Propulsion of 8,000-10,000

teu Container Vessel

Engineering the Future – since 1758.

MAN Diesel & Turbo

Content

Propulsion of 8,000-10,000 teu Container Vessel

Introduction

The maximum size of recent 8,000-10,000 teu container vessels, Fig. 1, is normally at the scantling draught within the deadweight range of 95,000-120,000 dwt and the ship's overall length is about 320-350 m and with a breadth of about 43-46 m.

Recent development steps have made it possible to offer solutions which will enable significantly lower transportation costs for container ships 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 container vessels, the CO_2 emission from new container vessels in gram per dwt per nautical mile must be equal to or lower than the reference emission figures valid for the specific container vessel.

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 25.0-26.0 knots. Today, the ship speed may be expected to be lower, possibly 24 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 – making it possible to install propellers with a larger propeller diameter and, thereby, obtaining higher propeller efficiency, but at a reduced optimum propeller speed

Fig. 1: An 8,000 teu container vessel

In the past, normally K98MC/ME with nominal 97 r/min and K98MC-C/ME-C with nominal 104 r/min were used. This speed range can now be reduced.

As the two-stroke main engine is directly coupled with the propeller, the introduction of the super long stroke S90ME-C9.2 engine specially designed for container ships with even lower than the above-mentioned usual shaft speed will meet this. The main dimensions for this engine type, and for other existing container vessel engines, are shown in Fig. 2.

Based on a case study of an 8,000 teu container vessel, this paper shows the influence on fuel consumption when choosing the new S90ME-C9.2 engine compared with existing container vessel engines. The layout ranges of 9 and 10S90ME-C9.2 engines compared with existing 9 and 10 K98 engines are shown in Fig. 3.

EEDI and Major Ship and Main Engine Parameters

Energy Efficiency Design Index (EEDI)

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

For container vessels, the EEDI value is essentially calculated on the basis of 70% of the maximum cargo capacity in dwt, propulsion power, ship speed, SFOC 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 maximum dwt cargo capacity is used for comparison.

The main engine's 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.

.

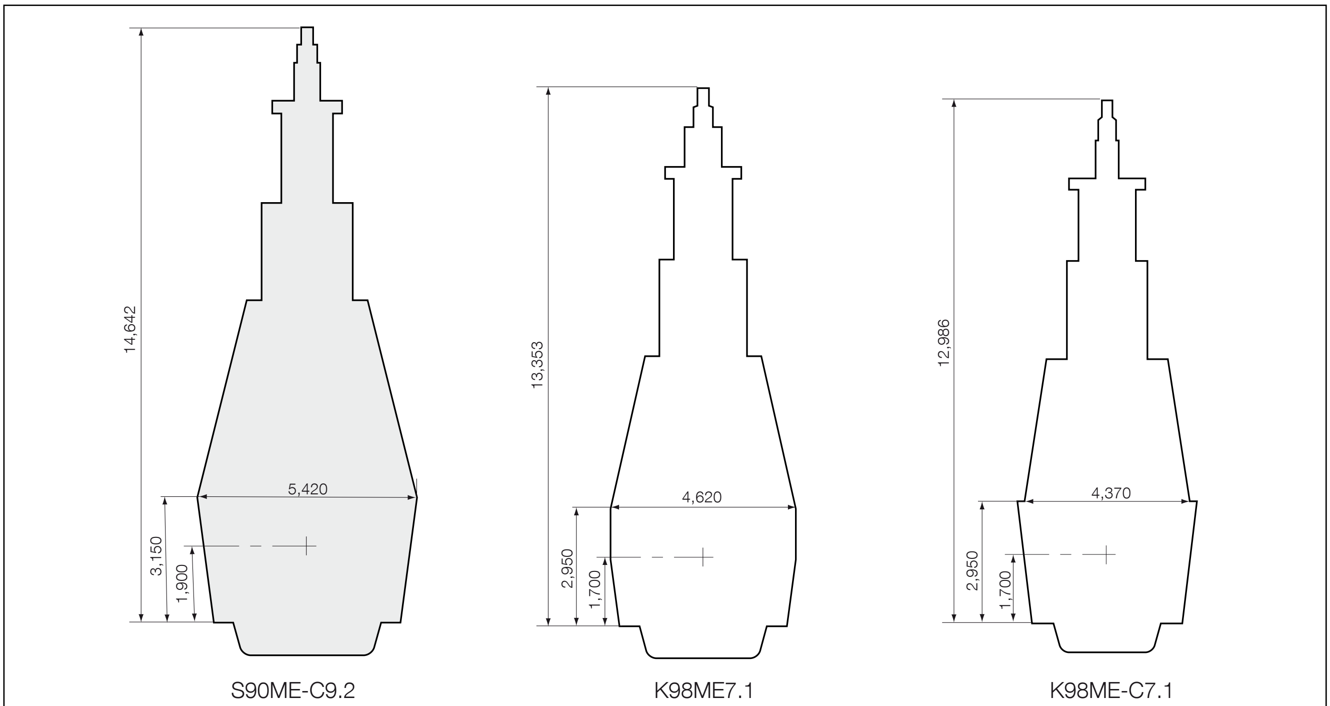
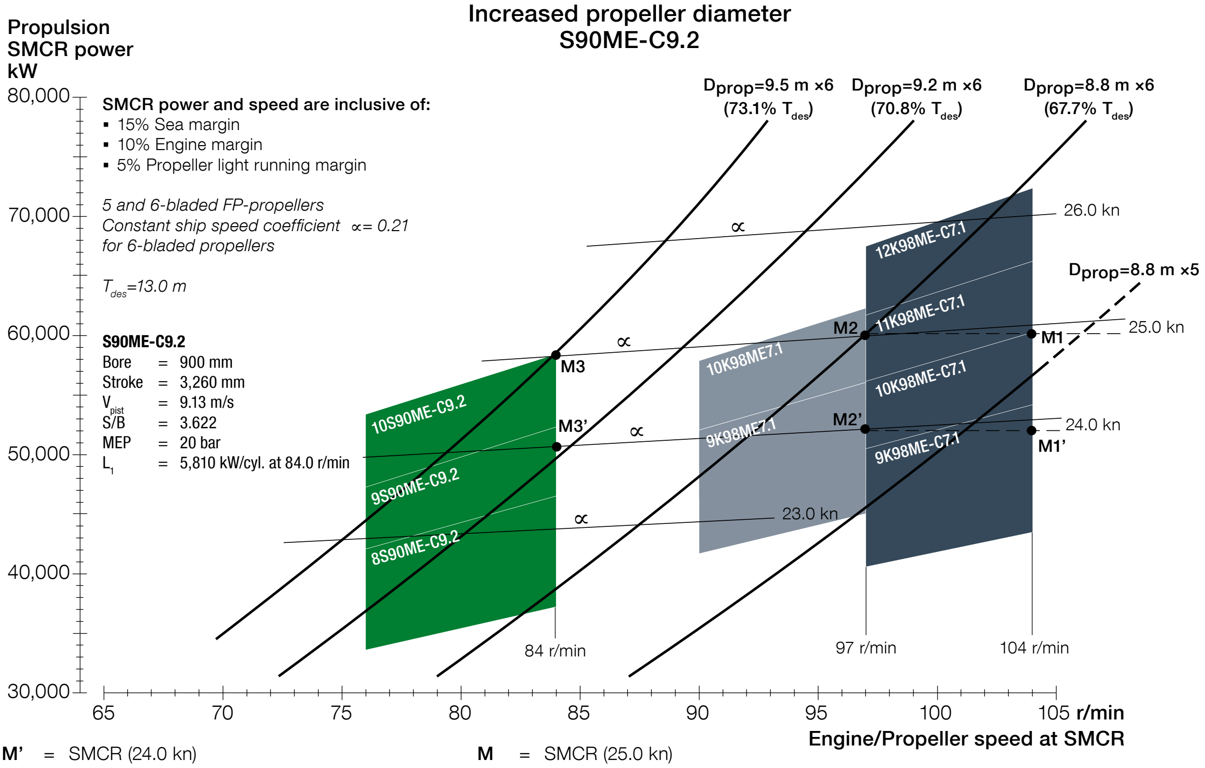


