IS A CONVENTIONAL MACHINERY REALLY OPTIMAL?

Kenneth J. Jofs

0. SYNOPSIS

The present development in propulsion machineries is to optimize the machinery for the actual operation of the vessel. During this optimization process many owners have noted that the conventional slow–speed engine alternative doesn't provide the advantage it is supposed to provide.

- The "slow–speed" of the engine is *not slow enough* for optimum propeller speed. The machinery should be geared to give the full freedom in propeller optimization.
- The "super–long–stroke" is also *super high* which steals space from cargo areas.
- The "heavily built engines" are *indeed heavy*, usually more than the double weight. Ships should be designed to carry cargo, not steel and cast iron.

Today's medium–speed engines are combining economy with reliability. There is no contradiction in this, but this is a proven fact through numerous successful sailing installations. This paper highlights these advantages and puts a price tag on the different items. When viewing the costs of a slow–speed instalation in any "typical" slow–speed engine ships the question really is: Is there a need for slow–speed engines in the future?

1. INTRODUCTION

Traditionally the slow–speed engine has been the choice for most of the large cargo vessels. The question is naturally why? All in the business knows about the disadvantages of slow–spedd engines, mainly the huge dimensions, high weight and high price. However many shipowners believe these disdvantages are outweighed by the assumed advantages in operating costs. Is this a fact or only fiction?

2. DEVELOPMENT INT PROPULSION MACHINERIES

During the last decade many things have happened in the propulsion field. Words like one fuel onboard, superlong stroke, large diameter propellers and optimization are the words of the day. This has changed the picture drastically. The optimum propulsion machinery of the nineties is something completely different than only a couple of years ago. The latest development in the medium–speed engine fields is worth studying.

Many shipowners are now investigating the influence of medium–speed machineries in ships that earlier were considered clear cases for slow–speed engines, e.g. large tankers, container vessels and bulk carriers. The main reasons for this is that modern medium–speed engine provides a nice potential for savings due to the flexibility offered.

- Lower weight
- Space savings
- Simplified systems
- Possibilities for propeller optimization
- Lower fuel consumption
- Lower maintenance costs

To show that these points are not empty arguments it is best to see how these factors can be emphasized in a study of a modern 2,000 TEU container vessel, a ship type which is commonly considered to be a typical slow-speed engine ship.

3. INVESTIGATION APPROACH

The approach of this study was that the views of the shipowner should play an important role. This study is based on an actual project and around this project an independent naval architect has made the project work for a slow-speed ship and a medium-speed ship. These both ships were optimized in both cases around the two machinery alternatives. The prices for the both vessels were established by shipyards. Since the intended sailing profile of the vessel is know it is easy to calculate the annual operating costs for the both vessels.

Important factors that were considered in the study were the characteristics of the different diesel engine types, latest development in hull shapes and propeller efficiency. Attention was also paid to vibration and noise questions. The following items were particulary analyzed:

- Engine room size
- Steel weight
- Propeller diameter
- Auxiliary systems
- Waste heat recovery

4. STUDY OF A 2,000 TEU CONTAINER VESSEL

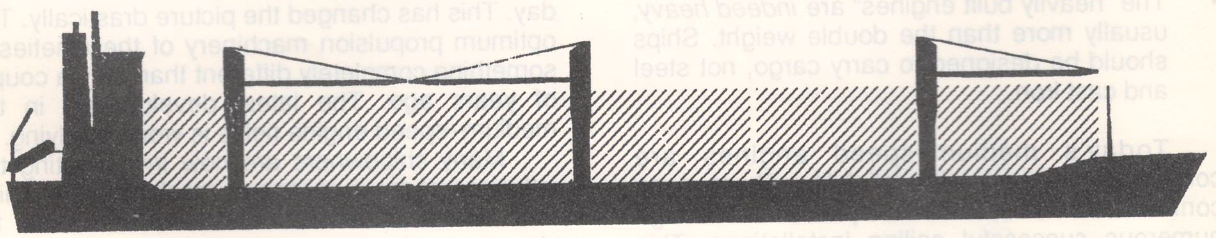
4.1 Background Data

The ship has been assumed to sail at a service speed of 19 knots on a fixed route. The ship makes 12 round trips per year and the distance for one voyage is 12,500 nautical miles. Total harbor time is 3 days per round trip.

