Ship Design Project & Presentation

NAME - 338

DESIGN OF A 1300 TONNES CAPACITY INLAND CARGO VESSEL

Prepared for

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Department: Naval Architecture and Marine Engineering

Level: 3 / Term: 2

Date of Submission: 15-07-2017

Forwarding Letter

15th July, 2017
To,
The Course Supervisor,
Dr. Refayet Ullah
Professor,
Department of Naval Architecture & Marine Engineering, BUET

Subject: Submission of report on
Design of a 1300 Tonnes Capacity Inland Cargo Vessel.

Dear Sir,
We are very grateful to you for giving us the chance of submitting the report. We have tried to make a useful report on "Design of a 1300 tonnes Capacity Inland Cargo Vessel". For preparing the report we have studied a lot. We took support from different books, respected teachers of our department and also internet.

We had much pleasure in creating the report and came to know a lot of things about cargo vessel designing. We are thanking you for all your help as our supervisor in completing the project assignment. And if there is any mistake, we hope that we shall have your forgiveness and kind consideration.

Sincerely yours,

Mohammad Khalikujjaman
Student No: 1312024
&
Abu Saleh Mohammad Arman
Student no: 1312038

Department of NAME
Level-3 / Term-2

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APPROXIMATION OF LIGHTWEIGHT, DEADWEIGHT & DISPLACEMENT

Owner's Requirement:

Ship Type : General Cargo

Cargo Capacity : 1300 tonnes

Route : Dhaka to Chittagong

Distance : 1863 Nautical mile

Speed : 9 knots

Endurance : 2 days

There is some restriction to design our ship. Which are given below:

The Maximum permissible draft for entering Chittagong Port is 9.15 m.

The Maximum permissible length for entering Chittagong Port is 186 m.

The Maximum permissible entry length for night navigation is 153 m.

The Maximum permissible draft for Main Jetty areas i.e. Jetty No. 2 to Jetty No.13 is 8.55 m.

The Maximum permissible draft for Dhaka-Chittagong Route is 3.96 m.

The entry permissible draft would however depend on the day's maximum permissible draft.

Selection of Basis Ship:

Principal Particulars of Basis Ship

Ship Type	**: General Cargo**
Length, L_{OA}	**: 60.15 m**
Length, L_{BP}	**: 51.13 m**
Breadth, B_{MLD}	**: 11.0 m**
Depth, D	**: 4.15 m**
Draught, T	**: 3.70 m**
Dead weight, DWT	**: 1400 tonnes**
Speed	**: 9 Knots**
Complement	**: 12 persons**

[***http://marinehousebd.com/completed-projects/***]

Determination of Lightweight, Deadweight & Principal Particulars:

Principal Particulars Calculation

Displacement of basis ship, $\Delta = L \times B \times T \times \rho \times C_B$

$= 51.13 \times 11.00 \times 3.7 \times 0.82$

$= 1706$ tonnes

Dead weight coefficient, $C_D = \frac{1400}{1706} = 0.82$

$\frac{L}{B} = 4.65$

$\frac{B}{T} = 2.97$

$\frac{B}{D} = 2.65$

Power Calculation

Where,

A_c = *Admiralty Coefficient*

$= 26\left\{\sqrt{L} + \frac{C}{V}\right\}$

$= 26\left\{\sqrt{51.13} + \frac{34.5}{9}\right\}$

$= 285.58$

Now,

Power, $P = \frac{\Delta^{2/3} \times V^3}{A_c}$

$= \frac{1457^{2/3} \times 9^3}{285.58}$

$= 328.07$ KW

$= 440$ HP Engine Power = 2 × 220 BHP (02 in numbers)

Deadweight of new ship

Weight of crew: 75 kg/person

Number of crew = 12

Weight = 75 × 12 = 900 kg

= 0.9 tonnes

Stores & Provisions: 5 kg/person/day

Weight = 5 × 12 × 2 × 1.20 kg

= 144 kg

= 0.144 tonnes

Fresh Water:

Consumption for crew = 20 kg/person/day

= 20 × 12 × 2 × 1.20 kg

= 576 kg

= 0.576 tonnes

Bath & Laundry: 200 kg/person/day

= 200 × 12 × 2 × 1.20 kg

= 5760 kg

= 5.76 tonnes

Cooking: 4 kg/person/day

= 4 × 12 × 2 × 1.20 kg

= 115.2 kg

= 0.115 tonnes

Main engine cooling: 7 g/ kWh

= 7 × 324.07 × 2 × 24 × 1.20 g

= 130.67 kg

= 0.14 tonnes

Auxiliary engine cooling: 0.20 × Main engine cooling water

= 0.20 × tonnes

= 0.028 tonnes

Total fresh water needed: 0.576 + 5.76 + 0.115 + 0.14 + 0.028

= 6.62 tonnes

Lubricating Oil:

Specific lubricating oil consumption = 0.95 g/BHPh

Weight = 0.95 × 328.07 × 2 × 24 × 1.20 g

= 18 kg

= 0.018 tonnes

Fuel Oil:

Engine: MAN B&W D2676 LE4x4

Engine power: 328.07 kW

SFC: 195 g/kWh

Fuel needed: 195 × 328.07 × 2 × 24 × 1.20 g

= 11232 kg

= 11.23 tonnes

Generator Fuel:

Model: 6090HF484

SFC: 59.1 lph(15.6gph)

Generator power: 2 × 220 kW

Fuel needed: 59.1 × 2 × 2 × 12 × 1.20 g

= 3404.16 kg

= 3.41 tonnes

Practical Ship Design

By D. G. M. Watson

	Conventional (all	GP Ratings	UMS	No C.P.O.	Altered catering	Auto-steering (no conditions	No R/O	No Pumpman	C/E to keep watcl	emergency manu	6 on 6 off watche	Semi-integrated J	Officers	Operator maintair	Matrix manning	Polyvalent or dua	Senior Officers	Combined Master	Engineer
Master	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1			
Mates	3	3	3	3	3	3	3	3	3	2	1	–		1	–	–			
Chief Engr.	1	1	1	1	1	1	1	1	1	1	1	1		1	1	–			
Engineers	6	6	3	3	3	3	3	3	2	2	1	1		1	–	–			
R/O	1	1	1	1	1	1	–	–	–	–	–	–		–	–	–			
Pumpman	1	1	1	1	1	1	1	–	–	–	–	–		–	–	–			
Bosun	1	–	–	–	–	–	–	–	–	–	–	–		–	–	–			
Deck ratings	6	–	–	–	–	–	–	–	–	–	–	–		–	–	–			
Eng. ratings	4	–	–	–	–	–	–	–	–	–	–	–		–	–	–			
G/Ps	–	7	7	6	6	4	4	4	4	4	4	3		3	3	3			
Catering	6	4	4	4	2	2	2	2	2	2	2	2		1	1	1			
Dual purpose Junior officers	–	–	–	–	–	–	–	–	–	–	2	2		2	2	2			
Dual purpose Senior officers	–	–	–	–	–	–	–	–	–	–	–	–		–	2	2			
Total manning	30	24	21	20	18	16	15	14	13	12	12	10		10	10	9			

Summary

Cargo : 1300 tonnes

Fresh Water : 6.62 tonnes

Engine Fuel : 11.23 tonnes

Generator Fuel : 3.41 tonnes

Lubricating Oil : 0.018 tonnes

Crew : 0.9 tonnes

Store & Provisions : 0.144 tonnes

Total Deadweight : 1322 tonnes

Lightweight Calculations

Displacement, $\Delta = \frac{DWT}{C_D} = \frac{1322}{0.82}$

$= 1612$ tonnes

$\therefore$ Lightweight, LWT = (1612 – 1322)

$= 290$ tonnes

LENGTH (L_{BP}):

There are lots of ways and methods to determine the length of ship.

Of them, we use the Cube root formula which is as follows –

$$L=\left(\frac{DWT \times \left(\frac{L}{B}\right)^2 \times \left(\frac{B}{H}\right)}{\rho \times C_B \times C_D}\right)^{1/3}$$

= 50.13 m

The remaining three particulars breadth, draught, depth are find out using various ratios. These ratios are taken from the book of - R. Munro – Smith (ELEMENTS OF SHIP DESIGN).

And,

$\frac{L}{B}$ = 4.65

Or, B = $\frac{50.13}{4.65}$ = 10.78 m

$\frac{B}{T}$ = 2.97

Or, T = $\frac{10.78}{2.97}$ = 3.63 m

$\frac{B}{D}$ = 2.65

Or, D = $\frac{10.78}{2.65}$ = 4.07 m

Summary of Principal Particulars:

Displacement, Δ = 1612 tonnes
Dead weight, DWT = 1322 tonnes
Light weight, LWT = 290 tonnes
Length, L_{OA} = 58.98 m
Length, L_{BP} = 50.13 m
Breadth, B_{MLD} = 10.78 m
Depth, D = 4.07 m
Draught, T = 3.63 m
Block coefficient, C_B =0 .82
Service Speed = 9 Knots

Manning of Ship:

Serial No.	Title	Persons
1.	**Owner**	**1**
2.	**Master**	**1**
3.	**Class-I Inland Driver**	**1**
4.	**Class-II Inland Driver**	**1**
5.	**Certified Crew(Sukani)**	**2**
6.	**Laskar**	**3**
7.	**Cook**	**1**
8.	**Oil-Man**	**1**
9.	**Store Keeper**	**1**
	Total	**12**

GENERAL ARRANGEMENT

Freeboard Calculation:

ILLC 1966, Cargo Vessel: Type 'B' Vessel.

Length (m)	Freeboard (mm)
50	443
51	455
50.13	444.56

[Source: Rules for Ships, January 2001; Pt.3 Ch.5 Sec.3 – Page 17]

By liniear inter pulation for length L = 50.13 FreeBoard Is 444.56 mm

Sheer Calculation :

AP	$\frac{1}{6}L$	$\frac{1}{3}L$	Midship	$\frac{2}{3}L$	$\frac{5}{6}L$	FP
$25(\frac{L}{3}+10)$	$11.1(\frac{L}{3}+10)$	$2.8(\frac{L}{3}+10)$	0	$5.6(\frac{L}{3}+10)$	$22.2(\frac{L}{3}+10)$	$25(\frac{L}{3}+10)$
667.57	296.481	74.788	0	149.576	592.962	667.75

Minimum bow height:

As Length, L < 250m

$$= \frac{56L\left(1-\frac{L}{500}\right)1.36}{C_B+0.68}\ mm$$

$$= 56 \times \frac{50.13\left(1-\frac{50.13}{500}\right)1.36}{0.82+0.68}\ mm$$

$$= 2290\ mm$$

Length of Poop Deck:

[According to: Ship Construction by David J. Eyres, George J. Bruce; page -238]

Poop deck covers 15% of ships length & Poop Deck's front should not exceed 50% Of Length Amidships.

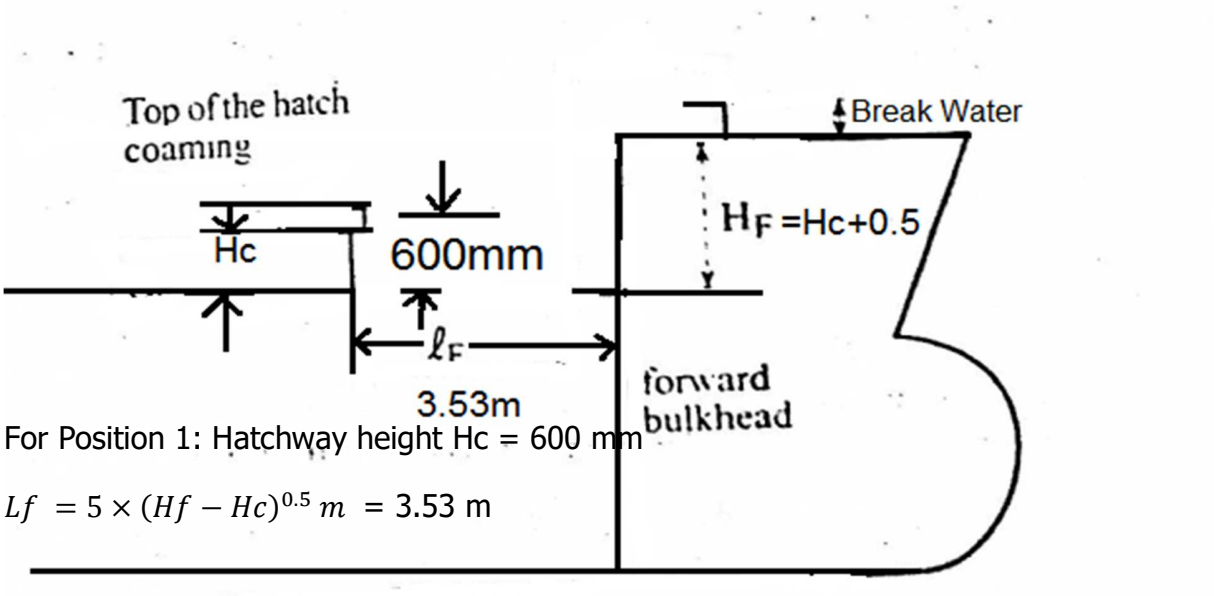
So poop deck length = 0.15 × 50.13

= 7.52 [Max]

Poop Deck's front should not exceed = 12.5 m [Amidships to aft]

Calculation of Determining the Distance of Cargo holds from Collision Bulkhead:

[According to GL-2008 Chapter 1, page -23-21, section -23G]



For Position 1: Hatchway height Hc = 600 mm

$Lf = 5 \times (Hf - Hc)^{0.5}\, m$ = 3.53 m

Hf = (Hc+0.5) mm = 600.5 mm

Length of Collision Bulkhead should not exceed 5% of ship length,

That is 0.05 × 50.13 = 2.51 m

[*According to GL 2008, Section 11A, Chapter 1, Page 11-1*]

Length of Cargo Hold:

Length remaining = L - (7% of L for Forecastle) – (15% of L/2 For Poop deck) – *Lf*

= 50.13 – (.07×50.13+.15×(50.13/2)+3.53) m

= 50.13 – 10.8 m

=39.33 m

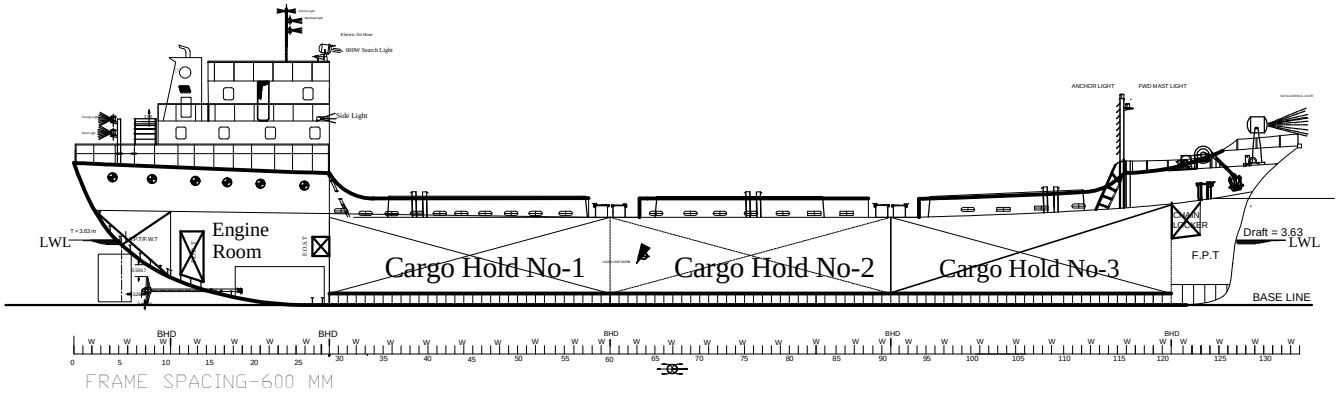
∵ Minimum length of a cargo hold for an Inland ship is 10m ,so no. of cargo hold will be

= 39.33/10

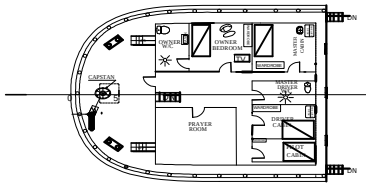
= 3.933

That is 3 [Approximately]

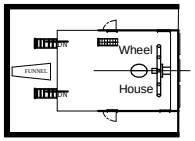
PRINCIPAL PARTICULARS	
LENGTH O.A	: 58.98m
LENGTH LWL	: 74.12m
LENGTH BP	: 50.13 m
BREADTH MLD	: 10.78 m
DEPTH MLD	: 4.07 m
DRAFT (DESIGN)	: 3.63m
BLOCK CO-EFFICIENT:	0.82



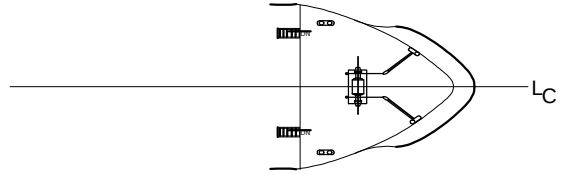
ELEVATION



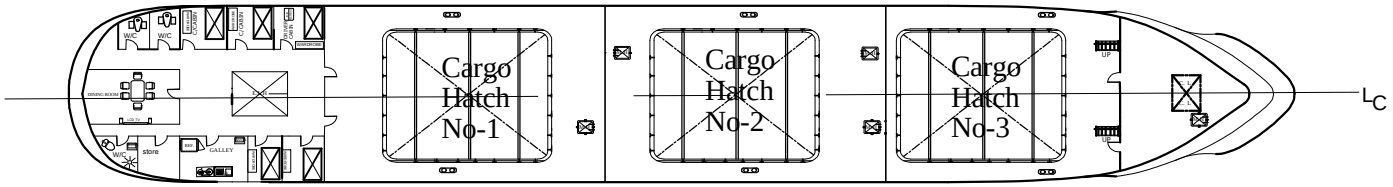
POOP DECK



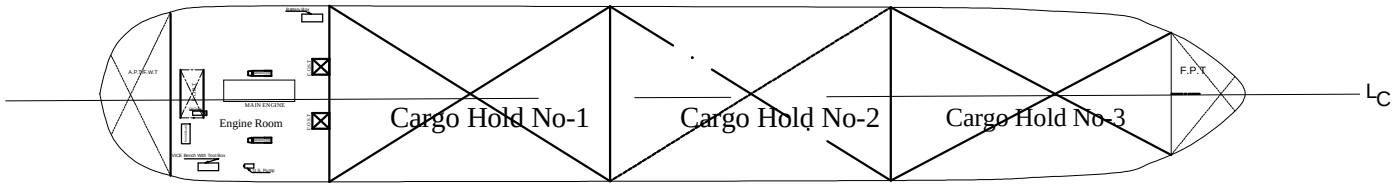
NAVIGATION DECK



FORECASTLE DECK

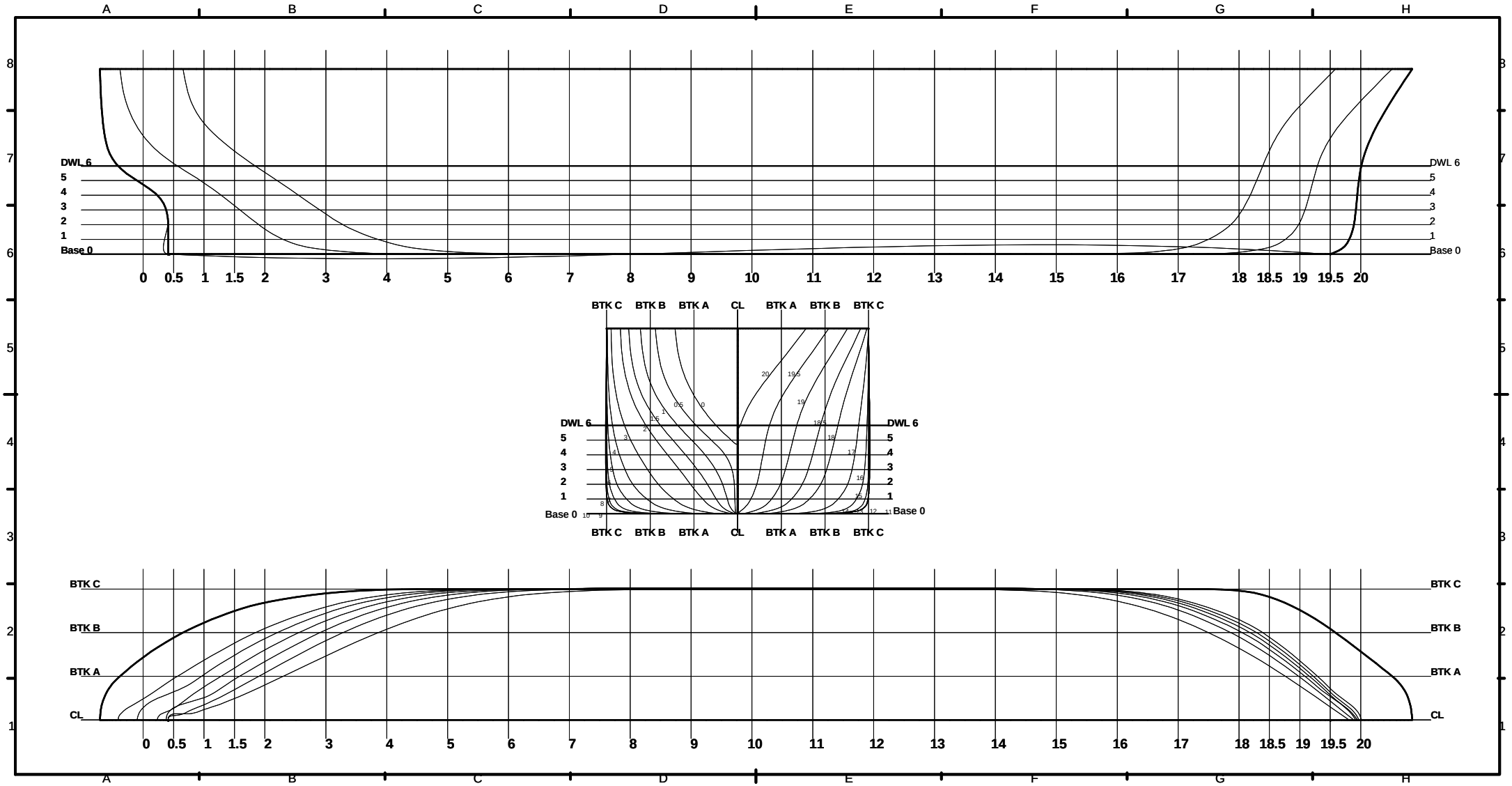


MAIN DECK



UNDER DECK

1322 DWT CARGO VESSEL
DESIGNER : KHALID, ARMAN
ID NO :1312024,1312038


A B C D E F G H
DWL 6
5
4
3
2
1
Base 0
0 0.5 1 1.5 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 18.5 19 19.5 20
BTK C BTK B BTK A CL BTK A BTK B BTK C
BTK C
BTK B
BTK A
CL

LINES PLAN

OFFSET TABLE

HALF BREADTH								ABOVE BASELINE			
STATION	WL-0	WL-1	WL-2	WL-3	WL-4	WL-5	WL-6	KEEL	B.T.K-A	B.T.K-B	B.T.K-C
0	0	0	0	0	0	257	885	2862.9	4187.9	0	0
0.5	9.5	137	245	500	707	1158	1707	0	3278.5	4932.8	0
1	19	427	623	913	1337	1889	2460	0	2485.6	3969.7	0
1.5	40	884	1245	1669	2146	2663	3166	0	2420	3903.9	0
2	312	1440	1937	2404	2883	3349	3768	0	507.7	2184.1	4098.5
3	570	2635	3264	3707	4082	4400	4653	0	70.7	652.9	2358.3
4	1031	3737	4312	4635	4863	5030	5148	0	15.5	133.1	882.9
5	1568	4572	4964	5138	5240	5305	5343	0	15.5	29.57	505.8
6	2029	5068	5273	5339	5367	5382	5388	0	15.5	29.57	505.8
7	2289	5289	5378	5390	5402	5404	5404	0	15.5	29.57	505.8
8	2366	5363	5416	5428	5432	5433	5431	0	15.5	29.57	505.8
9	2444	5373	5422	5435	5439	5439	5437	0	15.5	29.57	505.8
10	2444	5373	5422	5435	5439	5439	5437	0	15.5	29.57	505.8
11	2444	5373	5422	5435	5439	5439	5437	0	15.5	29.57	505.8
12	2444	5373	5422	5435	5439	5439	5437	0	15.5	29.57	505.8
13	2444	5373	5422	5435	5439	5439	5437	0	15.5	29.57	505.8
14	2362	5359	5415	5427	5432	5432	5430	0	15.5	29.57	505.8
15	2258	5246	5357	5380	5396	5396	5398	0	15.5	29.57	505.8
16	1952	4890	5137	5224	5304	5304	5326	0	15.5	29.57	505.8
17	1428	4138	4527	4707	4905	4905	4980	0	15.5	29.57	505.8
18	844	2955	3415	3665	3984	3984	4126	0	15.5	383.1	3275.3
18.5	497	2176	2218	2657	2904	3085	3247	0	125.5	1284.3	5459.7
19	90	1397	1759	1966	2274	2274	2434	0	543.7	4393.7	6825.9
19.5	47	547	784.2	914	1029	1144	1293	0	3624.8	6133.1	0
20	0	0	0	0	0	0	102	3501	5735.8	5456.3	0

HYDROSTATIC CALCULATION

(MANUAL)

Table 1. Waterplane area, Displacement, LCB VCB calculation for WL-1

Water planes		0		1		2		Area	Sectional			moments
	SM	5		8		-1		products	area	Volume		about
section	SM	y_0	y x SM	y_1	y x SM	y_2	y x SM	for	below	function	levers	amidship
0	0.5	0.0000	0	0.0000	0	2119.4598	1059.73	-2119.46	-213712	-106856.1	-10	1068561
0.5	2	9.5000	19	137.0000	274	2512.3192	5024.638	-1368.82	-138023	-276045.2	-9.5	2622429
1	1	19.0000	19	427.0000	427	2818.2433	2818.243	692.7567	69852.97	69852.967	-9	-628677
1.5	2	40.0000	80	884.0000	1768	3293.6362	6587.272	3978.364	401151.7	802303.37	-8.5	-6819579
2	1.5	312.0000	468	1440.0000	2160	3931.8951	5897.843	9148.105	922433.9	1383650.9	-8	-1.1E+07
3	4	570.0000	2280	2635.0000	10540	5366.8772	21467.51	18563.12	1871782	7487126.2	-7	-5.2E+07
4	2	1031.0000	2062	3737.0000	7474	7142.9978	14286	27908	2814057	5628113.8	-6	-3.4E+07
5	4	1568.0000	6272	4572.0000	18288	9296.5714	37186.29	35119.43	3541209	14164836	-5	-7.1E+07
6	2	2029.0000	4058	5068.0000	10136	10640.2165	21280.43	40048.78	4038252	8076504.7	-4	-3.2E+07
7	4	2289.0000	9156	5289.0000	21156	11603.1071	46412.43	42153.89	4250518	17002070	-3	-5.1E+07
8	2	2366.0000	4732	5363.0000	10726	12042.1853	24084.37	42691.81	4304758	8609516	-2	-1.7E+07
9	4	2444.0000	9776	5373.0000	21492	12041.0848	48164.34	43162.92	4352261	17409042	-1	-1.7E+07
10	2	2444.0000	4888	5373.0000	10746	12039.9844	24079.97	43164.02	4352372	8704743.2	0	0
11	4	2444.0000	9776	5373.0000	21492	12037.7835	48151.13	43166.22	4352593	17410374	1	17410374
12	2	2444.0000	4888	5373.0000	10746	12036.6830	24073.37	43167.32	4352704	8705408.9	2	17410818
13	4	2444.0000	9776	5373.0000	21492	12035.5826	48142.33	43168.42	4352815	17411262	3	52233785
14	2	2362.0000	4724	5359.0000	10718	12034.4821	24068.96	42647.52	4300291	8600582.8	4	34402331
15	4	2258.0000	9032	5246.0000	20984	11921.1362	47684.54	41336.86	4168134	16672535	5	83362675
16	2	1952.0000	3904	4890.0000	9780	10821.7902	21643.58	38058.21	3837536	7675072.3	6	46050434
17	4	1428.0000	5712	4138.0000	16552	9405.5156	37622.06	30838.48	3109547	12438189	7	87067321
18	1.5	844.0000	1266	2955.0000	4432.5	7350.9821	11026.47	20509.02	2067993	3101989	8	24815912
18.5	2	497.0000	994	2176.0000	4352	6071.1629	12142.33	13821.84	1393702	2787403.8	8.5	23692932
19	1	90.0000	90	1397.0000	1397	5243.6272	5243.627	6382.373	643555.9	643555.92	9	5792003
19.5	2	47.0000	94	547.0000	1094	3386.0737	6772.147	1224.926	123513.4	247026.81	9.5	2346755
20	0.5	0.0000	0	0.0000	0	0.0000	0	0	0	0	10	0
Different totals		**sum of the area products of water plane 0**	94066	**sum of the area products of water plane 1**	238226.5	**sum of the area products of water plane 2**	544919.6	**Summation of volume functions**		184648257	**Summation of moments**	1.05E+08
Waterplane area		**166622241.3**		**421978540.3**		**965234274**						
SM		5		8		-1		***VOLUME***		1.635E+11	***LCB***	1508.249
Volume products		833111206.7		3375828323		-965234274		**Summation of volume products**	3.24E+09	***VOLUME***		1.64E+11
levers		0		1		2						
Monent about the keel		0		3375828323		-1930468548		**Summation of moments**	1.45E+09	***VCB***		269.5814
Distance between two consecutive sections					2657	**Distance between two consecutive waterlines**						605