Fig. 2: Main dimensions for an S90ME-C9.2 engine and for other existing container ship engines

Propulsion of 8,000 teu Container Vessel



M’	=	SMCR (24.0 kn)		**M**	=	SMCR (25.0 kn)	
M1’	=	52,150 kW at 104.0 r/min	9K98ME-C7.1	**M1**	=	59,880 kW at 104.0 r/min	10K98ME-C7.1
M2’	=	52,150 kW at 97.0 r/min	9K98ME7.1	**M2**	=	59,880 kW at 97.0 r/min	10K98ME7.1
M3’	=	50,600 kW at 84.0 r/min	9S90ME-C9.2	**M3**	=	58,100 kW at 84.0 r/min	10S90ME-C9.2

Fig. 3: Different main engine and propeller layouts and SMCR possibilities (M1, M2, M3 for 25.0 knots and M1’, M2’, M3’, for 24.0 knots) for an 8,000 teu container vessel operating at 25.0 knots and 24.0 knots, respectively.

Major propeller and engine parameters

In general, the larger the propeller diameter, the higher the propeller efficiency and the lower the optimum propeller speed referring to an optimum ratio of the propeller pitch and propeller diameter.

A lower number of propeller blades, for example when going from 6 to 5 blades if possible, means approximately 10% higher optimum propeller speed, and the propeller efficiency will be slightly increased.

When increasing the propeller pitch for a given propeller diameter with optimum pitch/diameter ratio, the corresponding propeller speed may be reduced and the efficiency will also be slightly reduced, of course depending on the degree of the changed pitch. The same is valid for a reduced pitch, but here the propeller speed may increase.

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, it is a verified fact that the higher the stroke/bore ratio of a two-stroke engine, the higher the engine efficiency. This means, for example, that the long stroke engine type, S90ME-C9.2, may have a higher efficiency compared with the short stroke engine type K98.

Furthermore, the application of new propeller design technologies motivates use of main engines with lower rpm. Thus, for the same propeller diameter, these propeller types are calculated to have an about 6% improved overall efficiency gain at about 10% lower propeller speed.

8,000-10,000 teu container vessel

For an 8,000 teu container ship used as an example, the following case study illustrates the potential for reducing fuel consumption by increasing the propeller diameter and introducing the S90ME-C9.2 as main engine. The ship particulars assumed are as follows:

8,000 teu Container Vessel

Deadweight, max	dwt	97,000
Scantling draught	m	14.5
Design draught	m	13.0
Length overall	m	323.0
Length between pp	m	308.0
Breadth	m	42.8
Sea margin	%	15
Engine margin	%	10
Design ship speed	kn	25.0 and 24.0
Type of propeller		FPP
No. of propeller blades		6 (or 5 if possible)
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 container ship is found, see Fig. 3. The propeller diameter change for the 6-bladed propeller corresponds approximately to the constant ship speed factor α= 0.21 [$P_{M2} = P_{M1} \times (n_2/n_1)^{\alpha}$ where P = propulsion power and n = speed]. For the same propeller diameter and when going from 6 to 5 blades, the optimum propeller speed is increased and the propulsion power needed is slightly increased, but here assumed more or less unchanged.

Referring to the two ship speeds of 25.0 knots and 24.0 knots, respectively, three potential main engine types and pertaining layout diagrams and SMCR points have been drawn-in in Fig. 3, and the main engine operating costs have been calculated and described below individually for each ship speed case.

It should be noted that the ship speed stated refers to the design draught and 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 0.9 knots higher.

If based on 75% SMCR and 70% of maximum dwt, as applied for calculation of the EEDI, the ship speed will be about 0.2 knots higher, still based on calm weather conditions, i.e. without any sea margin.

Main Engine Operating Costs – 25.0 knots

The calculated main engine examples are as follows:

25.0 knots
1. 10K98ME-C7.1 M1 = 59,880 kW x 104.0 r/min
2. 10K98ME7.1 M2 = 59,880 kW x 97.0 r/min.
3. 10S90ME-C9.2 M3 = 58,100 kW x 84.0 r/min.

The K98 engine types have been chosen as cases 1 and 2 as these have been often used in the past.