The main dimension of the vessel are:

Lenght Lpp	202 m
Breadth, moulded	32.2 m
Depth, moulded	18.8 m
Draft, design	10.6 m
Under deck	1,150 TEU
On deck	853 TEU
Total	2,003 TEU

Containers are carried in 5 holds



The machinery alternatives are:

Fig 2 and 3

Alternative 1 (Conventional)

Main engine:	One slow-speed engine 7 cylinders 700 mm bore MCR: 16,520 kW at 90 rpm
Auxiliary engines:	2*Wärtsilä Vasa 6R22/26 2*870 kW at 750 rpm
Shaft generator:	1*1,000 kW with RCF (Constant speed gear)
Propeller:	Fixed ptich 7.4 m

Alternative 2 **Fig 4 and 5**

Main engine:	Two medium–speed engine Wärtsilä Vasa 9R46
	MCR: 2*8,145 kW at 450 rpm
Gearbox:	Twin in/Single out with two P.T.O. 1,000 kW
Auxiliary engines:	2*Wärtsilä Vasa 4R22/26
	2*870 kW at 750 rpm
Shaft generator:	2*1,000 kW on gearbox
Propeller:	Controllable pitch 8.4 m

4.2 Propeller Optimization

Traditionally such vessels have been built with direct coupled slow–speeds engines. The fact that the propeller is directly coupled to the engine gives a severe limitation, the naval architect must use the given speed of the engine and try to make the best of it. This is not optimization, but sub–optimization. Since the propeller speed is given by the engine manufacturer and the maximum propeller diameter is a result of the propeller speed.

Since a larger propeller diameter (and lower propeller speed) means a higher propulsion efficiency, the optimum case is to optimize the propeller diameter first regardles[s the speed. This is possible with a geared medium–speed engine machinery.

The conventional propeller is a fixed pitch propeller with a diameter of 7.4 m at 90 rpm. For the medium–speed engine alternative it is possible to select the optimum propeller diameter, which in this case is 8.4 m at 80 rpm. For the medium–speed case a controllable pitch propeller is selected for increased flexibility. Due to the increase in propeller diameter the power demand on 19 knots loaded condition is dropped from 14,000 kW to 13,050 kW. This means that any gear losses of 1.5 to 2 % are easily compensated by the about 7 % gain in propulsion efficiency (Fig 1). Since the medium–speed machinery is lighter the aft ship can be made more slender which further improves the propulsion efficiency. The daily fuel consumption (propulsion only) for the slow–speed alternative is about 60.5 ton/day compared with 56.4 ton/day for the medium–speed engine alternative. This corresponds to a total saving for the medium–speed alternative of 148,500 USD/year assuming HFO 380 cSt with a price of 110 USD/ton.

4.3 Space and Weight Savings

The medium–speed installation (Alternative 2, Fig 4 and 5) has considerably smaller dimensions, especially vertically. The extra deck that can be saved will give an increased container capacity of 44 containers.

Since the medium–speed engines doesn't require such heavy foundations as a slow–speed engine, there will be a saving in steel weight of 100 ton. This corresponds to a reduction of the steel building costs in the region of 250,000 USD. The weight of the slow–speed engine is about 600 ton compared to 300 ton for the medium–speed engines.

4.4 Simplicity in System Layout

A medium–speed engine has considerably simpler layout of the external supporting systems. The study shows that a 20 % reduction in the number of equipment is possible for the medium–speed engine case. The reduction in piping weight is 4,000 kg.

4.5 Savings in Investment Costs

Medium–speed engines are much more competitive in initial costs than slow–speed engines. In this output range the difference in engine price is about 3,300, 000 USD. However the gearbox and the CP–propeller are higher than in the slow–speed case, but the net saving in machinery investment is anyhow 1,960,000 USD. The difference in installation costs is 330,000 USD, so the total savings in investment costs is 2,290,000 USD.

4.6 Heat Recovery Potential

A slow–speed engine has much lower exhaust gas temperatures than a medium–speed engine. On normal cruising speed of this vessel the exhaust temperature fo the slow–speed engine is 244°C compared to 345°C for the medium–speed engines. This corresponds to 1,590 kW for the slow–speed engine and 3,535 kW for the medium–speed engines. This means that the potential for heat recovery is more than double for the medium–speed engine. At sea the average heat demand for such a vessel is 1,900 kW, so 300 kW must be produced by oil fired boilers in the conventional case corresponding to 720 kg of HFO per day.

4.7 Maintenance

A comparison of the maintenance manuals of the different engine types shows that the average man hours needed for servicing the slow–speed engine is 569 hours per year over the first 4 years operation (33,000 hours). The medium–speed alternative requires 455 hours per year. Of these the main engine will be stopped for 201 hours for the slow–speed case and 155 hours in the medium–speed case. Since the medium–speed engine machinery has two engine the ship can sail at a reduced speed of about 14 knots when one engine is over–hauled. This means that there will be no down time for the medium–speed case, while in the single engine case the ship wil be stopped during 201 hours per year. By calculating the service man–hours the difference in annual maintenance is 16,000 USD.

