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REPORT

Subject	Report
Preliminary ACP-max Tanker and Bulk Carrier Design.	2001-2682-1
	Project manager Per Stefenson
Customer/Contact Autoridad del Canal de Panama Attn: Mr Octavio Stagg Maritime Transit Division Edificio 710 BALBOA - Panama	**Author** Per Stefenson, Matz Brown, SSPA Thomas Milchert, Anders Englund Saltech
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This report is the result of a feasibility study on an oil tanker and a bulk carrier including the design according to the planned new maximum dimensions of the Panama Canal. The report consists of one explaining report and a number of appendices including calculation results and drawings according to the table of contents.

SSPA Sweden AB

Jim Sandkvist
Vice President

Per Stefenson
Project Manager

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ACP-T001 General arrangement tanker
ACP-T002 Midship section tanker
ACP-T003 Transverse members tanker

ACP-B001 General arrangement bulk carrier
ACP-B002 Midship section bulk carrier
ACP-B003 Transverse members bulk carrier

1 GENERAL

The overall aim with this preliminary design and feasibility study is to show two typical ships designed to fit the new Panamax Dimensions after the enlargement of the Panama Canal lock chambers.

1.1 About this report

This report is the result of a feasibility study of an oil tanker and a bulk carrier including the design according to the envisioned new maximum dimensions of the Panama Canal new locks.
The study comprises all pre-design tasks normally executed when the building of a new ship is planned and discussed with the Shipyard, Classification Society and Flag Authority. In addition some investigations on cost parameters are included. Under each headline the chosen design is discussed and often compared with similar existing vessels in order to give a full understanding of the reasoning behind the proposed solutions.

1.2 Project description

The work was performed in accordance with the requirements listed by ACP in the call for tender and furthermore based on the long experience of ship design and calculations at SSPA Sweden AB and SALTECH Consultants AB.

The study includes the preliminary design of
One ACP-Max Crude Oil Tanker
One ACP-Max Bulk Carrier

With respect to available maximum dimensions

LOA	1200'	365.76 m
Beam	185'	56.388 m
Draft TFW	50'	15.240 m

The following results are given:

- The vessels´ main dimensions and general arrangements
- Hull form and resistance calculations
- Tank, cargo and ballast capacity
- Comparisons with rules and regulations
- Longitudinal strength
- Midship sections
- Main machinery and propulsion
- Freeboard and Tonnage
- Trim and Stability including longitudinal strength and damage stability
- Brief description of equipment
- Building cost estimation
- Typical differences of an ACP-max design compared to standard ships

2 HYDROMECHANICAL DESIGN

The design of a hull form depends on a number of different criteria, that should be weighed together into an optimal solution regarding economy and safety. Factors such as cargo capacity, fuel consumption and investment costs are all important when the shipowner is planning for his new ship.
The preliminary parameters were chosen after statistical comparison with similar ships in the SSPA data bank.

2.1 ACP-max Tanker, hull form

In order to achieve optimal cargo capacity the Block Coefficient, Cb, should be chosen as big as possible. The statistics however show that a Cb larger than 0.825 should not be recommended due to increased wave resistance and accordingly increased fuel consumption.
The following dimensions are proposed:

Lpp	352 m	
B	56.388 m	
T	14.85 m (Salt Water)	
L/B	6.26	
B/T	3.70	
Cb	0.825	(Block Coefficient)
Cv	5.74	(Length displacement ratio)

Optimal Froude's number corresponding to the selected Cb and Cv is 0.147 at a speed of 17 knots however according to statistics it is possible to reach 0.152 at 17.5 knots with good results.

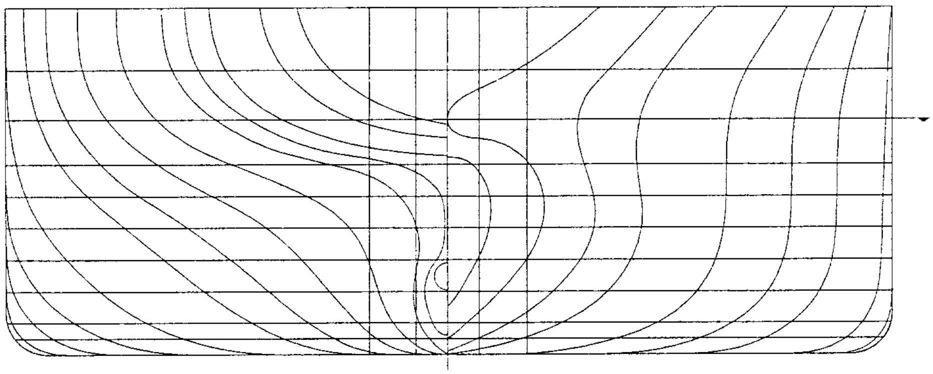


Fig 2.1 Body plan ACP-max Tanker and Bulk-carrier

2.1.1 Resistance and Propulsion

At a preliminary propeller power prognosis the optimal propeller diameter is 10.0 m at a revolution of 70 rpm and five blades however some trim constraints in ballast condition will make a propeller diameter of 9.5 m more suitable. The revolution will then be approx. 80 rpm.

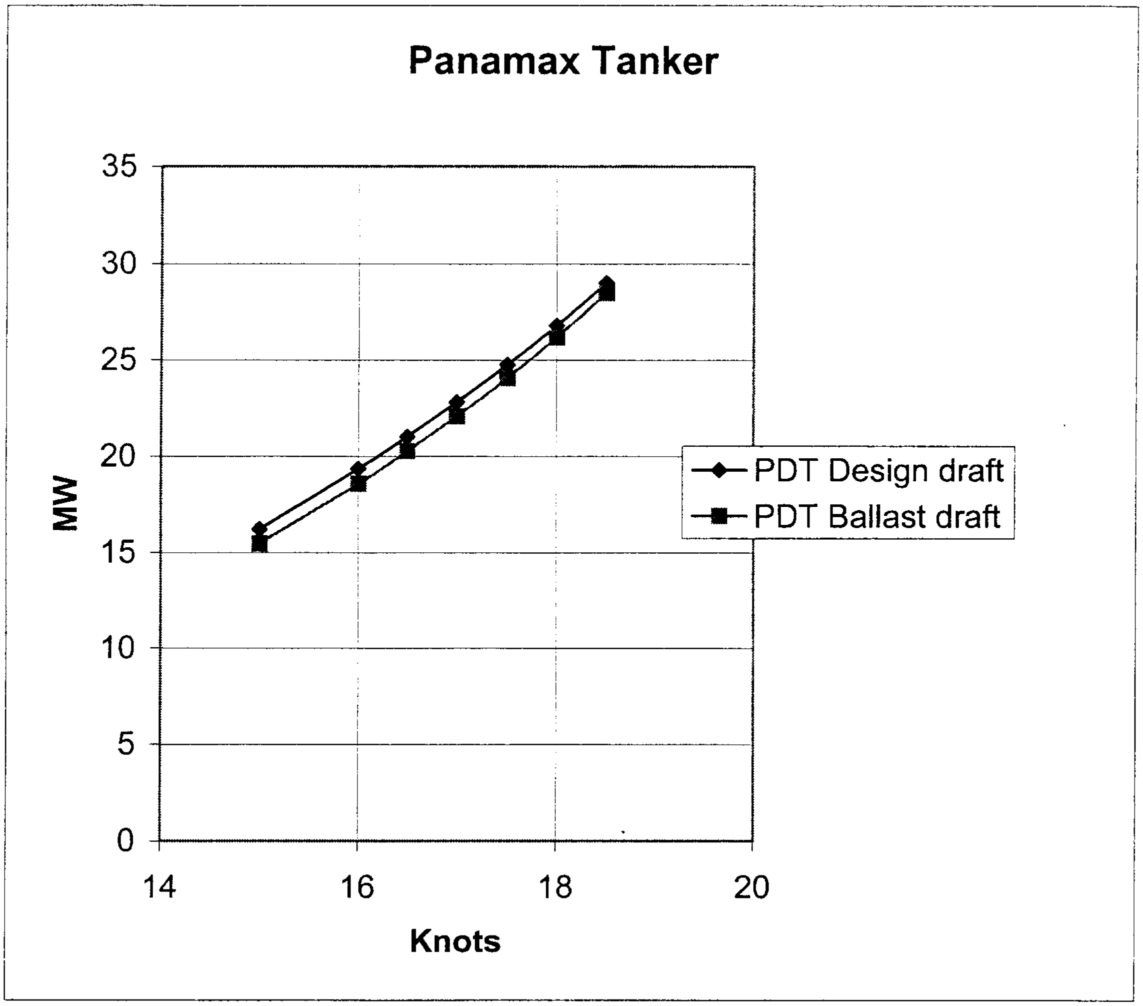
In the design draft condition (T=14.85), the delivered power (PDT) to reach 17.5 knots in calm sea will be 24.74 MW. (see attached diagram). The engine manufacturers usually calculate with 10% engine operational margin. Ship designers assume about 15% sea margin for average ocean conditions. The installed Engine Power (EP) at maximum continuous rating (MCR) will thus be:

EP =1.1 (PDT/0,85)

This would lead to approx. 32 MW installed engine power to reach 17.5 knots at normal continuous rating (NCR) and 29.5 MW to reach 17 knots

Typical engines in this power range are B&W S80MC 8 to 9 cylinders or Sultzer RTA84C 9 to10 cylinders. (see attached Main engine data, Appendix B).

The small difference (see Fig. 2.1.2.) in delivered power between the design draft condition and the ballast condition has to do with decreased propeller efficiency and less favourable hull form due to trim and shallow draft in the latter condition. An optimisation for the best ballast condition can be done in the final design phase. Normally this will lead to an increase in speed of approx. 1 knot in ballast condition compared with full load.



	Draft FP/AP	14.85/14.85	7.75/11.08
Speed (knots)	FnL (Froude Number)	PDT (MW)	PDT (MW)
15	0.130	16.205	15.469
16	0.139	19.338	18.559
16.5	0.143	21.020	20.266
17	0.147	22.822	22.080
17.5	0.152	24.739	24.061
18	0.156	26.790	26.178
18.5	0.160	29.000	28.481

Fig 2.1.2 Delivered power (to the propeller)

2.1.2 Fuel consumption

If a B&W 8S80MC 8 cylinder diesel engine is chosen, the maximum engine power at 79 r/min will be 29120 kW according to the manufacturers data sheet and the Normal Continuous Rating (NCR) is then 29120/1.1=26472 kW.
At this output the Specific Fuel Oil Consumption (SFOC) will be 167 g/kWh or 4420 kg/engine hour, and the service speed approx. 17 knots.

The tanker is designed with tanks for 7000 cubic meter fuel which corresponds to approx. 6000 tonnes. The fuel range at 17 knots speed is then estimated to 56 days or 22.800 Nautical miles.

The following diagram shows the fuel consumption at NCR for speeds between 15 and 18 knots in average ocean conditions (15% sea margin).