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 25.0 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. 4 shows the influence of the propeller diameter when going from about 8.8 to 9.5 m. Thus, N3 for the 10S90ME-C9.2 with a 9.5 m x 6 (number of blades) propeller diameter has a propulsion power demand that is about 3.0% lower compared with N1 and N2 valid for the 10K98ME-C7.1 and 10K98ME7.1, with a propeller diameter of about 8.8 m x 5 and 8.8 m x 6, respectively.

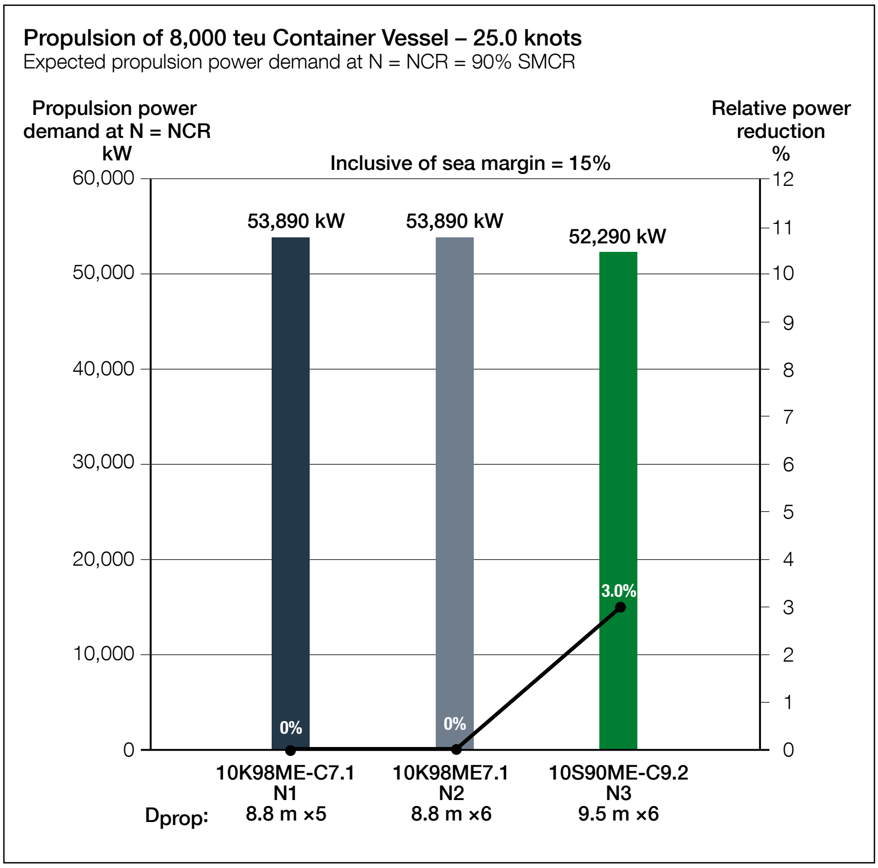


Fig. 4: Expected propulsion power demand at NCR for 25.0 knots

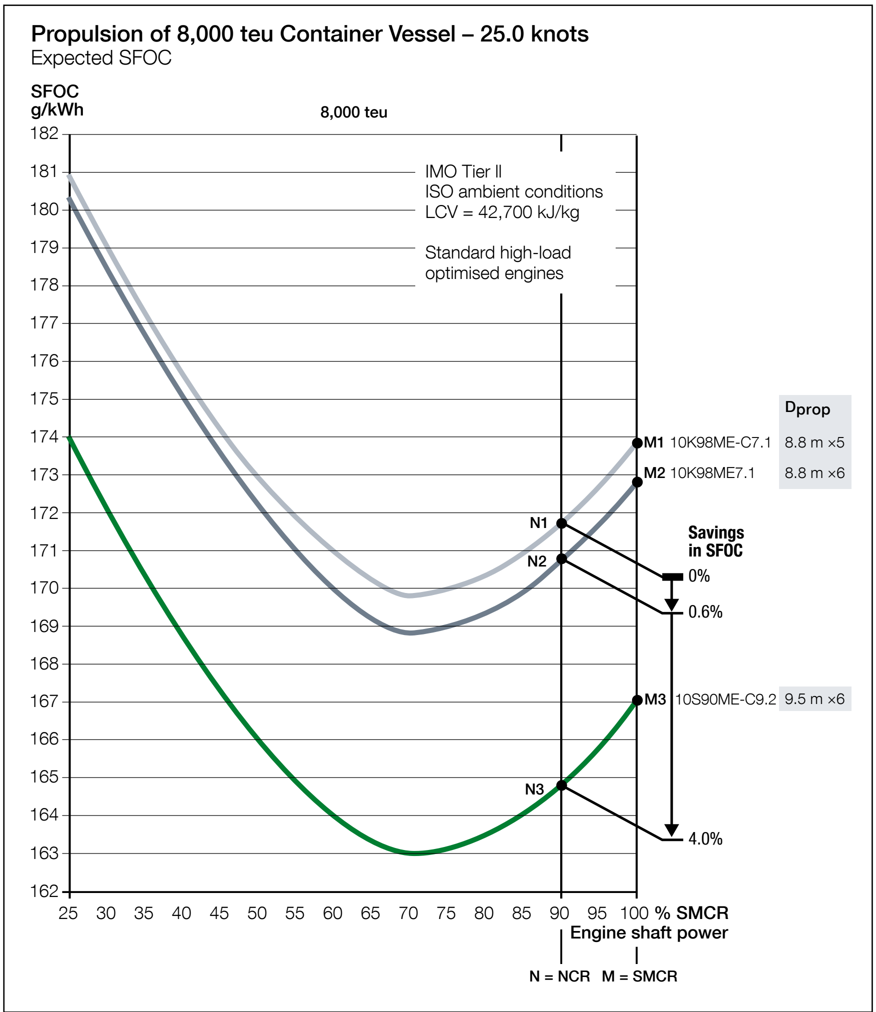


Fig. 5: Expected SFOC for 25.0 knots

Fig. 5 shows the influence on the main engine efficiency, indicated by the Specific Fuel Oil Consumption, SFOC, for the three cases. N3 = 90% M3 for the 10S90ME-C9.2 has an SFOC of 164.8 g/kWh. The 164.8 g/kWh SFOC of the N3 for the 10S90ME-C9.2 is 4.0% lower compared with N1 for the derated 10K98ME-C7.1 with an SFOC of 171.7 g/kWh. This is because of the higher stroke/bore ratio of this S-engine type.