Waterplane area, Displacement, LCB VCB calculation for WL-02												
Water planes		0		1		2		Area	Sectional			moments
	SM	1		4		1		products	area	Volume		about
section	SM	y_0	y x SM	y_1	y x SM	y_2	y x SM	for	below	function	levers	amidship
0	0.5	0.0000	0	0.0000	0	0.0000	0	0	0	0	-10	0
0.5	2	9.5000	19	137.0000	274	245.0000	490	802.5	323675	647350	-9.5	-6149825
1	1	19.0000	19	427.0000	427	623.0000	623	2350	947833.3	947833.3	-9	-8530500
1.5	2	40.0000	80	884.0000	1768	1245.0000	2490	4821	1944470	3888940	-8.5	-3.3E+07
2	1.5	312.0000	468	1440.0000	2160	1937.0000	2905.5	8009	3230297	4845445	-8	-3.9E+07
3	4	570.0000	2280	2635.0000	10540	3264.0000	13056	14374	5797513	23190053	-7	-1.6E+08
4	2	1031.0000	2062	3737.0000	7474	4312.0000	8624	20291	8184037	16368073	-6	-9.8E+07
5	4	1568.0000	6272	4572.0000	18288	4964.0000	19856	24820	10010733	40042933	-5	-2E+08
6	2	2029.0000	4058	5068.0000	10136	5273.0000	10546	27574	11121513	22243027	-4	-8.9E+07
7	4	2289.0000	9156	5289.0000	21156	5378.0000	21512	28823	11625277	46501107	-3	-1.4E+08
8	2	2366.0000	4732	5363.0000	10726	5416.0000	10832	29234	11791047	23582093	-2	-4.7E+07
9	4	2444.0000	9776	5373.0000	21492	5422.0000	21688	29358	11841060	47364240	-1	-4.7E+07
10	2	2444.0000	4888	5373.0000	10746	5422.0000	10844	29358	11841060	23682120	0	0
11	4	2444.0000	9776	5373.0000	21492	5422.0000	21688	29358	11841060	47364240	1	47364240
12	2	2444.0000	4888	5373.0000	10746	5422.0000	10844	29358	11841060	23682120	2	47364240
13	4	2444.0000	9776	5373.0000	21492	5422.0000	21688	29358	11841060	47364240	3	1.42E+08
14	2	2362.0000	4724	5359.0000	10718	5415.0000	10830	29213	11782577	23565153	4	94260613
15	4	2258.0000	9032	5246.0000	20984	5357.0000	21428	28599	11534930	46139720	5	2.31E+08
16	2	1952.0000	3904	4890.0000	9780	5137.0000	10274	26649	10748430	21496860	6	1.29E+08
17	4	1428.0000	5712	4138.0000	16552	4527.0000	18108	22507	9077823	36311293	7	2.54E+08
18	1.5	844.0000	1266	2955.0000	4432.5	3415.0000	5122.5	16079	6485197	9727795	8	77822360
18.5	2	497.0000	994	2176.0000	4352	2218.0000	4436	11419	4605663	9211327	8.5	78296277
19	1	90.0000	90	1397.0000	1397	1759.0000	1759	7437	2999590	2999590	9	26996310
19.5	2	47.0000	94	547.0000	1094	784.2000	1568.4	3019.2	1217744	2435488	9.5	23137136
20	0.5	0.0000	0	0.0000	0	0.0000	0	0	0	0	10	0
Different totals		**sum of the area products of water plane 0**	94066	**sum of the area products of water plane 1**	238226.5	**sum of the area products of water plane 2**	251212.4	**Summation of volume functions**		5.24E+08	**Summation of moments**	2.81E+08
Water plane area		**166622241.3**		**421978540.3**		**444980897.9**						
SM		1		4		1		***VOLUME***		4.64E+11	***LCB***	1425.6
Volume products		166622241.3		1687914161		444980897.9		**Summation of volume products**	2.3E+09	***VOLUME***		4.64E+11
levers		0		1		2						
Monent about the keel		0		1687914161		889961795.7		**Summation of moments**	2.58E+09	***VCB***		678.2358
Distance between two consecutive sections			2657	**Distance between two consecutive waterlines**								605

Waterplane area, Displacement, LCB VCB calculation for WL-03												
Water planes		1.00		2.00		3.00		Area				
	SM	1.00		4.00		1.00		products	Sectional area			moments about
section	SM	y_0	y x SM	y_1	y x SM	y_2	y x SM	for	below waterline	Volume function	levers	amidship
0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.00	0.00
0.50	2.00	137.00	274.00	245.00	490.00	500.00	1000.00	1617.00	652190.00	1304380.00	-9.50	-12391610.00
1.00	1.00	427.00	427.00	623.00	623.00	913.00	913.00	3832.00	1545573.33	1545573.33	-9.00	-13910160.00
1.50	2.00	884.00	1768.00	1245.00	2490.00	1669.00	3338.00	7533.00	3038310.00	6076620.00	-8.50	-51651270.00
2.00	1.50	1440.00	2160.00	1937.00	2905.50	2404.00	3606.00	11592.00	4675440.00	7013160.00	-8.00	-56105280.00
3.00	4.00	2635.00	10540.00	3264.00	13056.00	3707.00	14828.00	19398.00	7823860.00	31295440.00	-7.00	-219068080.00
4.00	2.00	3737.00	7474.00	4312.00	8624.00	4635.00	9270.00	25620.00	10333400.00	20666800.00	-6.00	-124000800.00
5.00	4.00	4572.00	18288.00	4964.00	19856.00	5138.00	20552.00	29566.00	11924953.33	47699813.33	-5.00	-238499066.67
6.00	2.00	5068.00	10136.00	5273.00	10546.00	5339.00	10678.00	31499.00	12704596.67	25409193.33	-4.00	-101636773.33
7.00	4.00	5289.00	21156.00	5378.00	21512.00	5390.00	21560.00	32191.00	12983703.33	51934813.33	-3.00	-155804440.00
8.00	2.00	5363.00	10726.00	5416.00	10832.00	5428.00	10856.00	32455.00	13090183.33	26180366.67	-2.00	-52360733.33
9.00	4.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	32496.00	13106720.00	52426880.00	-1.00	-52426880.00
10.00	2.00	5373.00	10746.00	5422.00	10844.00	5435.00	10870.00	32496.00	13106720.00	26213440.00	0.00	0.00
11.00	4.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	32496.00	13106720.00	52426880.00	1.00	52426880.00
12.00	2.00	5373.00	10746.00	5422.00	10844.00	5435.00	10870.00	32496.00	13106720.00	26213440.00	2.00	52426880.00
13.00	4.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	32496.00	13106720.00	52426880.00	3.00	157280640.00
14.00	2.00	5359.00	10718.00	5415.00	10830.00	5427.00	10854.00	32446.00	13086553.33	26173106.67	4.00	104692426.67
15.00	4.00	5246.00	20984.00	5357.00	21428.00	5380.00	21520.00	32054.00	12928446.67	51713786.67	5.00	258568933.33
16.00	2.00	4890.00	9780.00	5137.00	10274.00	5224.00	10448.00	30662.00	12367006.67	24734013.33	6.00	148404080.00
17.00	4.00	4138.00	16552.00	4527.00	18108.00	4707.00	18828.00	26953.00	10871043.33	43484173.33	7.00	304389213.33
18.00	1.50	2955.00	4432.50	3415.00	5122.50	3665.00	5497.50	20280.00	8179600.00	12269400.00	8.00	98155200.00
18.50	2.00	2176.00	4352.00	2218.00	4436.00	2657.00	5314.00	13705.00	5527683.33	11055366.67	8.50	93970616.67
19.00	1.00	1397.00	1397.00	1759.00	1759.00	1966.00	1966.00	10399.00	4194263.33	4194263.33	9.00	37748370.00
19.50	2.00	547.00	1094.00	784.20	1568.40	914.00	1828.00	4597.80	1854446.00	3708892.00	9.50	35234474.00
20.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00
Different totals		**sum of the area products of water plane 1**	238226.50	**sum of the area products of water plane 2**	251212.40	**sum of the area products of water plane 3**	259816.50	**Summation of volume functions**		606166682.00	**Summation of moments**	265442620.67
Water plane area		**421978540.33**		**444980897.87**		**460221627.00**						
SM		1.00		4.00		1.00		***VOLUME***		536861624691.33	***LCB***	1163.51
Volume products		421978540.33		1779923591.47		460221627.00		**Summation of volume products**	2662123758.80	***VOLUME***		536861624691.33
levers		0.00		1.00		2.00						
Monent about the keel		0.00		1779923591.47		920443254.00		**Summation of moments**	2700366845.47	***VCB***		613.69
Distance between two consecutive sections				2657.00		**Distance between two consecutive waterlines**						605.00

Table 5. Waterplane area, Displacement, LCB VCB calculation for WL-04

Water planes		0.00		1.00		2.00		3.00		4.00						
	SM	1.00		4.00		2.00		4.00		1.00		Area	Sectional area			moments about
section	SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	products	below waterline	Volume function	levers	amidship
0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.00	0.00
0.50	2.00	9.50	19.00	137.00	274.00	245.00	490.00	500.00	1000.00	707.00	1414.00	3754.50	1514315.00	3028630.00	-9.50	-28771985.00
1.00	1.00	19.00	19.00	427.00	427.00	623.00	623.00	913.00	913.00	1337.00	1337.00	7962.00	3211340.00	3211340.00	-9.00	-28902060.00
1.50	2.00	40.00	80.00	884.00	1768.00	1245.00	2490.00	1669.00	3338.00	2146.00	4292.00	14888.00	6004826.67	12009653.33	-8.50	-102082053.33
2.00	1.50	312.00	468.00	1440.00	2160.00	1937.00	2905.50	2404.00	3606.00	2883.00	4324.50	22445.00	9052816.67	13579225.00	-8.00	-108633800.00
3.00	4.00	570.00	2280.00	2635.00	10540.00	3264.00	13056.00	3707.00	14828.00	4082.00	16328.00	36548.00	14741026.67	58964106.67	-7.00	-412748746.67
4.00	2.00	1031.00	2062.00	3737.00	7474.00	4312.00	8624.00	4635.00	9270.00	4863.00	9726.00	48006.00	19362420.00	38724840.00	-6.00	-232349040.00
5.00	4.00	1568.00	6272.00	4572.00	18288.00	4964.00	19856.00	5138.00	20552.00	5240.00	20960.00	55576.00	22415653.33	89662613.33	-5.00	-448313066.67
6.00	2.00	2029.00	4058.00	5068.00	10136.00	5273.00	10546.00	5339.00	10678.00	5367.00	10734.00	59570.00	24026566.67	48053133.33	-4.00	-192212533.33
7.00	4.00	2289.00	9156.00	5289.00	21156.00	5378.00	21512.00	5390.00	21560.00	5402.00	21608.00	61163.00	24669076.67	98676306.67	-3.00	-296028920.00
8.00	2.00	2366.00	4732.00	5363.00	10726.00	5416.00	10832.00	5428.00	10856.00	5432.00	10864.00	61794.00	24923580.00	49847160.00	-2.00	-99694320.00
9.00	4.00	2444.00	9776.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	5439.00	21756.00	61959.00	24990130.00	99960520.00	-1.00	-99960520.00
10.00	2.00	2444.00	4888.00	5373.00	10746.00	5422.00	10844.00	5435.00	10870.00	5439.00	10878.00	61959.00	24990130.00	49980260.00	0.00	0.00
11.00	4.00	2444.00	9776.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	5439.00	21756.00	61959.00	24990130.00	99960520.00	1.00	99960520.00
12.00	2.00	2444.00	4888.00	5373.00	10746.00	5422.00	10844.00	5435.00	10870.00	5439.00	10878.00	61959.00	24990130.00	49980260.00	2.00	99960520.00
13.00	4.00	2444.00	9776.00	5373.00	21492.00	5422.00	21688.00	5435.00	21740.00	5439.00	21756.00	61959.00	24990130.00	99960520.00	3.00	299881560.00
14.00	2.00	2362.00	4724.00	5359.00	10718.00	5415.00	10830.00	5427.00	10854.00	5432.00	10864.00	61768.00	24913093.33	49826186.67	4.00	199304746.67
15.00	4.00	2258.00	9032.00	5246.00	20984.00	5357.00	21428.00	5380.00	21520.00	5396.00	21584.00	60872.00	24551706.67	98206826.67	5.00	491034133.33
16.00	2.00	1952.00	3904.00	4890.00	9780.00	5137.00	10274.00	5224.00	10448.00	5304.00	10608.00	57986.00	23387686.67	46775373.33	6.00	280652240.00
17.00	4.00	1428.00	5712.00	4138.00	16552.00	4527.00	18108.00	4707.00	18828.00	4905.00	19620.00	50767.00	20476023.33	81904093.33	7.00	573328653.33
18.00	1.50	844.00	1266.00	2955.00	4432.50	3415.00	5122.50	3665.00	5497.50	3984.00	5976.00	38138.00	15382326.67	23073490.00	8.00	184587920.00
18.50	2.00	497.00	994.00	2176.00	4352.00	2218.00	4436.00	2657.00	5314.00	2904.00	5808.00	27169.00	10958163.33	21916326.67	8.50	186288776.67
19.00	1.00	90.00	90.00	1397.00	1397.00	1759.00	1759.00	1966.00	1966.00	2274.00	2274.00	19334.00	7798046.67	7798046.67	9.00	70182420.00
19.50	2.00	47.00	94.00	547.00	1094.00	784.20	1568.40	914.00	1828.00	1029.00	2058.00	8488.40	3423654.67	6847309.33	9.50	65049438.67
20.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00
Different totals		**sum of the area products of water plane 0**	94066.00	**sum of the area products of water plane 1**	238226.50	**sum of the area products of water plane 2**	**251212.40**	**sum of the area products of water plane 3**	**259816.50**	**sum of the area products of water plane 4**	267403.50	**Summation of volume functions**		1151946741.00	**Summation of moments**	500533883.67
Water plane area		**166622241.33**		**421978540.33**		**444980897.87**		**460221627.00**		**473660733.00**						
SM		1.00		4.00		2.00		4.00		1.00		***VOLUME***		1020240830279.00	***LCB***	1154.50
Volume products		166622241.33		1687914161.33		889961795.73		1840886508.00		473660733.00		**Summation of volume products**	5059045439.40	***VOLUME***		1020240830279.00
levers		0.00		1.00		2.00		3.00		4.00						
Monent about the keel		0.00		1687914161.33		1779923591.47		5522659524.00		1894642932.00		**Summation of moments**	10885140208.80	***VCB***		1301.73
Distance between two consecutive sections			2657.00	**Distance between two consecutive waterlines**												605.00

Table 5. Waterplane area, Displacement, LCB VCB calculation for WL-05

Water planes		1.0		2.0		3.0		4.0		5.0						
	SM	1.0		4.0		2.0		4.0		1.0		Area products for sectional	Sectional area below waterline	Volume function	levers	moments about amidship
section	SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM					
0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	257.0	128.5	257.0	103656.7	51828.3	-10.0	-518283.3
0.5	2.0	137.0	274.0	245.0	490.0	500.0	1000.0	707.0	1414.0	1158.0	2316.0	6103.0	2461543.3	4923086.7	-9.5	-46769323.3
1.0	1.0	427.0	427.0	623.0	623.0	913.0	913.0	1337.0	1337.0	1889.0	1889.0	11982.0	4832740.0	4832740.0	-9.0	-43494660.0
1.5	2.0	884.0	1768.0	1245.0	2490.0	1669.0	3338.0	2146.0	4292.0	2663.0	5326.0	20449.0	8247763.3	16495526.7	-8.5	-140211976.7
2.0	1.5	1440.0	2160.0	1937.0	2905.5	2404.0	3606.0	2883.0	4324.5	3349.0	5023.5	28877.0	11647056.7	17470585.0	-8.0	-139764680.0
3.0	4.0	2635.0	10540.0	3264.0	13056.0	3707.0	14828.0	4082.0	16328.0	4400.0	17600.0	43833.0	17679310.0	70717240.0	-7.0	-495020680.0
4.0	2.0	3737.0	7474.0	4312.0	8624.0	4635.0	9270.0	4863.0	9726.0	5030.0	10060.0	54737.0	22077256.7	44154513.3	-6.0	-264927080.0
5.0	4.0	4572.0	18288.0	4964.0	19856.0	5138.0	20552.0	5240.0	20960.0	5305.0	21220.0	60969.0	24590830.0	98363320.0	-5.0	-491816600.0
6.0	2.0	5068.0	10136.0	5273.0	10546.0	5339.0	10678.0	5367.0	10734.0	5382.0	10764.0	63688.0	25687493.3	51374986.7	-4.0	-205499946.7
7.0	4.0	5289.0	21156.0	5378.0	21512.0	5390.0	21560.0	5402.0	21608.0	5404.0	21616.0	64593.0	26052510.0	104210040.0	-3.0	-312630120.0
8.0	2.0	5363.0	10726.0	5416.0	10832.0	5428.0	10856.0	5432.0	10864.0	5433.0	10866.0	65044.0	26234413.3	52468826.7	-2.0	-104937653.3
9.0	4.0	5373.0	21492.0	5422.0	21688.0	5435.0	21740.0	5439.0	21756.0	5439.0	21756.0	65126.0	26267486.7	105069946.7	-1.0	-105069946.7
10.0	2.0	5373.0	10746.0	5422.0	10844.0	5435.0	10870.0	5439.0	10878.0	5439.0	10878.0	65126.0	26267486.7	52534973.3	0.0	0.0
11.0	4.0	5373.0	21492.0	5422.0	21688.0	5435.0	21740.0	5439.0	21756.0	5439.0	21756.0	65126.0	26267486.7	105069946.7	1.0	105069946.7
12.0	2.0	5373.0	10746.0	5422.0	10844.0	5435.0	10870.0	5439.0	10878.0	5439.0	10878.0	65126.0	26267486.7	52534973.3	2.0	105069946.7
13.0	4.0	5373.0	21492.0	5422.0	21688.0	5435.0	21740.0	5439.0	21756.0	5439.0	21756.0	65126.0	26267486.7	105069946.7	3.0	315209840.0
14.0	2.0	5359.0	10718.0	5415.0	10830.0	5427.0	10854.0	5432.0	10864.0	5432.0	10864.0	65033.0	26229976.7	52459953.3	4.0	209839813.3
15.0	4.0	5246.0	20984.0	5357.0	21428.0	5380.0	21520.0	5396.0	21584.0	5396.0	21584.0	64414.0	25980313.3	103921253.3	5.0	519606266.7
16.0	2.0	4890.0	9780.0	5137.0	10274.0	5224.0	10448.0	5304.0	10608.0	5304.0	10608.0	62406.0	25170420.0	50340840.0	6.0	302045040.0
17.0	4.0	4138.0	16552.0	4527.0	18108.0	4707.0	18828.0	4905.0	19620.0	4905.0	19620.0	56185.0	22661283.3	90645133.3	7.0	634515933.3
18.0	1.5	2955.0	4432.5	3415.0	5122.5	3665.0	5497.5	3984.0	5976.0	3984.0	5976.0	43865.0	17692216.7	26538325.0	8.0	212306600.0
18.5	2.0	2176.0	4352.0	2218.0	4436.0	2657.0	5314.0	2904.0	5808.0	3085.0	6170.0	31063.0	12528743.3	25057486.7	8.5	212988636.7
19.0	1.0	1397.0	1397.0	1759.0	1759.0	1966.0	1966.0	2274.0	2274.0	2274.0	2274.0	23735.0	9573116.7	9573116.7	9.0	86158050.0
19.5	2.0	547.0	1094.0	784.2	1568.4	914.0	1828.0	1029.0	2058.0	1144.0	2288.0	10771.8	4344626.0	8689252.0	9.5	82547894.0
20.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
Different totals		**sum of the area products of water plane 1**	238226.5	**sum of the area products of water plane 2**	251212.4	**sum of the area products of water plane 3**	**259816.5**	**sum of the area products of water plane 4**	**267403.5**	**sum of the area products of water plane 5**	273217.0	**Summation of volume functions**		1252567840.3	**Summation of moments**	434697017.3
Water plane area		**421978540.3**		**444980897.9**		**460221627.0**		**473660733.0**		**483958379.3**						
SM		1.0		4.0		2.0		4.0		1.0		***VOLUME***		1109357583921.9	***LCB***	922.1
Volume products		421978540.3		1779923591.5		920443254.0		1894642932.0		483958379.3		**Summation of volume products**	5500946697.1	***VOLUME***		1109357583921.9
levers		0.0		1.0		2.0		3.0		4.0						
Monent about the keel		0.0		1779923591.5		1840886508.0		5683928796.0		1935833517.3		**Summation of moments**	11240572412.8	***VCB***		1236.3
Distance between two consecutive sections					2657.0	**Distance between two consecutive waterlines**										605.0

Table 6. Waterplane area, Displacement, LCB VCB calculation for WL-06

Water planes		0		1		2		3		4		5		6						
	SM	1		4		2		4		2		4		1		Area	Sectional area			moments about
section	SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	y	y x SM	products	below waterline	Volume function	levers	amidship
0	1	0	0	0	0	0	0	0	0	0	0	257	129	885	443	1913	771577	385788	-10	-3857883
1	2	10	19	137	274	245	490	500	1000	707	1414	1158	2316	1707	3414	10801	4356202	8712403	-10	-82767832
1	1	19	19	427	427	623	623	913	913	1337	1337	1889	1889	2460	2460	19315	7790383	7790383	-9	-70113450
2	2	40	80	884	1768	1245	2490	1669	3338	2146	4292	2663	5326	3166	6332	30852	12443640	24887280	-9	-211541880
2	2	312	468	1440	2160	1937	2906	2404	3606	2883	4325	3349	5024	3768	5652	42492	17138440	25707660	-8	-205661280
3	4	570	2280	2635	10540	3264	13056	3707	14828	4082	16328	4400	17600	4653	18612	62883	25362810	101451240	-7	-710158680
4	2	1031	2062	3737	7474	4312	8624	4635	9270	4863	9726	5030	10060	5148	10296	78137	31515257	63030513	-6	-378183080
5	4	1568	6272	4572	18288	4964	19856	5138	20552	5240	20960	5305	21220	5343	21372	87379	35242863	140971453	-5	-704857267
6	2	2029	4058	5068	10136	5273	10546	5339	10678	5367	10734	5382	10764	5388	10776	91853	37047377	74094753	-4	-296379013
7	4	2289	9156	5289	21156	5378	21512	5390	21560	5402	21608	5404	21616	5404	21616	93585	37745950	150983800	-3	-452951400
8	2	2366	4732	5363	10726	5416	10832	5428	10856	5432	10864	5433	10866	5431	10862	94389	38070230	76140460	-2	-152280920
9	4	2444	9776	5373	21492	5422	21688	5435	21740	5439	21756	5439	21756	5437	21748	94591	38151703	152606813	-1	-152606813
10	2	2444	4888	5373	10746	5422	10844	5435	10870	5439	10878	5439	10878	5437	10874	94591	38151703	76303407	0	0
11	4	2444	9776	5373	21492	5422	21688	5435	21740	5439	21756	5439	21756	5437	21748	94591	38151703	152606813	1	152606813
12	2	2444	4888	5373	10746	5422	10844	5435	10870	5439	10878	5439	10878	5437	10874	94591	38151703	76303407	2	152606813
13	4	2444	9776	5373	21492	5422	21688	5435	21740	5439	21756	5439	21756	5437	21748	94591	38151703	152606813	3	457820440
14	2	2362	4724	5359	10718	5415	10830	5427	10854	5432	10864	5432	10864	5430	10860	94358	38057727	76115453	4	304461813
15	4	2258	9032	5246	20984	5357	21428	5380	21520	5396	21584	5396	21584	5398	21592	93250	37610833	150443333	5	752216667
16	2	1952	3904	4890	9780	5137	10274	5224	10448	5304	10608	5304	10608	5326	10652	89832	36232240	72464480	6	434786880
17	4	1428	5712	4138	16552	4527	18108	4707	18828	4905	19620	4905	19620	4980	19920	80272	32376373	129505493	7	906538453
18	2	844	1266	2955	4433	3415	5123	3665	5498	3984	5976	3984	5976	4126	6189	62184	25080880	37621320	8	300970560
19	2	497	994	2176	4352	2218	4436	2657	5314	2904	5808	3085	6170	3247	6494	45660	18416200	36832400	9	313075400
19	1	90	90	1397	1397	1759	1759	1966	1966	2274	2274	2274	2274	2434	2434	33138	13365660	13365660	9	120290940
20	2	47	94	547	1094	784	1568	914	1828	1029	2058	1144	2288	1293	2586	15386	6205848	12411696	10	117911112
20	1	0	0	0	0	0	0	0	0	0	0	0	0	102	51	102	41140	20570	10	205700
		sum of the area products of water		**sum of the area products of water**		**sum of the area products of water**		**sum of the area products of water**		**sum of the area products of water**		**sum of the area products of water**						
Different totals		**plane 0**	94066	**plane 1**	238227	**plane 2**	**251212**	**plane 3**	**259817**	**plane 4**	**267404**	**plane 5**	**273217**	**plane 6**	279605	**Summation of volume functions**		1813363394	**Summation of moments**	592132094
Water plane area		**166622241**		**421978540**		**444980898**		**460221627**		**473660733**		**483958379**		**495272771**						
SM		1		4		2		4		2		4		1		***VOLUME***		1606035512915	***LCB***	868
Volume products		166622241		1687914161		889961796		1840886508		947321466		1935833517		495272771		**Summation of volume products**	7963812461	***VOLUME***		1606035512915
levers		0		1		1		2		3		4		5						
Monent about the keel		0		843957081		889961796		3681773016		2841964398		7743334069		2476363855		**Summation of moments**	18477354215	***VCB***		1404
Distance between two consecutive sections			2657	**Distance between two consecutive waterlines**																605

Displacement=	1606.035513
Cb =	0.818713692

LCF and BM$_L$ calculation for WL 0.5 TO 5

Section	SM	Levers from amid ships (M)	0.00				1.00				2.00				3.00				4.00				5.00				6.00			
			Y	y´sm	(y´sm) x	(y´sm) x^2	y	y´sm	(y´sm) x	(y´sm) x^2	y	y´sm	(y´sm) x	(y´sm) x^2	y	y´sm	(y´sm) x	(y´sm) x^2	y	y´sm	(y´sm) x	(y´sm) x^2	Y	y´sm	(y´sm) x	(y´sm) x^2	Y	y´sm	(y´sm) x	(y´sm) x^2
0.00	0.50	-10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	257.00	128.50	-1285.00	12850.00	885.00	442.50	-4425.00	44250.00
0.50	2.00	-9.50	0.00	0.00	0.00	0.00	137.00	274.00	-2603.00	24728.50	245.00	490.00	-4655.00	44222.50	500.00	1000.00	-9500.00	90250.00	707.00	1414.00	-13433.00	127613.50	1158.00	2316.00	-22002.00	209019.00	1707.00	3414.00	-32433.00	308113.50
1.00	1.00	-9.00	0.00	0.00	0.00	0.00	427.00	427.00	-3843.00	34587.00	623.00	623.00	-5607.00	50463.00	913.00	913.00	-8217.00	73953.00	1337.00	1337.00	-12033.00	108297.00	1889.00	1889.00	-17001.00	153009.00	2460.00	2460.00	-22140.00	199260.00
1.50	2.00	-8.50	0.00	0.00	0.00	0.00	884.00	1768.00	-15028.00	127738.00	1245.00	2490.00	-21165.00	179902.50	1669.00	3338.00	-28373.00	241170.50	2146.00	4292.00	-36482.00	310097.00	2663.00	5326.00	-45271.00	384803.50	3166.00	6332.00	-53822.00	457487.00
2.00	1.50	-8.00	0.00	0.00	0.00	0.00	1440.00	2160.00	-17280.00	138240.00	1937.00	2905.50	-23244.00	185952.00	2404.00	3606.00	-28848.00	230784.00	2883.00	4324.50	-34596.00	276768.00	3349.00	5023.50	-40188.00	321504.00	3768.00	5652.00	-45216.00	361728.00
3.00	4.00	-7.00	0.00	0.00	0.00	0.00	2635.00	10540.00	-73780.00	516460.00	3264.00	13056.00	-91392.00	639744.00	3707.00	14828.00	-103796.00	726572.00	4082.00	16328.00	-114296.00	800072.00	4400.00	17600.00	-123200.00	862400.00	4653.00	18612.00	-130284.00	911988.00
4.00	2.00	-6.00	0.00	0.00	0.00	0.00	3737.00	7474.00	-44844.00	269064.00	4312.00	8624.00	-51744.00	310464.00	4635.00	9270.00	-55620.00	333720.00	4863.00	9726.00	-58356.00	350136.00	5030.00	10060.00	-60360.00	362160.00	5148.00	10296.00	-61776.00	370656.00
5.00	4.00	-5.00	0.00	0.00	0.00	0.00	4572.00	18288.00	-91440.00	457200.00	4964.00	19856.00	-99280.00	496400.00	5138.00	20552.00	-102760.00	513800.00	5240.00	20960.00	-104800.00	524000.00	5305.00	21220.00	-106100.00	530500.00	5343.00	21372.00	-106860.00	534300.00
6.00	2.00	-4.00	0.00	0.00	0.00	0.00	5068.00	10136.00	-40544.00	162176.00	5273.00	10546.00	-42184.00	168736.00	5339.00	10678.00	-42712.00	170848.00	5367.00	10734.00	-42936.00	171744.00	5382.00	10764.00	-43056.00	172224.00	5388.00	10776.00	-43104.00	172416.00
7.00	4.00	-3.00	0.00	0.00	0.00	0.00	5289.00	21156.00	-63468.00	190404.00	5378.00	21512.00	-64536.00	193608.00	5390.00	21560.00	-64680.00	194040.00	5402.00	21608.00	-64824.00	194472.00	5404.00	21616.00	-64848.00	194544.00	5404.00	21616.00	-64848.00	194544.00
8.00	2.00	-2.00	0.00	0.00	0.00	0.00	5363.00	10726.00	-21452.00	42904.00	5416.00	10832.00	-21664.00	43328.00	5428.00	10856.00	-21712.00	43424.00	5432.00	10864.00	-21728.00	43456.00	5433.00	10866.00	-21732.00	43464.00	5431.00	10862.00	-21724.00	43448.00
9.00	4.00	-1.00	0.00	0.00	0.00	0.00	5373.00	21492.00	-21492.00	21492.00	5422.00	21688.00	-21688.00	21688.00	5435.00	21740.00	-21740.00	21740.00	5439.00	21756.00	-21756.00	21756.00	5439.00	21756.00	-21756.00	21756.00	5437.00	21748.00	-21748.00	21748.00
10.00	2.00	0.00	0.00	0.00	0.00	0.00	5373.00	10746.00	0.00	0.00	5422.00	10844.00	0.00	0.00	5435.00	10870.00	0.00	0.00	5439.00	10878.00	0.00	0.00	5439.00	10878.00	0.00	0.00	5437.00	10874.00	0.00	0.00
11.00	4.00	1.00	0.00	0.00	0.00	0.00	5373.00	21492.00	21492.00	21492.00	5422.00	21688.00	21688.00	21688.00	5435.00	21740.00	21740.00	21740.00	5439.00	21756.00	21756.00	21756.00	5439.00	21756.00	21756.00	21756.00	5437.00	21748.00	21748.00	21748.00
12.00	2.00	2.00	0.00	0.00	0.00	0.00	5373.00	10746.00	21492.00	42984.00	5422.00	10844.00	21688.00	43376.00	5435.00	10870.00	21740.00	43480.00	5439.00	10878.00	21756.00	43512.00	5439.00	10878.00	21756.00	43512.00	5437.00	10874.00	21748.00	43496.00
13.00	4.00	3.00	0.00	0.00	0.00	0.00	5373.00	21492.00	64476.00	193428.00	5422.00	21688.00	65064.00	195192.00	5435.00	21740.00	65220.00	195660.00	5439.00	21756.00	65268.00	195804.00	5439.00	21756.00	65268.00	195804.00	5437.00	21748.00	65244.00	195732.00
14.00	2.00	4.00	0.00	0.00	0.00	0.00	5359.00	10718.00	42872.00	171488.00	5415.00	10830.00	43320.00	173280.00	5427.00	10854.00	43416.00	173664.00	5432.00	10864.00	43456.00	173824.00	5432.00	10864.00	43456.00	173824.00	5430.00	10860.00	43440.00	173760.00
15.00	4.00	5.00	0.00	0.00	0.00	0.00	5246.00	20984.00	104920.00	524600.00	5357.00	21428.00	107140.00	535700.00	5380.00	21520.00	107600.00	538000.00	5396.00	21584.00	107920.00	539600.00	5396.00	21584.00	107920.00	539600.00	5398.00	21592.00	107960.00	539800.00
16.00	2.00	6.00	0.00	0.00	0.00	0.00	4890.00	9780.00	58680.00	352080.00	5137.00	10274.00	61644.00	369864.00	5224.00	10448.00	62688.00	376128.00	5304.00	10608.00	63648.00	381888.00	5304.00	10608.00	63648.00	381888.00	5326.00	10652.00	63912.00	383472.00
17.00	4.00	7.00	0.00	0.00	0.00	0.00	4138.00	16552.00	115864.00	811048.00	4527.00	18108.00	126756.00	887292.00	4707.00	18828.00	131796.00	922572.00	4905.00	19620.00	137340.00	961380.00	4905.00	19620.00	137340.00	961380.00	4980.00	19920.00	139440.00	976080.00
18.00	1.50	8.00	0.00	0.00	0.00	0.00	2955.00	4432.50	35460.00	283680.00	3415.00	5122.50	40980.00	327840.00	3665.00	5497.50	43980.00	351840.00	3984.00	5976.00	47808.00	382464.00	3984.00	5976.00	47808.00	382464.00	4126.00	6189.00	49512.00	396096.00
18.50	2.00	8.50	0.00	0.00	0.00	0.00	2176.00	4352.00	36992.00	314432.00	2218.00	4436.00	37706.00	320501.00	2657.00	5314.00	45169.00	383936.50	2904.00	5808.00	49368.00	419628.00	3085.00	6170.00	52445.00	445782.50	3247.00	6494.00	55199.00	469191.50
19.00	1.00	9.00	0.00	0.00	0.00	0.00	1397.00	1397.00	12573.00	113157.00	1759.00	1759.00	15831.00	142479.00	1966.00	1966.00	17694.00	159246.00	2274.00	2274.00	20466.00	184194.00	2274.00	2274.00	20466.00	184194.00	2434.00	2434.00	21906.00	197154.00
19.50	2.00	9.50	0.00	0.00	0.00	0.00	547.00	1094.00	10393.00	98733.50	784.20	1568.40	14899.80	141548.10	914.00	1828.00	17366.00	164977.00	1029.00	2058.00	19551.00	185734.50	1144.00	2288.00	21736.00	206492.00	1293.00	2586.00	24567.00	233386.50
20.00	0.50	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	102.00	51.00	510.00	5100.00
TOTALS				**0.00**	**0.00**	**0.00**		**238226.50**	**129440.00**	**4912116.00**		**251212.40**	**109557.80**	**5493268.10**		**259816.50**	**90451.00**	**5971545.00**		**267403.50**	**73097.00**	**6418196.00**		**273217.00**	**36800.00**	**6804930.00**		**279604.50**	**6806.00**	**7254954.50**
Distance between two sections			h=			0.00				2657.00				2657.00				2657.00				2657.00				2657.00				2657.00
Displacement			from previous calculation			0.00				163536806622.87				463735988940.89				536861624691.33				1109357583921.89				1109357583921.89				1606035512914.56
Water plane Area			formula			0.00				421978540.33				444980897.87				460221627.00				473660733.00				483958379.33				495272771.00
LCF from Amidship			formula			0.00				1443.68				1158.76				924.99				726.31				357.88				64.68
Moment of inertia about the amidship			formula			0.00				614259692953024000.00				686932714241127000.00				746741200361548000.00				802594870372020000.00				850955924568317000.00				907231450470257000.00
Moment of inertia about the LCF			formula			0.00				605464804359596000.00				680957837657964000.00				742803493146352000.00				800096162854655000.00				850336096379805000.00				907210733648144000.00
Longitudinal Metacenter BM$_L$			formula			0.00				370231.52				146841.71				138360.33				72122.48				76651.22				56487.59
Tons Per Inch Immersion (TPI)			formula			0.00				4219785.40				4449808.98				4602216.27				4736607.33				4839583.79				4952727.71
Moment to change trim 1 inch			formula			0.00				100649113032.71				113198656436.26				123479535399.02				133003551242.55				141355159315.75				150809683763.57