4,8 Economical Evaluation Data

In order to see how this totals on the annual operating costs of the ship it is easy to compare the impact of investment costs against the operating costs. In the study the following economical assumptions have been made:

- The own capital in this investment is 20 %
- The rest of the capital is borrowed at 8 % interest rate
- The internal company interest rate is 10 %
- The depreciation time is 8 years, equal annual amounts
- The increase of fuel price is 6 % per year

4.9 Results

	Medium–Speed	Slow–speed
Investment costs	Reference	+2,290,000 USD
Operating costs	Reference	+ 182,700 USD
Annual costs	Reference	+ 644,000 USD

4.10 Remarks

The shipowner will save 644,000 USD per year by installing a medium–speed engine in his 2,000 TEU container vessel. This saving is the pure result of lower investment costs and lower operating costs. This study has not taken into account the further advantages the shipowner will have with this machinery like:

- Increasing revenues due to 44 TEU higher capacity
- Higher redundancy due to a twin engine machinery

5. CONCLUSION

The latest development in medium–speed engines have given a new generation of diesel engines that combines the low fuel consumption of a slow–speed engine with the compactness and low costs of a medium–speed engine. There are many shipowners that noted the advantages of medium–speed engines already in the beginning of the seventies, but got a bad experience due to the fact that the medium–speed engines available on the market then were not realiable.

Today the situation is different. The new generation of really reliable medium–speed engines are showing their advantages and through the good operating experience gathered more and more shipowners are prepare to give the medium–speed engine a second chance. Medium–speed engines are introduced to ships that were "made" for slow–speed engines. One such example are the two 91,100 DWT crude oil tankers ordered by NesteTankers. The ships are equipped with two Wärtsilä Vasa 6R46 totalling 14,760 BHP (Fig 6 – Note the compact engine room!).

The Wärtsilä Vasa 46 engine has really been a success story, with 36 engines sold for marine installations in just 2 years (Fig 7).

With this track record and the potential in savings: *Is there a need for slow–speed engines in the future?*

6. REFERENCES

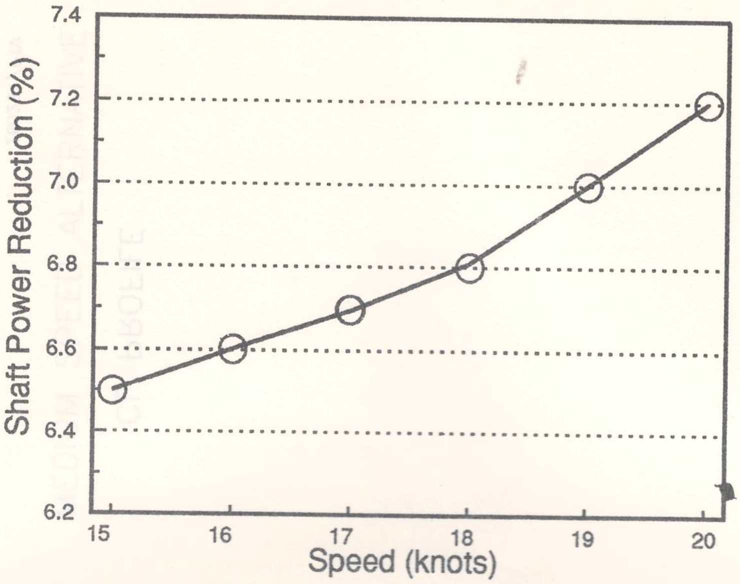
1 The engine room of the future
M. Kanerva, Elomatic OY 1989
2 Engine room evaluation for a 2,000 TEU container carrier for X Lines, Elomarine Ltd, 1991
3 Project Guide, Two–stroke engines, MAN–B&W, 1986
4 Project Guide for Wärstilä Vasa 46, Marine Applications,
WÄRSTILÄ DIESEL, 1990

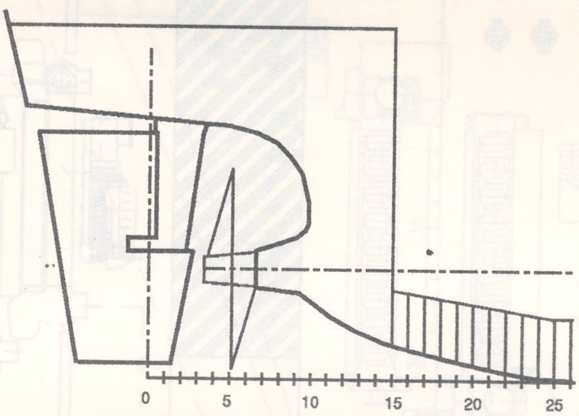
7. APPENDIXES

1 Propeller optimization for a 2,000 TEU container vessel
2 Engine room arrangement slow–speed, profile
3 Engine room arrangement slow–speed, floor level
4 Engine room arrangement medium–speed, profile
5 Engine room arrangement medium–speed, floor level
6 91,100 ton crude oil carrier for Neste Tankers equipped with two Wärtsilä Vasa 6R46 built by Masa–Yards, Finland
7 Reference list Wärtsilä Vasa 46, dated March 1991