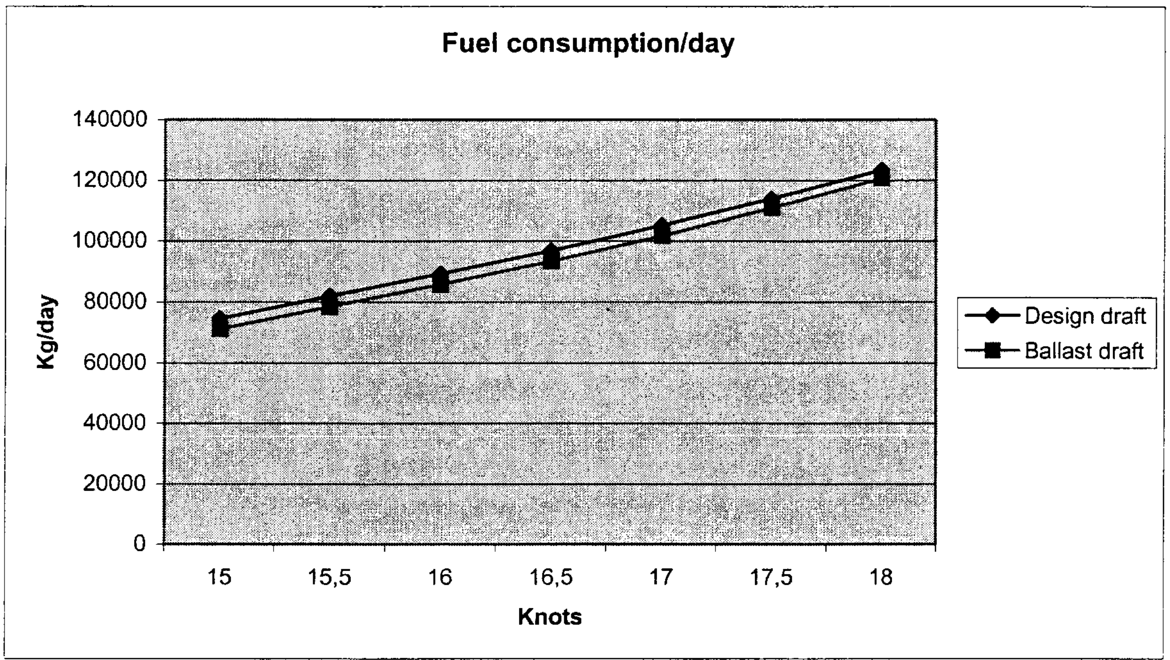


Fig. 2.1.3 Fuel consumption

2.2 ACP-max Bulk Carrier

2.2.1 Hull form, Resistance and Propulsion, bulk carrier

The same hull form was selected for the bulk carrier with the only difference that the moulded depth D is one meter higher in order to carry light bulk cargo (D=23m).

In general, bulk carriers on the market are a little slower than tankers and a speed of 15 knots may be more sufficient in this case.
This would result in approx. 30% less engine power required (see fig 2.1.2), which of course will affect both ship's price and operational cost.

2.2.2 Fuel consumption bulk carrier

A suitable engine in this case could be B&W 6S80MC. The maximum engine power at 79 r/min will then be 21 840 kW according to the manufacturers data sheet and the Normal Continuous Rating NCR is then 19854 kW. At 15 knots the needed power in average ocean conditions (15% sea margin) and full load condition is 19065 kW. At this output the Specific Fuel Oil Consumption (SFOC) will be 167 g/kWh or 3184 kg/engine hour or 76.416 kg/day.
The figure (Fig. 2.1.3) above shows the daily fuel consumption.

The bulk carrier is designed with tanks for 7000 cubm. fuel which corresponds to approx. 6000 tonnes. The fuel range at 15 knots speed is then estimated to 78 days or 28.000 Nautical miles

3 TANKER DESIGN

3.1 Arrangement and main dimensions

The following comparison can be made between the proposed ACP-max tanker and a typical double hull very large crude oil tanker (VLCC) of today

	APC-max	VLCC (typical)
L_{oa}	365.8 m (max)	332 m
$L=L_{bp}$	352 m	320 m
L_{rule}	340m (approx.)	307 m
B	56.4 m	58 m
D	22 m	31 m
T_{design}	14.85 m (salt water)	21 m
$T_{scantlings}$	ditto	22 m
$T_{Panama\ Canal\ (TFW)}$	15.24 m	-
$Deadweight_{scantlings}$	203,000 tonnes*	300,000 t
Cargo volume	260,000 cubm	348,000 cubm
Ballast volume	100,000 cubm	100,000 cubm
L/B	6.3	5.5
D/B	0.39	0.53
T/B	0.26	0.38
LBD	438,000 m^3	575,000
Block coeff. CB	0.825	0.81-0,83
Service speed	17 knots	15-16 kn
Lightweight	44,000 tonnes*	41,000-45,000 t
Tonnage gross	123,000	158,000
Tonnage net	64,000	109,000

*) ± 2000 tonnes

The ACP-max tanker is thus about 33 m (≈+10%) longer and 9 m (≈-30%) lower in depth than the typical VLCC. The deadweight capacity and cargo volume is about 70% of the VLCC. The lightweight is about the same. The ACP-max tanker is a typical shallow draft vessel with low D/B ratio compared to a standard tanker design. Due to low draft, the design is deadweight critical but insensitive to cargo volume requirements. The available displacement in salt water is approx. 247,000 tonnes.

The general arrangement, Fig 3.1.1 and drawing ACP-T001, was chosen with a tank subdivision similar to a typical VLCC, i.e. with five cargo tank sections in length, double hull (compulsory) and two longitudinal bulkheads. Two slop tanks are arranged at the aft

end of the cargo space close to the pump room. There will be 5 centre cargo tanks, 10 side cargo tanks, and two slop tanks, i.e. altogether 16 cargo tanks.
Lengths of engine room and pump room were chosen with respect to length and space requirements of main engine and equipment.

The height of the navigation bridge was chosen with respect to the required sight line forward according to Panama Canal regulations, Fig. 3.1.2.

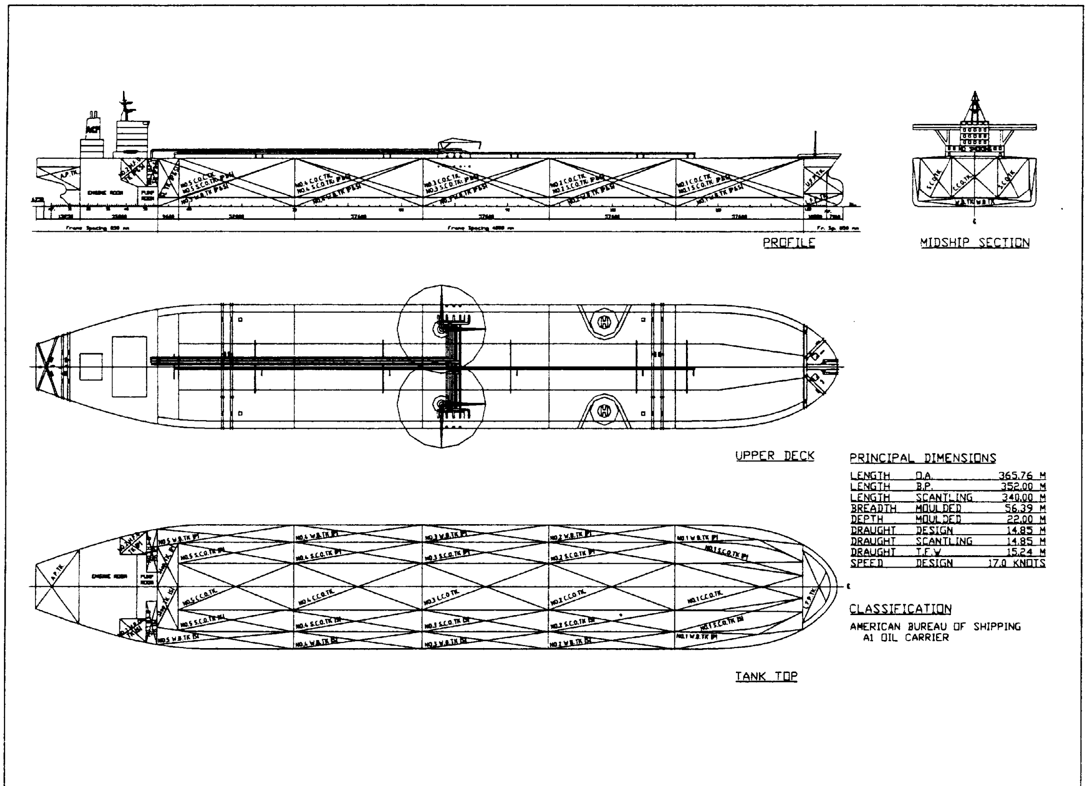


Fig. 3.1.1 General arrangement of tanker

Ballast volume and minimum ballast draft:
The minimum capacity of segregated water ballast tanks is defined by MARPOL Annex I, Ch. II, Reg. 13 which requires a minimum moulded draft amidships of not less than

$$T_m = d_m = 2.0 + 0.02L_{rule} = 8.8 \text{ m}$$

In association with a trim by the stern of $0.015L_{rule} = 5.1$ m.

The required ballast capacity is about 100,000 tonnes, whereof approx. 95,000 tonnes in the cargo part of the hull, the balance forward and aft. It can be noted that this ballast capacity is of the same order as for a typical VLCC.

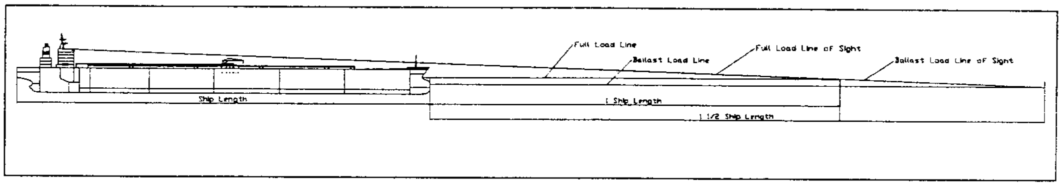


Fig. 3.1.2. Sight requirement for tanker with trim considered (Trim not shown)

Depth D and cargo volume:
Whereas length, draft and breadth are given by the new Panama Canal limitations, the depth D can be chosen more freely with respect to cargo density (specific gravity S.G.), consideration of MARPOL requirements and freeboard regulations.

For determination of the cargo density, comparison was made with a number of built crude oil tankers, see Fig. 3.1.3. A design density of 0.84 tonnes/cubm was selected.