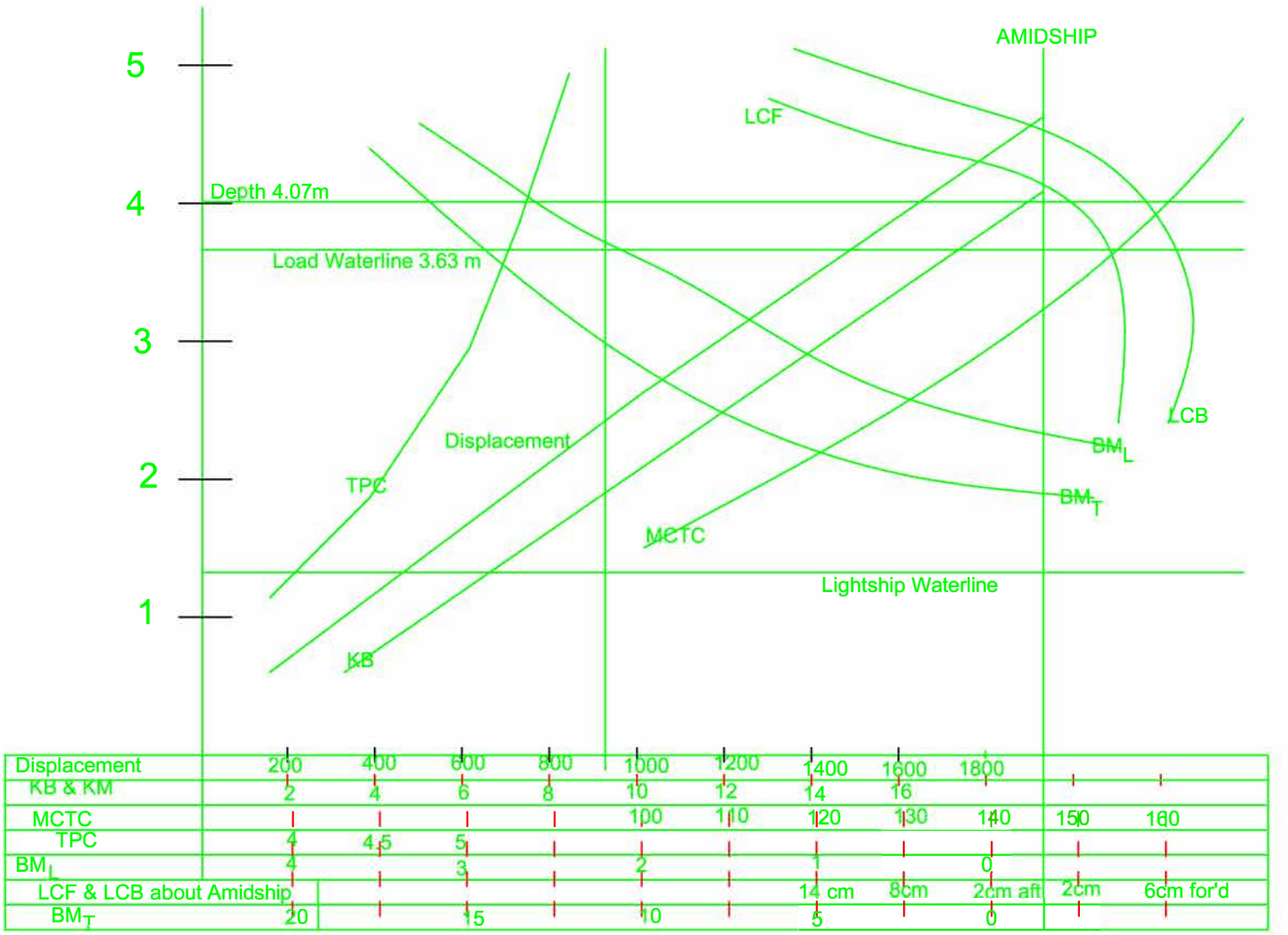
Transverse metacentric height BM_T calculation																							
		Water lines above base line			Water lines above base line			Water lines above base line			Water lines above base line			Water lines above base line			Water lines above base line			Water lines above base line		
		0			1			2			3			4			5			6		
Sections	SM	y	y^3	y^3 X SM	y	y^3	y3 X SM	y	y^3	y3 X SM	y	y^3	y3 X SM	y	y^3	y3 X SM	y	y^3	y3 X SM	y	y^3	y3 X SM
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257	16974593	8487297	885	693154125	346577063
1	2	10	857	1715	137	2571353	5142706	245	14706125	29412250	500	125000000	250000000	707	353393243	706786486	1158	1552836312	3105672624	1707	4973940243	9947880486
1	1	19	6859	6859	427	77854483	77854483	623	241804367	241804367	913	761048497	761048497	1337	2389979753	2389979753	1889	6740558369	6740558369	2460	14886936000	14886936000
2	2	40	64000	128000	884	690807104	1381614208	1245	1929781125	3859562250	1669	4649101309	9298202618	2146	9883008136	19766016272	2663	18884848247	37769696494	3166	31734578296	63469156592
2	2	312	30371328	45556992	1440	2985984000	4478976000	1937	7267563953	10901345930	2404	13893235264	20839852896	2883	23962599387	35943899081	3349	37561717549	56342576324	3768	53497400832	80246101248
3	4	570	185193000	740772000	2635	18295397875	73181591500	3264	34773663744	139094654976	3707	50941034243	203764136972	4082	68017239368	272068957472	4400	85184000000	340736000000	4653	100739353077	402957412308
4	2	1031	1095912791	2191825582	3737	52187836553	104375673106	4312	80174499328	160348998656	4635	99574747875	199149495750	4863	115003963647	230007927294	5030	127263527000	254527054000	5148	136431801792	272863603584
5	4	1568	3855122432	15420489728	4572	95569357248	382277428992	4964	122319393344	489277573376	5138	135638288072	542553152288	5240	143877824000	575511296000	5305	149298747625	597194990500	5343	152530088607	610120354428
6	2	2029	8353070389	16706140778	5068	130169674432	260339348864	5273	146613281417	293226562834	5339	152187773219	304375546438	5367	154594765863	309189531726	5382	155894602968	311789205936	5388	156416571072	312833142144
7	4	2289	11993263569	47973054276	5289	147951952569	591807810276	5378	155547270152	622189080608	5390	156590819000	626363276000	5402	157639024808	630556099232	5404	157814179264	631256717056	5404	157814179264	631256717056
8	2	2366	13244763896	26489527792	5363	154249367147	308498734294	5416	158867831296	317735662592	5428	159926162752	319852325504	5432	160279981568	320559963136	5433	160368517737	320737035474	5431	160191477991	320382955982
9	4	2444	14598344384	58393377536	5373	155113830117	620455320468	5422	159396411448	637585645792	5435	160545687875	642182751500	5439	160900419519	643601678076	5439	160900419519	643601678076	5437	160722988453	642891953812
10	2	2444	14598344384	29196688768	5373	155113830117	310227660234	5422	159396411448	318792822896	5435	160545687875	321091375750	5439	160900419519	321800839038	5439	160900419519	321800839038	5437	160722988453	321445976906
11	4	2444	14598344384	58393377536	5373	155113830117	620455320468	5422	159396411448	637585645792	5435	160545687875	642182751500	5439	160900419519	643601678076	5439	160900419519	643601678076	5437	160722988453	642891953812
12	2	2444	14598344384	29196688768	5373	155113830117	310227660234	5422	159396411448	318792822896	5435	160545687875	321091375750	5439	160900419519	321800839038	5439	160900419519	321800839038	5437	160722988453	321445976906
13	4	2444	14598344384	58393377536	5373	155113830117	620455320468	5422	159396411448	637585645792	5435	160545687875	642182751500	5439	160900419519	643601678076	5439	160900419519	643601678076	5437	160722988453	642891953812
14	2	2362	13177701928	26355403856	5359	153904483279	307808966558	5415	158779848375	317559696750	5427	159837789483	319675578966	5432	160279981568	320559963136	5432	160279981568	320559963136	5430	160103007000	320206014000
15	4	2258	11512557512	46050230048	5246	144372626936	577490507744	5357	153732234293	614928937172	5380	155720872000	622883488000	5396	157114339136	628457356544	5396	157114339136	628457356544	5398	157289104792	629156419168
16	2	1952	7437713408	14875426816	4890	116930169000	233860338000	5137	135559106353	271118212706	5224	142563879424	285127758848	5304	149214334464	298428668928	5304	149214334464	298428668928	5326	151078785976	302157571952
17	4	1428	2911954752	11647819008	4138	70855156072	283420624288	4527	92775111183	371100444732	4707	104287581243	417150324972	4905	118009517625	472038070500	4905	118009517625	472038070500	4980	123505992000	494023968000
18	2	844	601211584	901817376	2955	25803133875	38704700813	3415	39826498375	59739747563	3665	49229104625	73843656938	3984	63235067904	94852601856	3984	63235067904	94852601856	4126	70240512376	105360768564
19	2	497	122763473	245526946	2176	10303307776	20606615552	2218	10911504232	21823008464	2657	18757487393	37514974786	2904	24490059264	48980118528	3085	29360639125	58721278250	3247	34233150223	68466300446
19	1	90	729000	729000	1397	2726397773	2726397773	1759	5442488479	5442488479	1966	7598896696	7598896696	2274	11759026824	11759026824	2274	11759026824	11759026824	2434	14419882504	14419882504
20	2	47	103823	207646	547	163667323	327334646	784	482259192	964518383	914	763551944	1527103888	1029	1089547389	2179094778	1144	1497193984	2994387968	1293	2161700757	4323401514
20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	1061208	530604
Summation of y3 x SM				443218174562			5673190941675			6249924295255			6561259826057			6848362069850			7022426060383			72289935088891
Distance		H		2657	H		2657	H		2657	H		2657	H		2657	H		2657	H		2657
displacement		For waterplane 0		163536806623	For waterplane 01		163536806623	For waterplane 2		463735988941	for waterplane 3		536861624691	For waterplane 4		1020240830279	For waterplane 5		1109357583922	For waterplane 6		1606035512915
Moment of		I		261695708846793	I		3349704073784250	I		3690233078331900	I		3874059412851580	I		4043577337686690	I		4146352453875030	I		4268319056249350
metacentric		BM_T		1600	BM_T		20483	BM_T		7958	BM_T		7216	BM_T		3963	BM_T		3738	BM_T		2658

Summary of Hydrostatic Calculation:

Water Lines	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6
Displacement (t)	164	464	536	1020	1109	1606
LCF from Amidships (m)	0.61	0.68	0.74	0.80	0.85	0.9
BM_T (m)	1.6	2.05	7.2	3.9	3.7	2.7
BM_L *(m)*	370	147	138	72	65	56
TPC(t)	4.22	4.44	4.60	4.70	4.84	4.96
MCTC	101	113	123	133	141	151
VCB (KB)	0.270	0.678	0.967	1.30	1.23	1.4
LCB	1.5	1.4	1.2	1.1	0.9	0.8

HYDROSTATIC CURVES FOR A GENERAL CARGO VESSEL

LBP=50.13M BREADTH=10.78M DRAFT=3.63M CB=0.82



Displacement	200	400	600	800	1000	1200	1400	1600	1800		
KB & KM	2	4	6	8	10	12	14	16			
MCTC					100	110	120	130	140	150	160
TPC	4	4.5	5								
BM$_L$	4		3		2		1		0		
LCF & LCB about Amidship							14 cm	8cm	2cm aft	2cm	6cm for'd
BM$_T$	20		15		10		5		0		

SCANTLING CALCULATION

Principle Particulars:

L_{BP} = 51.13 m

B_{MLD} = 11.0 m

T= 3.7 m

D= 4.07 m

C_B= 0.82

Frame Spacing= 500 mm

Web Frame Spacing = 1500 mm

Bottom Shell Plating:

$t = \frac{s\sqrt{h}}{254} + 2.5$ mm Here, s= 500

$= \frac{500x\sqrt{5.113}}{254} + 2.5\ mm$ h= 0.1x51.13

$= 6.95$ mm = 7 mm

Ref: ABS rulebook; Chapter-2, Section-2, 3.3

3.3 Bottom Shell Plating

The thickness of the bottom shell plating throughout is not to be less than that obtained from the following equations:

3.3.1

$t = \frac{s\sqrt{h}}{254} + 2.5\ mm$ or

$t = \frac{s\sqrt{h}}{460} + 10\ in$

where

t = thickness of bottom shell plating, in mm (in.)

s = frame spacing, in mm (in.)

h = depth, *D*, in m (ft), as defined in 3-1-1/7.1, but not less than 0.1*L* or 1.18*d*, whichever is greater

d = draft for scantlings, as defined in 3-1-1/9, or 0.066*L*, whichever is greater

L = length of vessel, in m (ft), as defined in 3-1-1/3

Side Shell Plating:

$t = \frac{s\sqrt{h}}{268} + 2.5$ mm Here, s= 500

$= 6.719$ mm = 7 mm h= 0.1x51.13

Ref: ABS rulebook; Chapter-2, Section-2, 5.1

5 Side Shell Plating
5.1 General *(1998)*
The side shell plating is not to be less in thickness than that obtained from the following equation:
$t = \frac{s\sqrt{h}}{268} + 2.5mm$ or
$t = \frac{s\sqrt{h}}{485} + 10\ in$
where
t = thickness, in mm (in.)
s = spacing of transverse frames or longitudinals, in mm (in.)
h = depth, in m (ft), as defined in 3-1-1/7, but not less than 0.1L or 1.18d, whichever
is greater
d = draft for scantlings, as defined in 3-1-1/9, or 0.066L, whichever is greater
L = length of the vessel, as defined in 3-1-1/3

Side Shell Plating at Ends:

t = 0.0455L+ 0.009s mm Here, s= 500

= 6.83 mm = 7 mm L= 51.13

Ref: ABS rulebook; Chapter-2, Section-2, 5.5

5.5 Side Shell Plating at Ends
The minimum side shell plating thickness, t, at ends is to be obtained from the following equations and is not to extend for more than 0.1L from the ends. Between the midship 0.4L and the end 0.1L, the
thickness of the plating may be gradually tapered.
t = 0.0455L + 0.009s mm
t = 0.000545L + 0.009s in.
where
s = frame spacing, in mm (in.)
L = length of vessel, as defined in 3-1-1/3, in m (ft)
Where the strength deck at the ends is above the freeboard deck, the thickness of the side plating above the freeboard deck may be reduced to the thickness given for forecastle and poop sides at the forward and after ends, respectively.

Forecastle Side Plating :

$t = 0.038(L + 30.8) + 0.006s$ mm

= 6.11 mm = 7 mm

Poop Side Plating :

$t = 0.0296(L + 39.5) + 0.006s$ mm

= 5.68 mm = 6 mm

Ref: ABS rulebook; Chapter-2, Section-2, 5.7

5.7 Forecastle and Poop Side Plating

5.7.1 Forecastle Side Plating

The thickness, t, of the plating is to be not less than that obtained from the following equation:

$t = 0.038(L + 30.8) + 0.006s$ mm

$t = 0.00045(L + 103.3) + 0.006s$ in.

5.7.2 Poop Side Plating

The thickness, t, of the plating is to be not less than that obtained from the following equation:

$t = 0.0296(L + 39.5) + 0.006s$ mm

$t = 0.00035(L + 132.9) + 0.006s$ in.

where

s = spacing of frames, in mm (in.)

L = length of vessel, as defined in 3-1-1/3, in m (ft)

Deck Plating:

3.1.1 Exposed Freeboard Deck Having No Deck Below

$t = \frac{s\sqrt{h}}{254} + 2.5$ mm

$t = \frac{500\sqrt{2.512}}{254} + 2.5$ mm

= 5.62 mm = 6 mm

Here, $h = 0.028L + 1.08$ m

= 0.028x51.13+1.08m

= 2.512 m

3.1.2 Exposed Freeboard Deck Having a Deck Below, Forecastle Deck, Superstructure Deck Forward of Amidships 0.5L

$t = \frac{s\sqrt{h}}{254} + 2.5$ mm

Here, $h = 0.028L + 0.66$ m

$t = \frac{500\sqrt{2.092}}{254} + 2.5$ mm =0.028x51.1+.66m

= 5.347 mm = 6 mm =2.092 m

3.1.3 Freeboard Deck within Superstructure, Any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward of and 0.20L Aft of Amidships

$t = \frac{s\sqrt{h}}{254} + 2.5$ mm Here, $h = 0.014L + 0.87$ m

$t = \frac{500\sqrt{1.59}}{254} + 2.5$ mm =0.014x51.1+0.87m

= 4.9822 mm = 5 mm =1.59 m

Ref: ABS rulebook; Chapter-2, Section-3, 3.1.2

3 Deck Plating
The thickness of plating on each deck is to be not less than the greater of those obtained from the
following equations. The required thickness is not to be less than 5.0 mm (0.20 in.), except for platform
decks in enclosed passenger spaces where the thickness is not to be less than 4.5 mm (0.18 in.).
Thickness of strength deck inside line of openings may be reduced by 1.0 mm (0.04 in.) from *t*
obtained by 3-2-3/3.3 below.

3.1 All Decks

$t = \frac{s\sqrt{h}}{254} + 2.5$ mm or

$t = \frac{s\sqrt{h}}{460} + 10$ in

where

t = thickness, in mm (in.)

s = beam or longitudinal spacing, in mm (in.)

h = height, in m (ft), as follows:

= *for a deck or portion of deck forming a tank top*, the greater of the following distances:

• two-thirds of the distance from the tank top to the top of the overflow, or

• two-thirds of the distance from the tank top to the bulkhead deck or freeboard deck.

= *for a lower deck on which cargo or stores are carried,* the tween-deck height at side; where the cargo weights are greater than normal [7010 N/m3 (715 kgf/m3, 45 lbf/ft3)], *h* is to be suitably adjusted.

= *for an exposed deck on which cargo is carried,* 3.66 m (12 ft). Where it is intended
to carry deck cargoes in excess of 25850 N/m2 (2636 kgf/m2, 540 lbf/ft2), this head is to be increased in proportion to the added loads which will be imposed on the structure

Elsewhere, the value of h is to be not less than that obtained from the appropriate equation below,
where L is the length of vessel in m (ft), as defined in 3-1-1/3.
3.1.1 Exposed Freeboard Deck Having No Deck Below
$h = 0.028L + 1.08$ m
$h = 0.028L + 3.57$ ft
3.1.2 Exposed Freeboard Deck Having a Deck Below, Forecastle Deck, Superstructure
Deck Forward of Amidships 0.5L
$h = 0.028L + 0.66$ m
$h = 0.028L + 2.14$ ft
3.1.3 Freeboard Deck within Superstructure, Any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward of and 0.20L Aft of Amidships
$h = 0.014L + 0.87$ m
$h = 0.014L + 2.86$ ft
3.1.4 All Other Locations
$h = 0.014L + 0.43$ m
$h = 0.014L + 1.43$ ft

Strength Decks within the Midship 0.8L:

$t = 0.009s + 2.4$ mm

$= 6.9$ mm $= 7$ mm

Ref: ABS rulebook; Chapter-2, Section-4

3.3 Strength Decks within the Midship 0.8L *(2002)*
For vessels of length equal to or greater than 61 meters, the strength deck plating within the midship
0.8L shall meet the following requirement:
$t = 0.009s + 2.4$ mm
$t = 0.009s + 0.095$ in.
where
s = beam or longitudinal spacing, in mm (in.)

Inner Bottom Plating :

$t = 0.037L + 0.009s + c$ mm

$t_{engine} = 7.8918$ mm $= 8$mm

$t_{elsewhere} = 6.4418$ mm $= 7$ mm

Here, L= 51.13 m

s= 500 mm

c = 1.5 mm in engine room

and -.05 elsewhere

Ref: ABS rulebook; Chapter-2, Section-4

1.13 Inner-bottom Plating

The thickness of the inner-bottom plating throughout the length of the vessel is to be not less than that
obtained from the following equation. Where applicable, the plating is to meet deep tank requirements.

$t = 0.037L + 0.009s + c$ mm

$t = 0.000445L + 0.009s + c$ in.

where,

t = thickness, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3

s = frame spacing, in mm (in.)

c = 1.5 mm (0.06 in.) in engine space

= −0.5 mm (−0.02 in.) elsewhere

Center keelsons:

Center-girder Plate Thickness Amidships

$t = 0.063L + 5$ mm

$= 8.22$ mm

Center-girder Plates Thickness at Ends

t = 85% of center keelson thickness amidships

$= 6.987$ mm

Horizontal Top-plate Area Amidships

$A = 0.168L^{\frac{3}{2}} - 8$ cm^2

$= 53.4219$ cm^2

3.3.4 Horizontal Top-Plate Area at Ends [L ≥ 30.5 m (100 ft)]

$A = 0.127L^{\frac{3}{2}} - 1$ cm^2

$A = 45.43$ cm^2

Dimension of center Girder – T- 100X50X8

Ref: ABS rulebook; Chapter-2, Section-4, 3.3

3.3 Center Keelsons

Single-bottom vessels are to have center keelsons formed of continuous or intercostal center girder plates with horizontal top plates. The thickness of the keelson and the area of the horizontal top plate are to be not less than that obtained from the following equations. Vessels less than 30.5 m (100 ft) in length will be subject to special consideration. Tapering of the horizontal top plate area at the ends is not normally considered for vessels less than 30.5 m (100 ft) in length. The keelsons are to extend as far forward and aft as practicable.

3.3.1 Center-girder Plate Thickness Amidships

$t = 0.063L + 5$ mm

$t = 0.00075L + 0.2$ in.

3.3.2 Center-girder Plates Thickness at Ends

t = 85% of center keelson thickness amidships

3.3.3 Horizontal Top-plate Area Amidships

$A = 0.168L3/2 - 8$ cm2

$A = 0.0044L3/2 - 1.25$ in2

3.3.4 Horizontal Top-Plate Area at Ends [L ≥ 30.5 m (100 ft)]

$A = 0.127L3/2 - 1$ cm2

$A = 0.0033L3/2 - 0.15$ in2

where

t = thickness of center-girder plate, in mm (in.)

L = length of vessel, as defined in 3-1-1/3, in m (ft)

A = area of horizontal top plate, in cm2 (in2)

Side Keelson:

Side Keelson and Intercostal Thickness Amidships

$t = 0.063L + 4$ mm

= 7.22 mm =8mm

Side Keelson and Intercostal Thickness at Ends

t = 85% of center thickness amidships

= 6.137

Side Keelson and Intercostal, Horizontal Top Plate Area Amidships

$A = 0.038L3/2 + 17$ cm2

= 30.89 mm

3.5.4 Side Keelson and Intercostal, Horizontal Top Plate Area at Ends

A = 0.025$L$3/2 + 20 cm2

= 29.7829 cm^2

Dimension of Side keelsons – T- 80X40X6

Ref: ABS rulebook; Chapter-2, Section-4, 3.5

3.5 Side Keelsons

Side keelsons are to be arranged so that there are not more than 2.13 m (7 ft) from the center keelson to the inner side keelson, from keelson to keelson and from the outer keelson to the lower turn of bilge. Forward of the midship one-half length, the spacing of keelsons on the flat of floor is not to exceed 915 mm (36 in.). Side keelsons are to be formed of continuous rider plates on top of the floors.

They are to be connected to the shell plating by intercostal plates. The intercostal plates are to be attached to the floor plates. In the engine space, the intercostal plates are to be of not less thickness than the center girder plates. The scantlings of the side keelsons are to be obtained from the following equations but need not exceed 3-2-4/3.3, if that be less.

3.5.1 Side Keelson and Intercostal Thickness Amidships

t = 0.063L + 4 mm

t = 0.00075L + 0.16 in.

3.5.2 Side Keelson and Intercostal Thickness at Ends

t = 85% of center thickness amidships

3.5.3 Side Keelson and Intercostal, Horizontal Top Plate Area Amidships

A = 0.038$L$3/2 + 17 cm2

A = 0.001$L$3/2 + 2.6 in2

3.5.4 Side Keelson and Intercostal, Horizontal Top Plate Area at Ends

A = 0.025$L$3/2 + 20 cm2

A = 0.00065$L$3/2 + 3.1 in2

t, L and A are as defined in 3-2-4/3.3.

Floors:

SM = 7.8 $chsl^2$

= 7.8 x 0.55 x 3.7 x.5 x 10^2

=793.65cm^3

Dimension of floors – T- 635X80X8

Depth, h_f =62.5l

= 62.5 x (11 – 1)

=625 mm

Let assume 625 mm

Thickness, t = $.01h_f$ +3 mm

=9.25 mm

=10 mm

Ref: ABS rulebook;Part 3; Chapter-2, Section-4

3.7 Floors

3.7.1 Section Modulus

With transverse framing, a floor as shown in 3-2-4/Figure 1 is to be fitted on every frame and

is to be of the scantlings necessary to obtain a section modulus, *SM,* not less than that

obtained from the following equation:

SM = 7.8*chs*l2 cm3

SM = 0.0041*chs*l2 in3

where

c = 0.55

h = draft, *d*, in m (ft), as defined in section 3-1-1/9, but not to be less than 0.66*D* or 0.066*L*, whichever is greater.

s = floor spacing, in m (ft)

l = span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, inner bottom or side shell, the length, l, may be measured as permitted therein.