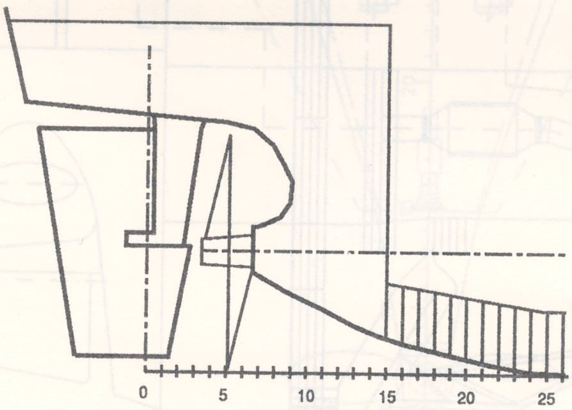
Propeller Diameter Optimization

2,000 TEU Container Vessel

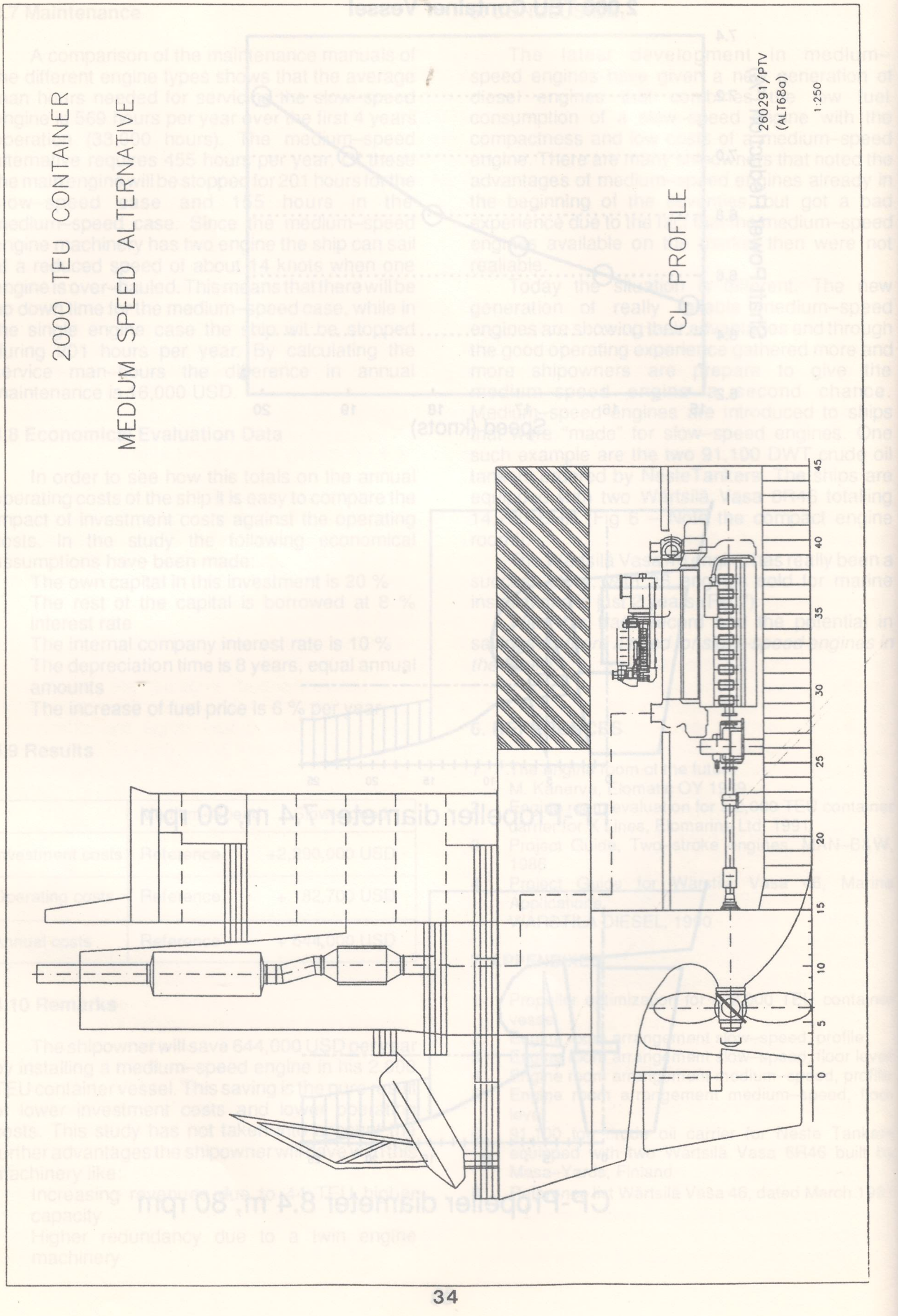




FP-Propeller diameter 7.4 m, 90 rpm

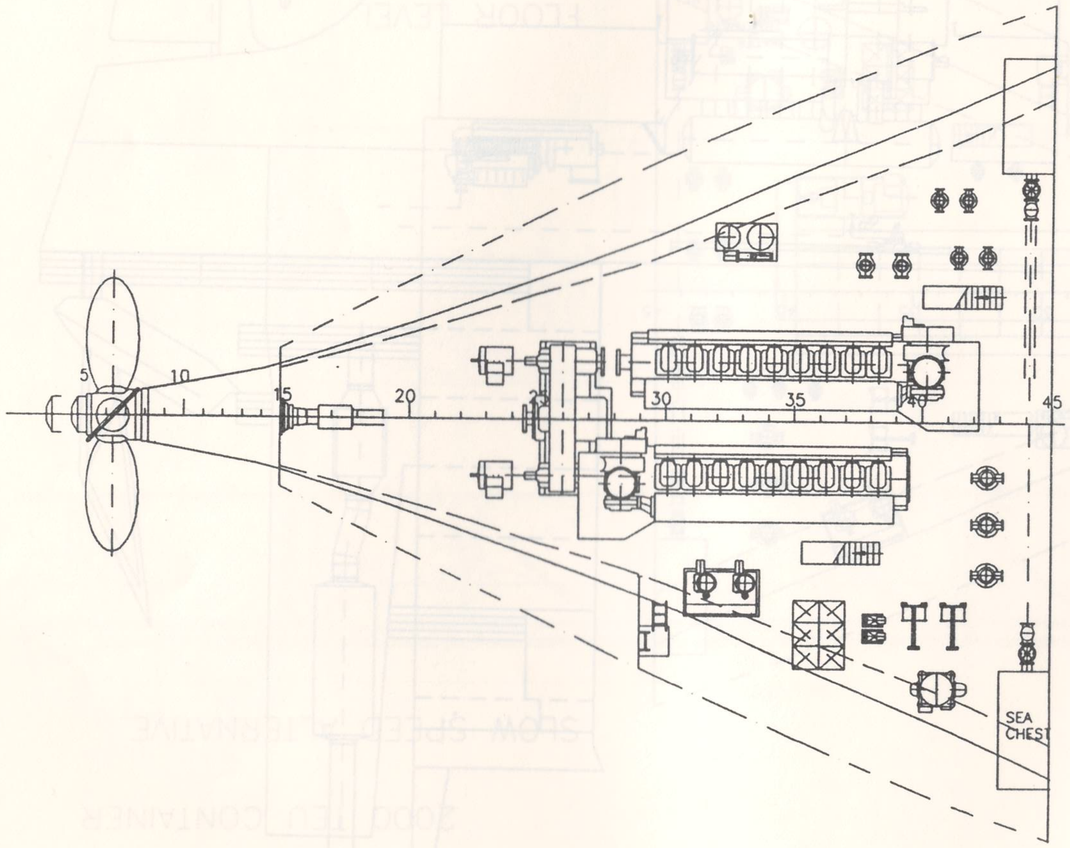


CP-Propeller diameter 8.4 m, 80 rpm