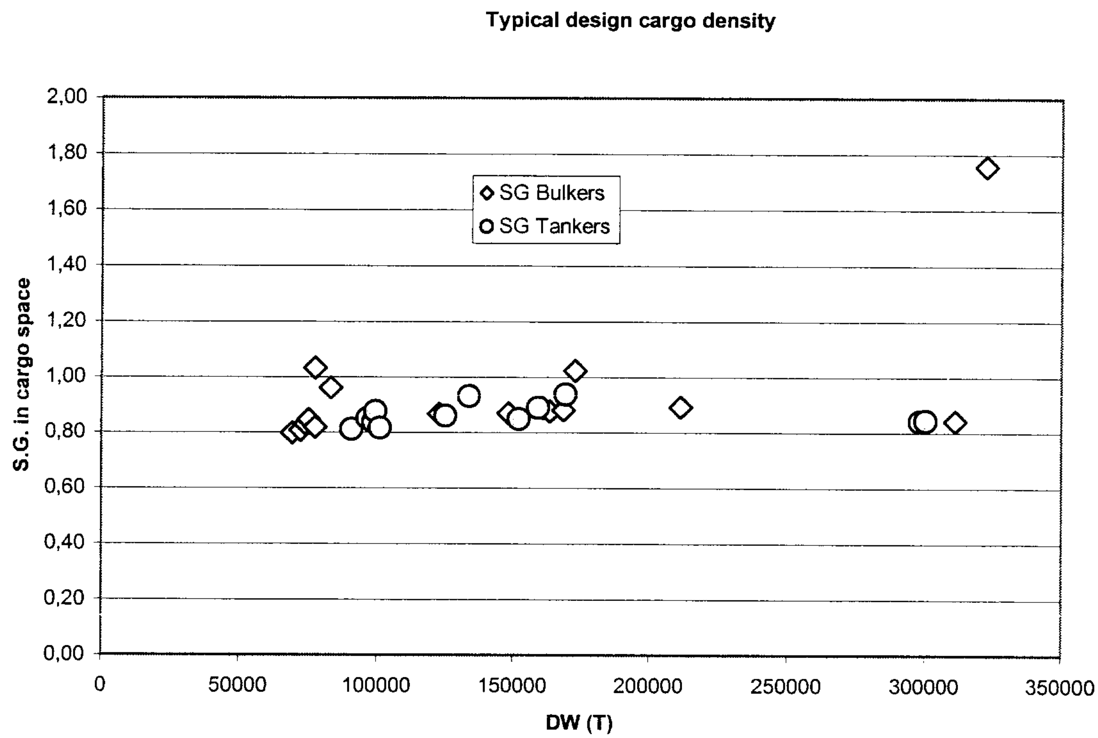


Fig. 3.1.3. Typical specific gravity (density) of cargo, tonnes/cubm, in tankers and bulk carriers of 60,000-300,000 tonnes deadweight

With a required capacity and weight of about 7,000-10,000 tonnes for fuel oil, diesel oil, fresh water, provision, spare parts, crew etc. the deadweight remaining for cargo is max. 196,000 tonnes. The cargo volume required is, with a filling rate of 98%,

Min req. cargo volume = 196,000/(0.84x0.98) = 238,000 cubm

With minimum bunker and provision intake when going through the Canal, i.e. cargo weight approx. 203,000 tonnes:

Cargo volume = 203,000/(0.84x0.98) = 247,000 cubm

The required depth would be 21-22 m. D being a "cheap" design parameter,

D = 22 m was chosen.

The actual net cargo volume (structures, pipes etc. excluded) is approx. 260,000 m^3.

Tank table:

The tank volumes can be summarised as follows. For further information, see the Trim and Stability calculations.

Cargo oil tanks	**Gross volume 100% full, m³**
No. 1 CO centre tank	19192
No. 1 CO side tank S	13178
No. 1 CO side tank P	13178
No. 2 CO centre tank	23114
No. 2 CO side tank S	15828
No. 2 CO side tank P	15828
No. 3 CO centre tank	23114
No. 3 CO side tank S	15828
No. 3 CO side tank P	15828
No. 4 CO centre tank	23114
No. 4 CO side tank S	15833
No. 4 CO side tank P	15833
No. 5 CO centre tank	21184
No. 5 CO side tank S	12831
No. 5 CO side tank P	12831
Slop tank S	3116
Slop tank P	3116
	262,946 m³
Ballast water tanks	
Fore peak WB tank lower	835
Fore peak WB tank upper	2811
No. 1 BW tank S	8537
No. 1 BW tank P	8537
No. 2 BW tank S	9362
No. 2 BW tank P	9362
No. 3 BW tank S	9370
No. 3 BW tank P	9370
No. 4 BW tank S	9304
No. 4 BW tank P	9304
No. 5 BW tank S	10023
No. 5 BW tank P	10023
Aft peak WB tank	1615
	98,453 m³
Fuel oil tanks	
No. 1&2 FOT S & P	7000
Diesel oil tanks	400
Fresh water tanks	500
Miscellaneous tanks in engine room	500
	8400 m³

3.2 MARPOL requirements. Hull damage and hypothetical outflow of oil

The selected tank arrangement and volumes were checked with respect to MARPOL Annex I, Reg. 22&23. These regulation define hypothetical hull damages and the hypothetical outflow of oil as per below. For actual tank sizes, dimensions of side and bottom ballast tanks etc. see G.A. drawing, Tank Table and Midship Section drawing.

Side damage:		
Longtl. extent lc	14.50 m	Actual length between transv. BHDs, about 60 m
Transverse extent tc	11.28 m	Actual distance from side to LBHD, about 17,6 m
Vertical extent vc	total height	
Bottom damage aft of 0.7L:		
Longtl. extent ls	5.0 m	
Transverse extent ts	5.0 m	
Vertical extent vs	3.76 m	Chose height of double bottom = 4.0 m
Bottom damage forward:		
Longtl. extent ls	34.50 m	
Transverse extent ts	9.40 m	
Vertical extent vs	3.76 m	Chose height of double bottom in cargo area = 4.0 m
Hypothetical outflow:		
Width of wing ballast tanks bi	3.36 m	Ki = 1- bi/tc = 1 – 0.3 = 0.7

Hypothetical outflow for side damage Oc = 2*0.7*15000 = 21,000 m^3
Hypoth. outflow for bottom damage Os = 0

Limitation 30,000 m^3.

Result **OK**

According to above, the selected arrangement is within the MARPOL requirements.

3.3 Longitudinal strength

The minimum longitudinal strength requirement for all types of ocean going vessels are agreed upon within IACS and are thus identical for the classification societies.

The requirements define the minimum inertia I and the minimum bending modulus Z of the main hull girder. For ships with low D/B and great length, such as the ACP-max vessels, the inertia requirement is decisive for the required longitudinal strength and the steel weight of the hull. It should be noted that the inertia requirement is independent of steel quality.

With the above dimensions, the minimum class requirements amidships are:

$I_{min} = 3*10.75*L^3*B\ (CB + 0.7)$ cm^4

$I_{min} = 1090\ m^4$ independent of steel quality

$Z_{min} = k*10,75*L^2*B\ (CB+0.7)$ cm^3 k=1 for mild steel
k=0.78 for HT32
k=0.72 for HT36

($Z_{min} =$ $107\ m^3$ for mild steel)

$Z_{min} =$ $84\ m^3$ net for 320 N/mm^2 higher tensile steel, which was selected.
Gross modulus incl. corrosion margin required by ABS is
$Z_{min} = 88.3\ m^3$

($Z_{min} =$ $77\ m^3$ for 360 N/mm^2 higher tensile steel)

The actual (designed) values amidships are:

Gross designed inertia	$I = 1106\ m^4$
Gross designed modulus at deck/bottom	$Z_d = 94.9\ m^3$; $Z_b = 106.9\ m^3$

The designed midship section modulus corresponds to an allowable still water bending moment SWBM of approx. 1,000,000 tonnes meters.
The actual calculated maximum SWBM in ballast condition is approx.820,000 tm, and in homogeneous laden condition below 100,000 tm.

Details are given in attached trim and stability calculations, Appendix E and ABS SafeHull calculations, Appendix C.

3.4 Midship Section. Typical web frame and transverse bulkhead

Drawing ACP-T002 shows the selected Midship Section and the scantlings of the longitudinal members. Due to the high requirement for longitudinal strength, most scantlings are in excess of class requirements for local strength. Only the side longitudinals and side shell plating may be determined by local strength requirements. ABS SafeHull A output for the scantlings of the longitudinal strength members is given in Appendix C.

Sketches of a typical web frame and a typical transverse bulkhead are given in drawings ACP-T003.
In comparison with a typical VLCC, it can be noted that, due to smaller breadth B of the ACP-max tanker, the main web frames and bulkhead stringers are slightly shorter.
Tank pressures are lower due to smaller depth D and smaller draft T.
Typical web frames are also deeper due to greater width of side tank and depth of double bottom. This is a consequence of the ballast capacity requirement, and the size of the ballast tanks in cargo area.
Consequently, there are greater local strength margins in the ACP-max design compared to a typical VLCC.

3.5 Main machinery

As already mentioned in chapter 2, the preliminary propeller power to reach 17.5 knots will be 24.74 MW. This gives a need for approx. 32MW engine power to reach 17.5 knots and 29 Mw to reach close to 17 knots

Typical engines in this power range are B&W S80MC 8 to 9 cylinders or Sulzer RTA84C 9 to10 cylinders. (see attached engine sheets, Appendix B).

3.6 Light weight estimate and distribution

The lightweight is governed by the longitudinal strength requirement, compare above. Other weights are similar to those of a typical VLCC scaled with respect to size of vessel. The following weights were estimated:

Steel weights:	
Cargo hold	33600 tonnes
Fore body	1100
Aft body	900
Engine room casing and funnel	2950
Deck house	420
Rudder and stock	150
Miscellaneous (weld, paint etc)	300
	39520
Hull outfit:	
Hull piping	850
Anchors and chains	240
Deck machinery	200
Pump room equipment	140
Accommodation outfit	250
Remaining items	400
	2080
Machinery:	
Main engine 29000 kW	1100
Aux. engine + boiler	60
Propeller and shaft	120
Piping in engine room	340
Steel outfit in engine room	200
Remaining machinery and electric	340
	2160
Total	**43660 tonnes**

The lightweight distribution along the hull is shown in Fig. 3.6.1.

The lightweight of typical tankers and bulk carriers is shown in Fig. 3.6.2. for comparison. The lightweight within a certain deadweight range can usually be expressed as

Lightweight = LW = Factor• LBD

It is noted that an ACP-max vessel will have a higher lightweight/deadweight ratio than a standard vessel due to the fact that main dimensions L,B,D,T and D/B ration of standard vessels are chosen with respect to hull weight optimization. A similar kind of optimization is not possible in this case.
For a 200,000 TDW standard crude oil tanker, the factor LW/LBD in above formula may be in the range 0.075. In case of the ACP-max tanker, this factor would rather be around 0.1, indicating a relatively high steel weight due to the longitudinal strength requirements.