The section modulus may be calculated at the centerline of the vessel, provided the rise of

floor is such that the depth at the toe of brackets is not less than one-half of the depth at the

centerline. The above requirements are limited to cargo holds where cargoes of specific

gravity 0.715 or less are uniformly loaded. In way of engine room and in the forward 0.2*L*,

the floor face bar area is to be doubled

3.7 Floors

3.7.1 Section Modulus

With transverse framing, a floor as shown in 3-2-4/Figure 1 is to be fitted on every frame and

is to be of the scantlings necessary to obtain a section modulus, *SM,* not less than that

obtained from the following equation:

SM = 7.8*chs*l2 cm3

SM = 0.0041*chs*l2 in3

where

c = 0.55

h = draft, *d*, in m (ft), as defined in section 3-1-1/9, but not to be less than 0.66*D* or 0.066*L*, whichever is greater.

s = floor spacing, in m (ft)

l = span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, inner bottom or side shell, the length, l, may be measured as permitted therein.
The section modulus may be calculated at the centerline of the vessel, provided the rise of
floor is such that the depth at the toe of brackets is not less than one-half of the depth at the
centerline. The above requirements are limited to cargo holds where cargoes of specific
gravity 0.715 or less are uniformly loaded. In way of engine room and in the forward 0.2*L*,
the floor face bar area is to be doubled
3.7.3 Thickness
The minimum thickness of floors is not to be less than that obtained from the following
equation:
$t = 0.01hf + 3$ mm
$t = 0.01hf + 0.12$ in.
where
t = floor thickness, in mm (in.)
hf = floor depth, in mm (in.)
Floors under engine girders are to be not less in thickness than the thickness required for
keelsons.

Bracket:

X = 1.4y +30 mm

= 1.4x 450 + 30 mm

= 660 mm

f = x/sin45

= 933.388 mm

TABLE 3
Brackets

Metric

Length of Face f, mm	*Thickness, mm*		*Width of Flange, mm*
	Plain	*Flanged*	
Not exceeding 305	5.0	—	—
Over 305 to 455	6.5	5.0	38
Over 455 to 660	8.0	6.5	50
Over 660 to 915	9.5	8.0	63
Over 915 to 1370	11.0	9.5	75

We take, plain plate.

So thickness of Bracket is 11.0 mm.

Transverse Side Frame:

SM= $7.8chsl^2$

$= 7.8x .915 x 1.48x .5x (4.07 - .625 – .5)^2$

$= 45.8055\ cm^3$

$= 46\ cm^3$

Dimension of Transverse Side Frames – T- 75X55X9

Ref: ABS rulebook; Part 3; Chapter-2, Section-5

5 Transverse Side Frames

5.1 Section Modulus

The section modulus, *SM*, of each transverse side frame other than tween deck frames above the chine or upper turn of bilge, in association with the plating to which the frame is attached, is not to be less than that obtained from the following equation. See 3-2-5/Figure 1, 3-2-5/Figure 2 and 3-2-5/Figure 3.

SM = 7.8*chs*l2 cm3

SM = 0.0041*chs*l2 in3

where

c = 0.915 for frames having no tween decks above

= 0.90 + 5.8/l3 (0.90 + 205/l3) for frames having tween decks above

s = frame spacing, in m (ft)

l = straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by decks or inner bottoms, the length l may be measured as permitted therein. Where tween decks are located above the frame, l is to be taken as the length between the toes of the brackets, except where beam knees are fitted on alternate frames, l is to be increased by one half the depth of the beam knees. l is not to be taken less than 2.1 m (7.0 ft).

h = on frames having no tween decks above, the vertical distance, in m (ft), from the mid length of the frame to the freeboard deck at side, but not less than 0.02*L* + 0.46 m (0.02*L* + 1.5 ft).

= on frames having tween decks above, the vertical distance, in m (ft), from the middle of l to the load line or 0.4l, whichever is greater, plus *bh*1/33 (*bh*1/100).

b = horizontal distance, in m (ft), from the outside of the frames to the first row of deck beam supports.

*h*1 = vertical distance, in m (ft), from the deck at the top of the frame to the bulkhead or freeboard deck plus the height of all cargo tween deck spaces above the bulkhead or freeboard deck plus one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plus 2.44 m (8 ft), if that is greater. Where the cargo load differs from 715 kgf/m3 (45 lbf/ft3), *h*1 is to be adjusted accordingly

Side Web Frame:

SM= $7.8chsl^2$

= 7.8 x0.915x1.48x0.5x $(4.07-.625-.5)^2$

= 45.81 cm^3

= 46 cm^3

Dimension of side Side Frames – T- 80X65X8

Ref: ABS rulebook; Part 3, Chapter-2, Section-5

7 Side Web Frames

7.1 Section Modulus

The section modulus, *SM*, of each side web frame supporting longitudinal framing or shell stringers above the chine or upper turn of bilge, in association with the plating to which the web frame is attached, is not to be less than that obtained from the following equation:

SM = 7.8*chsl*2 cm3

SM = 0.0041*chsl*2 in3

where

c = 0.915 aft of the forepeak

= 1.13 in the forepeak of vessel 61 m (200 ft) or greater in length.

s = frame spacing, in m (ft)

l = straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by decks or inner bottoms, the length, l, may be measured as permitted therein

h = on frames having no tween decks above, the vertical distance, in m (ft), from the mid length of the frame to the freeboard deck at side, but not less than 0.02*L* + 0.46 m (0.02*L* + 1.5 ft).

= on frames having tween decks above, the vertical distance, in m (ft), from the middle of l to the load line or 0.5l, whichever is greater, plus *bh*1/45*K* (*bh*1/150*K*).

b = horizontal distance, in m (ft), from the outside of the frames to the first row of deck beams supports.

*h*1 = vertical distance, in m (ft), from the deck at the top of the web frame to the bulkhead or freeboard deck plus the height of all cargo tween deck spaces above the bulkhead or freeboard deck plus one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plus 2.44 m (8 ft), if that is greater. Where the cargo load differs from 715 kgf/m3 (45 lbf/ft3), *h*1 is to be adjusted accordingly.

K = 1.0 where the deck is longitudinally framed and a deck transverse is fitted in way of each web frame.

= the number of transverse frame spaces between web frames where the deck is transversely framed.

Side Stringer:

SM= $7.8chsl^2$

= 7.8 x1.13x1.53x1.715x 1.5^2

= 52.036 cm^3

Dimension of Side stringer – T- 80X65X8

Ref: ABS rulebook; Part 3; Chapter-2, Section-5

11 Side Stringers

11.1 Section Modulus

The section modulus, *SM*, of each side stringer in association with the plating to which the side
stringer is attached is not to be less than that obtained from the following equation:

SM = 7.8*chs*l2 cm3

SM = 0.0041*chs*l2 in3

where

c = 0.915

= 1.13 in the forepeak of vessel 61 m (200 ft) or greater in length.

h = vertical distance, in m (ft), from the middle of *s* to the freeboard deck at side, but
not less than 0.02*L* + 0.46 m (0.02*L* + 1.5 ft).

= for stringers above the lowest deck or at a similar height in relation to the design
draft, not less than given in 3-2-5/5.3 appropriate to the tween deck location.

= for stringers in the peaks of vessels 61 m (200 ft) or greater in length, not less
than given in 3-2-5/5.5.

s = sum of the half lengths, in m (ft), (on each side of the stringer) of the frames
supported.

l = span, in m (ft), between web frames, or between web frame and bulkhead. Where
brackets are fitted in accordance with 3-1-2/5.5 and are supported by transverse
bulkheads, the length, l, may be measured as permitted therein.

Deck Girder:

SM= $7.8chbl^2$

= 7.8 x.6x1.57x2.512x 1.5^2

= 41.57cm^3

Dimension of Deck Girder – T- 75X55X5

Ref: ABS rulebook; Part 3; Chapter-2, Section-6

3 Deck Girders and Deck Transverses

3.1 General

Girders and transverses are to be fitted as required to support beams and longitudinals. Additional girders
are to be fitted as required under masts, king posts, deck machinery or other heavy concentrated loads.

3.3 Deck Girders and Transverses Clear of Tanks

Section modulus, *SM,* of each longitudinal deck girder and deck transverse clear of tanks is not to be
less than that obtained from the following equation:

SM = 7.8*cbhl*2 cm3

SM = 0.0041*cbhl*2 in3

where

c = 0.60

b = mean breadth of area of deck supported (for girders), or spacing of deck
transverses (for transverses), in m (ft)

h = height, in m (ft), as required by 3-2-6/1.3 for the beams supported

l = unsupported span, in m (ft). Where brackets are fitted at bulkhead supports, in
accordance with 3-1-2/5.5, the length, l, may be measured as permitted therein

Deck Beam

SM= $7.8chsl^2$ here,

= 7.8x.6x1.7826 x.8612x 1.5^2 h= .02 L+ .76

= 16.16 cm^3

Bulkhead:

L_f = 0.08x L

= .08x 51.13 m

= 4.09 m about ref point

Bulkhead plating:

Material Factor, k= 1 (for mild steel)

Now, for collision bulkhead

$t = sk \times \frac{\sqrt{ah}}{c}$

$t = 861 \times \frac{\sqrt{3.9166 x 0.77}}{254}$

$= 7.35$ mm

For other bulkhead:

$t = sk \times \frac{\sqrt{ah}}{c}$

$= 857 \times \frac{\sqrt{3.9166 x 0.37}}{290}$

$= 5.25$ mm $= 6$ mm

Here,

$s = (D - floor)/4$

$= (4.07-.625)/4$

$= 0.8612$

$h = D-T$

$= 4.07- 3.7$

$= 0.37$

Girder and Web:

$SM = 4.74 \times chsl^2$

$= 4.74 \times 1 \times (4.07-.45) \times 0.678 \times 8.673$

$= 125.49\ cm^3$

here,

$s = (D/3)/2$

$= .678$

$l = (D- \text{floor height} - y)^2$

$= (4.07-.625-.5)^2$

$= 8.673$

Dimension of Girder and Web – T- 130X65X10

Keel Plate:

According to GL rulebook,*[Sec-6,B,5]*

Keel plate thickness = bottom plate thickness +2

= 7+2 mm

= 9 mm

Stiffeners:

SM= 7.8 $chsl^2$

= 7.8 x .3 x (4.07- .625) x 1.13 x 1.5^2

= 20.50 cm^3

Here,

s = (D- Bracket height)/3

= (4.07- .625)/3

= 1.13

Dimension of Transverse Side Frames – L- 75X55X5

Ref: ABS rulebook; Part 3; Chapter-2, Section-7

5.3 Stiffeners *(1998)*
The section modulus, *SM* of each bulkhead stiffener, in association with the plating to which it is
attached, is to be not less than that obtained from the following equation:
SM = 7.8*chs*l2 cm3
SM = 0.0041*chs*l2 in3
where
c = 0.30 for a stiffener with effective brackets at both ends of its span. An effective
bracket for the application of this value of *c* is to have scantlings not less than shown in 3-1-2/Table 3 and is to extend onto the stiffener for a distance at least one-eighth of the length, l, of the stiffener.
= 0.43 for a stiffener with an effective bracket at one end and a clip connection or horizontal girder at the other end. An effective bracket for the application of this value of *c* is to have scantlings not less than shown in 3-1-2/Table 3 and is to extend onto the stiffener for a distance at least one-eighth of the length, l, of the stiffener.
h = distance from the middle of l to the deepest equilibrium waterline in the one compartment damaged condition, in m (ft)
• For passenger vessels, *h* is to be taken as not less than the distance to the margin line.
• For cargo vessels, *h* is to be taken as not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case, *h* is to be not less than the distance to the designated freeboard deck at center.
• For all vessels, where this distance is less than 6.10 m (20 ft), *h* is to be taken as 0.8 times the distance plus 1.22 m (4 ft).
s = spacing of stiffeners, in m (ft)
l = distance, in m (ft), between the heels of the end attachments. Where horizontal
girders are fitted, l is the distance from the heel of the end attachment to the first girder, or the distance between the horizontal girders.
In vessels under 46 meters (150 ft) in length, the above values for *c* may be 0.29, 0.38, 0.46 and 0.58,
respectively, and *h* may be taken as the distance in meters or in feet from the middle of l to the

bulkhead deck at center in every case. For vessels between 46 and 65.5 meters (150 and 215 feet),
intermediate values for *c* may be obtained by interpolation.
The section modulus of stiffeners on collision bulkheads is to be increased by 25% over the section
modulus of stiffeners on ordinary watertight bulkheads.

Deck beam-(*NKK Sec-10.2.1*):

The standard deck beam spacing is =2L+550= 653 mm

We take spacing 600mm

Sheer strakes plates-(*NKK Sec-16.3.3*):

The thickness of sheer strakes plates is not less than adjacent side sheel plate.

So the thickness of sheer strakes plate 8 mm

Side longitudinals-(*NKK Sec-7.4.1*):

The section modulus of side longitudinals is =8.5Shl^2 or 2.9√(L)Sl^2 cm^3 ,use whichever is greater.

Where,S=spacing of longitudinals= 0.5 m

l =distance between web frames=1.5m

h =d+.044L-.54-.76=4.65 m

Section modulus= 44.466 cm^3

So Dimensions of side longitudinals- L- 90X60X6

Bottom longitudinals-(*NKK Sec-6.6*):

Spacing of longitudinal is not less than=2L+550mm= 653 mm

So we use spacing 650mm

Section modulus =CShl^2

Where,s= 0.5m h= 0.55m l=d+.026L= 5.02 m C=4.1

So section modulus= 28.41 cm^3

So the size of bottom longitudinal-(L-75X50X5)

Summary:

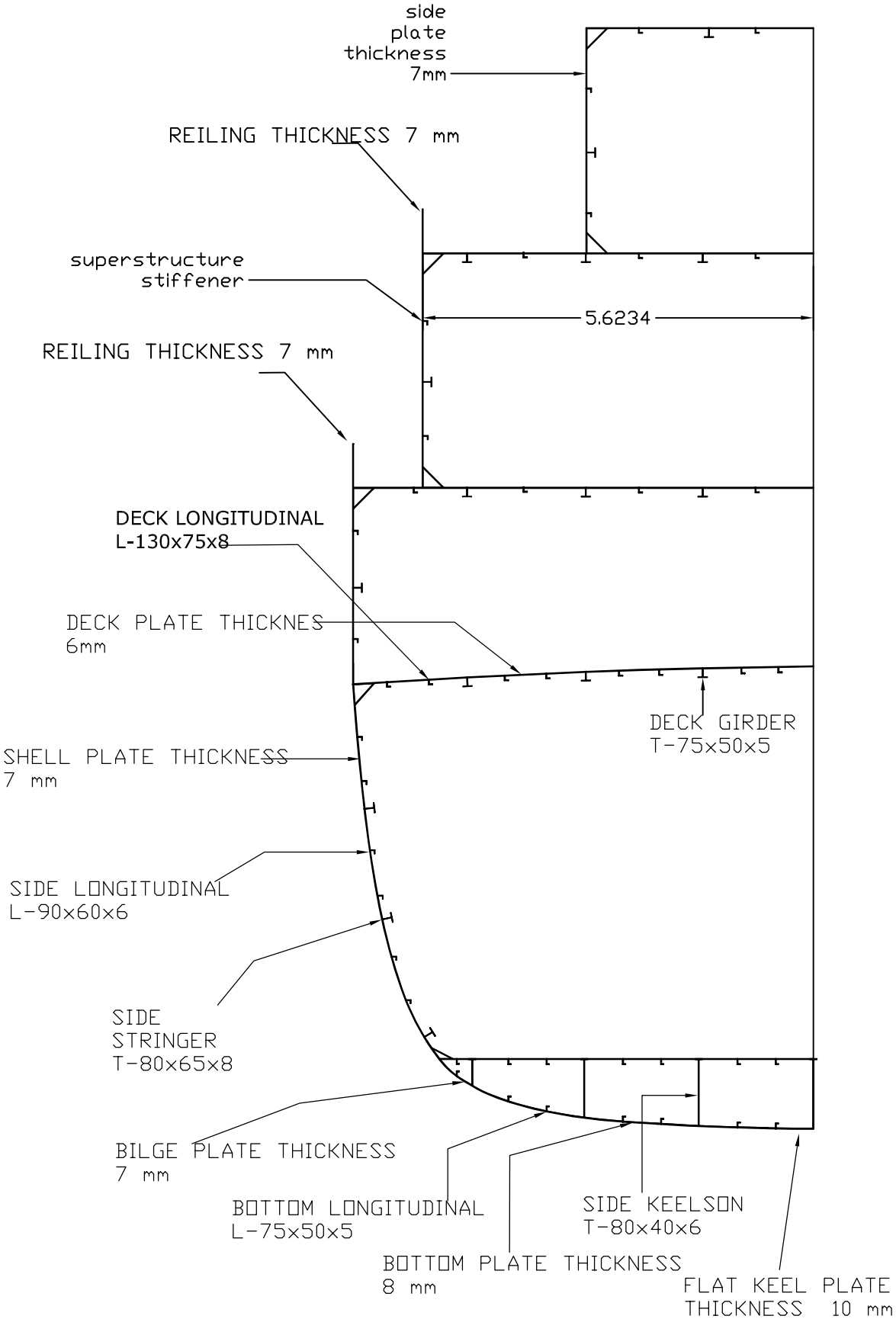
Thickness of different plate:

Member Name	Thickness
Bottom shell plating	7 mm
Side shell plating	7 mm
Side shell plating at ends	7 mm
Forecastle side plating	7 mm
Poop side plating	6 mm
Deck plating	6 mm
Strength Deck	7 mm
Inner Bottom Plating	8 mm (at Engine) 7 mm (at Others)
Centre keelsons	9 mm
Side keelsons	8 mm
Bracket	11 mm
Keel Plate	9 mm
Sheer strakes plate	8 mm
Blige plate	7 mm

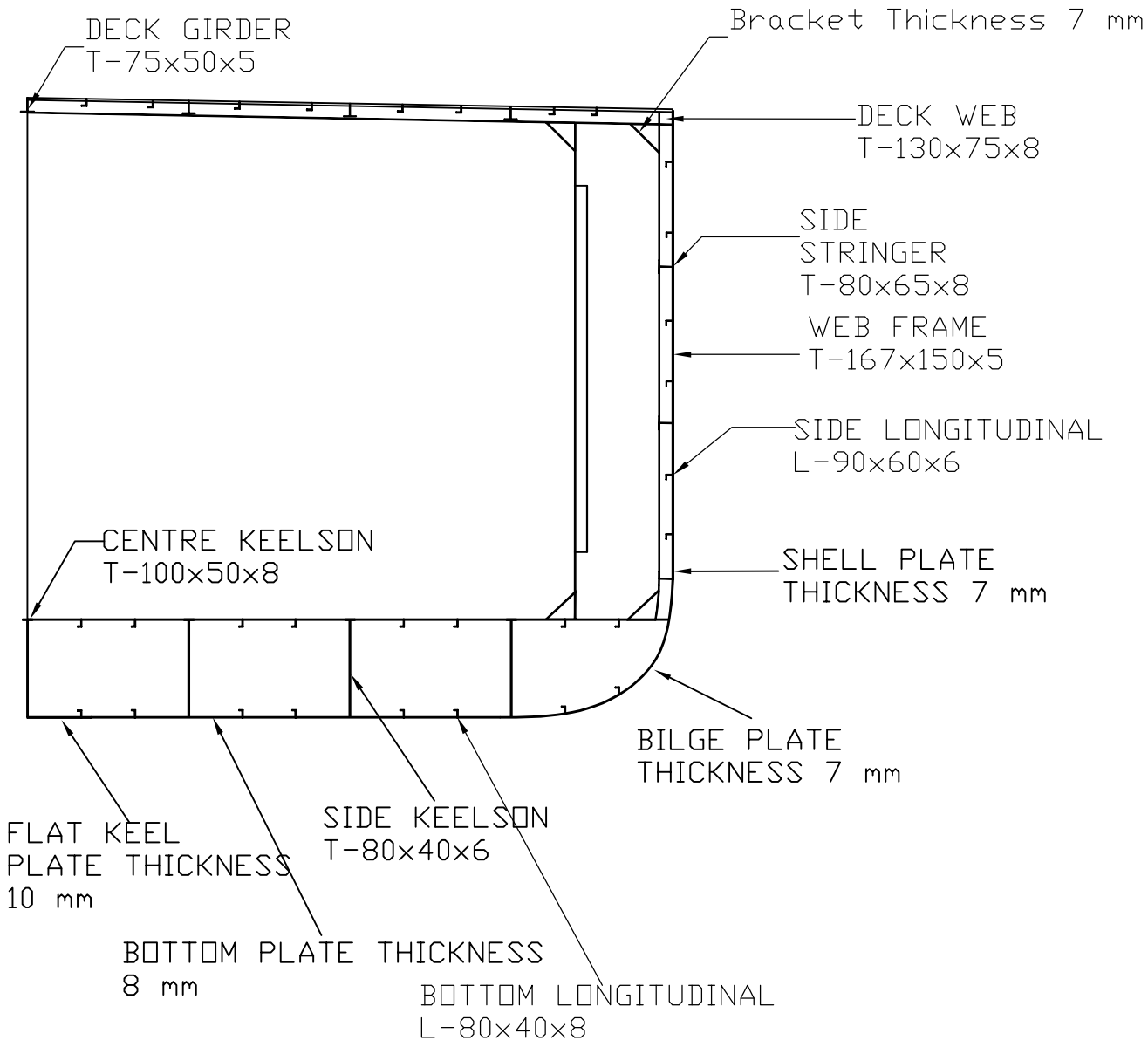
Dimension of construction items:

Member Name	Dimensions(mm)
Side Web Frame	T- 80X65X8
Side Stringer	T- 80X65X8
Deck Girder	T- 75X55X5
Girder and Web	T- 130X65X10
Stiffeners	L- 75X55X5
Deck Beam	
Center Keelson	T- 100X50X8
Side Keelson	T- 80X40X6
Transverse Side Frame	T- 75X55X5
Side Longitudinals	L- 90X60X6
Bottom Longitudinals	L-75X50X5
Floors	T- 635X80X8

MIDSHIP SECTION DRAWING



FRAME NO:16


DECK GIRDER
T-75x50x5
Bracket Thickness 7 mm
DECK WEB
T-130x75x8
SIDE
STRINGER
T-80x65x8
WEB FRAME
T-167x150x5
SIDE LONGITUDINAL
L-90x60x6
CENTRE KEELSON
T-100x50x8
SHELL PLATE
THICKNESS 7 mm
BILGE PLATE
THICKNESS 7 mm
FLAT KEEL
PLATE THICKNESS
10 mm
SIDE KEELSON
T-80x40x6
BOTTOM PLATE THICKNESS
8 mm
BOTTOM LONGITUDINAL
L-80x40x8

FRAME NO:62

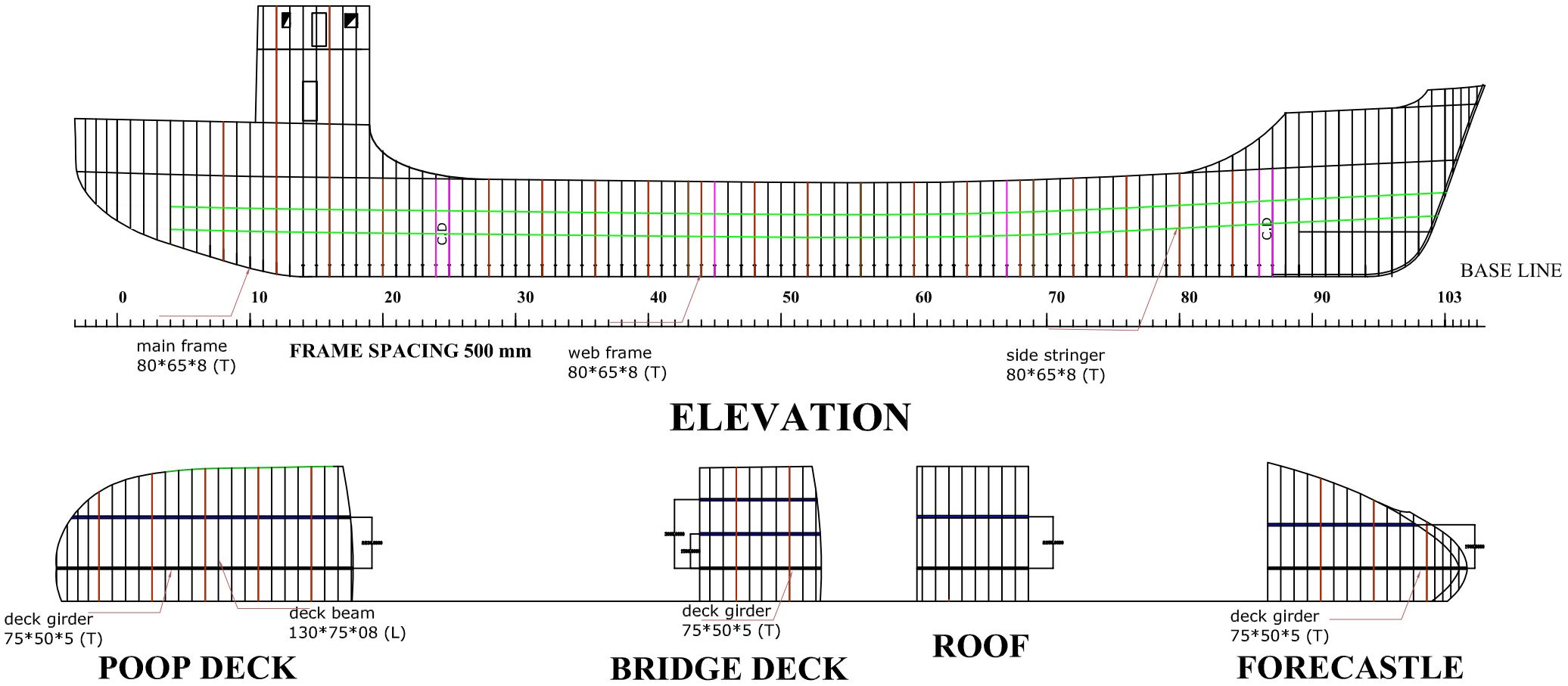
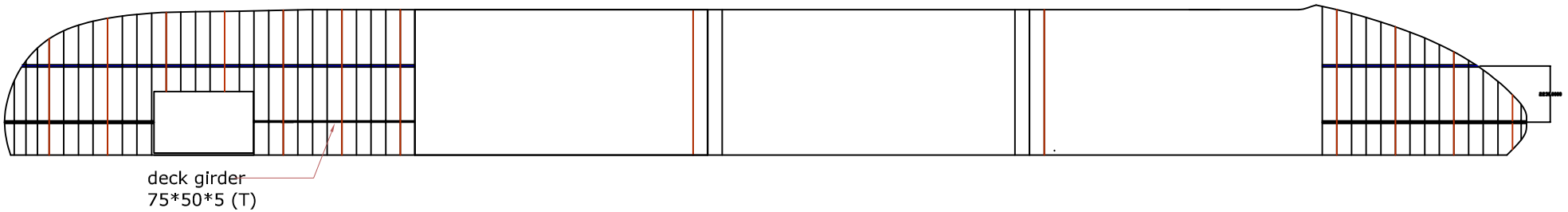
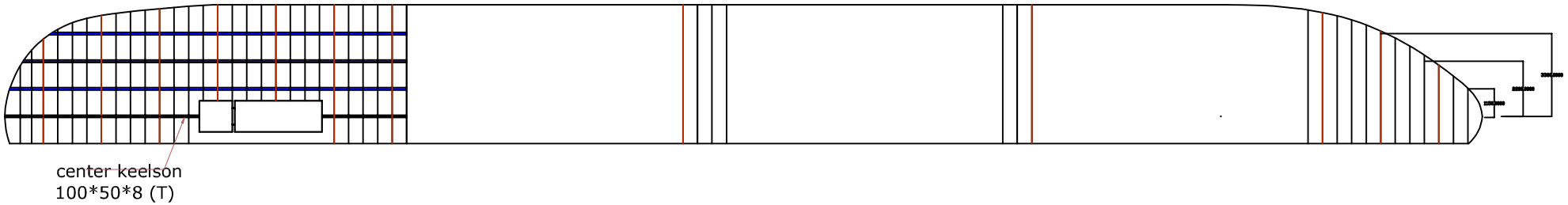


FIGURE : LONGITUDINAL CONSTRUCTION DRAWING



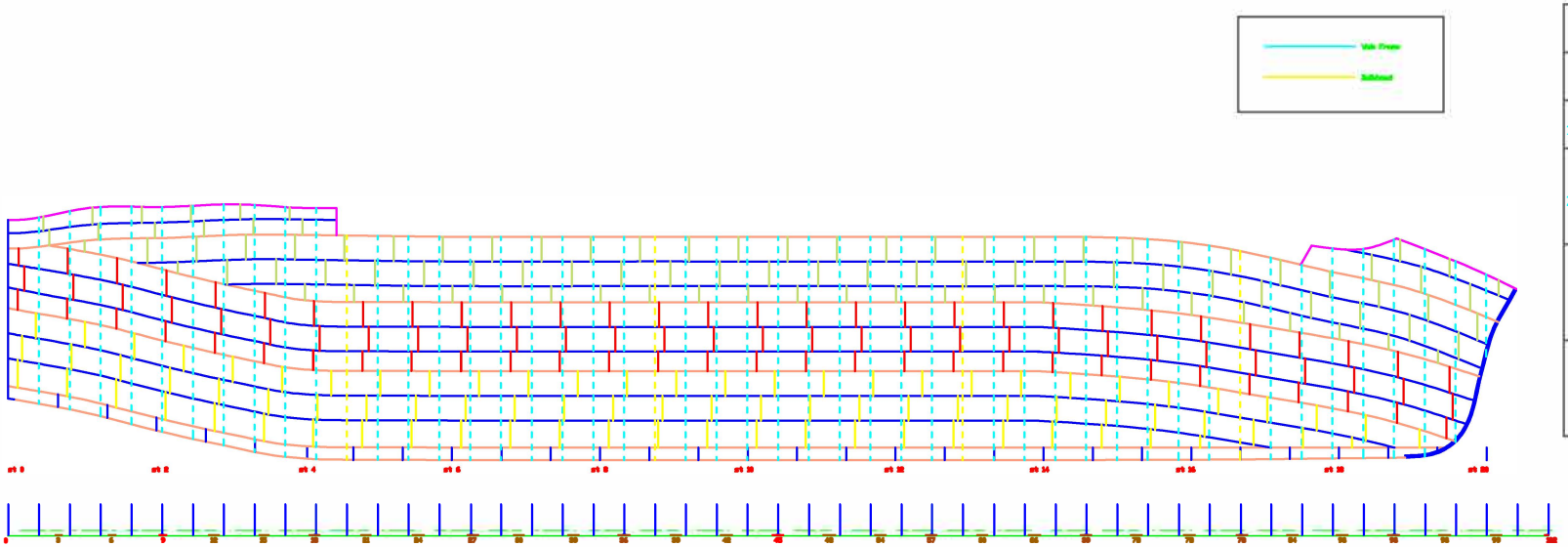
MAIN DECK



UNDER DECK

FIGURE : LONGITUDINAL CONSTRUCTION DRAWING

SHELL EXPANSION



FRAME SPACING 500 mm

ELEVATION

PLATE DESCRIPTION		
PLATE	*DIMENSION (mm)*	*NO. OF PLATES*
1. KEEL PLATE	2400 X 600 X 10	29
2. BOTTOM PLATE	2400 X 1200 X 8	60
	2400 X 1320 X8	27
3. BILGE PLATE	2400 X 1200 X 10	60
	2400 X 955 X 10	30
4. SHEAR STRAKE	2400 X 1200 X 8	63
	2400 X 790X 8	40
	TOTAL PLATE	309