2000 TEU CONTAINER
MEDIUM SPEED ALTERNAVE
CL PROFILE
260291 / PTV
(AT68a)
:250
0
5
10
15
20
25
30
35
40
45

2000 TEU CONTAINER

MEDIUM SPEED ALTERNATIVE



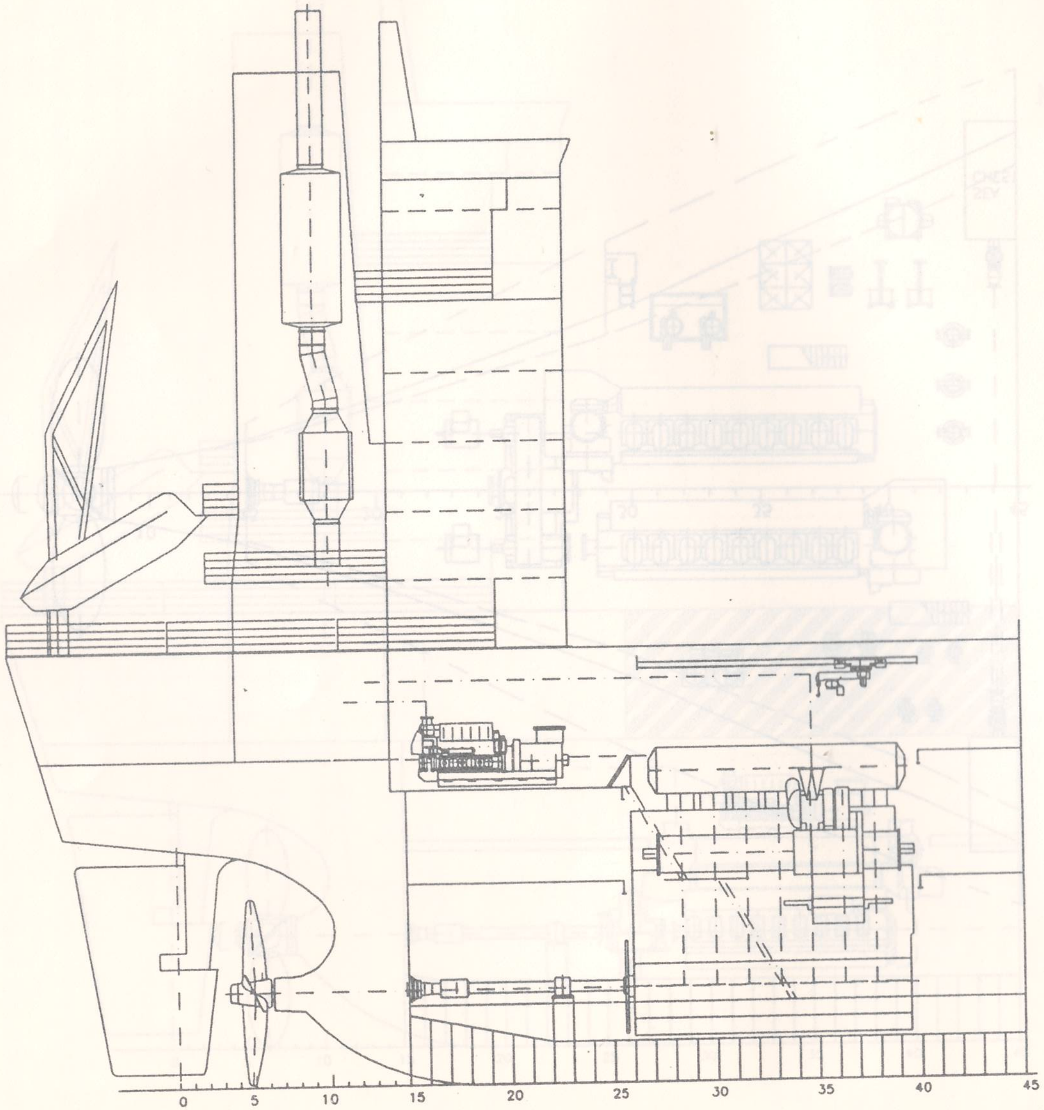
FLOOR LEVEL

260291/PTV
(ALT62a)