When multiplying the propulsion power demand at N (Fig. 4) with the SFOC (Fig. 5), the daily fuel consumption is found and is shown in Fig. 6. Compared with N1 for the 10K98ME-C7.1, the total reduction of fuel consumption of the 10S90ME-C9.2 at N3 is about 6.8%.

The reference and the actual EEDI figures have been calculated and are shown in Fig. 7 ($EEDI_{ref}$ =174.22 x dwt $^{-0.201}$, 15 July 2011). As can be seen for all three cases, the actual EEDI figures are lower than the reference figure. Particularly, case 3 with 10S90ME-C9.2 has a low EEDI – about 79% of the reference figure.

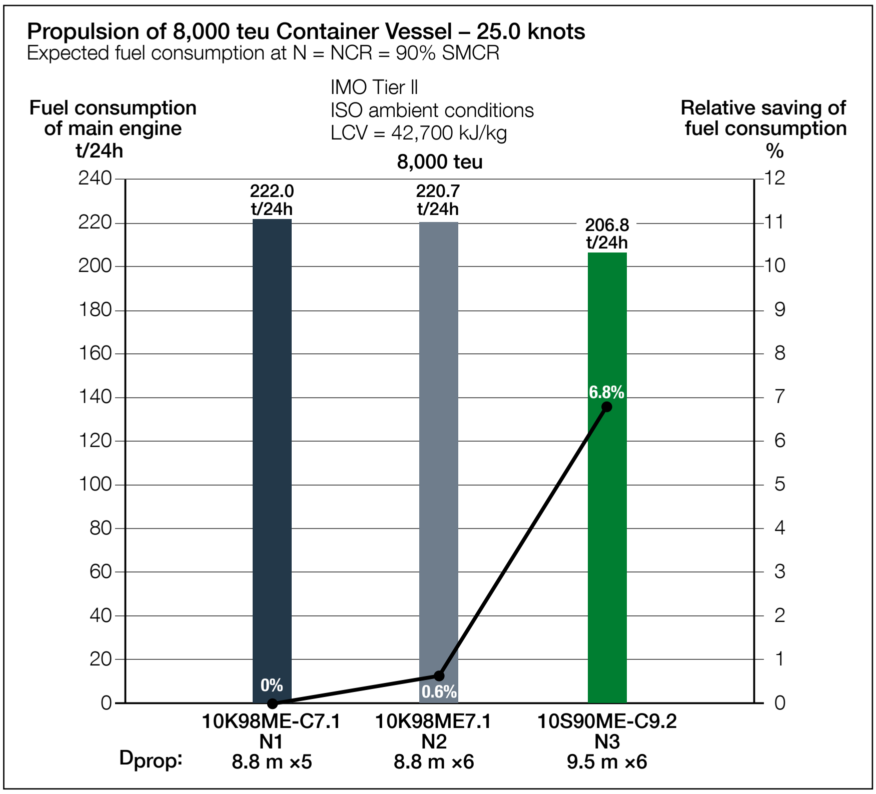


Fig. 6: Expected fuel consumption at NCR for 25.0 knots

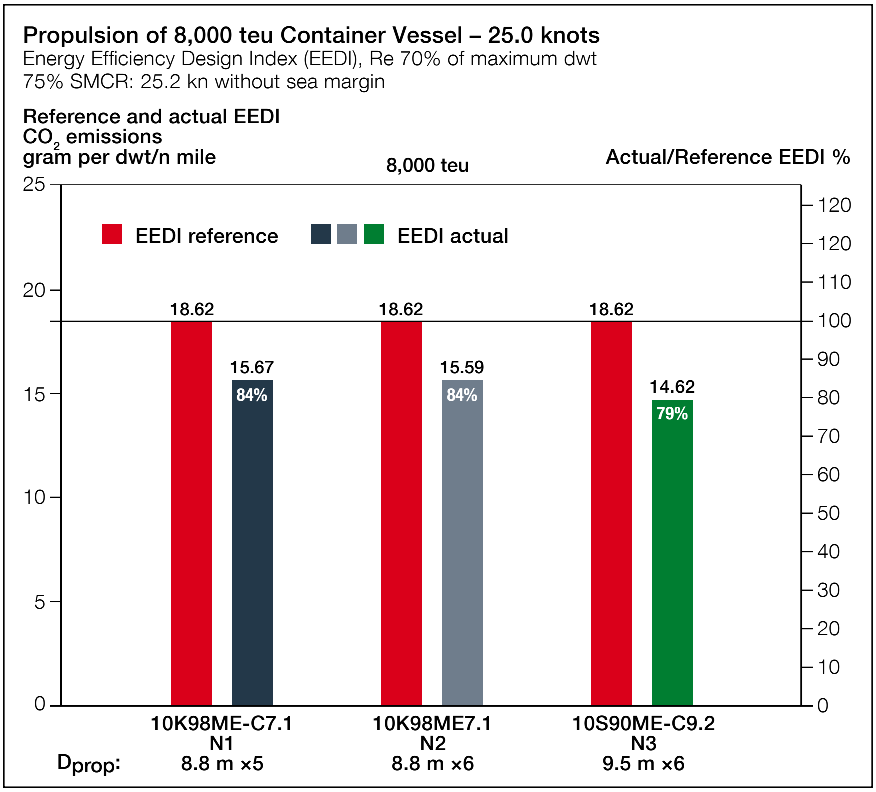


Fig. 7: Reference and actual Energy Efficiency Design Index (EEDI) for 25.0 knots