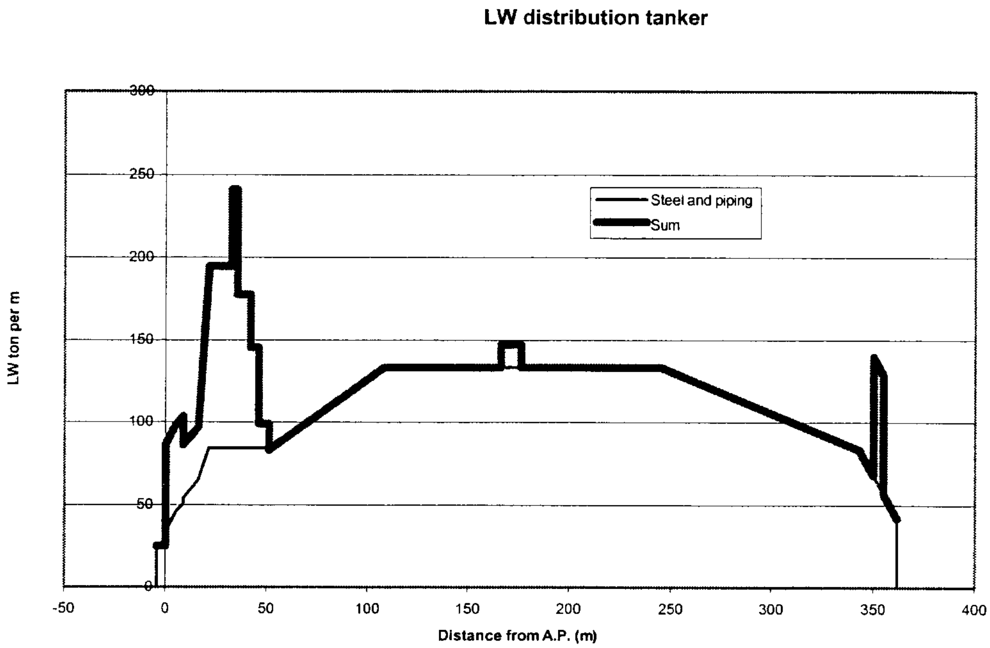


Fig. 3.6.1: Lightweight distribution of ACP-max tanker

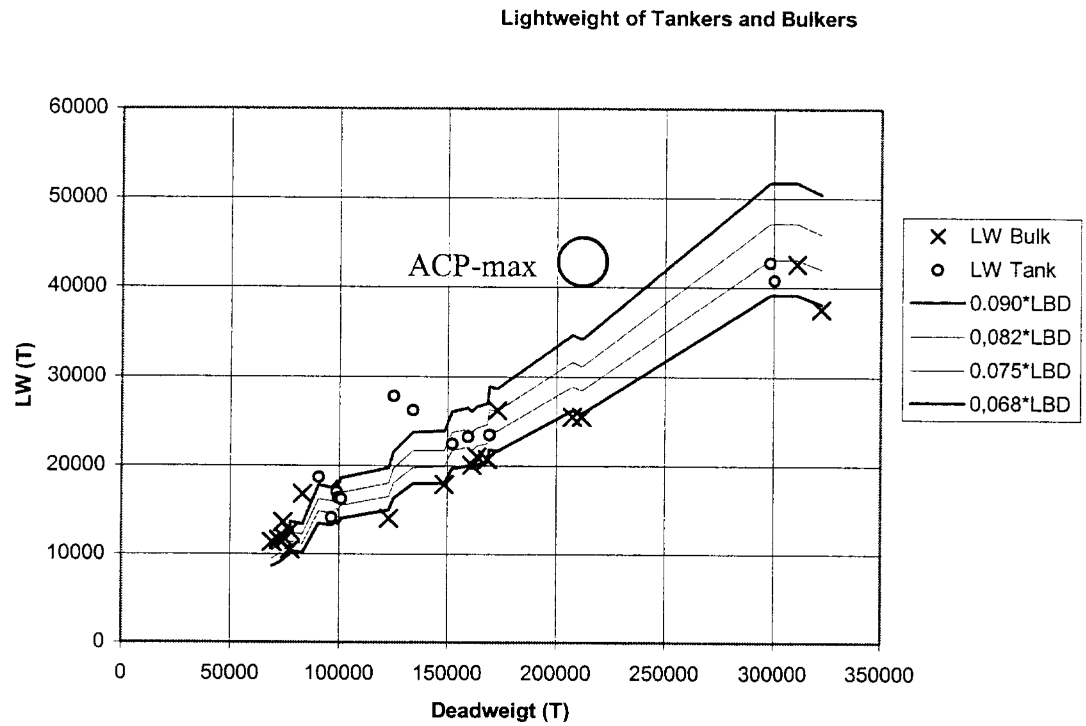


Fig. 3.6.2 Lightweight of typical crude oil tankers and bulk carriers versus deadweight and as functions of LxBxD.

3.7 Freeboard

Freeboard calculation according to the International Convention on Load Lines is attached below.
For an ACP-max tanker with A-type freeboard and without sheer or forecastle, the required minimum summer freeboard in salt water is approx. 6900 mm.
The actual freeboard in salt water is approx. 7200 mm.
Minimum required tropical fresh water freeboard is approx. 6300 mm.
Minimum required bow height is approx. 6300 mm.

For an ocean going vessel it may be recommendable to increase the freeboard forward in excess of the above minimum requirements, which would also influence the required deckhouse height according to Panama Canal Rules.

Freeboard calculation
With dimensions
Lf = 345m; B = 56.4m; CB=0.83; D=22m; T=14.8m

A freeboard without sheer:		
Tabular A-freeboard		3394 mm
Corrected for CB		3768
Corrected for sheer	+3127	6895
Min. summer freeboard in SW		6895 mm
Correction for tropical	-308	
Correction for FW	-308	6278
Min tropical FW freeboard		6278 mm
Min. Bow height: 6305 mm		

3.8 Tonnage

The gross and net tonnage is based on gross enclosed volume and cargo volume respectively and was calculated according the International Convention on Tonnage Measurement of Ships, 1969, Annex I.

For the ACP-max tanker with T=14.85 m; D = 22 m, and without sheer, the
Gross tonnage is GT approx. 123,000
Net tonnage is NT approx. 66,000

Calculation of tonnage:

V = Gross volume	395,500 cubm
$K_1 = 0.2+0.02\ {}^{10}\text{Log}\ V =$	0.3119
Gross tonnage $GT = K_1\ V =$	123,456
Vc = Cargo volume	263,000 cubm
$K_2 = 0.2+0.02\ {}^{10}\text{Log}\ V_c =$	0.3084
Net tonnage $NT = K_2\ Vc\ (4T/3D)^2 =$	65,698

3.9 Trim and Stability. Calculated bending moment and shear force

Intact stability requirements:
A tanker has to satisfy the IMO and national intact stability requirements; mainly defining GM values and the GZ curve.

The results of intact stability calculations for typical ballast and laden conditions are attached in Appendix E and summarized in below table. All regulations are satisfied. It can be noted that the GM values are very high due to the great beam of the vessel.

Longitudinal strength:
Still water bending moments, SWBM, were calculated for typical intact trim and stability conditions, see Appendix E and summary table below.
The actual, calculated SWBM values are below the allowable values.

Damage stability requirements:
The damage stability must satisfy the requirements according to the Load Line Convention, ICLL, Reg. 27 and IMO Reg. A320 and A514 for A type freeboard. This is a one-compartment requirement which is less severe than the MARPOL requirements.

The damage stability must also satisfy the requirements according to MARPOL Annex I, Reg.25. This is a deterministic rule, defining typical damages which the vessel must survive.
Large tankers with the actual subdivision have, generally speaking, no problems to fulfill those rules. Some typical damage conditions were calculated for demonstration, see Appendix E and below summary table.

Summary of intact stability and strength calculations for ACP-Max Tanker

Description	Unit	Condition 1	Condition 2	Condition 3
		Lightship cond.	Homo. design load dep. cond	Normal ballast dep. cond.
Lightship weight	[T]	43630,2	43630,2	43630,2
Bunkering	[T]	0,0	6800,0	6800,0
Water ballast	[T]	0,0	0,0	98982,0
Cargo	[T]	0,0	196124,0	0,0
Deadweight	[T]	0,0	202924,0	105782,0
Displacement	[T]	43630,2	246554,2	149412,2
Draught eqiv.	[M]	3,045	14,833	9,399
Draught at F.P.	[M]	1,423	14,835	7,752
Draught at A.P.	[M]	4,699	14,831	11,078
Trim*	[M]	3,276	-0,003	3,327
KG	[M]	12,500	13,392	8,315
GM0	[M]	74,578	12,011	24,268
Max B. Moment	[T-M]	458150	85925	815275
Max S. Force	[T]	5156	3012	8795
IMO Intact Stability Criteria				
Area30	[Mrad]	5,399	1,531	3,270
Area40	[Mrad]	7,565	2,378	5,303
Area30-40	[Mrad]	2,166	0,847	2,033
Max GZ 30	[°]	25**	35	40
GZ 0.2	[M]	13,045**	4,892	11,765
GM 0.15	[M]	74,578	12,011	24,268

Criteria

Area30:	The area under the GZ-curve to 30° not to be less than 0,055 mrad
Area40:	The area under the GZ-curve to 40° not to be less than 0,090 mrad
Area30-40:	The area under the GZ-curve from 30°-40° not to be less than 0,030 mrad
Max GZ 30:	The max value of GZ to occur at an angle equal or greater than 30°
GZ 0,2:	The value of GZ at an angle equal or greater to 30° not to be less than 0,20 m
GM 0,15:	The value of upright GM not to be less than 0,15 m

* Positive trim bow up, negative trim bow down

** For lightship conditions this is normally the case, however accepted due to ballast capacities

Summary of damage stability calculations for ACP-Max Tanker

All damage stability conditions calculated for Homo. des. load dep.
Compartment division in damage stability calculations was simplified

Intact ship data		Homo. Design dep. cond
Displacement	[T]	246554,0
Draught eqiv.	[M]	14,833
KG	[M]	13,392
GM0	[M]	12,011

Survival requirements as per MARPOL 73/78, Annex 1,Regulation 25

Water line:	The final water line shall be below margin points allowing progressive flooding
Heel 25:	The angle of heel due to unsymmetrical flooding shall not exceed 25°
Min GZ 20 *:	The GZ curve shall after flooding have a range of 20° beyond equilibrium heel angle
Min GZ 0.1:	The min GZ within the 20° range mentioned above shall be at least 0.10 m
Min 0.0175:	The min area within the 20° range mentioned above shall be at least 0.0175 mrad

* Result presented as estimated stability width

Damages	Damage 1	Damage 2	Damage 3	Damage 4	Damage 5
Flooded comp.	No.1 W.B.TK (S)	No.2 W.B.TK (S)	No.3 W.B.TK (S)	No.4 W.B.TK (S)	No.5 W.B.TK (S)
Flooded comp.	N0.1 S.C.O TK. (S)	N0.2 S.C.O TK. (S)	N0.3 S.C.O TK. (S)	N0.4 S.C.O TK. (S)	N0.5 S.C.O TK. (S)