1:200

2000 TEU CONTAINER

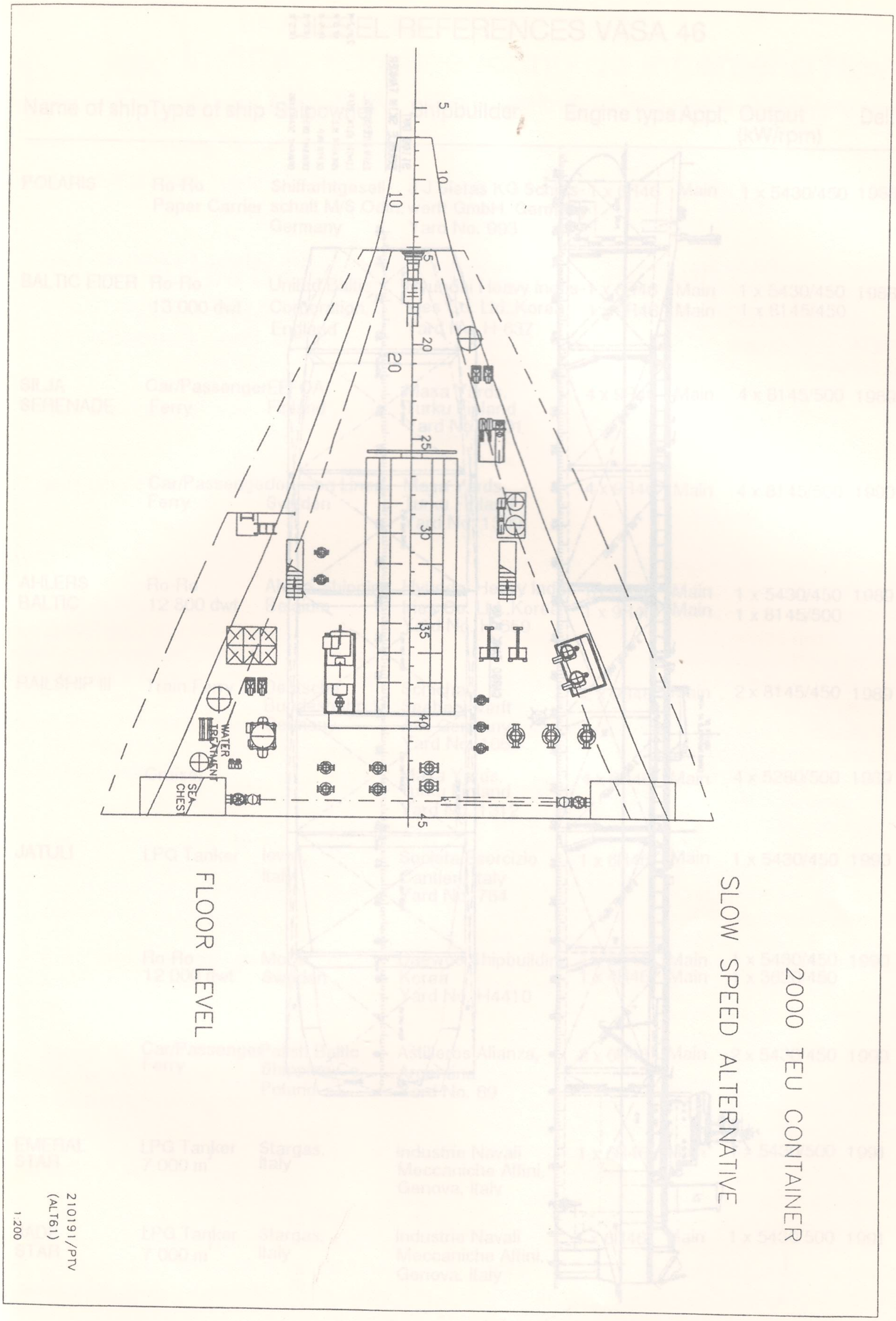
SLOW SPEED ALTERNATIVE