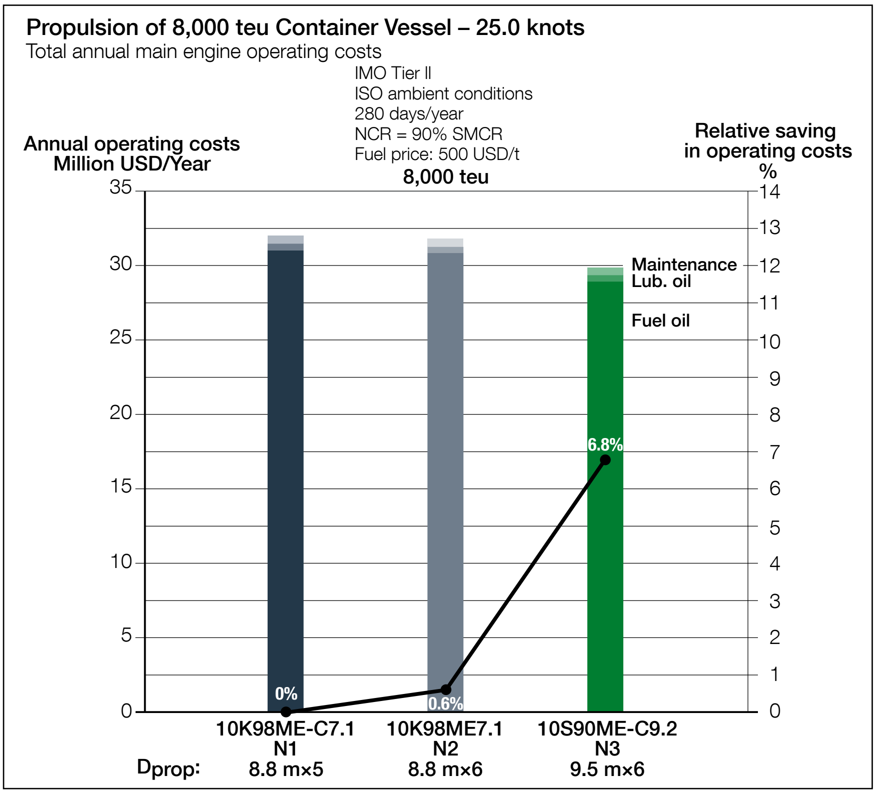


Fig. 8: Total annual main engine operating costs for 25.0 knots

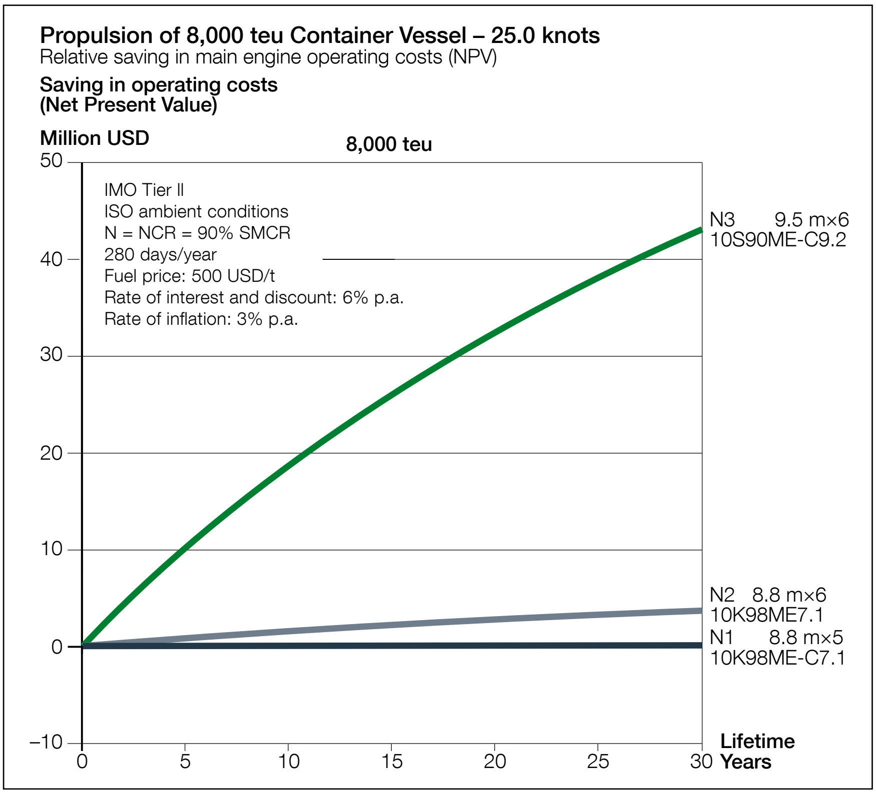


Fig. 9: Relative saving in main engine operating costs (NPV) for 25.0 knots

Operating costs

The total main engine operating costs per year, operating at N = 90% SMCR in 280 days/year, and fuel price of 500 USD/t, are shown in Fig. 8. The lube oil and maintenance costs are shown too. As can be seen, the major operating costs originate from the fuel costs and are about 97%.

The relative savings in operating costs in Net Present Value (NPV), see Fig. 9, with the 10K98ME-C7.1 used as basis with the propeller diameter of about 8.8 m x 5, indicates an NPV saving for the 10S90ME-C9.2 engine after some years in service. After 25 year in operation, the saving is about 38.0 million USD for N3 with 10S90ME-C9.2 with the SMCR speed of 84.0 r/min and propeller diameter of about 9.5 m x 6.

Main Engine Operating Costs – 24.0 knots

The calculated main engine examples are as follows:

1'.	9K98ME-C7.1 M1' = 52,150 kW x 104.0 r/min
2'.	9K98ME7.1 M2' = 52,150 kW x 97.0 r/min.
3'.	9S90ME-C9.2 M3' = 50,600 kW x 84.0 r/min.

The K98 engine types have been chosen as cases 1' and 2' as these have been most often used in the past.

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 24.0 knots, which is probably going to be a more normal choice in the future, maybe even lower. Furthermore, the EEDI has been calculated on the basis of the 75% SMCR-related figures (without sea margin).

Fuel consumption and EEDI

Fig. 10 shows the influence of the propeller diameter when going from about 8.6 to 9.2 m. Thus, N3' for the 9S90ME-C9.2 with a 9.2 m x 6 (number of blades) propeller diameter has a propulsion power demand that is about 3.0% lower compared with the N1' for the 9K98ME-C7.1 with an about 8.8 m x 5 propeller diameter.