Survival requirements

Criteria	Damage 1	Damage 2	Damage 3	Damage 4	Damage 5
Water line:	Ok	Ok	Ok	Ok	Ok
Heel 25 [°]:	5,55	6,65	6,30	6,21	4,64
Min GZ 20 [°]:	70	70	70	70	70
Min GZ 0.1 [M]:	2,40	2,16	2,28	2,35	2,72
Min 0.0175:	Ok	Ok	Ok	Ok	Ok

Continuation:

Damages	Damage 6	Damage 7	Damage 8	Damage 9	Damage 10
Flooded comp.	No.1 H.F.O. TK (S)	No.1 W.B.TK (S)	No.2 W.B.TK (S)	No.3 W.B.TK (S)	No.4 W.B.TK (S)
Flooded comp.	No.1 H.F.O. TK (S)	N0.1 S.C.O TK. (S)	N0.2 S.C.O TK. (S)	N0.3 S.C.O TK. (S)	N0.4 S.C.O TK. (S)
Flooded comp.	No.2 H.F.O. TK (P)	No.2 W.B.TK (S)	No.3 W.B.TK (S)	No.4 W.B.TK (S)	No.5 W.B.TK (S)
Flooded comp.	No.2 H.F.O. TK (P)	N0.2 S.C.O TK. (S)	N0.3 S.C.O TK. (S)	N0.4 S.C.O TK. (S)	N0.5 S.C.O TK. (S)
Flooded comp.	Engine Room				
Flooded comp.	Slop TK. (S)				
Flooded comp.	Slop TK. (P)				

Survival requirements

Criteria	Damage 6	Damage 7	Damage 8	Damage 9	Damage 10
Water line:	Ok	Ok	Ok	Ok	Ok
Heel 25 [°]:	0,00	17,85	17,83	15,59	13,15
Min GZ 20 [°]:	75	40	40	50	55
Min GZ 0.1 [M]:	3,60	0,65	0,72	0,90	1,35
Min 0.0175 [Mrad]:	Ok	Ok	Ok	Ok	Ok

Continuation:

Damages	Damage 11
Flooded comp.	No.5 W.B.TK (S)
	N0.5 S.C.O TK. (S)
	No.1 H.F.O. TK (S)
	No.1 H.F.O. TK (S)
	No.2 H.F.O. TK (P)
	No.2 H.F.O. TK (P)
	Engine Room
	Slop TK. (S)
	Slop TK. (P)

Survival requirements

Criteria	Damage 11
Water line:	Ok
Heel 25 [°]:	6,28
Min GZ 20 [°]:	65
Min GZ 0.1 [M]:	1,867
Min 0.0175 [Mrad]:	Ok

3.10 Equipment

It is assumed that the vessel would be equipped as a typical large crude oil tanker for worldwide trade. Cargo and ballast pumps would be installed in a pump room forward of the engine room. Cargo pumps would be steam driven. Exhaust gases produced by the boiler(s) are used as inert gas for filling of cargo tanks. Ballast pumps may either be steam driven or electric motor driven.

The equipment is governed by a number of main requirements:

- Typical unloading time including crude oil washing (COW) about 20-24 hours
- Manifold arrangement must satisfy OCIMF requirements
- Mooring arrangement must satisfy OCIMF requirements
- Anchoring and mooring arrangement and equipment must satisfy class requirements
- Prevention of oil spillage as per MARPOL, USCG and oil company requirements

Below, typical essential equipment and machinery are listed in order to satisfy the main formal requirements and with respect to typical practical choices.

Equipment and piping for cargo handling and ballast system:

- 3 cargo oil pumps 3x4000 cubm per hour, 15 bar. Steam turbine driven centrifugal pumps.
- 1 set of automatic vacuum system with 2 vacuum pump and 3 gas separators
- 1 cargo stripping pump 450 cubm per hour
- 2 cargo stripping ejectors, 2x700 cubm per hour, cargo oil driven
- 2 ballast pumps 2x3500 cubm per hour. Electric motor driven
- 1 ballast ejector 400 cubm per hour
- Inert gas system. Capacity as per Rules
- Tank cleaning machines. No. and capacity as per Rules
- Pressure vacuum valves for each cargo tank. Capacity as per Rules
- Tank level gauging system with overfill alarm
- Oily water monitoring system
- Loading computer

- Piping manifold amidships as per OCIMF requirements with connections for cargo handling, inert gas recovery, fuel oil bunkering. Crane for hose handling.
- Cargo piping for three segregations
- Inert gas piping
- Ballast piping in double bottom
- Heating piping in slop tanks

- Gutter bars around upper deck, deck scupper plugs, oil spillage pump, oil coamings etc. as per MARPOL, USCG and EXXON requirements

Anchoring, mooring and towing equipment:

- 2 windlasses forward with capacity as per Class Rules combined with mooring winches
- 2 anchors, 20 ton, with chain 770 mx111 mm ABS grade 3
- 10 mooring winches 35 ton with warping head. Break capacity and arrangement as per OCIMF
- Single mooring equipment, 200 ton, forward, as per OCIMF
- Emergency towing equipment at stern, 200 ton, as per IMO Rules
- 24 mooring lines on winch drums. 42 mm diameter, 275 m. Breaking strength as per OCIMF

Machinery:

- Main engine, see above
- Propeller, see above
- 3 diesel generators, about 3x1000 kW
- 1 emergency diesel generator, 250 kW
- 2 HFO and 2 LO purifiers
- 2 oil fire steam boilers 2x30 ton per hour
- 1 exhaust gas steam boiler 3 ton per hour
- Steam system with vacuum condenser etc. for cargo turbines

4 BULK CARRIER DESIGN

4.1 Arrangement and main dimensions

The proposed main dimensions are listed below and compared with two selected bulk carries. A direct comparison with typical bulkers of this size cannot be made as only a few ore carriers of similar size exist. The typical large bulk carrier is rather of so called Capesize type with a deadweight of 150,000-170,000 tonnes.

	APC-max	Capesize bulk	Very large
L_{oa}	365.8 m (max)	280	312
$L=L_{bp}$	352 m	270	300
L_{rule}	340 m (approx.)	260	288
B	56.4 m	45	50
D	23 m	24	25
$T=T_{scantlings\ (SW)}$	14.85 m (salt water)	17.5	18.3
$T_{Panama\ Canal\ (TFW)}$	15.24 m		
Deadweight	203,000 tonnes*	161,000	211,000
Cargo vol. (grain)	279,000 cubm	176,000	228,000
Ballast vol.	95,000 cubm	71,000	75,000
L/B	6.3	6.0	6.0
D/B	0.41	0.53	0.50
T/B	0.26	0.31	0.37
LBD	457,000 m^3	292,000	375,000
Block coeff. CB	0.825	0.83	0,84
Service speed	15-16 kn.	15.3	14.5
Lightweight	44,000 tonnes*	20,000	25,500
Tonnage gross	131,000	81,000	108,000
Tonnage net	64,000		

*) ± 2000 tonnes

The ACP-max bulk carrier has a considerably larger hull (LBD is 22% greater) and lightweight than a typical bulk carrier of similar deadweight. The ACP-max bulk carrier is a typical shallow draft vessel with low D/B ratio compared to standard bulk carrier designs. Due to low draft, the design is deadweight critical but insensitive to cargo volume requirements. The available displacement in salt water is approx. 247,000 tonnes.

The general arrangement, Fig. 4.1.1 and drawing ACP-B001, was chosen with a cargo hold and ballast tank subdivision similar to other large bulk carriers. A conventional single side shell design was chosen in order to minimise the hull weight. Eleven cargo holds with a length of 27.6 m were arranged. This hold length was chosen in order to limit the length (span) of the side rolling hatch covers and the girders in double bottom. Odd number of cargo holds was chosen in order to limit the shear forces forward and aft in case of ore cargo load condition with alternate cargo holds empty. The transverse bulkheads are corrugated with stools at top and bottom.

Ballast tanks are arranged in double bottom and hoppers in bottom and top of the self-trimming cargo holds.

Lengths of engine room and pump room were chosen with respect to length and space requirements of main engine and equipment.

The height of the navigation bridge was chosen with respect to the required sight line forward according to Panama Canal regulations, Fig. 4.1.2.

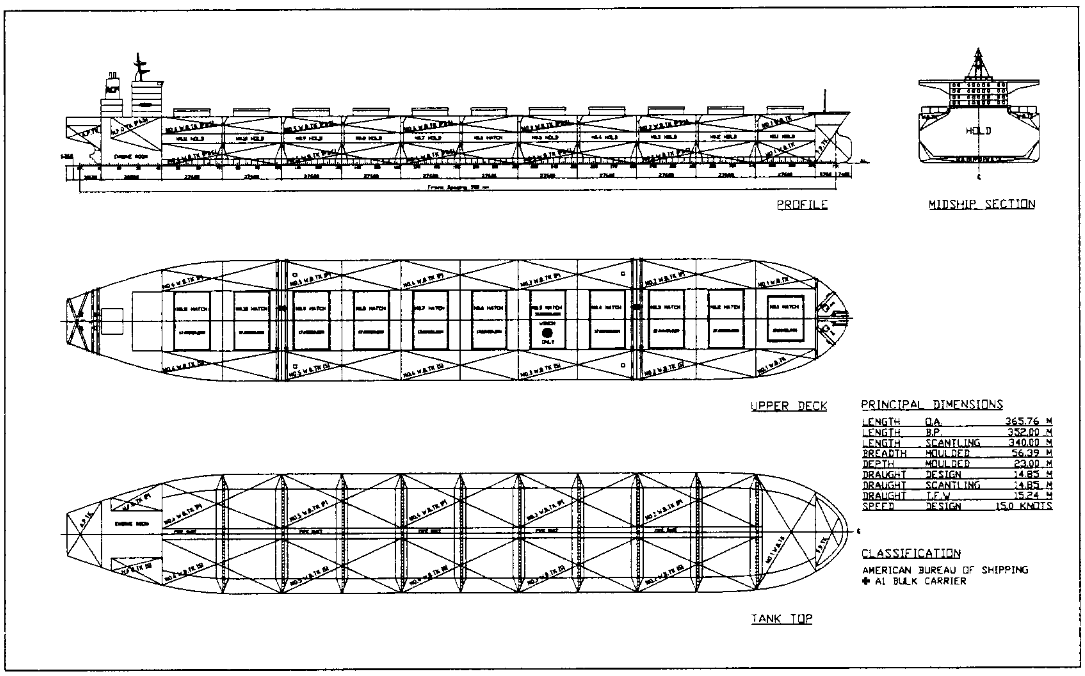


Fig. 4.1.1. General arrangement of bulk carrier

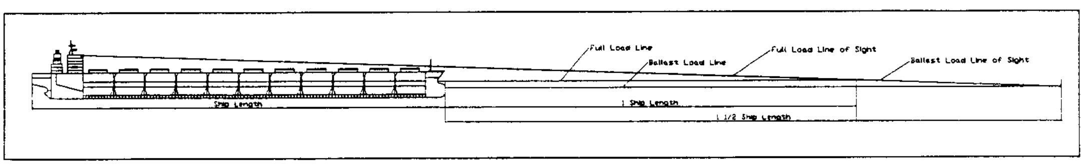


Fig. 4.1.2. Sight requirement for bulk carrier (Trim not shown)

Ballast volume and minimum ballast draft:
There are no particular rule requirements on the ballast capacity of bulk carriers. However, following the tanker rules described in section 3.1, the required ballast capacity would be in the range of 90,000-100,000 tonnes.
With such a ballast capacity, it would not be necessary to fill a cargo hold for heavy (gale) ballast conditions.
Large ballast tanks in the cargo area require a relatively large depth D. D is however a "cheap" parameter in this case.