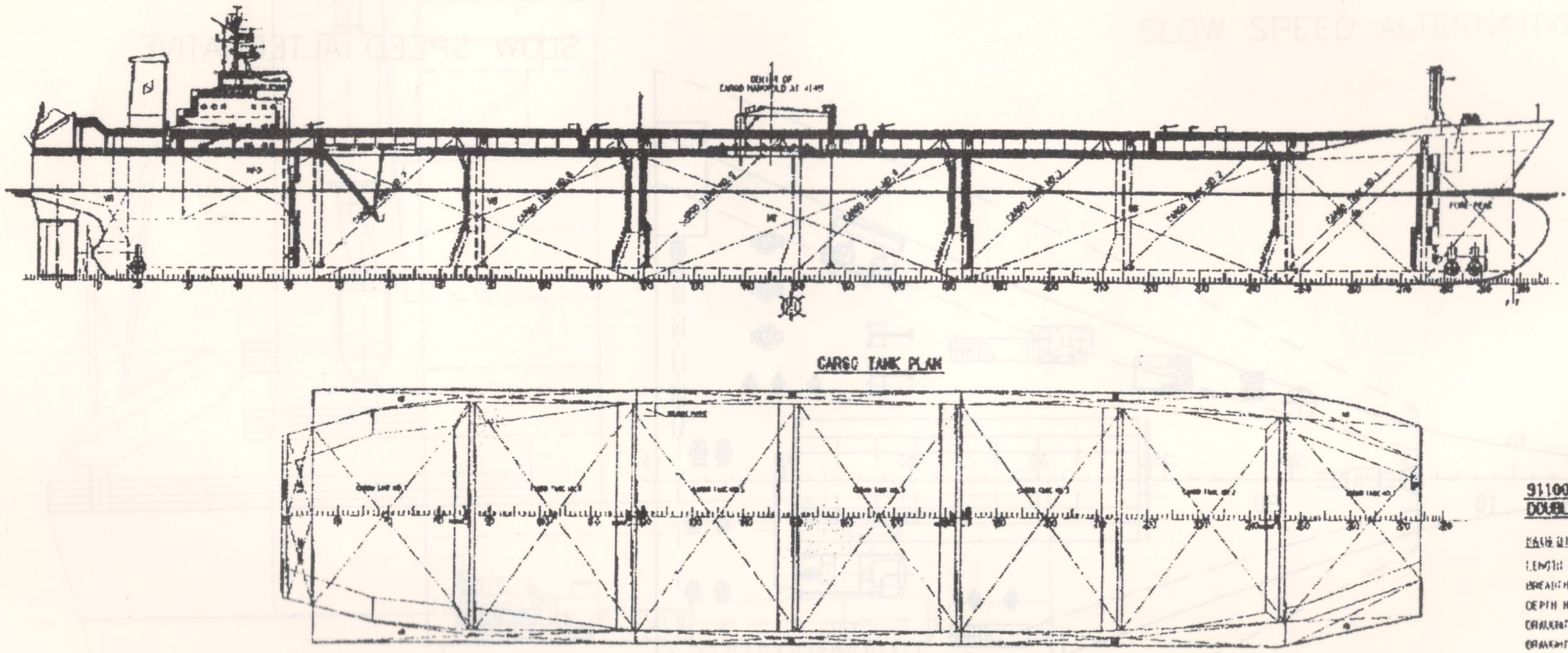


CL PROFILE

210191/PTV
(ALT67)

