fig. 16: Relative saving in main engine operating costs (NPV) for 13.0 knots

Operating costs

The total main engine operating costs per year, 250 days/year, and fuel price of 700 USD/t, are shown in Fig. 15. Lube oil and maintenance costs are also shown at the top of each column. As can be seen, the major operating costs originate from the fuel costs – about 96%.

After some years in service, the relative savings in operating costs in Net Present Value, NPV, see Fig. 16, with the existing 6S40ME-B9.3 with the propeller diameter of about 5.0 m used as basis, indicates an NPV saving after some years in service for the new 6G40ME-B9.3 engine. After 25 years in operation, the saving is about 3.7 million USD for N3' with the 6G40ME-B9.3 with the SMCR speed of 106.0 r/min and propeller diameter of about 5.7 m.

Summary

Traditionally, super long stroke S-type engines, with relatively low engine speeds, have been applied as prime movers in bulk carriers.

Following the efficiency optimisation trends in the market, the possibility of using even larger propellers has been thoroughly evaluated with a view to using engines with even lower speeds for propulsion of particularly bulk carriers and tankers.

Handysize bulk carriers and tankers may be compatible with propellers with larger propeller diameters than the current designs, and thus high efficiencies following an adaptation of the aft hull design to accommodate the larger propeller, together with optimised hull lines and bulbous bow, considering operation in ballast conditions.

The new ultra long stroke G40ME-B9.3 engine type meets this trend in the Handysize bulk carrier and tanker market. This paper indicates, depending on the propeller diameter used, an overall efficiency increase of 6-9% when using G40ME-B9.3, compared with existing main engine type S40ME-B9.3 applied so far.

Compared with the existing S42MC7 often used in the past, the overall efficiency increase will be even higher when using G40ME-B9.3.

The Energy Efficiency Design Index (EEDI) will also be reduced when using G40ME-B9.3. In order to meet the stricter given reference figure in the future, the design of the ship itself and the design ship speed applied (reduced speed) has to be further evaluated by the shipyards to further reduce the EEDI.

MAN Diesel & Turbo – a member of the MAN Group