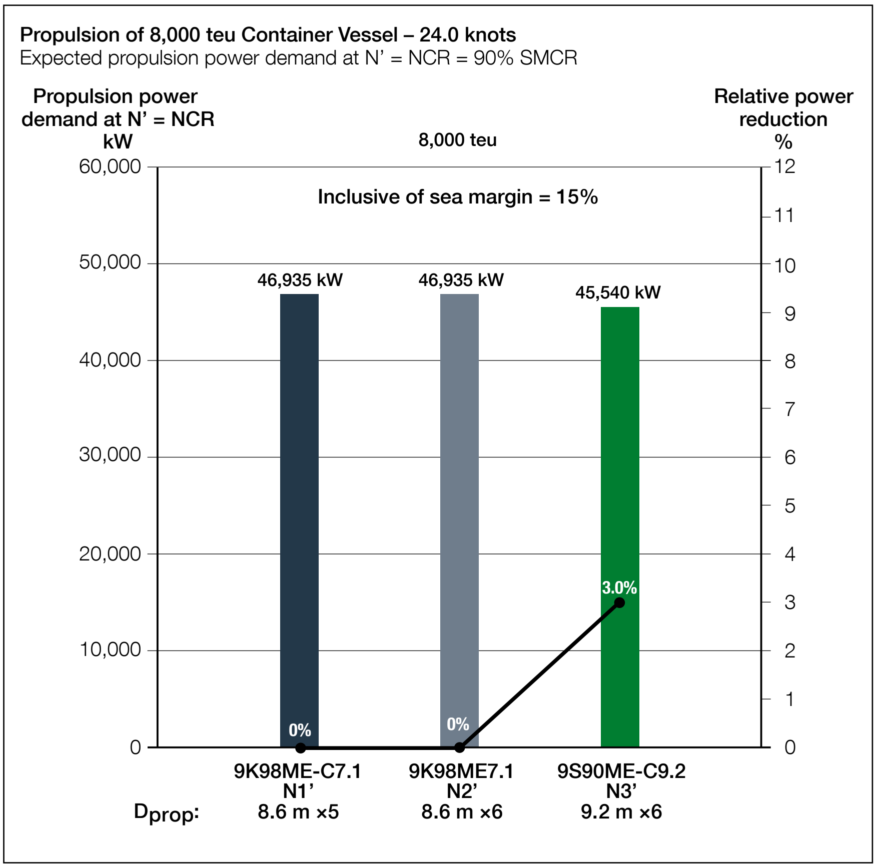


Fig. 10: Expected propulsion power demand at NCR for 24.0 knots

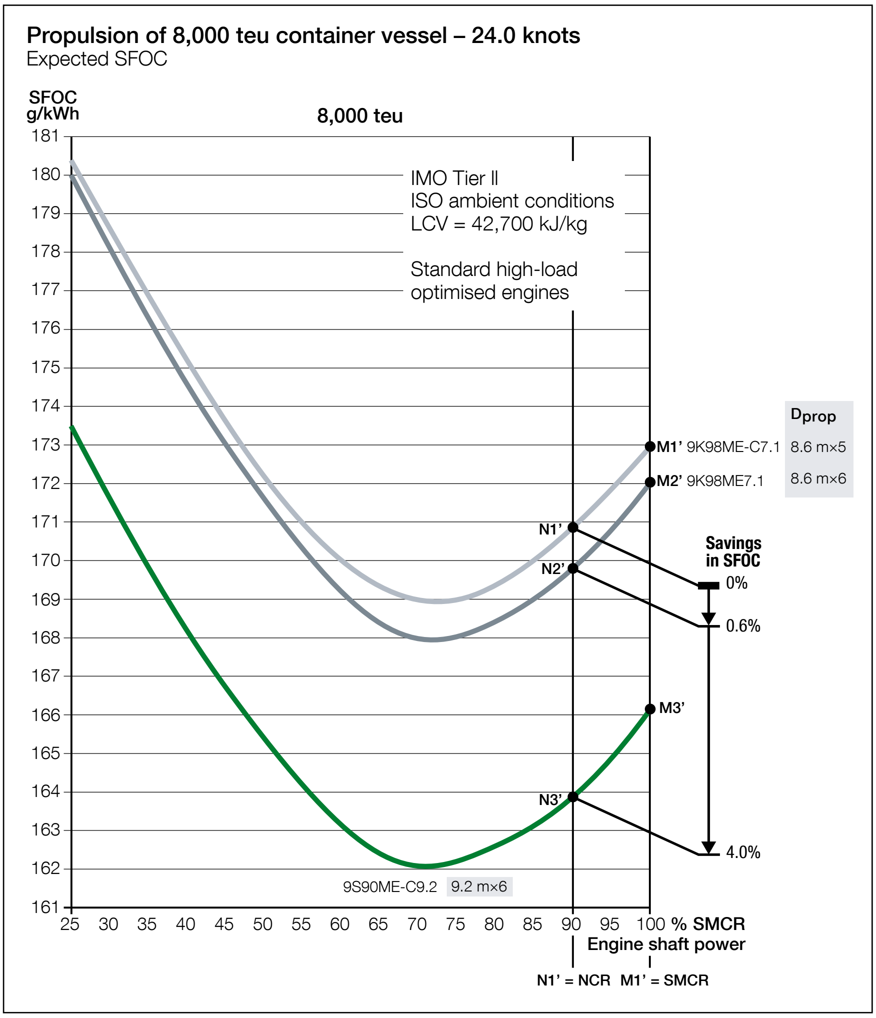


Fig. 11: Expected SFOC for 24.0 knots

Fig. 11 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 9S90ME-C9.2 has a relatively low SFOC of 163.8 g/kWh compared with the 170.7 g/kWh for N1' = 90% M1' for the 9K98ME-C7.1, i.e. an SFOC reduction of about 4.0%, mainly caused by the higher stroke/bore ratio of the S90ME-C9.2 engine type.

The daily fuel consumption is found by multiplying the propulsion power demand at N' (Fig. 10) with the SFOC (Fig. 11), see Fig. 12. The total reduction of fuel consumption of the 9S90ME-C9.2 is about 6.9% compared with the 9K98ME-C7.1.

The reference and the actual EEDI figures have been calculated and are shown in Fig. 13 (EEDIref = 174.22 x dwt -0.201, 15 July 2011). As can be seen for all three cases, the actual EEDI figures are all lower than the reference figure. Particularly, case 3' with 9S90ME-C9.2 has a low EEDI – about 71% of the reference figure, i.e. will almost meet the EEDI demand from 2025.