DETAIL WEIGHT CALCULATION

(LIGHTWEIGHT & DEADWEIGHT)

HULL STEEL WEIGHT

Type Of Plate		Dimension	Number		Area (m^2)	Thickness (m) or Total Length (m)	Volume (m^3)	Density (t/m^3)	Weight (ton)	Total Weight (ton)	LCG (m)	Moment (t-m) (about midship)	VCG (m)	Moment (t-m) (about keel)
Keel					82.2	0.011	9.04E-01	7.87	7.12	7.12	-1.94	-13.81	0.0055	-98.23815559
Bottom A					145	0.0085	1.23E+00	7.87	9.70	16.97	3.21	54.48	0.00425	0.072129534
Bottom B					115.5	0.008	9.24E-01	7.87	7.27					
Bilge A					75.2	0.0095	7.14E-01	7.87	5.62	11.24	3.21	36.10	0.79	8.88327824
Bilge B					75.2	0.0095	7.14E-01	7.87	5.62					
Side Shell A					135.5	0.008	1.08E+00	7.87	8.53	17.06	1.04	17.74	2.50	42.6554
Side Shell B					135.5	0.008	1.08E+00	7.87	8.53					
Sheer Strake A					65	0.0125	8.13E-01	7.87	6.39	6.39	0.43	2.75	4.5	84.110625
Sheer Strake B					65	0.0125	8.13E-01	7.87	6.39	6.39	0.43	2.75	4.5	0.109267458
Deck Plate					125	0.019	2.38E+00	7.87	18.69	18.69	1.98	37.01	4.5	84.110625
Side Longitudinal		L-120×60×6			8.64E-04	4.5	3.89E-03	7.87	0.03	0.03	-26.625	-0.81	3.571	0.109267458
Side Longitudinal		L-120×60×7			8.64E-04	3.6	3.11E-03	7.87	0.02	0.02	-26.2	-0.64	2.861	0.070033984
Side Longitudinal		L-120×60×8			8.64E-04	5.6	4.84E-03	7.87	0.038078208	0.04	-25.591	-0.97	1.7	0.064732954
Side Longitudinal		L-120×60×9			8.64E-04	95	8.21E-02	7.87	0.65	0.65	5.241	3.39	3.571	2.306757442
Side Longitudinal		L-120×60×10			8.64E-04	76	6.57E-02	7.87	0.52	0.52	12.231	6.32	2.861	1.47849522
Side Longitudinal		L-120×60×11			8.64E-04	65	5.62E-02	7.87	0.44	0.44	11.977	5.29	1.7	0.75136464
Side Web Frame		L-200×200×8	40		0.003136			7.87	13.90	13.90	-1.18863	-16.52	4.492984	62.44119306
Side Stringer		T-100×50×5	80		0.000864			7.87	7.91	7.91	-3.24234	-25.65	4.982622	39.4117237
Center Girder		T-615×90×9	1		6.54E-03	58.05	3.80E-01	7.87	2.99	2.99	2.073	6.19	0.382	1.141347962
Side Girder (A)		T-615×80×10	2		5.98E-03	58.05	6.94E-01	7.87	5.46	5.46	0.36	1.95	0.62	3.360902164
Side Girder (B)		T-615×80×11	2		5.98E-03	58.05	6.94E-01	7.87	5.46	5.46	-1.12	-6.14	0.62	3.360902164
Deck Side Girder		T-120×120×8	3		0.001856	45.67	2.54E-01	7.87	2.00	3.97	1.23	4.88	4.28	16.99
Deck Side Girder		T-120×120×9	3		0.001856	44.9	2.50E-01	7.87	1.97					
Floors		T-615×90×9	93		6.26E-03			7.87	39.37	39.37	-2.25E+00	-88.56	4.91E-01	1.93E+01
Superstructure Side Plate			2		1.39E+01	7.60E-03	2.11E-01	7.87	1.66	1.66	-20.058	-33.24	8.172	1.35E+01
Superstructure Side Plate			2		2.85E+01	7.60E-03	4.33E-01	7.87	3.41	3.41	-22.606	-77.09	5.691	1.94E+01
Superstructure Side Stringer					0.000879	22.13	1.95E-02	7.87	0.15	0.15		0.00		0.00E+00
Deck Beam		L-200×120×80	102		4.56E-03			7.87	65.90	65.90	-3.41172	-224.82	4.5	2.97E+02
									235.76					

Machinery Space														
Side Longitudinal		L-100×50×6			6.00E-04	16.516	9.91E-03	7.87	0.08	0.08	21.353	1.67	1.7	0.132580538
Side Stringer		T-500×130×11			0.003402	16.5	0.056133	7.87	0.44	0.44	21.353	9.43	2.144	0.947147826
Deck Side Girder			2		0.001856	7.15	0.0132704	7.87	0.10	0.10	14.5	1.51	2.4	0.250651315
Deck Side Girder			2		0.001856	7.15	0.0132704	7.87	0.10	0.10	14.5	1.51	2.4	0.250651315
Floors			8					7.87	8.13	8.13	15.19	123.42	0.3075	2.49843865
									8.85					

Bulkhead														
BHD 1														
Plate					1.56E+01	9.00E-03	0.140673175	7.87	1.11	1.11	-25.482	-28.21	3.379	3.740883766
Vertical Stiffener		L-100×65×7			1.11E-03	5.024	0.005556544	7.87	0.04	0.04	-25.482	-1.11	1.831	0.080069632
Transverse Stiffener		T-365×65×6.5			2.75E-03	16.5	0.045420375	7.87	0.36	0.36	-25.482	-9.11	2.144	0.766390705
BHD Web Frame		L-130×80×10			2.00E-02	8.57	0.1714	7.87	1.35	1.35	-25.482	-34.37	2.144	2.892080192
BHD 2														
Plate					3.31E+01	9.00E-03	0.297756432	7.87	2.34	2.34	-17.224	-40.36	2.264	5.305328823
Vertical Stiffener		L-90×60×8			1.14E-03	8.132	0.009237952	7.87	0.07	0.07	-17.224	-1.25	2.428	0.176522112
Transverse Stiffener		T-365×65×6.5			2.75E-03	18.5	0.050925875	7.87	0.40	0.40	-17.224	-6.90	2.144	0.859286548
BHD Web Frame		L-130×80×10			2.00E-02	8.57	0.1714	7.87	1.35	1.35	-17.224	-23.23	2.144	2.892080192
BHD 3														
Plate					3.51E+01	9.00E-03	0.315756432	7.87	2.49	2.49	-2.934	-7.29	2.264	5.626047063
Vertical Stiffener		L-90×60×8			1.14E-03	8.132	0.009237952	7.87	0.07	0.07	-2.934	-0.21	2.428	0.176522112
Transverse Stiffener		T-365×65×6.5			2.75E-03	18.5	0.050925875	7.87	0.40	0.40	-2.934	-1.18	2.428	0.973109953
BHD Web Frame		L-130×80×10			2.00E-02	8.57	0.1714	7.87	1.35	1.35	-2.934	-3.96	2.428	3.275172904
BHD 4														
Plate					3.31E+01	9.00E-03	0.297756432	7.87	2.34	2.34	11.367	26.64	2.264	5.305328823
Vertical Stiffener		L-90×60×8			1.14E-03	8.132	0.009237952	7.87	0.07	0.07	11.367	0.83	2.428	0.176522112
Transverse Stiffener		T-365×65×6.5			2.75E-03	18.5	0.050925875	7.87	0.40	0.40	11.367	4.56	2.144	0.859286548
BHD Web Frame		L-130×80×10			2.00E-02	8.56	0.1712	7.87	1.35	1.35	11.367	15.32	2.144	2.888705536
Collision BHD														
Plate					1.95E+01	9.00E-03	0.17591101	7.87	1.38	1.38	22.917	31.73	2.909	4.027276763
Vertical Stiffener		L-90×60×8			1.14E-03	6.048	0.006870528	7.87	0.05	0.05	22.917	1.24	3.043	0.164538221
Transverse Stiffener		T-395×65×6.5			2.95E-03	16.5	0.048637875	7.87	0.38	0.38	22.917	8.77	2.14	0.819149363
BHD Web Frame		L-130×80×10			2.00E-02	8.57	0.1714	7.87	1.35	1.35	22.917	30.91	2.15	2.9001737
									18.66					

Upper Deck														
Plate					86.05117	1.40E-02	1.20E+00	7.87	9.48	9.48	-21.605	-204.84	6.983	66.20664252
Girder		T-128×50×5			0.000625	11.073	6.92E-03	7.87	0.05	0.05	-22.162	-1.21	6.981	0.38022239
Beam		L-60×40×5	19		4.75E-04	85.756	4.07E-02	7.87	0.32	0.32		0.00	6.981	2.237950599
Side Girder		T-128×50×5			0.000625	19.136	1.20E-02	7.87	0.09	0.09	-21.41	-2.02	6.981	0.657088021
Side Girder		T-128×50×5			0.000625	21.378	1.34E-02	7.87	0.11	0.11	-21.97	-2.31	6.981	0.734073355
Transverse Side Frame		T-462×70×7							10.06	10.06				
Roof														
Plate					25.46539	1.40E-02	3.57E-01	7.87	2.81	2.81	-19.199	-53.87	9.44	26.48653156
Girder		T-128×50×5			0.000625	5.118	3.20E-03	7.87	0.03	0.03	-19.185	-0.48	9.44	0.237644094
Side Girder		T-128×50×6			0.000625	10.012	6.26E-03	7.87	0.05	0.05	-19.175	-0.94	9.44	0.464887196
Beam		L-60×40×5			4.75E-04	45.03	2.14E-02	7.87	0.17	0.17	-19.175	-3.23	9.44	1.589067272
									3.05	3.05				
												-477.96		748.9924454
								Total	**276.38**					
								LCG	-1.73					
								VCG	2.71					

Floor											
	Area	Length	Weight	LCG	Moment	VCG	Moment		1.00	0.23	1.00
Floor 1	0.01	0.23	0.02	-27.00	-0.61	1.25	0.03	Machinery	2.00	0.43	2.00
Floor 2	0.01	0.43	0.04	-26.50	-1.12	1.05	0.04		3.00	0.63	3.00
Floor 3	0.01	0.63	0.06	-26.00	-1.61	0.99	0.06		4.00	0.83	4.00
Floor 4	0.01	0.83	0.08	-25.50	-2.09	0.77	0.06		5.00	1.03	5.00
Floor 5	0.01	1.03	0.10	-25.00	-2.54	0.78	0.08		6.00	1.25	6.00
Floor 6	0.01	1.25	0.12	-24.50	-3.02	0.68	0.08		7.00	1.47	7.00
Floor 7	0.01	1.47	0.14	-24.00	-3.48	0.46	0.07		8.00	1.69	8.00
Floor 8	0.01	1.69	0.17	-23.50	-3.92	42.00	7.00		9.00	1.91	9.00
Floor 9	0.01	1.91	0.19	-23.00	-4.33	0.38	0.07		10.00	2.13	10.00
Floor 10	0.01	2.13	0.21	-22.50	-4.73	0.37	0.08		11.00	2.34	11.00
Floor 11	0.01	2.34	0.23	-22.00	-5.08	0.39	0.09		12.00	2.54	12.00
Floor 12	0.01	2.54	0.25	-21.50	-5.38	0.31	0.08		13.00	2.74	13.00
Floor 13	0.01	2.74	0.27	-21.00	-5.67	0.31	0.08		14.00	2.95	14.00
Floor 14	0.01	2.95	0.29	-20.50	-5.96	0.31	0.09		15.00	3.17	15.00
Floor 15	0.01	3.17	0.31	-20.00	-6.25	0.31	0.10		16.00	3.38	16.00
Floor 16	0.01	3.38	0.33	-19.50	-6.50	0.31	0.10		17.00	3.58	17.00
Floor 17	0.01	3.58	0.35	-19.00	-6.71	0.31	0.11		18.00	3.77	18.00
Floor 18	0.01	3.77	0.37	-18.50	-6.88	0.31	0.11		19.00	3.96	19.00
Floor 19	0.01	3.96	0.39	-18.00	-7.03	0.31	0.12		20.00	4.15	20.00
Floor 20	0.01	4.15	0.41	-17.50	-7.16	0.31	0.13		21.00	4.32	21.00
Floor 21	0.01	4.32	0.43	-17.00	-7.24	0.31	0.13		22.00	4.49	22.00
Floor 22	0.01	4.49	0.44	-16.50	-7.30	0.31	0.14		23.00	4.65	23.00
Floor 23	0.01	4.65	0.46	-16.00	-7.34	0.31	0.14		24.00	4.79	24.00
Floor 24	0.01	4.79	0.47	-15.50	-7.32	0.31	0.15		25.00	4.92	25.00
Floor 25	0.01	4.92	0.49	-15.00	-7.28	0.31	0.15		26.00	5.03	26.00
Floor 26	0.01	5.03	0.50	-14.50	-7.19	0.31	0.15		27.00	5.12	27.00
Floor 27	0.01	5.12	0.50	-14.00	-7.07	0.31	0.16		28.00	5.18	28.00
Floor 28	0.01	5.18	0.51	-13.50	-6.89	0.31	0.16		29.00	5.22	29.00
Floor 29	0.01	5.22	0.51	-13.00	-6.69	0.31	0.16		30.00	5.23	30.00
Floor 30	0.01	5.23	0.52	-12.50	-6.45	0.31	0.16				
Floor 31	0.01	5.23	0.52	-12.00	-6.19	0.31	0.16				
Floor 32	0.01	5.23	0.52	-11.50	-5.93	0.31	0.16				
Floor 33	0.01	5.23	0.52	-11.00	-5.67	0.31	0.16				
Floor 34	0.01	5.23	0.52	-10.50	-5.41	0.31	0.16				
Floor 35	0.01	5.23	0.52	-10.00	-5.16	0.31	0.16				
Floor 36	0.01	5.23	0.52	-9.50	-4.90	0.31	0.16				
Floor 37	0.01	5.23	0.52	-9.00	-4.64	0.31	0.16				
Floor 38	0.01	5.23	0.52	-8.50	-4.38	0.31	0.16				
Floor 39	0.01	5.23	0.52	-8.00	-4.13	0.31	0.16				
Floor 40	0.01	5.23	0.52	-7.50	-3.87	0.31	0.16				
Floor 41	0.01	5.23	0.52	-7.00	-3.61	0.31	0.16				
Floor 42	0.01	5.23	0.52	-6.50	-3.35	0.31	0.16				
Floor 43	0.01	5.23	0.52	-6.00	-3.09	0.31	0.16				
Floor 44	0.01	5.23	0.52	-5.50	-2.84	0.31	0.16				
Floor 45	0.01	5.23	0.52	-5.00	-2.58	0.31	0.16				
Floor 46	0.01	5.23	0.52	-4.50	-2.32	0.31	0.16				
Floor 47	0.01	5.23	0.52	-4.00	-2.06	0.31	0.16				
Floor 48	0.01	5.23	0.52	-3.50	-1.80	0.31	0.16				
Floor 49	0.01	5.23	0.52	-3.00	-1.55	0.31	0.16				
Floor 50	0.01	5.23	0.52	-2.50	-1.29	0.31	0.16				
Floor 51	0.01	5.23	0.52	-2.00	-1.03	0.31	0.16				
Floor 52	0.01	5.23	0.52	-1.50	-0.77	0.31	0.16				
Floor 53	0.01	5.23	0.52	-1.00	-0.52	0.31	0.16				
Floor 54	0.01	5.23	0.52	-0.50	-0.26	0.31	0.16				
Floor 55	0.01	5.23	0.52	0.00	0.00	0.31	0.16				
Floor 56	0.01	5.23	0.52	0.50	0.26	0.31	0.16				
Floor 57	0.01	5.23	0.52	1.00	0.52	0.31	0.16				
Floor 58	0.01	5.23	0.52	1.50	0.77	0.31	0.16				
Floor 59	0.01	5.23	0.52	2.00	1.03	0.31	0.16				
Floor 60	0.01	5.23	0.52	2.50	1.29	0.31	0.16				

Floor 61	0.01	5.23	0.52	3.00	1.55	0.31	0.16				
Floor 62	0.01	5.23	0.52	3.50	1.80	0.31	0.16				
Floor 63	0.01	5.23	0.52	4.00	2.06	0.31	0.16				
Floor 64	0.01	5.23	0.52	4.50	2.32	0.31	0.16				
Floor 65	0.01	5.23	0.52	5.00	2.58	0.31	0.16				
Floor 66	0.01	5.23	0.52	5.50	2.84	0.31	0.16				
Floor 67	0.01	5.23	0.52	6.00	3.09	0.31	0.16				
Floor 68	0.01	5.23	0.52	6.50	3.35	0.31	0.16				
Floor 69	0.01	5.23	0.52	7.00	3.61	0.31	0.16				
Floor 70	0.01	5.23	0.52	7.50	3.87	0.31	0.16				
Floor 71	0.01	5.23	0.52	8.00	4.13	0.31	0.16				
Floor 72	0.01	5.23	0.52	8.50	4.38	0.31	0.16				
Floor 73	0.01	5.23	0.52	9.00	4.64	0.31	0.16				
Floor 74	0.01	5.23	0.52	9.50	4.90	0.31	0.16				
Floor 75	0.01	5.23	0.52	10.00	5.16	0.31	0.16				
Floor 76	0.01	5.23	0.52	10.50	5.41	0.31	0.16				
Floor 77	0.01	5.23	0.52	11.00	5.67	0.31	0.16				
Floor 78	0.01	5.23	0.52	11.50	5.93	0.31	0.16				
Floor 79	0.01	5.23	0.52	12.00	6.19	0.31	0.16				
Floor 80	0.01	5.23	0.52	12.50	6.45	0.31	0.16				
Floor 81	0.01	5.23	0.52	13.00	6.70	0.31	0.16				
Floor 82	0.01	5.23	0.52	13.50	6.96	0.31	0.16				
Floor 83	0.01	5.23	0.52	14.00	7.22	0.31	0.16				
Floor 84	0.01	5.18	0.51	14.50	7.41	0.31	0.16				
Floor 85	0.01	5.10	0.50	15.00	7.54	0.31	0.15				
Floor 86	0.01	4.98	0.49	15.50	7.61	0.31	0.15				
Floor 87	0.01	4.81	0.47	16.00	7.59	0.31	0.15				
Floor 88	0.01	4.61	0.45	16.50	7.50	0.31	0.14				
Floor 89	0.01	4.35	0.43	17.00	7.29	0.31	0.13				
Floor 90	0.01	4.04	0.40	17.50	6.97	0.31	0.12				
Floor 91	0.01	3.65	0.36	18.00	6.48	0.31	0.11				
Floor 92	0.01	3.04	0.30	18.50	5.55	0.31	0.09				
Floor 93	0.01	2.18	0.21	19.00	4.08	0.31	0.07			LCG	VCB
			39.37		-88.56		19.35			-2.25	0.49

Machinary					Moment		Moment				
Floor 1	0.01	5.23	0.58	18.44	10.70	0.31	0.18				
Floor 2	0.01	5.23	0.58	17.94	10.41	0.31	0.18				
Floor 3	0.01	5.23	0.58	17.44	10.12	0.31	0.18				
Floor 4	0.01	5.23	0.58	16.94	9.83	0.31	0.18				
Floor 5	0.01	5.23	0.58	16.44	9.54	0.31	0.18				
Floor 6	0.01	5.23	0.58	15.94	9.25	0.31	0.18				
Floor 7	0.01	5.23	0.58	15.44	8.96	0.31	0.18				
Floor 8	0.01	5.23	0.58	14.94	8.67	0.31	0.18				
Floor 9	0.01	5.23	0.58	14.44	8.38	0.31	0.18				
Floor 10	0.01	5.23	0.58	13.94	8.09	0.31	0.18				
Floor 11	0.01	5.23	0.58	13.44	7.80	0.31	0.18				
Floor 12	0.01	5.23	0.58	12.94	7.51	0.31	0.18				
Floor 13	0.01	5.23	0.58	12.44	7.22	0.31	0.18				
Floor 14	0.01	5.23	0.58	11.94	6.93	0.31	0.18				
										LCG	VCG
			8.13		123.42		2.50			15.19	0.31

WEB FRAME								
	Dimension	Area	Length	Weight	LCG	Moment	VCG	Moment
Web-1		0.003136	1.01	0.049854	-29.55	-1.47319	1.0795	0.053818
Web-2		0.003136	1.21	0.059726	-28.05	-1.67532	1.1695	0.06985
Web-3		0.003136	4.23	0.208796	-26.55	-5.54352	2.5285	0.527939
Web-4		0.003136	5.5	0.271484	-25.05	-6.80066	3.1	0.841599
Web-5		0.003136	5.9	0.291228	-23.55	-6.85841	3.28	0.955227
Web-6		0.003136	6.5	0.320844	-22.05	-7.07461	3.55	1.138997
Web-7		0.003136	6.84	0.337627	-20.55	-6.93823	3.703	1.250232
Web-8		0.003136	7.36	0.363294	-19.05	-6.92076	3.937	1.43029
Web-9		0.003136	7.5	0.370205	-17.55	-6.49709	4	1.480819
Web-10		0.003136	7.9	0.389949	-16.05	-6.25868	4.18	1.629987
Web-11		0.003136	8.38	0.413642	-14.55	-6.01849	4.396	1.818371
Web-12		0.003136	8.8	0.434374	-13.05	-5.66858	4.585	1.991603
Web-13		0.003136	9.16	0.452143	-11.55	-5.22226	4.747	2.146325
Web-14		0.003136	9.16	0.452143	-10.05	-4.54404	4.747	2.146325
Web-15		0.003136	9.16	0.452143	-8.55	-3.86583	4.747	2.146325
Web-16		0.003136	9.16	0.452143	-7.05	-3.18761	4.747	2.146325
Web-17		0.003136	9.16	0.452143	-5.55	-2.5094	4.747	2.146325
Web-18		0.003136	9.16	0.452143	-4.05	-1.83118	4.747	2.146325
Web-19		0.003136	9.16	0.452143	-2.55	-1.15297	4.747	2.146325
Web-20		0.003136	9.16	0.452143	-1.05	-0.47475	4.747	2.146325
Web-21		0.003136	9.16	0.452143	0.45	0.203465	4.747	2.146325
Web-22		0.003136	9.16	0.452143	1.95	0.88168	4.747	2.146325
Web-23		0.003136	9.16	0.452143	3.45	1.559895	4.747	2.146325
Web-24		0.003136	9.16	0.452143	4.95	2.23811	4.747	2.146325
Web-25		0.003136	9.16	0.452143	6.45	2.916325	4.747	2.146325
Web-26		0.003136	9.16	0.452143	7.95	3.594541	4.747	2.146325
Web-27		0.003136	9.16	0.452143	9.45	4.272756	4.747	2.146325
Web-28		0.003136	9.16	0.452143	10.95	4.950971	4.747	2.146325
Web-29		0.003136	9.16	0.452143	12.45	5.629186	4.747	2.146325
Web-30		0.003136	9.16	0.452143	13.95	6.307401	4.747	2.146325
Web-31		0.003136	9.16	0.452143	15.45	6.985616	4.747	2.146325
Web-32		0.003136	9.16	0.452143	16.95	7.663832	4.747	2.146325
Web-33		0.003136	9.14	0.451156	18.45	8.323833	4.738	2.137578
Web-34		0.003136	9.1	0.449182	19.95	8.961177	4.72	2.120138
Web-35		0.003136	8.98	0.443259	21.45	9.507896	4.666	2.068244
				13.89749		-16.5189		62.44119
						-1.18863		4.492984

FRAME							
	Area	Length	Weight	LCG	Moment	VCG	Moment
Frame-1	0.000864	2.7	0.036718	-29.45	-1.08135	1.975	0.072519
Frame-2	0.000864	4.6	0.062557	-28.45	-1.77975	2.925	0.182979
Frame-3	0.000864	5.4	0.073437	-27.95	-2.05255	3.325	0.244177
Frame-4	0.000864	6.3	0.085676	-26.95	-2.30897	3.775	0.323427
Frame-5	0.000864	6.6	0.089756	-26.45	-2.37404	3.925	0.352291
Frame-6	0.000864	7.6	0.103355	-25.45	-2.63039	4.425	0.457346
Frame-7	0.000864	7.94	0.107979	-24.95	-2.69407	4.595	0.496163
Frame-8	0.000864	8.15	0.110835	-23.95	-2.65449	4.7	0.520923
Frame-9	0.000864	8.28	0.112603	-23.45	-2.64053	4.765	0.536552
Frame-10	0.000864	8.56	0.116411	-22.45	-2.61342	4.905	0.570994
Frame-11	0.000864	8.7	0.118314	-21.95	-2.597	4.975	0.588614
Frame-12	0.000864	8.9	0.121034	-20.95	-2.53567	5.075	0.614249
Frame-13	0.000864	9.05	0.123074	-20.45	-2.51687	5.15	0.633832
Frame-14	0.000864	9.12	0.124026	-19.45	-2.41231	5.185	0.643076
Frame-15	0.000864	9.15	0.124434	-18.95	-2.35803	5.2	0.647058
Frame-16	0.000864	9.16	0.12457	-17.95	-2.23603	5.205	0.648388
Frame-17	0.000864	9.16	0.12457	-17.45	-2.17375	5.205	0.648388
Frame-18	0.000864	9.16	0.12457	-16.45	-2.04918	5.205	0.648388
Frame-19	0.000864	9.16	0.12457	-15.95	-1.98689	5.205	0.648388
Frame-20	0.000864	9.16	0.12457	-14.95	-1.86232	5.205	0.648388
Frame-21	0.000864	9.16	0.12457	-14.45	-1.80004	5.205	0.648388
Frame-22	0.000864	9.16	0.12457	-13.45	-1.67547	5.205	0.648388
Frame-23	0.000864	9.16	0.12457	-12.95	-1.61318	5.205	0.648388
Frame-24	0.000864	9.16	0.12457	-11.95	-1.48861	5.205	0.648388
Frame-25	0.000864	9.16	0.12457	-11.45	-1.42633	5.205	0.648388
Frame-26	0.000864	9.16	0.12457	-10.45	-1.30176	5.205	0.648388
Frame-27	0.000864	9.16	0.12457	-9.95	-1.23947	5.205	0.648388
Frame-28	0.000864	9.16	0.12457	-8.95	-1.1149	5.205	0.648388
Frame-29	0.000864	9.16	0.12457	-8.45	-1.05262	5.205	0.648388
Frame-30	0.000864	9.16	0.12457	-7.45	-0.92805	5.205	0.648388
Frame-31	0.000864	9.16	0.12457	-6.95	-0.86576	5.205	0.648388
Frame-32	0.000864	9.16	0.12457	-5.95	-0.74119	5.205	0.648388
Frame-33	0.000864	9.16	0.12457	-5.45	-0.67891	5.205	0.648388
Frame-34	0.000864	9.16	0.12457	-4.45	-0.55434	5.205	0.648388
Frame-35	0.000864	9.16	0.12457	-3.95	-0.49205	5.205	0.648388
Frame-36	0.000864	9.16	0.12457	-2.95	-0.36748	5.205	0.648388
Frame-37	0.000864	9.16	0.12457	-1.45	-0.18063	5.205	0.648388
Frame-38	0.000864	9.16	0.12457	-0.45	-0.05606	5.205	0.648388
Frame-39	0.000864	9.16	0.12457	0.05	0.006229	5.205	0.648388
Frame-40	0.000864	9.16	0.12457	1.05	0.130799	5.205	0.648388

Frame-41	0.000864	9.16	0.12457	1.55	0.193084	5.205	0.648388
Frame-42	0.000864	9.16	0.12457	2.55	0.317654	5.205	0.648388
Frame-43	0.000864	9.16	0.12457	3.05	0.379939	5.205	0.648388
Frame-44	0.000864	9.16	0.12457	4.05	0.504509	5.205	0.648388
Frame-45	0.000864	9.16	0.12457	4.55	0.566794	5.205	0.648388
Frame-46	0.000864	9.16	0.12457	5.55	0.691364	5.205	0.648388
Frame-47	0.000864	9.16	0.12457	6.05	0.753649	5.205	0.648388
Frame-48	0.000864	9.16	0.12457	7.05	0.878219	5.205	0.648388
Frame-49	0.000864	9.16	0.12457	7.55	0.940505	5.205	0.648388
Frame-50	0.000864	9.16	0.12457	8.55	1.065075	5.205	0.648388
Frame-51	0.000864	9.16	0.12457	9.05	1.12736	5.205	0.648388
Frame-52	0.000864	9.16	0.12457	10.05	1.25193	5.205	0.648388
Frame-53	0.000864	9.16	0.12457	10.55	1.314215	5.205	0.648388
Frame-54	0.000864	9.16	0.12457	11.55	1.438785	5.205	0.648388
Frame-55	0.000864	9.16	0.12457	12.05	1.50107	5.205	0.648388
Frame-56	0.000864	9.16	0.12457	13.05	1.62564	5.205	0.648388
Frame-57	0.000864	8.91	0.12117	13.55	1.641858	5.08	0.615545
Frame-58	0.000864	8.56	0.116411	14.55	1.693773	4.905	0.570994
Frame-59	0.000864	8.38	0.113963	15.05	1.715138	4.815	0.54873
Frame-60	0.000864	8.23	0.111923	16.05	1.79636	4.74	0.530514
Frame-61	0.000864	8.1	0.110155	16.55	1.823062	4.675	0.514974
Frame-62	0.000864	7.9	0.107435	17.55	1.885483	4.575	0.491515
Frame-63	0.000864	7.6	0.103355	18.05	1.86556	4.425	0.457346
Frame-64	0.000864	7.58	0.103083	19.05	1.963734	4.415	0.455112
Frame-65	0.000864	7.52	0.102267	19.55	1.999324	4.385	0.448442
Frame-66	0.000864	7.45	0.101315	20.55	2.082028	4.35	0.440721
Frame-67	0.000864	7.423	0.100948	21.05	2.124956	4.3365	0.437761
Frame-68	0.000864	7.37	0.100227	22.05	2.210012	4.31	0.43198
			7.909837		-25.6464		39.41172
					-3.24234		4.982622