Depth D and cargo volume:
Whereas length, draft and breadth are given by the Panama Canal limitations, the depth D can be chosen more freely with respect to cargo density (specific gravity S.G.), and with consideration of the freeboard regulations.

For determination of the cargo density, a comparison was made with a number of built bulk carriers, see Fig. 3.6.2. A design density of 0.8 tonnes/cubm was selected as a starting point.

With a required capacity and weight of 7,000-10,000 tonnes for fuel oil, diesel oil, fresh water, provision, spare parts, crew etc. the deadweight remaining for cargo is maximum 196,000 tonnes.
The cargo volume required is, with a filling rate of 96%,

Min req. cargo volume = 196,000/(0.8x0.96) ≈ 255,000 cubm

With minimum bunker and provision intake when going through the Canal:

Cargo volume = 203,000/(0.84x0.96) ≈ 264,000 cubm

The required depth would be 22-23 m. D being a "cheap" design parameter,

D = 23 m was chosen.

The actual, designed cargo volume is approx. 279,000 m^3 (grain), which would allow for a cargo density down to 0.73 tonnes/cubm in ocean going condition.

The chosen depth D is sufficient for the B-60 freeboard requirements without sheer, see further section 4.7.

Owners may find it attractive to increase the cargo hold volume further, for carriage of light cargoes such as coal. This can be done by increase of the depth D by, say, 1 m, i.e. from 23 to 24 m. Such a design alteration could be done without increase of lightweight (steel weight) or loss of deadweight.

Hold and Tank table:
The hold and tank volumes can be summarised as follows. For further information, see the Trim and Stability calculations.

Cargo holds	**Volume 100% full, m³**
No. 1 cargo hold	19700
No. 2 cargo hold	25700
No. 3 cargo hold	26600
No. 4 cargo hold	26600
No. 5 cargo hold	26600
No. 6 cargo hold	26600
No. 7 cargo hold	26600
No. 8 cargo hold	26600
No. 9 cargo hold	26400
No. 10 cargo hold	25500
No. 11 cargo hold	22200
	279100 m³ (grain)
Ballast water tanks	
Fore peak BW tank	3383
No. 1 BW tank	8192
No. 2 BW tank S	8505
No. 2 BW tank P	8505
No. 3 BW tank S	8732
No. 3 BW tank P	8732
No. 4 BW tank S	8732
No. 4 BW tank P	8732
No. 5 BW tank S	8612
No. 5 BW tank P	8612
No. 6 BW tank S	6731
No. 6 BW tank P	6731
Aft peak BW tank	1150
	95349 m³
Fuel oil tanks	7000
Diesel oil tanks	400
Fresh water tanks	200
Misc. tanks in E/R	400
	8000 m³

4.2 IMO and Class requirements with respect to cargo holds flooded at sea

Due to loss of bulk carriers, SOLAS and class rules were changed recently.
Additional safety measures are required according to SOLAS Chapter XII.
Vessels built after July 1999 shall be able to withstand flooding of any one of the cargo holds and remain afloat.

A practical consequence is that the strength of the transverse bulkheads is increased in new bulk carriers adding to the lightweight. A comparison with lightweights of bulk carriers built before 1999 is thus not completely relevant.

4.3 Longitudinal strength

The minimum longitudinal strength requirement for all types of ocean going vessels are agreed upon within IACS and are thus identical for the classification societies, compare section 3.3.

With the above dimensions, the class minimum requirements amidships are:

I_{min} = 1090 m^4 independent of steel quality

Z_{min} = 84 m^3 (net) for 320 N/mm^2 higher tensile steel which is the selected material.
ABS gross requirement including corrosion margin is 92.7 m^3.

The actual values are:
Designed inertia of midship section $I = 113{,}7\ m^4$

Gross modulus midship section $Z_{deck} = 93.3\ m^3$; $Z_{bottom} = 105.3\ m^3$

The designed midship section modulus corresponds to an allowable still water bending moment SWBM of approx. 930,000 tonnes meters

The actual maximum SWBM is in ballast condition approx.	530,000 tm
In homogeneous load condition approx.	400,000 tm
In ore loading condition approx.	920,000 tm

Ore loading conditions with alternate holds empty require a careful cargo distribution, compare the attached trim and stability calculations, Appendix F

4.4 Midship Section. Typical web frame and transverse bulkhead

Drawing ACP-B002 shows the selected Midship Section and the scantlings of the longitudinal members. Due to the high requirement for longitudinal strength, most longitudinal scantlings are in excess of class requirements for local strength. ABS SafeHull An output for the scantlings of the longitudinal strength members is given in Appendix D.

Sketches of a typical web frame and a typical transverse bulkhead are given in drawings ACP-B003.
In comparison with a typical large bulk carrier it can be noted that hold and tank pressures are slightly lower due to smaller depth D and smaller draft T.
Longitudinal girders in the double bottom are equal in length but greater in depth compared to standard designs. This is a consequence of the selected ballast capacity.

4.5 Main machinery

As mentioned in chapter 2, the bulk carrier has an operational speed at 15 knots which gives an estimated propeller power of 19065 kW in average ocean conditions (15% sea margin) and full load condition.

A suitable engine in this case could be B&W 6S80MC. The maximum engine power at 79 r/min will then be 21 840 kW according to the manufacturers data sheet and the Normal Continuous Rating NCR is then 19854 kW. (Appendix B)

4.6 Light weight estimate and distribution

The lightweight is governed by the longitudinal strength requirement, compare above. Other weights are similar to those of a typical large bulk carriers scaled with respect to size of vessel.
The following weights were estimated:

Steel weights:	
Cargo hold	33900 tonnes
Fore body	1000
Aft body	900
Engine room casing and funnel	2450
Deck house	400
Rudder and stock	150
Miscellaneous (weld, paint etc)	300
	39100
Hull outfit:	
Hatch covers	1650
Hull piping	150
Anchors and chains	240
Deck machinery	200
Accommodation outfit	250
Remaining items	310
	2800
Machinery:	
Main engine 22000 kW	900
Aux. engine + boiler	50
Propeller and shaft	120
Piping in engine room	250
Steel outfit in engine room	200
Remaining machinery and electric	330
	1850
Total	**43750 tonnes**

The lightweight distribution along the hull is shown in Fig. 4.6.1.

The lightweight of typical tankers and bulk carriers is shown in Fig. 3.6.2. for comparison.

It is noted that an ACP-max vessel will have a considerably higher lightweight/deadweight ratio than a standard vessel due to the fact that main dimensions L,B,D,T and D/B ration of standard vessels are chosen with respect to hull weight optimization. A similar kind of optimization is not possible in this case.

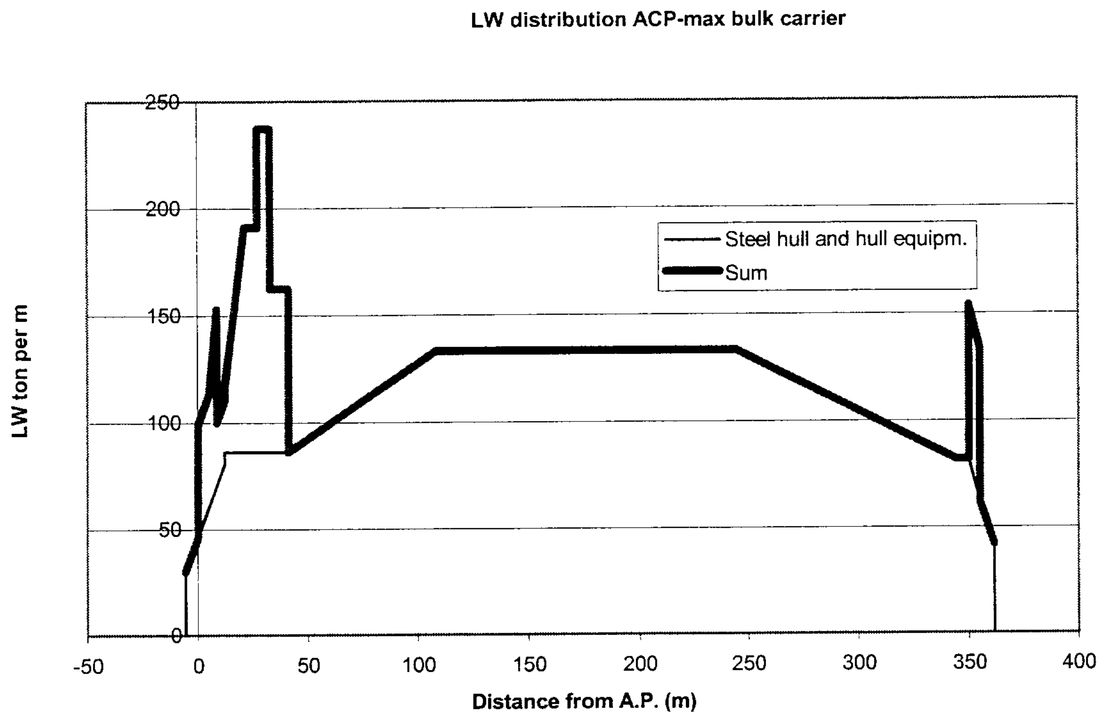


Fig. 4.6.1: Lightweight distribution of ACP-max bulk carrier

4.7 Freeboard

Freeboard calculation according to the International Convention on Load Lines are attached below.
For an ACP-max tanker with B-60 type freeboard, depth D=23m, and without sheer or forecastle, the required minimum summer freeboard in salt water is approx. 7600 mm. The actual freeboard is approx. 8100 mm.
Minimum required tropical fresh water freeboard is approx. 7000 mm.
Minimum required bow height is approx. 6300 mm.

B type freeboard requirements can be satisfied with a sheer forward of about 2000 mm at FP.

For an ocean going vessel, and especially a bulk carrier with hatch openings, it may be recommendable to increase the freeboard forward in excess of the minimum requirements by increased sheer and/or separate forecastle. This would also influence the required deckhouse height according to Panama Canal Rules.