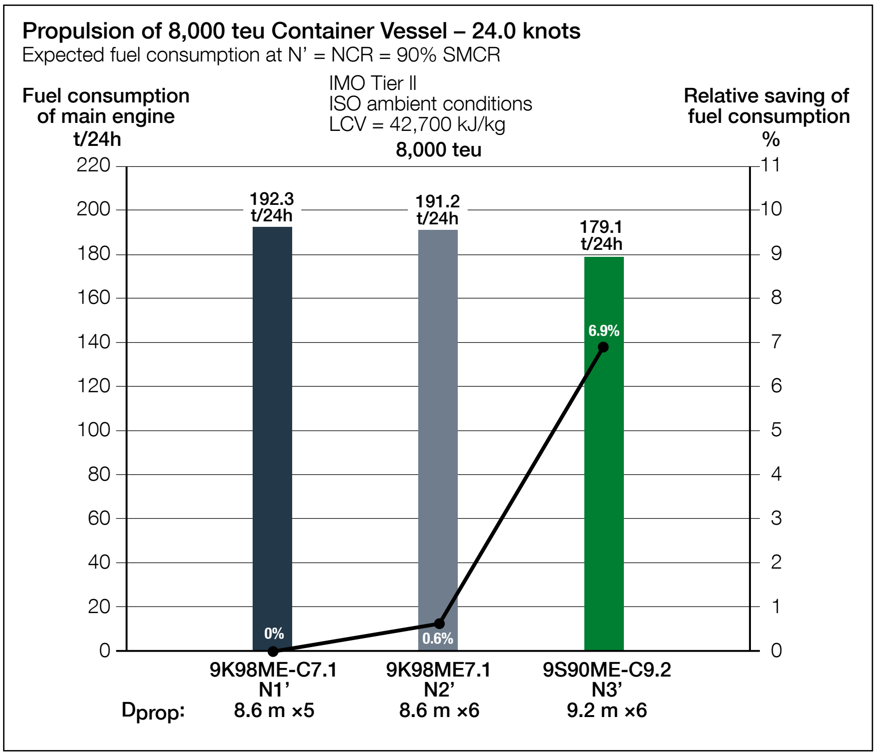


Fig. 12: Expected fuel consumption at NCR for 24.0 knots

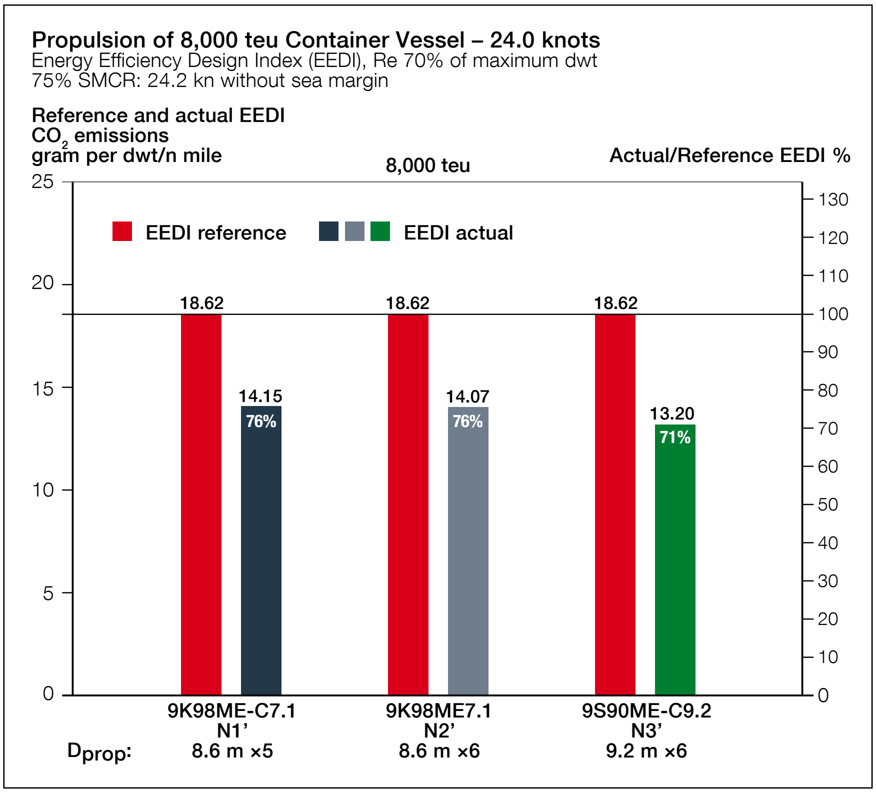


Fig. 13: Reference and actual Energy Efficiency Design Index (EEDI) for 24.0 knots