Deck Beam	Area	Length	Weight	LCG	Moment	VCG	Moment
Deck Beam-1	0.004564	2.7	0.193961	-29.6	-5.74124	4.5	0.872824
Deck Beam-2	0.004564	4.6	0.330452	-29.1	-9.61615	4.5	1.487033
Deck Beam-3	0.004564	5.4	0.387922	-28.6	-11.0946	4.5	1.745648
Deck Beam-4	0.004564	6.3	0.452575	-28.1	-12.7174	4.5	2.036589
Deck Beam-5	0.004564	6.6	0.474127	-27.6	-13.0859	4.5	2.13357
Deck Beam-6	0.004564	7.6	0.545964	-27.1	-14.7956	4.5	2.456838
Deck Beam-7	0.004564	7.94	0.570389	-26.6	-15.1723	4.5	2.566749
Deck Beam-8	0.004564	8.15	0.585474	-26.1	-15.2809	4.5	2.634635
Deck Beam-9	0.004564	8.28	0.594813	-25.6	-15.2272	4.5	2.67666
Deck Beam-10	0.004564	8.56	0.614928	-25.1	-15.4347	4.5	2.767175
Deck Beam-11	0.004564	8.7	0.624985	-24.6	-15.3746	4.5	2.812433
Deck Beam-12	0.004564	8.9	0.639353	-24.1	-15.4084	4.5	2.877086
Deck Beam-13	0.004564	9.16	0.65803	-23.6	-15.5295	4.5	2.961136
Deck Beam-14	0.004564	9.16	0.65803	-23.1	-15.2005	4.5	2.961136
Deck Beam-15	0.004564	9.16	0.65803	-22.6	-14.8715	4.5	2.961136
Deck Beam-16	0.004564	9.16	0.65803	-22.1	-14.5425	4.5	2.961136
Deck Beam-17	0.004564	9.16	0.65803	-21.6	-14.2135	4.5	2.961136
Deck Beam-18	0.004564	9.16	0.65803	-21.1	-13.8844	4.5	2.961136
Deck Beam-19	0.004564	9.16	0.65803	-20.6	-13.5554	4.5	2.961136
Deck Beam-20	0.004564	9.16	0.65803	-20.1	-13.2264	4.5	2.961136
Deck Beam-21	0.004564	9.16	0.65803	-19.6	-12.8974	4.5	2.961136
Deck Beam-22	0.004564	9.16	0.65803	-19.1	-12.5684	4.5	2.961136
Deck Beam-23	0.004564	9.16	0.65803	-18.6	-12.2394	4.5	2.961136
Deck Beam-24	0.004564	9.16	0.65803	-18.1	-11.9103	4.5	2.961136
Deck Beam-25	0.004564	9.16	0.65803	-17.6	-11.5813	4.5	2.961136
Deck Beam-26	0.004564	9.16	0.65803	-17.1	-11.2523	4.5	2.961136
Deck Beam-27	0.004564	9.16	0.65803	-16.6	-10.9233	4.5	2.961136
Deck Beam-28	0.004564	9.16	0.65803	-16.1	-10.5943	4.5	2.961136
Deck Beam-29	0.004564	9.16	0.65803	-15.6	-10.2653	4.5	2.961136
Deck Beam-30	0.004564	9.16	0.65803	-15.1	-9.93626	4.5	2.961136
Deck Beam-31	0.004564	9.16	0.65803	-14.6	-9.60724	4.5	2.961136
Deck Beam-32	0.004564	9.16	0.65803	-14.1	-9.27823	4.5	2.961136
Deck Beam-33	0.004564	9.16	0.65803	-13.6	-8.94921	4.5	2.961136
Deck Beam-34	0.004564	9.16	0.65803	-13.1	-8.6202	4.5	2.961136
Deck Beam-35	0.004564	9.16	0.65803	-12.6	-8.29118	4.5	2.961136
Deck Beam-36	0.004564	9.16	0.65803	-12.1	-7.96217	4.5	2.961136
Deck Beam-37	0.004564	9.16	0.65803	-11.6	-7.63315	4.5	2.961136
Deck Beam-38	0.004564	9.16	0.65803	-11.1	-7.30414	4.5	2.961136
Deck Beam-39	0.004564	9.16	0.65803	-10.6	-6.97512	4.5	2.961136
Deck Beam-40	0.004564	9.16	0.65803	-10.1	-6.64611	4.5	2.961136
Deck Beam-41	0.004564	9.16	0.65803	-9.6	-6.31709	4.5	2.961136
Deck Beam-42	0.004564	9.16	0.65803	-9.1	-5.98807	4.5	2.961136
Deck Beam-43	0.004564	9.16	0.65803	-8.6	-5.65906	4.5	2.961136
Deck Beam-44	0.004564	9.16	0.65803	-8.1	-5.33004	4.5	2.961136
Deck Beam-45	0.004564	9.16	0.65803	-7.6	-5.00103	4.5	2.961136
Deck Beam-46	0.004564	9.16	0.65803	-7.1	-4.67201	4.5	2.961136
Deck Beam-47	0.004564	9.16	0.65803	-6.6	-4.343	4.5	2.961136
Deck Beam-48	0.004564	9.16	0.65803	-6.1	-4.01398	4.5	2.961136
Deck Beam-49	0.004564	9.16	0.65803	-5.6	-3.68497	4.5	2.961136
Deck Beam-50	0.004564	9.16	0.65803	-5.1	-3.35595	4.5	2.961136
Deck Beam-51	0.004564	9.16	0.65803	-4.6	-3.02694	4.5	2.961136
Deck Beam-52	0.004564	9.16	0.65803	-4.1	-2.69792	4.5	2.961136
Deck Beam-53	0.004564	9.16	0.65803	-3.6	-2.36891	4.5	2.961136
Deck Beam-54	0.004564	9.16	0.65803	-3.1	-2.03989	4.5	2.961136
Deck Beam-55	0.004564	9.16	0.65803	-2.6	-1.71088	4.5	2.961136

Deck Beam-56	0.004564	9.16	0.65803	-2.1	-1.38186	4.5	2.961136
Deck Beam-57	0.004564	9.16	0.65803	-1.6	-1.05285	4.5	2.961136
Deck Beam-58	0.004564	9.16	0.65803	-1.1	-0.72383	4.5	2.961136
Deck Beam-59	0.004564	9.16	0.65803	-0.6	-0.39482	4.5	2.961136
Deck Beam-60	0.004564	9.16	0.65803	-0.1	-0.0658	4.5	2.961136
Deck Beam-61	0.004564	9.16	0.65803	0.4	0.263212	4.5	2.961136
Deck Beam-62	0.004564	9.16	0.65803	0.9	0.592227	4.5	2.961136
Deck Beam-63	0.004564	9.16	0.65803	1.4	0.921242	4.5	2.961136
Deck Beam-64	0.004564	9.16	0.65803	1.9	1.250257	4.5	2.961136
Deck Beam-65	0.004564	9.16	0.65803	2.4	1.579273	4.5	2.961136
Deck Beam-66	0.004564	9.16	0.65803	2.9	1.908288	4.5	2.961136
Deck Beam-67	0.004564	9.16	0.65803	3.4	2.237303	4.5	2.961136
Deck Beam-68	0.004564	9.16	0.65803	3.9	2.566318	4.5	2.961136
Deck Beam-69	0.004564	9.16	0.65803	4.4	2.895333	4.5	2.961136
Deck Beam-70	0.004564	9.16	0.65803	4.9	3.224348	4.5	2.961136
Deck Beam-71	0.004564	9.16	0.65803	5.4	3.553363	4.5	2.961136
Deck Beam-72	0.004564	9.16	0.65803	5.9	3.882378	4.5	2.961136
Deck Beam-73	0.004564	9.16	0.65803	6.4	4.211393	4.5	2.961136
Deck Beam-74	0.004564	9.16	0.65803	6.9	4.540409	4.5	2.961136
Deck Beam-75	0.004564	9.16	0.65803	7.4	4.869424	4.5	2.961136
Deck Beam-76	0.004564	9.16	0.65803	7.9	5.198439	4.5	2.961136
Deck Beam-77	0.004564	9.16	0.65803	8.4	5.527454	4.5	2.961136
Deck Beam-78	0.004564	9.16	0.65803	8.9	5.856469	4.5	2.961136
Deck Beam-79	0.004564	9.16	0.65803	9.4	6.185484	4.5	2.961136
Deck Beam-80	0.004564	9.16	0.65803	9.9	6.514499	4.5	2.961136
Deck Beam-81	0.004564	9.16	0.65803	10.4	6.843514	4.5	2.961136
Deck Beam-82	0.004564	9.16	0.65803	10.9	7.172529	4.5	2.961136
Deck Beam-83	0.004564	9.16	0.65803	11.4	7.501544	4.5	2.961136
Deck Beam-84	0.004564	9.16	0.65803	11.9	7.83056	4.5	2.961136
Deck Beam-85	0.004564	9.16	0.65803	12.4	8.159575	4.5	2.961136
Deck Beam-86	0.004564	9.16	0.65803	12.9	8.48859	4.5	2.961136
Deck Beam-87	0.004564	9.16	0.65803	13.4	8.817605	4.5	2.961136
Deck Beam-88	0.004564	9.16	0.65803	13.9	9.14662	4.5	2.961136
Deck Beam-89	0.004564	9.16	0.65803	14.4	9.475635	4.5	2.961136
Deck Beam-90	0.004564	9.16	0.65803	14.9	9.80465	4.5	2.961136
Deck Beam-91	0.004564	9.16	0.65803	15.4	10.13367	4.5	2.961136
Deck Beam-92	0.004564	9.16	0.65803	15.9	10.46268	4.5	2.961136
Deck Beam-93	0.004564	9.16	0.65803	16.4	10.7917	4.5	2.961136
Deck Beam-94	0.004564	9.16	0.65803	16.9	11.12071	4.5	2.961136
Deck Beam-95	0.004564	9.16	0.65803	17.4	11.44973	4.5	2.961136
Deck Beam-96	0.004564	9.16	0.65803	17.9	11.77874	4.5	2.961136
Deck Beam-97	0.004564	9.16	0.65803	18.4	12.10776	4.5	2.961136
Deck Beam-98	0.004564	9.16	0.65803	18.9	12.43677	4.5	2.961136
Deck Beam-99	0.004564	9.16	0.65803	19.4	12.76579	4.5	2.961136
Deck Beam-100	0.004564	9.16	0.65803	19.9	13.0948	4.5	2.961136
Deck Beam-101	0.004564	9.16	0.65803	20.4	13.42382	4.5	2.961136
Deck Beam-102	0.004564	9.16	0.65803	20.9	13.75283	4.5	2.961136
Deck Beam-103	0.004564	9.16	0.65803	21.4	14.08185	4.5	2.961136
			65.89569		-224.818		296.5306
				LCG	-3.41172	VCG	4.5

MACHINARY

Items	Quantity	Unit weight (tonne)	Total weight (tonnes)	L.C.G from Aft (m)	Moment abt Aft (tonne-m)	V.C.G from keel (m)	Moment abt keel (tone-m)
main engine	1	12.55	12.55	22.4	281.12	2.6	32.63
gear box	1						
generator	2	2	4	21.4	85.6	2.3	
pump	8	1	8	23.5	188	1.89	15.12
Auxilliary Machinery	5	2	10	22	-220	2.2	22
HFO preheater	1	1.5	1.5	22	-33	2.5	3.75
Turbocharger	2	1.5	3	22.5	-67.5	2.5	7.5
Exhaust and Chimney	1	0.85	0.85	23	-19.55	4.29	3.6465
Engine Control Room equipment	1	3	3	23	-69	7.2	21.6
Cargo control room equipment	1	2	2	-21	-42	4.28	8.56
Rudder & Steering Arrangement		2	2	-26.5	-53	1.2	2.4
Anchor, Chain, Bollard, Capstan and other fittings		2.5	2.5	26	65	4.28	10.7
Propeller, Propeller Shaft		2.5	1.5	-26	-39	0.85	1.275
Complete Electrical System		1.5	1.5	-18.5	-27.75	4.3	6.45
Hatch Coaming Girder		1.5	1.5	8.5	12.75	4.28	6.42
Complete Piping		1.25	1.25	0.25	0.3125	4.3	5.375
Total			42.6		-219.138		114.7965

LCG	-5.14407
VCG	2.694754

WOOD AND OUTFIT WEIGHT

	Item	No. of Items	Weight (kg)	total weight (ton)	LCG(m)	LCG moment	VCG(m)	VCG Moment
	Control Panel	1	450	0.45	20.03	9.0135	5.8	2.61
	Wing Control Panel (Starboard)	1	15	0.015	18.56	0.2784	4.67	0.07005
	Wing Control Panel (Port side)	1	15	0.015	18.24	0.2736	6.78	0.1017
	Cabinet	2	30	0.06	19.65	1.179	4.56	0.2736
	Chart Table	1	15	0.015	19.65	0.29475	6.5	0.0975
	Chart Table-Chair	1	12	0.012	18.34	0.22008	5.6	0.0672
	Map Table	1	18	0.018	20.98	0.37764	6.2	0.1116
	Map Table- Chair	1	15	0.015	20.98	0.3147	6.3	0.0945
	Control Panel- Chair	2	15	0.03	20.85	0.6255	4.67	0.1401
	Radio Instrument Table	1	50	0.05	24.38	1.219	6.54	0.327
	Radio Operator's Chair	1	18	0.018	24.38	0.43884	6.54	0.11772
	Sofa	2	60	0.12	24.38	2.9256	4.5	0.54
	Wash cabin item	2	40	0.08	26.81	2.1448	3.56	0.2848
Bath house	Shower	2	3	0.006	18.23	0.10938	5.34	0.03204
1st class driver	Single bed	1	25	0.025	19.56	0.489	5.78	0.1445
	Locker	1	15	0.015	19.56	0.2934	5.78	0.0867
	chair	1	12	0.012	19.56	0.23472	5.78	0.06936
2nd class master	Single bed	1	25	0.025	21.56	0.539	5.98	0.1495
	Locker	1	15	0.015	21.56	0.3234	5.98	0.0897
	chair	1	12	0.012	21.56	0.25872	5.98	0.07176
1st class master	Single bed	1	30	0.03	18.56	0.5568	5.67	0.1701
	Cabinet	1	20	0.02	18.56	0.3712	5.67	0.1134
	Table	1	14	0.014	18.56	0.25984	5.67	0.07938
	Chair	1	10	0.01	18.56	0.1856	5.67	0.0567
	Sofa	2	25	0.05	18.56	0.928	5.67	0.2835
	Wardrobe	1	30	0.03	18.56	0.5568	5.67	0.1701
sailor (7 people)	Single bed	7	175	1.225	22.34	27.3665	4.512	5.5272
	Locker	7	105	0.735	22.34	16.4199	4.512	3.31632
	chair	7	84	0.588	22.34	13.13592	4.512	2.653056
Greaser 1	Single bed	1	25	0.025	23.24	0.581	5.78	0.1445
	Cabinet	1	15	0.015	23.24	0.3486	5.78	0.0867
	Wardrobe	1	20	0.02	23.24	0.4648	5.78	0.1156
	Wash room items	3	30	0.09	23.24	2.0916	5.78	0.5202
Greaser 2	Single bed	1	25	0.025	18.34	0.4585	6.45	0.16125
	Cabinet	1	15	0.015	18.34	0.2751	6.45	0.09675
	Wardrobe	1	20	0.02	18.34	0.3668	6.45	0.129
	Wash room items	3	30	0.09	18.34	1.6506	6.45	0.5805
Greaser 3	Single bed	1	20	0.02	19.52	0.3904	5.76	0.1152
	Cabinet	1	12	0.012	19.52	0.23424	5.76	0.06912
	Wardrobe	1	15	0.015	19.52	0.2928	5.76	0.0864
	Wash room items	3	30	0.09	19.52	1.7568	5.76	0.5184

Cook	Single bed	1	25	0.025	20.14	0.5035	4.35	0.10875
	Locker	1	15	0.015	20.14	0.3021	4.35	0.06525
	chair	1	12	0.012	20.14	0.24168	4.35	0.0522
Store - 1	Cabinet	1	25	0.025	21.2	0.53	3.678	0.09195
Deck Store	Cabinet	2	30	0.06	21.2	1.272	3.678	0.22068
Engine Office	Table	2	30	0.06	23.21	1.3926	4.78	0.2868
	Chair	10	140	1.4	23.21	32.494	4.78	6.692
Engine Controll Room	Controll Room Electronics	1	200	0.2	20.85	4.17	3.67	0.734
Deck Workshop		1	60	0.06	25.84	1.5504	2.58	0.1548
Radio Operator's Room	Single bed	1	23	0.023	18.57	0.42711	4.98	0.11454
	Cabinet	1	12	0.012	18.57	0.22284	4.98	0.05976
	Sofa	2	26	0.052	18.57	0.96564	4.98	0.25896
	Wardrobe	1	20	0.02	18.57	0.3714	4.98	0.0996
	Wash room items	3	35	0.105	18.57	1.94985	4.98	0.5229
Crew Mess	Cabinet	1	30	0.03	21.64	0.6492	6.89	0.2067
	Table	1	15	0.015	21.64	0.3246	6.89	0.10335
	Chair	8	12	0.096	21.64	2.07744	6.89	0.66144
Common Room	Table	1	15	0.015	21.96	0.3294	5.234	0.07851
	Chair	4	12	0.048	21.96	1.05408	5.234	0.251232
	Sports' Cabinet	1	10	0.01	21.96	0.2196	5.234	0.05234
Dispensary	Cabinet	2	50	0.1	22.61	2.261	3.21	0.321
Pantry	Beverage Storage	1	200	0.2	23.54	4.708	3.67	0.734
	Vegetable Storage	1	60	0.06	23.54	1.4124	3.67	0.2202
	Frogen Food Storage	1	400	0.4	23.54	9.416	3.67	1.468
	Cabinet	1	50	0.05	23.54	1.177	3.67	0.1835
					23.54			0
Fan Room	Fan Controller	2	35	0.07	21.45	1.5015	5.87	0.4109
Co2 Room	Co2 Room Equipments	1	90	0.09	18.97	1.7073	3.45	0.3105
Deck Store 2	Cabinet	1	30	0.03	20.21	0.6063	5.76	0.1728
Lash Storage		1	50	0.05	24.33	1.2165	4.5	0.225
Deck Workshop			50		21.26	0	2.76	0
Store		1	500	0.5	27.21	13.605	2.56	1.28
Electric Room		1	300	0.3	19	5.7	2.5	0.75
Boatswine Store		1	100	0.1	18.5	1.85	5.87	0.587
Paint Store		1	100	0.1	26.73	2.673	4.67	0.467
		Total Weight		8.48		189.1263	5.78	38.41837

Final Weight	8.904
LCG	22.30263
VCG	4.530468

SUMMARY OF FINAL WEIGHT

			Weight	LCG	Moment	VCG	Moment
LIGHTWEIGHT	HULL WEIGHT		284.29	-0.39	-110.873	2.89	821.5938
	MACHINARY WEIGHT		42.6	7.3	310.98	2.7	115.02
	WOOD AND OUTFIT WEIGHT		8.904	22.17	197.4017	4.33	38.55432
DEADWEIGHT	Cargo Hold-1		338	11.43	3863.34	2.8	946.4
	Cargo Hold-2		327	-2.57	-840.39	2.92	954.84
	Cargo Hold-3		322	-16.16	-5203.52	2.78	895.16
	Fuel Oil		4.4	22.4	98.56	1.8	7.92
	Generator Oil		3.5	23.5	82.25	2.9	10.15
	Crew		0.975	26.7	26.0325	4.9	4.7775
	Fresh Water		13	20.8	270.4	6.5	84.5
	Summation		1344.668		-1305.82		3878.916

Total weight		1344.667503
LCG		-0.971108719
VCG		2.884665231

STABILITY CALCULATION

GZ CALCULATION FOR LOADED CONDITION

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 0 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 0^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	0.744144	0.5537503	0.41206996	0.744144	0.55375029	0.41206996
1	4	2.849958	8.1222606	23.1481016	11.399832	32.4890424	92.5924063
2	2	4.197076	17.615447	73.9333696	8.394152	35.2308939	147.866739
3	4	4.996588	24.965892	124.744275	19.986352	99.8635666	498.977098
4	2	5.5249	30.52452	168.644921	11.0498	61.04904	337.289841
5	4	5.524727	30.522608	168.629079	22.098908	122.090434	674.516315
6	2	5.548723	30.788327	170.835898	11.097446	61.5766539	341.671796
7	4	5.561947	30.935254	172.060246	22.247788	123.741018	688.240982
8	2	5.586354	31.207351	174.33531	11.172708	62.414702	348.67062
9	4	5.590048	31.248637	174.681379	22.360192	124.994547	698.725515
10	2	5.590048	31.248637	174.681379	11.180096	62.4972733	349.362758
11	4	5.590048	31.248637	174.681379	22.360192	124.994547	698.725515
12	2	5.590048	31.248637	174.681379	11.180096	62.4972733	349.362758
13	4	5.590048	31.248637	174.681379	22.360192	124.994547	698.725515
14	2	5.590048	31.248637	174.681379	11.180096	62.4972733	349.362758
15	4	5.556837	30.878437	171.586444	22.227348	123.51375	686.345775
16	2	5.502852	30.28138	166.633953	11.005704	60.5627603	333.267906
17	4	5.275949	27.835638	146.859406	21.103796	111.342551	587.437623
18	2	4.494714	20.202454	90.8042526	8.989428	40.4049079	181.608505
19	4	1.465112	2.1465532	3.14494081	5.860448	8.58621269	12.5797632
20	1	0.100264	0.0100529	0.00100794	0.100264	0.01005287	0.00100794
		0	SUMMATION		288.098982	1505.90479	8075.74327

WL 6 ANGLE OF HEEL 0^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.566247	0.3206357	0.18155898	0.566247	0.32063567	0.18155898
1	4	2.257734	5.0973628	11.5084893	9.030936	20.3894513	46.0339573
2	2	3.559682	12.671336	45.1059265	7.119364	25.3426719	90.2118529
3	4	4.539526	20.607296	93.5473574	18.158104	82.4291852	374.189429
4	2	5.45172	29.721251	162.031938	10.90344	59.4425019	324.063877
5	4	5.451102	29.714513	161.976841	21.804408	118.858052	647.907365
6	2	5.537168	30.660229	169.770841	11.074336	61.3204589	339.541683
7	4	5.558739	30.899579	171.762696	22.234956	123.598317	687.050785
8	2	5.602337	31.38618	175.835957	11.204674	62.7723597	351.671913
9	4	5.598496	31.343157	175.474542	22.393984	125.37263	701.898167
10	2	5.598496	31.343157	175.474542	11.196992	62.6863149	350.949083
11	4	5.598496	31.343157	175.474542	22.393984	125.37263	701.898167
12	2	5.598496	31.343157	175.474542	11.196992	62.6863149	350.949083
13	4	5.598496	31.343157	175.474542	22.393984	125.37263	701.898167
14	2	5.598496	31.343157	175.474542	11.196992	62.6863149	350.949083
15	4	5.552541	30.830712	171.18879	22.210164	123.322846	684.75516
16	2	5.452191	29.726387	162.073938	10.904382	59.4527734	324.147876
17	4	5.142537	26.445687	135.997923	20.570148	105.782747	543.991691
18	2	4.254726	18.102693	77.022	8.509452	36.2053867	154.044
19	4	1.36315	1.8581779	2.53297524	5.4526	7.43271169	10.1319009
20	1	0.100264	0.0100529	0.00100794	0.100264	0.01005287	0.00100794
			SUMMATION		280.616403	1450.85699	7736.46581

displacement for WL 1	1610
distance between two sections	2.657
difference of angles	0.2618
KG (assume)	2.9
KB (calculated)	1.35
BG (Assume)	1.55

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 7.5 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 7.5^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	0.902361	0.8142554	0.734752	0.902361	0.814255374	0.734752
1	4	2.588375	6.6996851	17.3413	10.3535	26.79874056	69.36519
2	2	3.958402	15.668946	62.02399	7.916804	31.33789279	124.048
3	4	4.539526	20.607296	93.54736	18.1581	82.42918522	374.1894
4	2	5.45172	29.721251	162.0319	10.90344	59.44250192	324.0639
5	4	5.001871	25.018714	125.1404	20.00748	100.074854	500.5615
6	2	5.47272	29.950664	163.9116	10.94544	59.9013284	327.8232
7	4	5.524649	30.521747	168.6219	22.0986	122.0869863	674.4877
8	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
9	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
10	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
11	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
12	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
13	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
14	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
15	4	5.547908	30.779283	170.7606	22.19163	123.1171327	683.0425
16	2	5.545445	30.75196	170.5333	11.09089	61.5039205	341.0666
17	4	5.517689	30.444892	167.9854	22.07076	121.7795676	671.9418
18	2	5.164788	26.675035	137.7709	10.32958	53.35007017	275.5418
19	4	1.397611	1.9533165	2.729977	5.590444	7.813266029	10.91991
20	1	0.104682	0.0109583	0.001147	0.104682	0.010958321	0.001147
			SUMMATION		283.594	1465.736789	7790.425

WL 6 ANGLE OF HEEL 7.5^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.902361	0.8142554	0.734752	0.902361	0.814255374	0.734752
1	4	2.588375	6.6996851	17.3413	10.3535	26.79874056	69.36519
2	2	3.958402	15.668946	62.02399	7.916804	31.33789279	124.048
3	4	4.539526	20.607296	93.54736	18.1581	82.42918522	374.1894
4	2	5.45172	29.721251	162.0319	10.90344	59.44250192	324.0639
5	4	5.001871	25.018714	125.1404	20.00748	100.074854	500.5615
6	2	5.47272	29.950664	163.9116	10.94544	59.9013284	327.8232
7	4	5.524649	30.521747	168.6219	22.0986	122.0869863	674.4877
8	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
9	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
10	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
11	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
12	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
13	4	5.546513	30.763806	170.6319	22.18605	123.0552258	682.5274
14	2	5.546513	30.763806	170.6319	11.09303	61.52761292	341.2637
15	4	5.547908	30.779283	170.7606	22.19163	123.1171327	683.0425
16	2	5.545445	30.75196	170.5333	11.09089	61.5039205	341.0666
17	4	5.517689	30.444892	167.9854	22.07076	121.7795676	671.9418
18	2	5.164788	26.675035	137.7709	10.32958	53.35007017	275.5418
19	4	1.397611	1.9533165	2.729977	5.590444	7.813266029	10.91991
20	1	0.104682	0.0109583	0.001147	0.104682	0.010958321	0.001147
			SUMMATION		283.594	1465.736789	7790.425

WL COMBINATION TABLE FOR 7.5 ^{0} INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	$\sum y_i^2$ x SM	SM	Σy_i^2 x SM x SM	Σy_e^2 x SM	SM	Σy_e^2 x SM x SM
0	1505.905	5	7529.524	1450.857	5	7254.28493
7.5	1465.737	8	11725.894	1465.737	8	11725.89431
15	1592.027	-1	-1592.0273	1544.613	-1	-1544.613266
	Summation		17663.391	Summation		17435.56598

Angle of heel (α)	$\sum y_i^3$ x SM + y_e^3 x SM	SM	$\Sigma(y_i^3$ x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	$\Sigma(y_i^3$ x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	5	79061.045	15	0.965926	76367.09306
7.5	15580.85	8	124646.79	7.5	0.991445	123580.4164
15	17142.26	-1	-17142.265	0	1	-17142.26478
				summation		182805.2447

Multiplier for moment	1/3 x (h/3) x (Θ/3)	0.003220382
multiplier for volume	1/2 x (h/3) x (Θ/3)	0.004830574
volume immersed wedge	vi=multiplier x ΣΣyi2 x SM x SM	85.3243103
volume emmerged wedge	ve=multiplier x ΣΣye2 x SM x SM	84.2237849
Volume of layer	vi-ve	1.100525399
Area of water plane	Awp= (Σyi SM +Σye SM) x h/3	502.3394504
Center of floation	moment function/area function x	0
Calculated moment	M0=Σ(yi3 x SM + ye3 x SM) x SM x	588.7027941
Layer correction	Lc=v x C.G. of waterplane	0
Corrected moment	M=Mo-Lc	588.7027941
Volume of displacement	Vo	1610
corrected volume	$V=V_0+v_i-v_e$	1611.100525
BR	M/V	0.365404135
BG x SinΘ	BG x SinΘ	0.202316068
GZ	BR-BG SinΘ	0.163088067