Freeboard calculation
With dimensions
Lf = 345m; B = 56.4m; CB=0.83; D=23m; T=14.8m
(Actual freeboard in SW: 8150 mm)

B-60 freeboard without sheer:		
(Tabular A-freeboard	3394 mm)	
(Tabular B-freeboard	5005 mm)	
Tabular B-60 freeboard		4038 mm
Corrected for CB		4484
Corrected for sheer	+3127	7610
Min. summer freeboard in SW		7610 mm
Correction for tropical	-308	
Correction for FW	-308	6994
Min tropical FW freeboard		6994 mm

B-freeboard with 2000 mm sheer forward:		
Tabular B-freeboard		5005 mm
Corrected for CB		5557
Corrected for sheer	+2220	7777
Min. summer freeboard in SW		7777 mm
Correction for tropical	-308	
Correction for FW	-308	7161
Min tropical FW freeboard		7161 mm

4.8 Tonnage

The gross and net tonnage is based on gross enclosed volume and cargo volume respectively and was calculated according the International convention on Tonnage Measurement of Ships, 1969, Annex I.

For the ACP-max bulk carrier with D = 23 m without sheer, the following was calculated

Gross volume	420,000 cubm
Gross tonnage	approx. 131,000
Cargo volume	279,000 cubm
Net tonnage	approx. 64,000

For the calculation procedure, compare section 3.8.

4.9 Trim and Stability. Calculated bending moment and shear force

Intact stability requirements:
A bulk carrier has to satisfy the IMO and national intact stability requirements, mainly defining GM values and the shape of the GZ curve.

The results of intact stability calculations for typical ballast and laden conditions are attached in Appendix F and below summary table. All regulations are satisfied. It can be noted that the GM-values are very high due to the great beam of the vessel.

Damage stability requirements:
The damage stability must satisfy the requirements according to the Load Line Convention, ICLL, Reg. 27 and IMO Reg. A320 and A514 for B-60 type freeboard. This is a one-compartment requirement.
In case of a B-type freeboard, the vessel must satisfy the one-compartment damage criterion as per SOLAS, Ch. XII.
The damage cases required by ICLL and SOLAS were checked for B and B-60 freeboard and found satisfactory, compare the simplified (conservative) one-compartment cases 1-12 in Appendix F.

The damage stability must also satisfy the probabilistic index rules for cargo ships according to SOLAS Part B-1, Reg. 25, or equivalent regulations as defined in SOLAS. The required index is here R=0.69. The attained index is A=0.85.

Large bulk carriers with the actual subdivision have, generally speaking, no problems to fulfill those rules. Attached calculations in Appendix F and in below summary table show the calculated damage cases. All mentioned requirements are met.

Longitudinal strength:
Still water bending moments, SWBM, and shear forces, SWSF, were calculated for typical intact trim and stability conditions, Appendix F and summary table.
The actual designed SWBM values are close to the allowable ones.

The large shear forces which occur in bulk carriers, especially in ore loading conditions with alternate holds empty, are to be considered at a later stage of hull design by local adjustment of side shell scantlings.

Summary of intact stability and strength calculations for ACP-Max Bulk Carrier

Description	Unit	Condition 1	Condition 2	Condition 3	Condition 4
		Lightship cond.	Homo. design load dep. cond	Ore load dep. cond.	Normal ballast dep. cond.
Lightship weight	[T]	43966,0	43966,0	43966,0	43966,0
Bunkering	[T]	0,0	6800,0	6800,0	0
Water ballast	[T]	0,0	3383,0	0,0	97542
Cargo	[T]	0,0	195999,0	195991,0	0
Deadweight	[T]	0,0	206182,0	202791,0	97542,0
Displacement	[T]	43966,0	250148,0	246757,0	141508,0
Draught eqiv.	[M]	3,057	14,903	14,719	8,800
Draught at F.P.	[M]	1,376	13,675	13,083	8,284
Draught at A.P.	[M]	4,738	16,131	16,355	9,317
Trim*	[M]	3,362	2,456	3,272	1,033
KG	[M]	12,500	13,074	13,181	10,296
GM0	[M]	73,071	12,386	12,448	23,413
Max B. Moment	[T-M]	400952	403621	918815	534589
Max S. Force	[T]	5213	5623	20129	5555
IMO Intact Stability Criteria					
Area30	[Mrad]	5,377	1,654	1,671	3,113
Area40	[Mrad]	7,540	2,631	2,661	5,040
Area30-40	[Mrad]	2,163	0,977	0,990	1,927
Max GZ 30	[°]	25**	35	35	40
GZ 0.2	[M]	13,028**	5,638	5,720	11,143
GM 0.15	[M]	73,071	12,386	12,448	23,413

Criteria

Area30:	The area under the GZ-curve to 30° not to be less than 0,055 mrad
Area40:	The area under the GZ-curve to 40° not to be less than 0,090 mrad
Area30-40:	The area under the GZ-curve from 30°-40° not to be less than 0,030 mrad
Max GZ 30:	The max value of GZ to occur at an angle equal or greater than 30°
GZ 0,2:	The value of GZ at an angle equal or greater to 30° not to be less than 0,20 m
GM 0,15:	The value of upright GM not to be less than 0,15 m

* Positive trim bow up, negative trim bow down

** For lightship conditions this is normally the case, however accepted due to ballast capacities

Summary of damage stability calculations for ACP-Max Bulk Carrier

All damage stability conditions calculated for Homo. des. load dep.
Compartment division in damage stability calculations was simplified.

Intact ship data		Homo. design load dep. cond
Displacement	[T]	250148,0
Draught eqiv.	[M]	14,903
KG	[M]	13,074
GM0	[M]	12,387

Subdivision and damage stability according to SOLAS B-1, regulations 25-1 - 25-6.

Damage stability of the bulk carrier is calculated according to SOLAS index rule. The complete calculation is presented in attached separate document. Stability criteria comprise:

1. Final equilibrium angle of heel
2. GZ max
3. Stability width

All damaged cases presented fulfil the SOLAS requirements.

Damages	**Damage 1**	**Damage 2**	**Damage 3**	**Damage 4**	**Damage 5**
Flooded comp.	NO.1 HOLD	NO.2 HOLD	NO.3 HOLD	NO.4 HOLD	NO.5 HOLD
Flooded comp.	No.1 W.B.TK	No.2 W.B.TK (S)	No.3 W.B.TK (S)	No.4 W.B.TK (S)	No.5 W.B.TK (S)
Flooded comp.		No.2 W.B.TK (P)	No.3 W.B.TK (P)	No.4 W.B.TK (P)	No.5 W.B.TK (P)

Continuation:

Damages	**Damage 6**	**Damage 7**	**Damage 8**	**Damage 9**	**Damage 10**
Flooded comp.	NO.6 HOLD	NO.7 HOLD	NO.8 HOLD	NO.9 HOLD	NO.10 HOLD
Flooded comp.	No.6 W.B.TK (S)	No.7 W.B.TK (S)	No.8 W.B.TK (S)	No.9 W.B.TK (S)	No.10 W.B.TK (S)
Flooded comp.	No.6 W.B.TK (P)	No.7 W.B.TK (P)	No.8 W.B.TK (P)	No.9 W.B.TK (P)	No.10 W.B.TK (P)

Continuation:

Damages	**Damage 11**	**Damage 12**	**Damage 13**	**Damage 14**	**Damage 15**
Flooded comp.	NO.11 HOLD	H.F.O. TK (S)	NO.1 HOLD	NO.2 HOLD	NO.3 HOLD
Flooded comp.	No.11 W.B.TK (S)	H.F.O. TK (S)	No.1 W.B.TK	No.2 W.B.TK (S)	No.3 W.B.TK (S)
Flooded comp.	No.11 W.B.TK (P)	Engine Room	NO.2 HOLD	No.2 W.B.TK (P)	No.3 W.B.TK (P)
Flooded comp.			No.2 W.B.TK (S)	NO.3 HOLD	NO.4 HOLD
Flooded comp.			No.2 W.B.TK (P)	No.3 W.B.TK (S)	No.4 W.B.TK (S)
Flooded comp.				No.3 W.B.TK (P)	No.4 W.B.TK (P)

Continuation:

Damages	**Damage 16**	**Damage 17**	**Damage 18**	**Damage 19**	**Damage 20**
Flooded comp.	NO.4 HOLD	NO.5 HOLD	NO.6 HOLD	NO.7 HOLD	NO.8 HOLD
Flooded comp.	No.4 W.B.TK (S)	No.5 W.B.TK (S)	No.6 W.B.TK (S)	No.7 W.B.TK (S)	No.8 W.B.TK (S)
Flooded comp.	No.4 W.B.TK (P)	No.5 W.B.TK (P)	No.6 W.B.TK (P)	No.7 W.B.TK (P)	No.8 W.B.TK (P)
Flooded comp.	NO.5 HOLD	NO.6 HOLD	NO.7 HOLD	NO.8 HOLD	NO.9 HOLD
Flooded comp.	No.5 W.B.TK (S)	No.6 W.B.TK (S)	No.7 W.B.TK (S)	No.8 W.B.TK (S)	No.9 W.B.TK (S)
Flooded comp.	No.5 W.B.TK (P)	No.6 W.B.TK (P)	No.7 W.B.TK (P)	No.8 W.B.TK (P)	No.9 W.B.TK (P)

Continuation:

Damages	**Damage 21**	**Damage 22**	**Damage 23**
Flooded comp.	NO.9 HOLD	NO.10 HOLD	NO.11 HOLD
Flooded comp.	No.9 W.B.TK (S)	No.10 W.B.TK (S)	No.11 W.B.TK (S)
Flooded comp.	No.9 W.B.TK (P)	No.10 W.B.TK (P)	No.11 W.B.TK (P)
Flooded comp.	NO.10 HOLD	NO.11 HOLD	H.F.O. TK (S)
Flooded comp.	No.10 W.B.TK (S)	No.11 W.B.TK (S)	H.F.O. TK (S)
Flooded comp.	No.10 W.B.TK (P)	No.11 W.B.TK (P)	Engine Room

4.10 Equipment

It is assumed that the vessel would be equipped as a typical bulk carrier for worldwide trade.
There would be side rolling hatch covers for the cargo holds. Cargo gear would not be fitted.
Electric ballast pumps would be installed in the engine room.

Below, typical essential equipment and machinery are listed in order to satisfy the main formal requirements and with respect to typical practical choices.

Equipment and piping for cargo handling and ballast system:

- 11 pairs of side rolling cargo hatch covers, about 17x28 m as shown on G.A. drawing
- 2 ballast pumps 2x3000 cubm per hour. Electric motor driven
- 1 ballast ejector 400 cubm per hour
- Ballast piping in double bottom
- Bilge system in cargo holds

Anchoring, mooring and towing equipment:

- 2 windlasses forward with capacity as per Class Rules combined with mooring winches
- 2 anchors, 20 ton, with chain 770 mx111 mm ABS grade 3
- 10 mooring winches 35 ton with double drums and warping head.
- 24 mooring lines on winch drums. 42 mm diameter, 275 m.

Machinery:

- Main engine, see above
- Propeller, see above
- 3 diesel generators, about 3x700 kW
- 1 emergency diesel generator, 250 kW
- 2 HFO and 2 LO purifiers
- 1 oil fire steam boilers 3 ton per hour
- 1 exhaust gas steam boiler

5 BUILDING PRICE ESTIMATION

5.1 General

The building price for new ships is fluctuating all the time. Some institutes are specialised in analysing the world market and deliver quarterly reports on market statistics to the stakeholders in the maritime industry. The following price estimations are made after studies of the present market statistics.