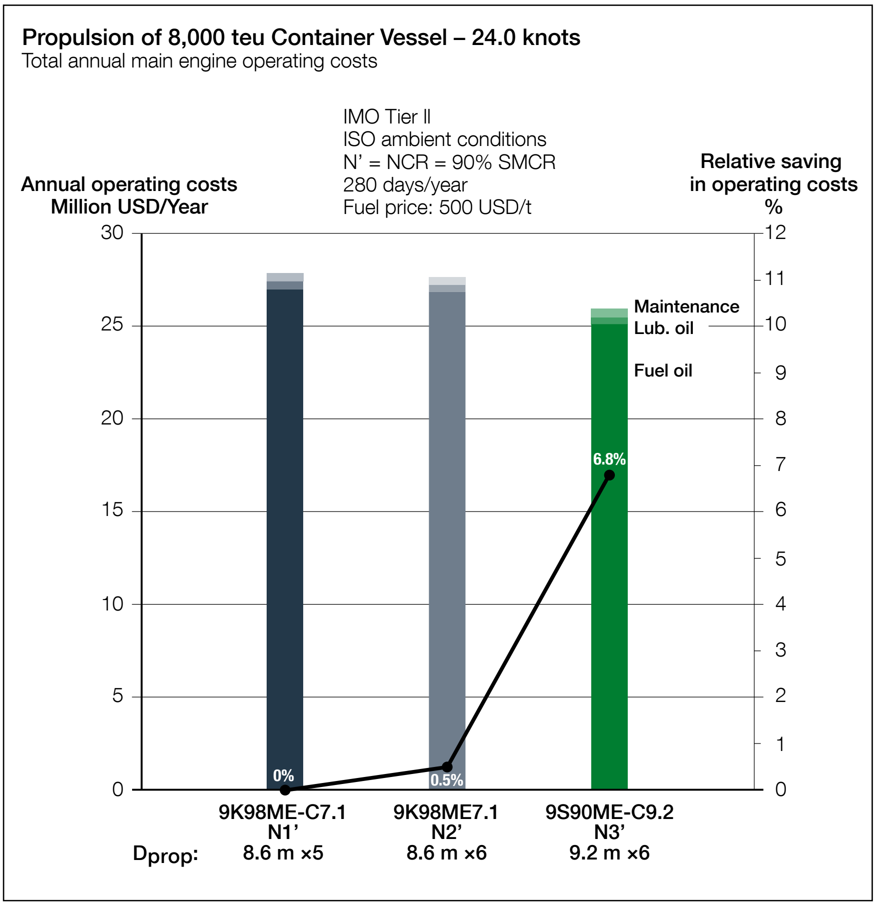


Fig. 14: Total annual main engine operating costs for 24.0 knots

Operating costs

The total main engine operating costs per year, 280 days/year, and fuel price of 500 USD/t, are shown in Fig. 14. 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 and are about 97%.

The relative savings in operating costs in Net Present Value, NPV, see Fig. 15, with the 9K98ME-C7.1 with the propeller diameter of about 8.6 m x 5 used as basis, indicates an NPV saving after some years in service for the 9S90ME-C9.2 engine. After 25 years in operation, the saving is about 33 million USD for the 9S90ME-C9.2 with the SMCR speed of 84.0 r/min and propeller diameter of about 9.2 m x 6.

Summary

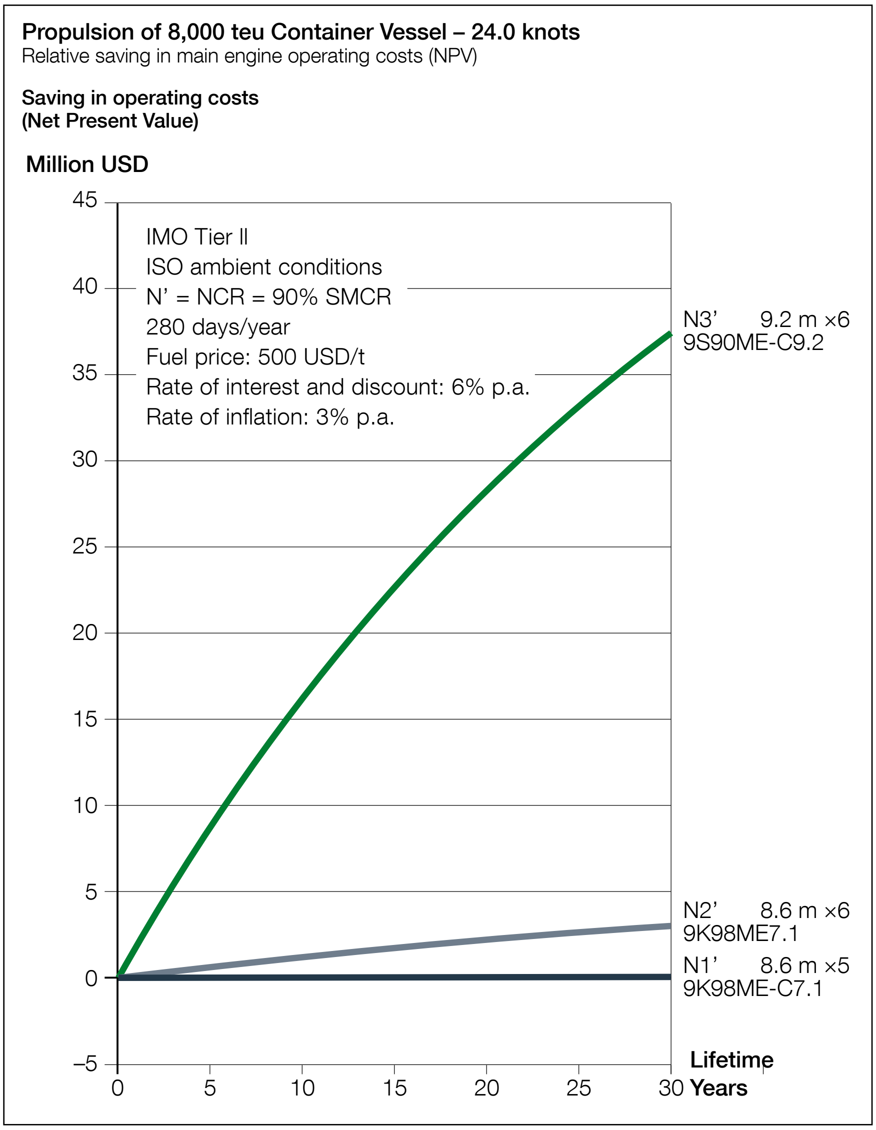


Fig. 15: Relative saving in main engine operating costs (NPV) for 24.0 knots

Traditionally, K-type engines, with relatively high engine and thereby propeller speeds, have been applied as prime movers in the container vessels size bracket of 8,000-10,000 teu capacity.

Following the efficiency optimisation trends in the market, also with lower ship speeds for container ships, the possibility of using even larger propellers has been thoroughly evaluated with a view to using engines with even lower speeds for propulsion.

Container ships are indeed 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. Even in cases where an increased size of the propeller is limited, the use of propellers based on the New Propeller Technology will be an advantage.

The new higher powered long stroke S90ME-C9.2 engine type meets this trend in the market. This paper indicates, depending on the propeller diameter used, an overall efficiency increase of about 7% when using S90ME-C9.2, compared with existing main engines applied so far.

The Energy Efficiency Design Index (EEDI) will also be reduced when using S90ME-C9.2. 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. Among others, the installation of WHR may reduce the EEDI value.

5510-0109-01ppr Aug 2012 Printed in Denmark

MAN Diesel & Turbo
Teglholmsgade 41
2450 Copenhagen SV, Denmark
Phone +45 33 85 11 00
Fax +45 33 85 10 30
info-cph@mandieselturbo.com
www.mandieselturbo.com