1:250


2000 TEU CONTAINER
SLOW SPEED ALTERNATIVE
FLOOR LEVEL
WATER TREATMENT
SEA CHEST
210191/PTV
(ALT61)
1:200



91100 DWT
DOUBLE SKIN TANKER

MAIN DIMENSIONS.

LENGTH BETW. PERP.	231.2 M
BREADTH MLD	40.0 M
DEPTH MLD	19.5 M
DRAUGHT DESIGN	14.0 M
DRAUGHT SCANTLING	14.5 M

DIESEL REFERENCES VASA 46

Name of ship	Type of ship	Shipowner	Shipbuilder	Engine type	Appl.	Output (kW/rpm)	Del.
POLARIS	Ro-Ro Paper Carrier	Shiffarhtgesellschaft M/S Odin, Germany	J J Sietas KG Schiffswerft GmbH, Germany Yard No. 993	1 x 6R46	Main	1 x 5430/450	1988
BALTIC EIDER	Ro-Ro 13 000 dwt	United Baltic Corporation, England	Hyundai Heavy Industries Co. Ltd.,Korea Yard No. H-637	1 x 6R46 1 x 9R46	Main Main	1 x 5430/450 1 x 8145/450	1988
SILJA SERENADE	Car/Passenger Ferry	EFFOA, Finland	Masa Yards, Turku Finland Yard No. 1301	4 x 9R46	Main	4 x 8145/500	1989
	Car/Passenger Ferry	Johnson Line, Sweden	Masa Yards, Turku Finland Yard No. 1309	4 x 9R46	Main	4 x 8145/500	1990
AHLERS BALTIC	Ro-Ro 12 800 dwt	Ahlers Shipping, Belgium	Hyundai Heavy Industries Co. Ltd.,Korea Yard No. H-659	1 x 6R46 1 x 9R46	Main Main	1 x 5430/450 1 x 8145/500	1989
RAILSHIP III	Train Ferry	Deutsche Bundesbahn Germany	Schichau Seebeckwerft AG, Germany Yard No. 1069	2 x 9R46	Main	2 x 8145/450	1989
	Cruiser		Masa Yards, Turku Finland Yard No. 1312	4 x 6R46	Main	4 x 5280/500	1989
JATULI	LPG Tanker	Ievoli, Italy	Societa Esercizio Cantieri, Italy Yard No. 764	1 x 6R46	Main	1 x 5430/450	1990
	Ro-Ro 12 000 dwt	MoDo, Sweden	Daewoo Shipbuilding, Korea Yard No. H4410	1 x 6R46 1 x 4R46	Main Main	1 x 5430/450 1 x 3620/450	1990
	Car/Passenger Ferry	Polish Baltic Shipping Co., Poland	Astilleros Alianza, Argentina Yard No. 69	2 x 6R46	Main	2 x 5430/450	1990
EMERAL STAR	LPG Tanker 7 000 m^3	Stargas, Italy	Industrie Navali Meccaniche Affini, Genova, Italy	1 x 6R46	Main	1 x 5430/500	1991
JADE STAR	LPG Tanker 7 000 m^3	Stargas, Italy	Industrie Navali Meccaniche Affini, Genova, Italy	1 x 6R46	Main	1 x 5430/500	1991

DIESEL REFERENCES VASA 46

Name of ship	Type of ship	Shipowner	Shipbuilder	Engine type	Appl.	Output (kW/rpm)	Del.
OPAL STAR	LPG Tanker 7 000 m	Stargas, Italy	Industrie Navali Meccaniche Affini, Genova, Italy	1 x 6R46	Main	1 x 5430/500	1992
VIKING STAR	LPG Tanker 15 000 m		San Giorgio di Porto, Genova, Italy	1 x12V46	Main	1 x 9030/500	1990
COSTA ALLEGRA	Cruiser	Costa Crociere, Italy	T.Mariotti, Genova, Italy	4 x 6R46	Main	4 x 4800/500	1992
	Tanker 91.000 dwt	NESTE OY Finland	Masa Yards, Turku, Finland Yard No. 1318	2 x 6R46	Main	2 x 5430/450	1991
	Tanker 91.000 dwt	NESTE OY Finland	Masa Yards, Turku, Finland Yard No. 1318	2 x 6R46	Main	2 x 5430/450	1992