In order to estimate the ACP-max ships, which are not mainstream ships, we have also used statistics from the Marine Equipment suppliers to split the costs of a ship into some different cost categories such as Auxiliary Engines, Electrical Equipment, Steel and Pipes etc.

In this way it is possible to isolate the main difference between the ACP-max vessels and ordinary vessels, namely the steel weight, and come to a reasonable estimation of the market price. It should be noted that the market price could differ considerably from the actual building cost

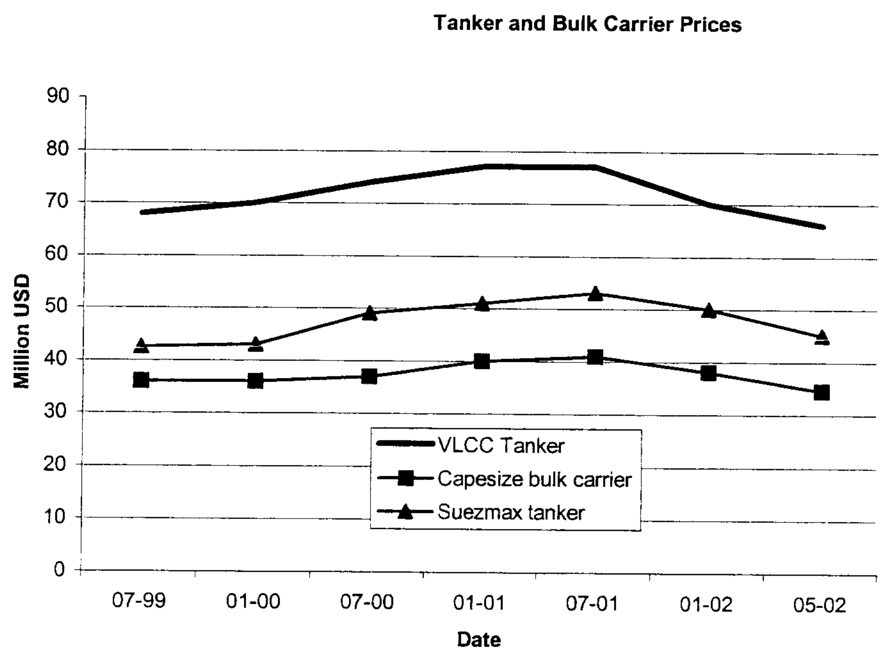


Fig 5.1.1. World market tanker and bulk carrier newbuilding prices

5.2 Tanker prices

According to a Marine Equipment Market Survey, made by BALance Technology Consulting for the European Commission, the total Newbuilding Marine Equipment Purchasing Value for Crude Oil Tankers the year 1999 was 12.092 million USD. This sum was split over different supply markets as shown below:

Ship Operation, painting	11%
Cargo Handling	10%
Accommodation	6%
Propulsion, power generation	29%
Auxiliary engines without pipes	11%
Electrical plans, electronics, automation	6%
Steel + Pipes (materials)	27%
Total	**100%**

Recent figures from shipyards in Asia indicates a steel purchase price of 420 to 450 USD/ton and a steel construction cost between 900 and 1000 USD/ton depending on complexity of the ship. If labour costs are added to the figures above, the share of steel and pipes will increase to over 50% of the total cost.
The same indicators for complete machineries installed including auxiliary engines gives 330 USD/kW installed power.
When considering this, it is even clearer that steel weight and propulsion installations are the pre-dominant factors on the ship's price.

Another well established, indicator for tankers is that Steel and Machinery represents approximately 2/3 of the ship's building cost, and other installations the remaining 1/3.

Cost estimation with indicators

Building costs Tanker (incl. labour)	**Cost in USD**
Welded steel 39 520 ton (950 USD/ton)	37 544 000
Propulsion and auxiliary power (330 USD/kW)	9 735 000
Ship operation, painting, cargo handling, Accommodation, electronics and automation (1/3)	23 639 000
Total	**70 918 000**

Price estimation from market statistics

When comparing the ACP-max Tanker with existing VLCCs (Chapter 3) we can see that steel weight and engine power are similar between the two ship sizes. Since VLCCs normally are designed without shallow draft restrictions, these ships are optimised regarding longitudinal strength and steel weight allowing up to 50% more cargo carrying capacity than the ACP-max ship. The level of equipment is about the same on the ACP-max design and the VLCC.

From the reasoning above, it is clear that the ACP-Max tanker will have about the same building cost and a similar price level as an ordinary VLCC of 300 000 TDW. According to the latest statistics, the VLCC price in May 2002 would be approx. 66 million USD in series production. For this new design, a development cost of 5-10 percent should be added. A price around 70 million USD could be expected.

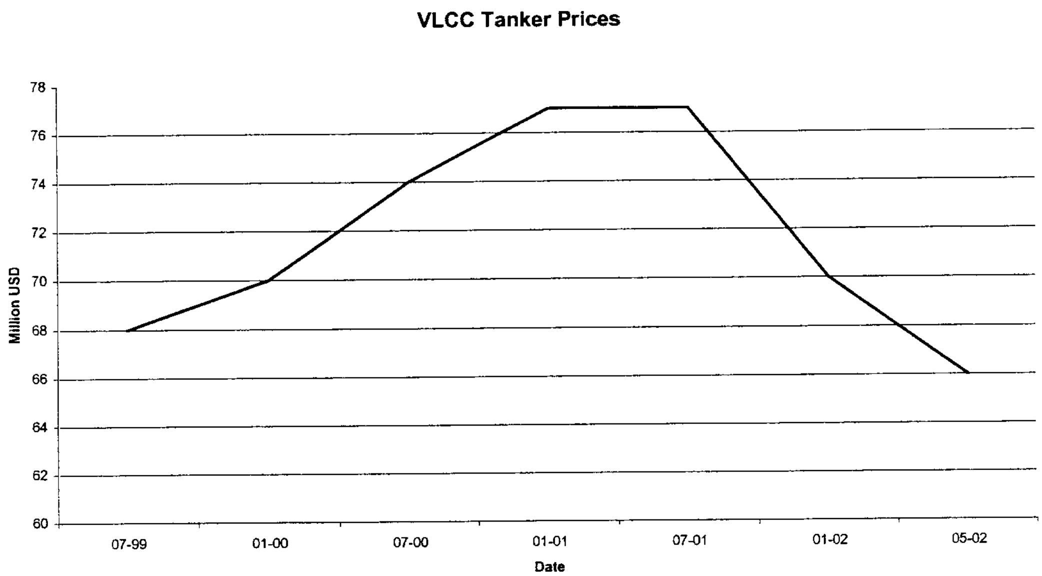


Fig. 5.2.1. World market VLCC tanker newbuilding prices

5.3 Bulk carrier prices

A bulk carrier has generally a lower newbuilding market price than a tanker. The reason for this is mainly less need for equipment and lower speed requiring less engine power. The total purchasing equipment value for Bulk Carriers the year 1999 was 25.396 million USD. This sum was split over different supply markets as shown below:

Ship Operation, painting	11%	(11%)
Cargo Handling	4%	(10%)
Accommodation	6%	(6%)
Propulsion, power generation	28%	(29%)
Auxiliary engines without pipes	9%	(11%)
Electrical plans, electronics, automation	11%	(6%)
Steel + Pipes (materials)	31%	(27%)
Total	**100%**	

These figures shows the increased share of Steel + Pipes (materials) compared with VLCCs which indicates a lower level of equipment on the Bulk Carriers. With the same reasoning about building prices as for the tanker it is clear that the steel is even more dominant in this case.
For bulk carriers, Steel and Machinery represents approximately 75% of the ship's building cost, and other installations the remaining 25%.

Cost estimation with indicators

Building costs Tanker (incl. labour)	**Cost in USD**
Welded steel 39 100 ton (950 USD/ton)	37 145 000
Propulsion and auxiliary power (330 USD/kW)	7 207 000
Ship operation, painting, cargo handling, Accommodation, electronics and automation (1/4)	14 784 000
Total	**59 136 000**

Price estimation from market statistics

The following graph of the world market newbuilding prices of Aframax Bulk Carriers (170 000 TDW) compared with Suezmax Tankers (150 000 TDW) shows clearly the difference between the two ship types.

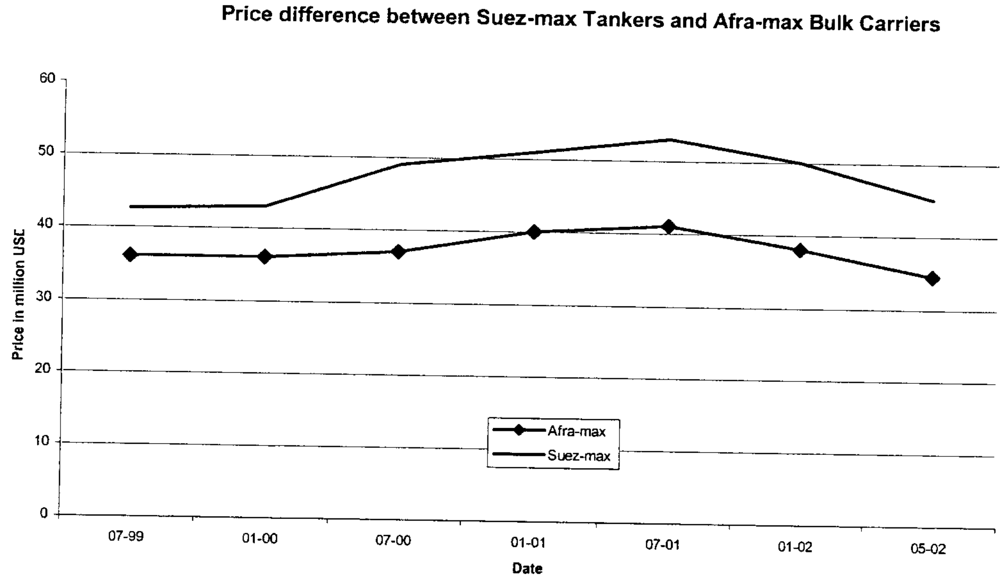


Fig. 5.3.1. World market newbuilding prices for bulk carrier and tankers of about 150-170,000 TDW.

As seen in the graph, the price difference between the Aframax and the Suezmax vessels is approx. 23% but, considering the difference in deadweight, the price difference would be even bigger for vessels of equal size.

In our case, the vessels are larger which increases the importance of the steel weight. This will probably close the price gap a little. Our Estimation is therefore that the ACP-max Bulk Carrier price will follow the VLCC Tanker curve in the same way as shown above, but the price difference will stay at about 20 %. This gives us an estimated price for the Bulk Carrier of 53 million USD in May 2002 in case of series production.
For this new design, a development cost of 5-10 percent should be added. A price just below 60 million USD could be expected.