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 15 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 15^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	1.193685	1.424884	1.700863	1.193685	1.424884	1.700863
1	4	2.185344	4.775728	10.43661	8.741376	19.10291	41.74644
2	2	4.65289	21.64939	100.7322	9.30578	43.29877	201.4644
3	4	4.556803	20.76445	94.61952	18.22721	83.05781	378.4781
4	2	5.338647	28.50115	152.1576	10.67729	57.0023	304.3152
5	4	5.46553	29.87202	163.2664	21.86212	119.4881	653.0656
6	2	5.683215	32.29893	183.5618	11.36643	64.59787	367.1236
7	4	5.683215	32.29893	183.5618	22.73286	129.1957	734.2471
8	2	5.718122	32.69692	186.965	11.43624	65.39384	373.9299
9	4	5.713625	32.64551	186.5242	22.8545	130.582	746.0968
10	2	5.713625	32.64551	186.5242	11.42725	65.29102	373.0484
11	4	5.713625	32.64551	186.5242	22.8545	130.582	746.0968
12	2	5.713625	32.64551	186.5242	11.42725	65.29102	373.0484
13	4	5.713625	32.64551	186.5242	22.8545	130.582	746.0968
14	2	5.713625	32.64551	186.5242	11.42725	65.29102	373.0484
15	4	5.73119	32.84654	188.2498	22.92476	131.3862	752.999
16	2	5.729297	32.82484	188.0633	11.45859	65.64969	376.1266
17	4	5.708874	32.59124	186.0593	22.8355	130.365	744.2372
18	2	5.487294	30.1104	165.2246	10.97459	60.22079	330.4492
19	4	2.924451	8.552414	25.01111	11.6978	34.20965	100.0445
20	1	0.121136	0.014674	0.001778	0.121136	0.014674	0.001778
			SUMMATION		298.4006	1592.027	8717.365
WL 6 ANGLE OF HEEL 15^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.757932	0.574461	0.435402	0.757932	0.574461	0.435402
1	4	3.311848	10.96834	36.32547	13.24739	43.87335	145.3019
2	2	3.515701	12.36015	43.4546	7.031402	24.72031	86.90921
3	4	4.539526	20.6073	93.54736	18.1581	82.42919	374.1894
4	2	5.45172	29.72125	162.0319	10.90344	59.4425	324.0639
5	4	4.710546	22.18924	104.5235	18.84218	88.75697	418.0938
6	2	5.688506	32.3591	184.0749	11.37701	64.7182	368.1499
7	4	5.713625	32.64551	186.5242	22.8545	130.582	746.0968
8	2	5.743666	32.9897	189.4818	11.48733	65.9794	378.9636
9	4	5.743666	32.9897	189.4818	22.97466	131.9588	757.9273
10	2	5.743666	32.9897	189.4818	11.48733	65.9794	378.9636
11	4	5.743666	32.9897	189.4818	22.97466	131.9588	757.9273
12	2	5.743666	32.9897	189.4818	11.48733	65.9794	378.9636
13	4	5.743666	32.9897	189.4818	22.97466	131.9588	757.9273
14	2	5.743666	32.9897	189.4818	11.48733	65.9794	378.9636
15	4	5.745269	33.00812	189.6405	22.98108	132.0325	758.562
16	2	5.742504	32.97635	189.3668	11.48501	65.9527	378.7337
17	4	5.707776	32.57871	185.952	22.8311	130.3148	743.8078
18	2	5.198199	27.02127	140.462	10.3964	54.04255	280.9239
19	4	1.356931	1.841262	2.498465	5.427724	7.365047	9.993861
20	1	0.121136	0.014674	0.001778	0.121136	0.014674	0.001778
			SUMMATION		291.2877	1544.613	8424.9

WL COMBINATION TABLE FOR 15 ^{0} INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	Σy_i^2 x SM	SM	Σy_i^2 x SM x SM	Σy_e^2 x SM	SM	Σy_e^2 x SM x SM
0	1505.905	1	1505.905	1450.857	1	1450.857
7.5	1465.737	4	5862.947	1465.737	4	5862.947
15	1592.027	1	1592.027	1544.613	1	1544.613
	Summation		8960.879	Summation		8858.417
Angle of heel (α)	Σy_i^3 x SM + y_e^3 x SM	SM	$\Sigma(y_i^3$ x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	$\Sigma(y_i^3$ x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	1	15812.21	15	0.965926	15273.42
7.5	15580.85	4	62323.4	7.5	0.991445	61790.21
15	17142.26	1	17142.26	0	1	17142.26
Summation						94205.89
Multiplier for moment			1/3 x (h/3) x (Θ/3)			0.012882
multiplier for volume			1/2 x (h/3) x (Θ/3)			0.019322
volume immersed wedge			vi=multiplier x ∑Σyi2 x SM x SM			173.1447
volume emmerged wedge			ve=multiplier x ΣΣye2 x SM x SM			171.1649
Volume of layer			vi-ve			1.979798
Area of water plane			Awp= (Σyi SM +Σye SM) x h/3			522.2673
Center of floation			moment function/area function x .5			0.040203
Calculated moment			M0=Σ(yi3 x SM + ye3 x SM) x SM x Cos (ϕ-α) x multiplier			1213.516
Layer correction			Lc=v x C.G. of waterplane			0.079593
Corrected moment			M=Mo-Lc			1213.436
Volume of displacement			Vo			1610
corrected volume			$V=V_0+v_i-v_e$			1611.98
BR			M/V			0.752762
BG x SinΘ			BG x SinΘ			0.40117
GZ			BR-BG SinΘ			0.351591

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 30 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 30^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	2.408172	5.799292	13.96569	2.408172	5.799292	13.96569
1	4	1.802371	3.248541	5.855076	7.209484	12.99416	23.42031
2	2	2.002263	4.009057	8.027187	4.004526	8.018114	16.05437
3	4	5.611851	31.49287	176.7333	22.4474	125.9715	706.9332
4	2	4.444453	19.75316	87.792	8.888906	39.50632	175.584
5	4	6.140444	37.70505	231.5258	24.56178	150.8202	926.1031
6	2	6.158992	37.93318	233.6302	12.31798	75.86636	467.2603
7	4	6.188919	38.30272	237.0524	24.75568	153.2109	948.2097
8	2	6.188919	38.30272	237.0524	12.37784	76.60544	474.1048
9	4	6.320676	39.95095	252.517	25.2827	159.8038	1010.068
10	2	6.360987	40.46216	257.3792	12.72197	80.92431	514.7585
11	4	6.360987	40.46216	257.3792	25.44395	161.8486	1029.517
12	2	6.360987	40.46216	257.3792	12.72197	80.92431	514.7585
13	4	6.360987	40.46216	257.3792	25.44395	161.8486	1029.517
14	2	6.360987	40.46216	257.3792	12.72197	80.92431	514.7585
15	4	6.360987	40.46216	257.3792	25.44395	161.8486	1029.517
16	2	6.36984	40.57486	258.4554	12.73968	81.14972	516.9108
17	4	6.368847	40.56221	258.3345	25.47539	162.2488	1033.338
18	2	6.358582	40.43157	257.0874	12.71716	80.86313	514.1748
19	4	6.2754	39.38065	247.1293	25.1016	157.5226	988.5172
20	1	3.815714	14.55967	55.55555	3.815714	14.55967	55.55555
		0.155233	SUMMATION		338.6018	2033.259	12503.03

WL 6 ANGLE OF HEEL 30^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.687164	0.472194	0.324475	0.687164	0.472194	0.324475
1	4	4.391382	19.28424	84.68445	17.56553	77.13694	338.7378
2	2	3.31903	11.01596	36.5623	6.63806	22.03192	73.1246
3	4	4.539526	20.6073	93.54736	18.1581	82.42919	374.1894
4	2	5.45172	29.72125	162.0319	10.90344	59.4425	324.0639
5	4	4.591394	21.0809	96.79071	18.36558	84.3236	387.1629
6	2	6.349238	40.31282	255.9557	12.69848	80.62565	511.9114
7	4	6.360987	40.46216	257.3792	25.44395	161.8486	1029.517
8	2	6.357735	40.42079	256.9847	12.71547	80.84159	513.9694
9	4	6.357735	40.42079	256.9847	25.43094	161.6832	1027.939
10	2	6.357735	40.42079	256.9847	12.71547	80.84159	513.9694
11	4	6.357735	40.42079	256.9847	25.43094	161.6832	1027.939
12	2	6.357735	40.42079	256.9847	12.71547	80.84159	513.9694
13	4	6.357735	40.42079	256.9847	25.43094	161.6832	1027.939
14	2	6.357735	40.42079	256.9847	12.71547	80.84159	513.9694
15	4	6.35968	40.44553	257.2206	25.43872	161.7821	1028.883
16	2	6.355987	40.39857	256.7728	12.71197	80.79714	513.5456
17	4	6.292902	39.60062	249.2028	25.17161	158.4025	996.8112
18	2	5.473236	29.95631	163.958	10.94647	59.91262	327.9159
19	4	1.427261	2.037074	2.907436	5.709044	8.148296	11.62974
20	1	0.155233	0.024097	0.003741	0.155233	0.024097	0.003741
			SUMMATION		317.748	1845.793	11057.51

WL COMBINATION TABLE FOR 30^0 INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	y_i^2 x SM	SM	y_i^2 x SM x SM	y_e^2 x SM	SM	y_e^2 x SM x SM
0	1505.905	1	1505.905	1450.857	1	1450.857
15	1592.027	4	6368.109	1544.613	4	6178.453
30	2033.259	1	2033.259	1845.793	1	1845.793
	Summation		9907.273	Summation		9475.103

Angle of heel (α)	y_i^3 x SM + y_e^3 x SM	SM	(y_i^3 x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	(y_i^3 x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	1	15812.21	30	0.866025	13693.77
15	17142.26	4	68569.06	15	0.965926	66232.61
30	23560.54	1	23560.54	0	1	23560.54
			Summation			103486.9

Multiplier for moment	1/3 x (h/3) x (Θ/3)	0.025763
multiplier for volume	1/2 x (h/3) x (Θ/3)	0.038645
volume immersed wedge	vi=multiplier x ΣΣyi2 x SM x SM	382.8625
volume emmerged wedge	ve=multiplier x ΣΣye2 x SM x	366.1615
Volume of layer	vi-ve	16.70102
Area of water plane	Awp= (Σyi SM +Σye SM) x h/3	581.3072
Center of floation	moment function/area function x	0.142809
Calculated moment	M0=Σ(yi3 x SM + ye3 x SM) x SM	2666.14
Layer correction	Lc=v x C.G. of waterplane	2.385058
Corrected moment	M=Mo-Lc	2663.755
Volume of displacement	Vo	1610
corrected volume	$V=V_0+v_i-v_e$	1626.701
BR	M/V	1.637519
BG x SinΘ	BG x SinΘ	0.775002
GZ	BR-BG SinΘ	0.862518

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 45 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 45^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	3.119569	9.731711	30.35874	3.119569	9.731711	30.35874
1	4	1.995625	3.982519	7.947615	7.9825	15.93008	31.79046
2	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
3	4	4.448089	19.7855	88.00765	17.79236	79.14198	352.0306
4	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
5	4	6.257811	39.1602	245.0571	25.03124	156.6408	980.2285
6	2	6.312675	39.84987	251.5593	12.62535	79.69973	503.1185
7	4	6.312675	39.84987	251.5593	25.2507	159.3995	1006.237
8	2	6.238056	38.91334	242.7436	12.47611	77.82669	485.4872
9	4	6.334062	40.12034	254.1247	25.33625	160.4814	1016.499
10	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
11	4	6.334062	40.12034	254.1247	25.33625	160.4814	1016.499
12	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
13	4	6.334062	40.12034	254.1247	25.33625	160.4814	1016.499
14	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
15	4	6.33409	40.1207	254.1281	25.33636	160.4828	1016.512
16	2	6.327545	40.03783	253.3411	12.65509	80.07565	506.6823
17	4	6.33409	40.1207	254.1281	25.33636	160.4828	1016.512
18	2	6.334062	40.12034	254.1247	12.66812	80.24068	508.2495
19	4	6.334062	40.12034	254.1247	25.33625	160.4814	1016.499
20	1	0.234257	0.054876	0.012855	0.234257	0.054876	0.012855
			SUMMATION		345.1936	2102.836	13044.46

WL 6 ANGLE OF HEEL 45^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.664029	0.440935	0.292793	0.664029	0.440935	0.292793
1	4	5.819817	33.87027	197.1188	23.27927	135.4811	788.4751
2	2	3.350646	11.22683	37.61713	6.701292	22.45366	75.23426
3	4	4.539526	20.6073	93.54736	18.1581	82.42919	374.1894
4	2	5.45172	29.72125	162.0319	10.90344	59.4425	324.0639
5	4	4.578057	20.95861	95.94969	18.31223	83.83442	383.7988
6	2	5.707931	32.58048	185.9671	11.41586	65.16095	371.9342
7	4	5.731692	32.85229	188.2992	22.92677	131.4092	753.1969
8	2	5.73491	32.88919	188.6166	11.46982	65.77839	377.2331
9	4	5.73491	32.88919	188.6166	22.93964	131.5568	754.4662
10	2	5.73491	32.88919	188.6166	11.46982	65.77839	377.2331
11	4	5.73491	32.88919	188.6166	22.93964	131.5568	754.4662
12	2	5.73491	32.88919	188.6166	11.46982	65.77839	377.2331
13	4	5.73491	32.88919	188.6166	22.93964	131.5568	754.4662
14	2	5.73491	32.88919	188.6166	11.46982	65.77839	377.2331
15	4	5.735022	32.89048	188.6276	22.94009	131.5619	754.5104
16	2	5.741027	32.95939	189.2208	11.48205	65.91878	378.4415
17	4	5.728888	32.82016	188.023	22.91555	131.2806	752.092
18	2	5.420314	29.3798	159.2478	10.84063	58.75961	318.4955
19	4	1.635453	2.674707	4.374357	6.541812	10.69883	17.49743
20	1	0.234257	0.054876	0.012855	0.234257	0.054876	0.012855
			SUMMATION		302.0136	1636.71	9064.566

WL COMBINATION TABLE FOR 45^0 INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	y_i^2 x SM	SM	y_i^2 x SM x SM	y_e^2 x SM	SM	y_e^2 x SM x SM
0	1505.905	0.5	752.9524	1450.857	0.5	725.4285
7.5	1465.737	2	2931.474	1465.737	2	2931.474
15	1592.027	1.5	2388.041	1544.613	1.5	2316.92
30	2033.259	4	8133.035	1845.793	4	7383.173
45	2102.836	1	2102.836	1636.71	1	1636.71
	Summation		16308.34	Summation		14993.71

Angle of heel (α)	y_i^3 x SM + y_e^3 x SM	SM	(y_i^3 x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	(y_i^3 x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	0.5	7906.105	45	0.707105	5590.45
7.5	15580.85	2	31161.7	37.5	0.793352	24722.21
15	17142.26	1.5	25713.4	30	0.866025	22268.44
30	23560.54	4	94242.16	15	0.965926	91030.92
45	22109.03	1	22109.03	0	1	22109.03
			Summation			165721

Multiplier for moment	1/3 x (h/3) x (Θ/3)	0.025763
multiplier for volume	1/2 x (h/3) x (Θ/3)	0.038645
volume immersed wedge	vi=multiplier x ΣΣyi2 x SM x SM	630.229
volume emmerged wedge	ve=multiplier x ΣΣye2 x SM x	579.4256
Volume of layer	vi-ve	50.80345
Area of water plane	Awp= (Σyi SM +Σye SM) x h/3	573.2099
Center of floation	moment function/area function x	0.360105
Calculated moment	M0=Σ(yi3 x SM + ye3 x SM) x SM	4269.481
Layer correction	Lc=v x C.G. of waterplane	18.2946
Corrected moment	M=Mo-Lc	4251.187
Volume of displacement	Vo	1610
corrected volume	$V=V_0+v_i-v_e$	1660.803
BR	M/V	2.559717
BG x SinΘ	BG x SinΘ	1.096018
GZ	BR-BG SinΘ	1.463699

STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 60 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 60^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	5.165241	26.67971	137.8072	5.165241	26.67971	137.8072
1	4	5.17174	26.74689	138.328	20.68696	106.9876	553.3119
2	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
3	4	4.397548	19.33843	85.04167	17.59019	77.35371	340.1667
4	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
5	4	5.120474	26.21925	134.255	20.4819	104.877	537.02
6	2	5.157581	26.60064	137.195	10.31516	53.20128	274.3899
7	4	5.157581	26.60064	137.195	20.63032	106.4026	548.7799
8	2	5.108038	26.09205	133.2792	10.21608	52.1841	266.5584
9	4	5.17174	26.74689	138.328	20.68696	106.9876	553.3119
10	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
11	4	5.17174	26.74689	138.328	20.68696	106.9876	553.3119
12	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
13	4	5.17174	26.74689	138.328	20.68696	106.9876	553.3119
14	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
15	4	5.171763	26.74713	138.3298	20.68705	106.9885	553.3193
16	2	5.166419	26.69189	137.9015	10.33284	53.38377	275.8029
17	4	5.171763	26.74713	138.3298	20.68705	106.9885	553.3193
18	2	5.17174	26.74689	138.328	10.34348	53.49379	276.656
19	4	5.17174	26.74689	138.328	20.68696	106.9876	553.3119
20	1	5.171763	26.74713	138.3298	5.171763	26.74713	138.3298
			SUMMATION		306.7733	1570.707	8051.989

WL 6 ANGLE OF HEEL 60^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.689591	0.475536	0.327925	0.689591	0.475536	0.327925
1	4	2.185244	4.775291	10.43518	8.740976	19.10117	41.74071
2	2	3.621665	13.11646	47.50341	7.24333	26.23291	95.00683
3	4	4.539526	20.6073	93.54736	18.1581	82.42919	374.1894
4	2	5.45172	29.72125	162.0319	10.90344	59.4425	324.0639
5	4	4.486878	20.13207	90.33016	17.94751	80.5283	361.3206
6	2	4.699609	22.08632	103.7971	9.399218	44.17265	207.5942
7	4	4.699631	22.08653	103.7985	18.79852	88.34613	415.1942
8	2	4.699631	22.08653	103.7985	9.399262	44.17306	207.5971
9	4	4.699631	22.08653	103.7985	18.79852	88.34613	415.1942
10	2	4.699631	22.08653	103.7985	9.399262	44.17306	207.5971
11	4	4.699631	22.08653	103.7985	18.79852	88.34613	415.1942
12	2	4.699631	22.08653	103.7985	9.399262	44.17306	207.5971
13	4	4.699631	22.08653	103.7985	18.79852	88.34613	415.1942
14	2	4.699631	22.08653	103.7985	9.399262	44.17306	207.5971
15	4	4.699608	22.08632	103.797	18.79843	88.34526	415.1881
16	2	4.704952	22.13657	104.1515	9.409904	44.27315	208.303
17	4	4.699608	22.08632	103.797	18.79843	88.34526	415.1881
18	2	4.69326	22.02669	103.377	9.38652	44.05338	206.754
19	4	2.086866	4.35501	9.088322	8.347464	17.42004	36.35329
20	1	5.171763	26.74713	138.3298	5.171763	26.74713	138.3298
			SUMMATION		255.7858	1151.643	5315.525

WL COMBINATION TABLE FOR 60 ^{0} INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	y_i^2 x SM	SM	y_i^2 x SM x SM	y_e^2 x SM	SM	y_e^2 x SM x SM
0	1505.905	1	1505.905	1450.857	1	1450.857
15	1592.027	4	6368.109	1544.613	4	6178.453
30	2033.259	2	4066.518	1845.793	2	3691.586
45	2102.836	4	8411.344	1636.71	4	6546.842
60	1570.707	1	1570.707	1151.643	1	1151.643
	Summation		21922.58	Summation		19019.38

Angle of heel (α)	y_i^3 x SM + y_e^3 x SM	SM	(y_i^3 x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	(y_i^3 x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	1	15812.21	60	0.499998	7906.071
15	17142.26	4	68569.06	45	0.707105	48485.56
30	23560.54	2	47121.08	30	0.866025	40808.02
45	22109.03	4	88436.12	15	0.965926	85422.72
60	13367.51	1	13367.51	0	1	13367.51
			Summation			195989.9

Multiplier for moment	1/3 x (h/3) x (Θ/3)	0.025763
multiplier for volume	1/2 x (h/3) x (Θ/3)	0.038645
volume immersed wedge	vi=multiplier x ΣΣyi2 x SM x SM	847.1892
volume emmerged wedge	ve=multiplier x ΣΣye2 x SM x	734.9962
Volume of layer	vi-ve	112.193
Area of water plane	Awp= (Σyi SM +Σye SM) x h/3	498.2398
Center of floation	moment function/area function x	0.372462
Calculated moment	M0=Σ(yi3 x SM + ye3 x SM) x SM	5049.299
Layer correction	Lc=v x C.G. of waterplane	41.78764
Corrected moment	M=Mo-Lc	5007.511
Volume of displacement	Vo	1610
corrected volume	$V=V_0+v_i-v_e$	1722.193
BR	M/V	2.907637
BG x SinΘ	BG x SinΘ	1.342341
GZ	BR-BG SinΘ	1.565295

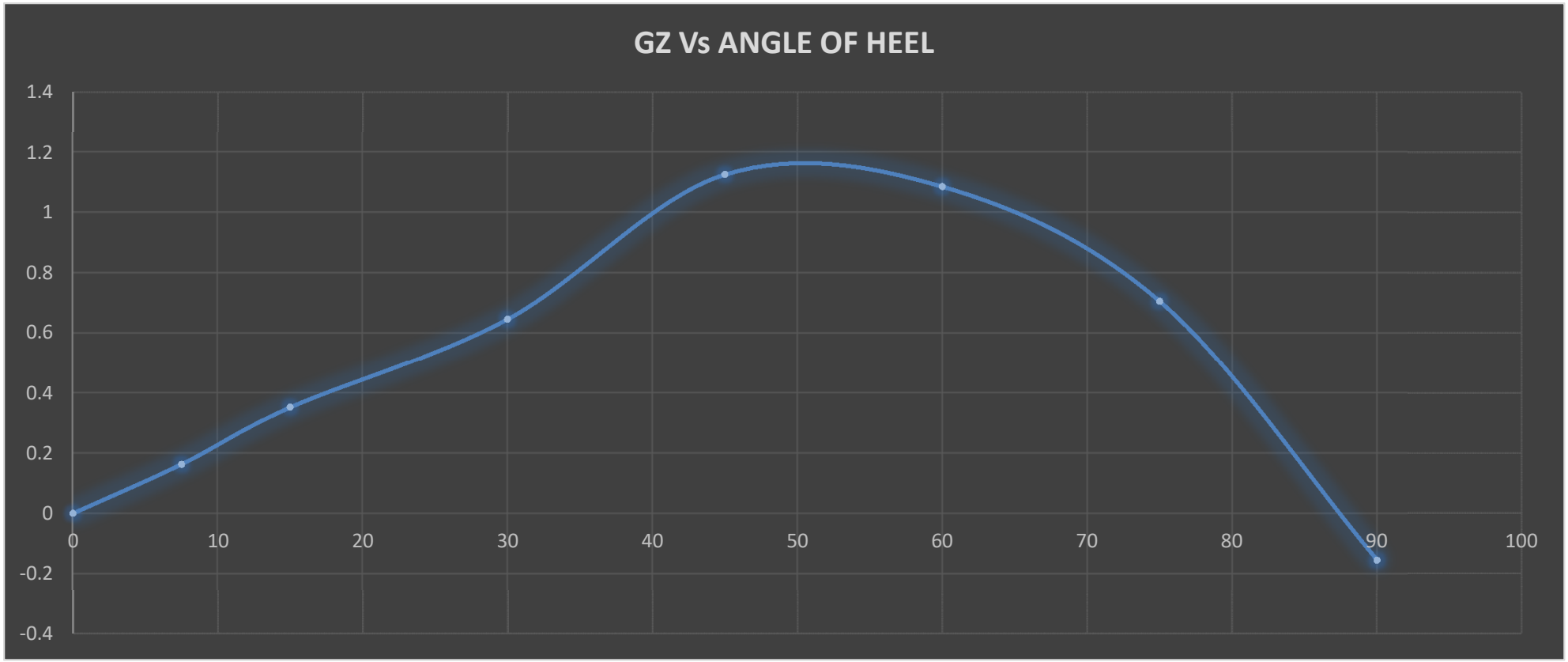
STABILITY CALCULATIONS BY BRANES METHOD							
GZ Calculations for WL 6 at 75 degree inclinations							
first time integration with respect to dx							
WL 6 ANGLE OF HEEL 75^0							
IMMERESED WEDGE							
sections	SM	y_i	y_i^2	y_i^3	y_i x SM	y_i^2 x SM	y_i^3 x SM
0	1	4.476028	20.03483	89.67645	4.476028	20.03483	89.67645
1	4	4.636855	21.50042	99.69435	18.54742	86.0017	398.7774
2	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
3	4	4.194498	17.59381	73.79722	16.77799	70.37525	295.1889
4	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
5	4	4.601853	21.17705	97.45368	18.40741	84.7082	389.8147
6	2	4.626331	21.40294	99.01708	9.252662	42.80588	198.0342
7	4	4.626331	21.40294	99.01708	18.50532	85.61175	396.0683
8	2	4.58943	21.06287	96.66656	9.17886	42.12574	193.3331
9	4	4.636855	21.50042	99.69435	18.54742	86.0017	398.7774
10	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
11	4	4.636855	21.50042	99.69435	18.54742	86.0017	398.7774
12	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
13	4	4.636855	21.50042	99.69435	18.54742	86.0017	398.7774
14	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
15	4	4.636876	21.50062	99.6957	18.5475	86.00248	398.7828
16	2	4.632084	21.4562	99.38693	9.264168	42.9124	198.7739
17	4	4.636876	21.50062	99.6957	18.5475	86.00248	398.7828
18	2	4.636855	21.50042	99.69435	9.27371	43.00085	199.3887
19	4	4.636855	21.50042	99.69435	18.54742	86.0017	398.7774
20	1	4.636876	21.50062	99.6957	4.636876	21.50062	99.6957
			SUMMATION		275.9737	1270.093	5848.37

WL 6 ANGLE OF HEEL 75^0							
EMMERGED WEDGE							
sections	SM	y_e	y_e^2	y_e^3	y_e x SM	y_e^2 x SM	y_e^3 x SM
0	1	0.86002	0.739634	0.6361	0.86002	0.739634	0.6361
1	4	2.760628	7.621067	21.03893	11.04251	30.48427	84.15572
2	2	3.985548	15.88459	63.30881	7.971096	31.76919	126.6176
3	4	4.539526	20.6073	93.54736	18.1581	82.42919	374.1894
4	2	5.45172	29.72125	162.0319	10.90344	59.4425	324.0639
5	4	4.242253	17.99671	76.3466	16.96901	71.98684	305.3864
6	2	4.213573	17.7542	74.80861	8.427146	35.50839	149.6172
7	4	4.213574	17.75421	74.80866	16.8543	71.01682	299.2346
8	2	4.213574	17.75421	74.80866	8.427148	35.50841	149.6173
9	4	4.213574	17.75421	74.80866	16.8543	71.01682	299.2346
10	2	4.213574	17.75421	74.80866	8.427148	35.50841	149.6173
11	4	4.213574	17.75421	74.80866	16.8543	71.01682	299.2346
12	2	4.213574	17.75421	74.80866	8.427148	35.50841	149.6173
13	4	4.213574	17.75421	74.80866	16.8543	71.01682	299.2346
14	2	4.213574	17.75421	74.80866	8.427148	35.50841	149.6173
15	4	4.213554	17.75404	74.80759	16.85422	71.01615	299.2304
16	2	4.218345	17.79443	75.06306	8.43669	35.58887	150.1261
17	4	4.213554	17.75404	74.80759	16.85422	71.01615	299.2304
18	2	4.213464	17.75328	74.8028	8.426928	35.50656	149.6056
19	4	3.04187	9.252973	28.14634	12.16748	37.01189	112.5854
20	1	4.636876	21.50062	99.6957	4.636876	21.50062	99.6957
			SUMMATION		242.8335	1010.101	4270.548

WL COMBINATION TABLE FOR 75 ^{0} INCLINATION						
second time integration with respect to dΘ						
Angle of heel (α)	y_i^2 x SM	SM	y_i^2 x SM x SM	y_e^2 x SM	SM	y_e^2 x SM x SM
0	1505.905	0.5	752.9524	1450.857	0.5	725.4285
7.5	1465.737	2	2931.474	1465.737	2	2931.474
15	1592.027	1.5	2388.041	1544.613	1.5	2316.92
30	2033.259	4	8133.035	1845.793	4	7383.173
45	2102.836	2	4205.672	1636.71	2	3273.421
60	1570.707	4	6282.828	1151.643	4	4606.573
75	1270.093	1	1270.093	1010.101	1	1010.101
Summation			25964.1	Summation		22247.09
Angle of heel (α)	y_i^3 x SM + y_e^3 x SM	SM	(y_i^3 x SM + y_e^3 x SM) x SM	(ϕ-α)	Cos(ϕ-α)	(y_i^3 x SM + y_e^3 x SM) x SM x Cos (ϕ-α)
0	15812.21	0.5	7906.105	75	0.258816	2046.227
7.5	15580.85	2	31161.7	67.5	0.382681	11924.99
15	17142.26	1.5	25713.4	60	0.499998	12856.64
30	23560.54	4	94242.16	45	0.707105	66639.15
45	22109.03	2	44218.06	30	0.866025	38293.94
60	13367.51	4	53470.06	15	0.965926	51648.1
75	10118.92	1	10118.92	0	1	10118.92
			Summation			193528

Multiplier for moment	1/3 x (h/3) x (Θ/3)	0.025763
multiplier for volume	1/2 x (h/3) x (Θ/3)	0.038645
volume immersed wedge	vi=multiplier x ΣΣyi2 x SM x SM	1003.372
volume emmerged wedge	ve=multiplier x ΣΣye2 x SM x	859.7296
Volume of layer	vi-ve	143.6422
Area of water plane	Awp= (Σyi SM +Σye SM) x h/3	459.4902
Center of floation	moment function/area function x	0.250567
Calculated moment	M0=Σ(yi3 x SM + ye3 x SM) x SM	4985.872
Layer correction	Lc=v x C.G. of waterplane	35.992
Corrected moment	M=Mo-Lc	4949.88
Volume of displacement	Vo	1610
corrected volume	$V=V_0+v_i-v_e$	1753.642
BR	M/V	2.822628
BG x SinΘ	BG x SinΘ	1.497186
GZ	BR-BG SinΘ	1.325442

GZ VS ANGLE OF HEEL GRAPH



IMO CRITERIA

No of criteria	IMO criteria	Minimum requirement	Collected data	Status
1	Area under GZ curve upto 30 degree	≥.055rad-m	0.275rad-m	Passed
2	Area under GZ curve from 30 to 40 degree	≥.03rad-m	0.1055rad-m	Passed
3	GZ at 30 degree	≥0.2-m	0.79m	Passed
4	Maximum GZ occurance	≥15 degree	52.5degree	Passed
5	Initial metacentric height	≥0.15 m	1.12m	Passed

EMERSED WEDGE

W6	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	0.566247	2.257734	3.559682	4.539526	5.45172	5.451102	5.537168	5.558739	5.602337	5.598496	5.598496	5.598496	5.598496	5.598496	5.598496	5.552541	5.452191	5.142537	4.254726	1.36315	0.100264
7.5	0.902361	2.588375	3.958402	4.539526	5.45172	5.001871	5.47272	5.524649	5.546513	5.546513	5.546513	5.546513	5.546513	5.546513	5.546513	5.547908	5.545445	5.517689	5.164788	1.397611	0.104682
15	0.757932	3.311848	3.515701	4.539526	5.45172	4.710546	5.688506	5.713625	5.743666	5.743666	5.743666	5.743666	5.743666	5.743666	5.743666	5.745269	5.742504	5.707776	5.198199	1.356931	0.121136
30	0.687164	4.391382	3.31903	4.539526	5.45172	4.591394	6.349238	6.360987	6.357735	6.357735	6.357735	6.357735	6.357735	6.357735	6.357735	6.35968	6.355987	6.292902	5.473236	1.427261	0.155233
45	0.664029	5.819817	3.350646	4.539526	5.45172	4.578057	5.707931	5.731692	5.73491	5.73491	5.73491	5.73491	5.73491	5.73491	5.73491	5.735022	5.741027	5.728888	5.420314	1.635453	0.234257
60	0.689591	2.185244	3.621665	4.539526	5.45172	4.486878	4.699609	4.699631	4.699631	4.699631	4.699631	4.699631	4.699631	4.699631	4.699631	4.699608	4.704952	4.699608	4.69326	2.086866	5.171763
75	0.86002	2.760628	3.985548	4.539526	5.45172	4.242253	4.213573	4.213574	4.213574	4.213574	4.213574	4.213574	4.213574	4.213574	4.213574	4.213554	4.218345	4.213554	4.213464	3.04187	4.636876
90		4.07	4.478858	4.539526	5.45172	4.103941	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.06998	4.074608	4.06998	4.07	4.07	

W5	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.5	0	1.725448	3.131926	4.237434	5.381351	5.380315	5.520542	5.551244	5.598496	5.597413	5.597413	5.597413	5.597413	5.597413	5.597413	5.546742	5.419341	5.065177	4.114847	1.22331	0
15	0	1.451102	3.549364	4.604953	5.223145	4.784205	5.446214	5.446214	5.525402	5.548931	5.548931	5.548931	5.548931	5.548931	5.548931	5.550433	5.547787	5.516892	5.097809	1.244419	0
30	0	1.91979	4.333068	5.185946	5.070196	4.401323	5.682778	5.682778	5.716872	5.737945	5.737945	5.737945	5.737945	5.737945	5.737945	5.739494	5.737037	5.70035	5.097055	1.211578	0
45	0	3.2134	5.458565	6.067978	4.950169	4.197427	6.348152	6.348152	6.365975	6.171076	6.171076	6.171076	6.171076	6.171076	6.171076	6.173612	6.178974	6.079319	5.161058	1.273383	0
60	0	5.509239	7.034736	7.273942	4.551297	4.032148	4.786009	4.786009	4.792033	4.792807	4.792807	4.792807	4.792807	4.792807	4.792807	4.79284	4.817042	4.791356	4.677229	1.457799	0
75	0	1.461632	5.955031	5.939149	3.945157	3.757408	3.91634	3.91634	3.91634	3.91634	3.91634	3.91634	3.91634	3.91634	3.91634	3.91634	3.936343	3.91634	3.915663	2.58923	0
90	0	1.987796	5.339135	5.324895	3.550442	3.477661	3.511294	3.511294	3.511295	3.511295	3.511295	3.511295	3.511295	3.511295	3.511295	3.511295	3.529228	3.511295	3.511176	3.319272	0

W4	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.5	0	1.248004	2.686813	3.886973	5.272936	5.271433	5.48678	5.527759	5.597413	5.591695	5.591695	5.591695	5.591695	5.591695	5.591695	5.536137	5.368982	4.964626	3.955069	1.106673	0
15	0	1.009327	3.088008	4.300537	4.869873	4.502094	5.401623	5.588299	5.523899	5.548451	5.548451	5.548451	5.548451	5.548451	5.548451	5.55	5.547322	5.514144	5.019598	1.122429	0
30	0	1.24756	3.888297	4.983469	4.38795	4.070682	5.669851	5.869589	5.719232	5.721979	5.721979	5.721979	5.721979	5.721979	5.721979	5.723444	5.720872	5.677457	4.943747	1.103184	0
45	0	1.941493	5.205986	5.975754	3.67036	3.765031	6.346432	6.570017	6.370563	5.33165	5.33165	5.33165	5.33165	5.33165	5.33165	5.332255	5.338671	5.305642	4.694836	1.164738	0
60	0	5.018508	6.983121	7.533803	2.856254	3.475699	7.777727	8.051568	7.7814	3.837116	3.837116	3.837116	3.837116	3.837116	3.837116	3.837118	3.843653	3.836665	3.811968	1.330893	0
75	0	1.170737	6.738299	6.738314	2.349805	3.102618	3.167246	3.082424	3.133072	3.133072	3.133072	3.133072	3.133072	3.133072	3.133072	3.133072	3.138416	3.132619	3.133078	1.651486	0
90	0	1.608315	6.041393	6.041402	2.106758	2.82178	2.839675	2.763626	2.809036	2.809036	2.809036	2.809036	2.809036	2.809036	2.809036	2.809036	2.813827	2.808498	2.808923	2.168952	0
	0	2.03499	2.71332	2.713436	2.03499	2.713312	2.742916	2.676463	2.71332	2.71332	2.71332	2.71332	2.71332	2.71332	2.71332	2.71332	2.717948	2.712734	2.71332	2.683874	0

EMERSED WEDGE

W3	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.5	0	0.872848	2.244079	3.49082	5.087814	5.084729	5.40301	5.415141	5.59182	5.576223	5.576223	5.576223	5.576223	5.576223	5.576223	5.507808	5.269282	4.807584	3.767942	0.986628	0
15	0	0.973018	2.606763	3.940818	5.082692	4.185284	5.327599	5.506769	5.686296	5.543918	5.543918	5.543918	5.543918	5.543918	5.543918	5.545437	5.542856	5.507868	4.916888	1.002395	0
30	0	1.24756	3.329192	4.703817	4.816835	3.673662	5.646219	5.844269	5.892753	5.654165	5.654165	5.654165	5.654165	5.654165	5.654165	5.656761	5.651905	5.56602	4.642922	0.983033	0
45	0	1.941493	4.785438	5.833405	4.440062	3.241075	6.342791	6.566332	6.566131	4.062148	4.062148	4.062148	4.062148	4.062148	4.062148	4.062212	4.071131	4.059383	3.880588	1.029163	0
60	0	5.018508	6.87735	7.507961	3.767085	2.763404	7.776747	8.050556	8.02139	2.877911	2.877911	2.877911	2.877911	2.877911	2.877911	2.877911	2.884456	2.877911	2.876389	1.147478	0
75	0	1.170737	7.521567	7.521567	3.172924	2.37773	2.415016	2.299156	2.415017	2.349804	2.349804	2.349804	2.349804	2.349804	2.349804	2.349804	2.355148	2.349804	2.349693	1.359842	0
90	0	1.608315	6.743652	6.743652	2.846571	2.120147	2.165244	2.061367	2.165245	2.106777	2.106777	2.106777	2.106777	2.106777	2.106777	2.106777	2.111568	2.106777	2.106682	1.688228	0

W2	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.5	0	0.612687	1.809388	2.983334	4.708174	4.702351	5.183287	4.43721	5.509979	5.509979	5.509979	5.509979	5.509979	5.509979	5.509979	5.381554	5.009723	4.480368	3.38673	0.831212	0
15	0	0.697591	2.125557	3.503663	4.871623	3.790997	5.17646	5.369971	5.672543	5.531384	5.531384	5.531384	5.531384	5.531384	5.531384	5.532807	5.530376	5.490695	4.748544	0.872243	0
30	0	0.804009	2.717123	4.328778	4.38795	3.13072	5.597873	5.802805	5.891946	4.969576	4.969576	4.969576	4.969576	4.969576	4.969576	4.970944	4.978904	4.914698	4.095556	0.835379	0
45	0	1.076875	4.115518	5.613491	3.67036	2.488492	6.332105	6.557911	6.569766	2.71332	2.71332	2.71332	2.71332	2.71332	2.71332	2.71332	2.722576	2.71332	2.702552	0.846444	0
60	0	2.629878	6.670654	7.452627	2.856254	1.962619	7.775495	8.049525	8.028233	1.918607	1.918607	1.918607	1.918607	1.918607	1.918607	1.918607	1.925152	1.918607	1.91852	0.905865	0
75	0	8.283295	8.304835	8.304835	2.349805	1.60834	1.566535	1.566535	1.566536	1.566536	1.566536	1.566536	1.566536	1.566536	1.566536	1.566536	1.57188	1.566536	1.566407	1.021956	0
90	0	1.163728	7.445911	7.445911	2.106758	1.417132	1.404517	1.404517	1.404518	1.404518	1.404518	1.404518	1.404518	1.404518	1.404518	1.404518	1.409309	1.404518	1.40445	1.17282	0

W1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.5	0	0.422312	1.3126	2.262448	3.768652	3.747374	4.233363	4.18752	4.376688	4.491321	4.491321	4.491321	4.491321	4.491321	4.491321	4.574429	4.140294	3.742828	2.748263	0.567242	0
15	0	0.479001	1.596266	2.859469	4.60761	3.103935	5.220716	5.206855	5.784155	5.480903	5.480903	5.480903	5.480903	5.480903	5.480903	5.483229	5.571821	5.399836	4.371933	1.098589	0
30	0	0.540603	2.10018	3.857713	3.829862	2.142327	5.517663	5.920455	6.076449	2.620851	2.620851	2.620851	2.620851	2.620851	2.620851	2.620852	2.638723	2.620792	2.583993	0.564684	0
45	0	0.673774	3.217834	5.27667	2.737634	1.416095	6.310414	6.752136	6.781596	1.356661	1.356661	1.356661	1.356661	1.356661	1.356661	1.356661	1.365917	1.35666	1.356467	0.539508	0
60	0	1.00187	6.277435	7.350172	1.998002	1.008701	7.773774	8.305542	8.289686	0.959304	0.959304	0.959304	0.959304	0.959304	0.959304	0.959304	0.965849	0.959304	0.959155	0.537554	0
75	0	8.151658	9.088103	9.088103	1.631728	0.802771	0.783268	0.783267	0.783268	0.783268	0.783268	0.783268	0.783268	0.783268	0.783268	0.783268	0.788612	0.783268	0.783187	0.555952	0
90	0	0.627487	8.14817	8.14817	1.462971	0.702257	0.702259	0.702258	0.702259	0.702259	0.702259	0.702259	0.702259	0.702259	0.702259	0.702259	0.70705	0.702259	0.702223	0.617592	0

IMMMERSED WEDGE

WL-3	ST	0	1	2	3	4	5	6	7	8	9				13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
			1.023713	2.762751	4.15714	5.405505	5.404571	5.526969	5.554626	5.598058	5.598234	5.598234	5.598234	5.598234	5.598234	5.598234	5.549062	5.431126	5.060551	4.06125	1.03569
			0.973018	2.606763	3.97553	4.333304	4.642763	5.476024	5.278901	5.353045	5.519146	5.519146	5.519146	5.519146	5.519146	5.519146	5.545438	5.542857	5.507868	4.916888	2.055312
			0.914013	2.267874	3.477108	5.015503	5.180142	5.452163	5.233575	5.455285	5.720308	5.720308	5.720308	5.720308	5.720308	5.720308	5.745941	5.743249	5.71181	5.27866	2.280135
			0.905155	2.125991	3.075864	6.003391	6.020379	4.157177	3.955329	4.164751	6.374569	6.374569	6.374569	6.374569	6.374569	6.374569	6.39591	6.393623	6.368741	6.074515	2.748119
			0.979386	2.095032	2.657019	7.559704	7.499753	2.957779	2.815881	2.95778	7.787853	7.787853	7.787853	7.787853	7.787853	7.787853	7.796249	7.79529	7.785563	7.706764	3.898149
			7.521567	2.088569	2.325355	6.696412	7.482936	7.440195	7.556292	7.384966	7.521567	7.521567	7.521567	7.521567	7.521567	7.521567	7.521567	7.516223	7.521567	7.521567	7.521567
			6.743652	2.059142	2.108449	6.003838	6.732685	6.673828	6.777967	6.635186	6.743652	6.743652	6.743652	6.743652	6.743652	6.743652	6.743652	6.738861	6.743652	6.743652	6.743652
			6.513868	6.513868	6.513868	5.799263	6.513868	6.449044	6.55224	6.42086	6.513868	6.513868	6.513868	6.513868	6.513868	6.513868	6.513868	6.50924	6.513868	6.513868	6.513868

WL-2	ST	0	1	2	3	4	5	6	7	8	9				13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
			0.674806	2.21753	3.727411	5.303255	5.301817	5.501071	5.53989	5.594546	5.594546	5.594546	5.594546	5.594546	5.594546	5.594546	5.540751	5.384963	4.95365	3.858723	0.893324
			0.697591	2.125557	3.538375	3.955809	4.302733	5.427829	5.234318	5.339293	5.505917	5.505917	5.505917	5.505917	5.505917	5.505917	5.532808	5.530376	5.490695	4.748544	1.838415
			0.661174	1.832215	2.904168	4.724015	4.975111	4.784607	4.680948	4.866494	5.719283	5.719283	5.719283	5.719283	5.719283	5.719283	5.746147	5.743375	5.709238	5.195026	2.08912
			0.675182	1.673093	2.326221	5.856031	5.901292	2.713281	2.712946	2.713305	6.377753	6.377753	6.377753	6.377753	6.377753	6.377753	6.402495	6.399865	6.37072	5.99538	2.544142
			0.743889	1.558247	1.861569	7.533449	7.423625	1.918606	1.918606	1.918607	7.794093	7.794093	7.794093	7.794093	7.794093	7.794093	7.807967	7.806438	7.790316	7.647447	3.507806
			0.896713	1.449645	1.565694	7.521567	8.266175	8.287933	8.288272	8.230105	8.304835	8.304835	8.304835	8.304835	8.304835	8.304835	8.304835	8.299491	8.304835	8.304835	8.304835
			7.445911	1.390615	1.406361	6.743652	7.434931	7.434246	7.434549	7.394519	7.445911	7.445911	7.445911	7.445911	7.445911	7.445911	7.445911	7.44112	7.445911	7.445911	7.445911
			7.192198	7.192198	7.192198	6.513868	7.192198	7.18385	7.186456	7.155666	7.192198	7.192198	7.192198	7.192198	7.192198	7.192198	7.192198	7.18757	7.192198	7.192198	7.192198

WL-1	ST	0	1	2	3	4	5	6	7	8	9				13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
		0	0.45782	1.677039	3.17189	5.130771	5.127758	5.443164	5.42321	5.583417	5.584026	5.584026	5.584026	5.584026	5.584026	5.584026	5.522185	5.304023	4.768306	3.540707	0.646622
		0	0.479002	1.596266	2.89418	3.560511	3.791226	5.470051	4.890332	5.087388	5.435771	5.435771	5.435771	5.435771	5.435771	5.435771	5.483229	5.571821	5.399837	4.371934	1.460145
		0	0.457567	1.291996	1.981485	4.384531	4.782401	2.620213	2.61519	2.619452	5.714981	5.714981	5.714981	5.714981	5.714981	5.714981	5.742395	5.73968	5.703736	5.082778	1.80603
		0	0.466045	1.032703	1.318502	5.659515	5.832422	1.356659	1.356659	1.35666	6.379762	6.379762	6.379762	6.379762	6.379762	6.379762	6.407269	6.404369	6.371239	5.914902	2.309138
		0	0.5007	0.864918	0.960225	7.485197	7.42877	0.959303	0.959303	0.959304	7.799936	7.799936	7.799936	7.799936	7.799936	7.799936	7.819059	7.816986	7.794751	7.565589	3.222777
		0	0.553927	0.764304	0.785377	8.239622	9.070653	9.070515	9.071172	9.011719	9.088103	9.088103	9.088103	9.088103	9.088103	9.088103	9.088103	9.082759	9.088103	9.088103	9.088103
		0	8.14817	0.701508	0.703342	7.387443	8.14817	8.136219	8.136808	8.096778	8.14817	8.14817	8.14817	8.14817	8.14817	8.14817	8.14817	8.143379	8.14817	8.14817	8.14817
		0	7.870528	7.870528	7.870528	7.135722	7.870645	7.86218	7.871131	7.835241	7.870528	7.870528	7.870528	7.870528	7.870528	7.870528	7.870528	7.8659	7.870528	7.870528	7.870528

IMMMERSED WEDGE

WL-6	ST	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
	7.5	0.744144	2.849958	4.197076	4.996588	5.5249	5.524727	5.548723	5.561947	5.586354	5.590048	5.590048	5.590048	5.590048	5.590048	5.590048	5.556837	5.502852	5.275949	4.494714	1.465112
	15	0.905876	2.588375	3.958402	4.851324	4.851323	5.163574	5.502639	5.502639	5.524649	5.524649	5.524649	5.524649	5.524649	5.524649	5.524649	5.547909	5.545447	5.51769	5.164787	2.59585
	30	1.193685	2.185344	4.65289	4.556803	5.338647	5.46553	5.683215	5.683215	5.718122	5.713625	5.713625	5.713625	5.713625	5.713625	5.713625	5.73119	5.729297	5.708874	5.487294	2.924451
	45	1.802371	2.002263	5.611851	4.444453	6.140444	6.158992	6.188919	6.188919	6.320676	6.360987	6.360987	6.360987	6.360987	6.360987	6.360987	6.36984	6.368847	6.358582	6.2754	3.815714
	60	3.119569	1.995625	6.334062	4.448089	6.334062	6.257811	6.312675	6.312675	6.238056	6.334062	6.334062	6.334062	6.334062	6.334062	6.334062	6.33409	6.327545	6.33409	6.334062	6.334062
	75	5.165241	5.17174	5.17174	4.397548	5.17174	5.120474	5.157581	5.157581	5.108038	5.17174	5.17174	5.17174	5.17174	5.17174	5.17174	5.171763	5.166419	5.171763	5.17174	5.17174
		4.476028	4.636855	4.636855	4.194498	4.636855	4.601853	4.626331	4.626331	4.58943	4.636855	4.636855	4.636855	4.636855	4.636855	4.636855	4.636876	4.632084	4.636876	4.636855	4.636855
			4.478858	4.07	4.478892	4.478858	4.445178	4.47051	4.47051	4.441185	4.478858	4.478858	4.478858	4.478858	4.478858	4.478858	4.478878	4.47425	4.478878	4.478858	4.478858

WL-5	ST	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
			2.227795	3.79953	4.792467	5.503701	5.503374	5.546087	5.562003	5.590048	5.595052	5.595052	5.595052	5.595052	5.595052	5.595052	5.556414	5.485447	5.209513	4.345777	1.287377
			1.451102	3.549365	4.639665	4.629787	5.024001	5.499665	5.499665	5.525402	5.525402	5.525402	5.525402	5.525402	5.525402	5.525402	5.550434	5.547788	5.516893	5.09781	2.434103
			1.266183	3.105656	4.268115	5.210801	5.394707	5.662794	5.662794	5.712506	5.716872	5.716872	5.716872	5.716872	5.716872	5.716872	5.737698	5.735368	5.711102	5.41884	2.710496
			1.213172	2.923515	4.089337	6.091469	6.132629	5.933702	5.933702	6.121052	6.365975	6.365975	6.365975	6.365975	6.365975	6.365975	6.379261	6.377644	6.362374	6.222633	3.380317
			1.26371	2.952546	3.963388	7.239895	7.278103	7.270553	7.270553	7.190861	7.293393	7.293393	7.293393	7.293393	7.293393	7.293393	7.293393	7.268896	7.293393	7.293393	5.781739
			6.738299	3.156375	3.752613	5.91135	5.965977	5.940186	5.940186	5.888244	5.955031	5.955031	5.955031	5.955031	5.955031	5.955031	5.955031	5.935028	5.955031	5.955031	6.067328
			6.041393	3.354098	3.521554	5.299971	5.372579	5.328325	5.328325	5.290423	5.339135	5.339135	5.339135	5.339135	5.339135	5.339135	5.339135	5.321201	5.339135	5.339135	5.447683
			5.835538	5.157208	5.143454	5.119379	5.200076	5.14886	5.14886	5.119535	5.157208	5.157208	5.157208	5.157208	5.157208	5.157208	5.157208	5.139885	5.157208	5.157208	5.25476

WL-4	ST	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer	immer
			1.549908	3.3063	4.514912	5.46716	5.466626	5.540046	5.560124	5.595052	5.598082	5.598082	5.598082	5.598082	5.598082	5.598082	5.553975	5.462371	5.14104	4.202499	1.157879
			1.009327	3.088008	4.335176	3.958174	4.887925	5.492288	5.297444	5.523899	5.523899	5.523899	5.523899	5.523899	5.523899	5.523899	5.550001	5.547323	5.513928	5.019599	2.223132
			0.914013	2.686225	3.909796	4.724015	5.329521	5.610411	5.407025	5.694963	5.719232	5.719232	5.719232	5.719232	5.719232	5.719232	5.742839	5.740338	5.712323	5.349774	2.449488
			0.905155	2.529808	3.624353	5.856031	6.111184	5.274938	5.105594	5.317896	6.370563	6.370563	6.370563	6.370563	6.370563	6.370563	6.388049	6.386158	6.366037	6.152427	2.972985
			0.979386	2.541413	3.372283	7.533449	7.571252	3.878092	3.773437	3.837059	7.7814	7.7814	7.7814	7.7814	7.7814	7.7814	7.784192	7.78382	7.780976	7.755528	4.572646
			7.521567	2.660952	3.04575	7.521567	6.699703	6.688624	6.77371	6.668427	6.738299	6.738299	6.738299	6.738299	6.738299	6.738299	6.738299	6.732955	6.738752	6.738299	6.738299
			6.743652	2.711879	2.809117	6.743652	6.030441	5.999672	6.075993	5.991395	6.041393	6.041393	6.041393	6.041393	6.041393	6.041393	6.041393	6.036602	6.041931	6.041393	6.041393
			6.513868	5.835538	5.835538	6.513868	5.835538	5.797595	5.87424	5.797865	5.835538	5.835538	5.835538	5.835538	5.835538	5.835538	5.835538	5.83091	5.836124	5.835538	5.835538

TRIM CALCULATION

Displacement	1630	tonne
LOA	53.26	m
Draft	4.05	m
LCG	0.974	m(aft)
LCB	-0.867	m(aft)
MCT 1m	4532.8	tonne - m
LCF	0.046	m
Trim	0.662025679	m
Aft Trim	0.330441056	m
Fore Trim	0.219235458	m
Aft Draft	3.580441056	m
Fore draft	3.53076452	m

TRIM=(LCG-LCB)*Δ /MCT 1m		
Change in Draft Aft=(L/2-CF)*Trim/L		
Final Draft Aft=Draft+Change in Draft Aft		
Final Draft Forward=Draft-Change in Draft Aft		

So the ship is trimmed by stern

RESISTANCE AND POWER CALCULATION

Approximate Calculation of Ship's Resistance

Holtrop & Mennen's Method

Parameters	Value	Unit
Waterline Length, L_{WL}	53.26	m
Length Between Perpendicular, L_{BP}	50.13	m
Breadth moulded, B	10.78	m
Draft moulded, T	3.63	m
Block Coefficient, C_b	0.82	
Ship Speed, V	9	knots
Prismatic Coefficient, C_p	0.854	
Midship Coefficient, C_m	0.96	
Density of water, ρ	1	tons/m^3
Volume of displacement, ∇	1706.41	m^3
Displacement, Δ	1706.410	tonnes
Water plane Co-efficient, C_{wp}	0.78	
Longitudinal Center of Buoyancy, L.C.B.	1.31	m (fore,mid)
L.C.B as a % of L_{WL}	2.459632	% of L_{WL}
Transverse sectional area of BULB, A_{BT}	0	m^2
Immersed Transom area, A_T	0	m^2
Dynamic Viscosity , μ	1.22E-03	m^2/s
Propeller Dia, D	2.178	m
Pitch ratio, P/D	0.58	

Parameter	Symbol		Values	Unit	Note	Values
1. Frictional resistance	R_F	$0.5\ \rho\ V^2\ S\ C_F$	15.583833	KN		
Frictional resist. coef.	C_F	$0.075 / (\text{Log}_{10}R_e - 2)^2$	0.0018859			
Reynold's No.	R_E	ρVL /μ	2.02E+08			
Form factor of the hull	$1+k_1$	$c_{13}\{0.93 + c_{12}\,(B/L_R)^{0.92497}\,(0.95\text{-}C_P)^{-0.521448}\,(1\text{-}CP+0.0225lcb)^{0.6906}\}$	1.2243127			
Length of the run	L_R	$L\ \{1 - C_P + 0.06\ C_P\ lcb\ (4C_P\text{-}1)\}$	23.991979			
	C_{12}	$(T/L)^{0.2228446}$, if T/L > 0.05; $48.20\ (T/L\text{-}0.02)^{2.078} + 0.479948$, if 0.02<T/L<0.05; 0.479948, if T/L<0.02	0.5496079		T/L=	0.068156
	C_{13}	1+0.003 Cstern	1		Cstern=	0
Wetted area of the hull	S	$L\ (2T+B)\ \sqrt{C_M}(0.453 + 0.4425C_B - 0.2862\ C_M - 0.003467\ B/T + 0.3696\ C_{WP}) + 2.38\ A_{BT}/C_B$	771.08982		A_{BT}	0

2. Appendage Resistance	R_{APP}	$0.5\ \rho\ V^2\ S_{APP}\ (1+k_2)_{eq}\ C_F$	0.467515	KN	S_{APP}	15.4218
Appendage resist. factor	$1+k_2$		1.5			
3. Wave Resistance	R_W	$c_1 c_2 c_5\ \nabla\ \rho\ g\ \exp\{m_1 F_n^{\ d} + m_2 \cos(\lambda F_n^{\ -2}\}$	10.84007	KN	F_n	0.202539
	c_1	$2223105\ c_7^{\ 3.78613} (T/B)^{1.07961} (90-i_E)^{-1.37656}$	10.281422		T/B	0.336735
	c_7	$0.229577(B/L)^{0.33333}$, if B/L<0.11; B/L , if 0.11<B/L<0.25; 0.5-0.0625 L/B, if B/L>0.25	0.2024033		B/L	0.202403
	c_2	$\exp(-1.89\sqrt{c_{3)}}$	1			
	c_5	$1-0.8\ A_T/(BTC_M)$	1			
	λ	$1.446C_p$-0.03 L/B, if L/B < 12; $1.446C_p$-0.36, if L/B>12	1.0869061		L/B	4.940631
	m_1	$0.0140407\ L/T - 1.75254\ \nabla^{1/3}/L - 4.79323B/L - c_{16}$	-2.2929842		L/T	14.67218
	c_{16}	$8.07981C_p - 13.8673C_p^{\ 2} + 6.984388C_P^{\ 3}$, if Cp<0.8; $1.73014 - 0.7067C_p$, if CP > 0.8	1.1365874		C_P	0.854
	m_2	$c_{15}C_p^{\ 2}\ \exp(-0.1Fn^{-2})$	-0.1079626			
	c_{15}	-1.69385 for L^3/∇<512; 0 for L^3/∇>1727; $-1.69385+(L^3/\nabla-8.0)/2.36$ if $512<L^3/\nabla<1727$	-1.69385		L^3/∇	88.53604
	d		-0.9			
Half angle of entrance	i_E		50.5			
	c_3	$0.56\ A_{BT}^{\ 1.5} / \{B\ T\ (0.31\sqrt{A_{BT}} + T_F - h_B)\}$	0		h_B	0
4. Additional pressure resistance due to bulbous bow	R_B	$0.11\ \exp(-3P_B^{\ -2})\ F_{ni}^{\ 3}\ A_{BT}\ 1.5\ \rho g/(1+F_{ni}^{\ 2})$	0	KN	A_{BT}	0
	P_B	$0.56\ \sqrt{A_{BT}} / (T_F - 1.5h_B)$	0			
	F_{ni}	$V / \sqrt{\{ g\ (T_F - h_B - 0.25\sqrt{A_{BT}}) + 0.15\ V^2 \}}$	0.7429955			
5. Additional pressure resistance of immersed transom stern	R_{TR}	$.5\ \rho\ V^2\ A_T\ c_6$	0	KN	A_T	0
	c_6	$0.2\ (1-0.2F_{nT})$, if F_{nT}<5; 0, if $F_{nT} \geq 5$	0.2			
	F_{nT}	$V / \sqrt{\{ 2g\ A_T / (B+BC_{WP}) \}}$	0			
6. Model-ship correlation resistance	R_A	$0.5\ \rho\ V^2\ S\ C_A$	5.3543175	KN		
	C_A	$0.006\ (L+100)^{-0.16} - 0.00205 + 0.003\ \sqrt{(L/7.5)}\ C_B^{\ 4} c_2\ (0.04-c_4)$	0.0006321			
	c_4	T_F/L, when $T_F/L \leq 0.04$; 0.04,when T_F/L>0.04	0.04		T_F/L	0.068156
		Rw	4.488		Wind Resistance	
Total resistance	R_T =	$R_F(1+k_1) + R_{APP} + R_w + R_B + R_{TR} + R_A$	40.229388	KN		
Effective Power	P_E	$R_T * V$	186.24598	KW		
			249.56961	HP		
Wake fraction	w	$0.395\ C_B + 10\ C_V C_B - 0.23\ D/\sqrt{(BT)}$	0.2679368		C_V	0.002941
Thrust deduction factor	t	$0.325\ C_B - 0.1885\ D/\sqrt{(BT)}$	0.2008694			
Relative rotative effic.	η_R	$0.9737 + 0.111(C_p - 0.0225\ lcb) - 0.06325P/D$	1.0256846			
Hull efficiency	ηH	$(1-t)/(1-w)$	1.0916142			
Shaft efficiency	η_s		0.95		1-w	0.732063
Open water efficiency	η_o		0.51		1- t	0.799131
QPC		$\eta H \times \eta O \times \eta S$	0.5288871			
	P_S		343.32871	KW		
			460.22615	HP		
Gear efficiency	η_g		0.94			
Break Power	P_B		365.2433	KW		
			489.42603	HP		

Approximate Calculation of Ship's Resistance Holtrop & Mennen's method			
Ship Speed, V	9	knots	
Parameter	**Symbol**	**Values**	**Unit**
1. Frictional resistance	RF	15.58383303	KN
2. Appendage Resistance	RAPP	0.467514991	KN
3. Wave Resistance	RW	10.8400703	KN
4. Additional pressure resistance due to bulbous bow	RB	0	KN
5. Additional pressure resistance of immersed transom stern	RTR	0	KN
6. Model-ship correlation resistance	RA	5.354317528	KN
Total resistance	RT =	40.22938826	KN
		249.5696077	HP
Effective Power	PE	186.2459759	KW
		249.5696077	HP
0	PS	343.3287064	KW
Break Power	PB	365.2433047	KW
		489.4260283	HP

RUDDER AND STEERING ARRANGEMENT

RUDDER CALCULATION

PRINCIPAL PARTICULARS:

Length of ship $L = 50.13\ m$

Breadth of ship $B = 10.78\ m$

Draft $T = 3.63\ m$

Depth $H = 4.07\ m$

Block coefficient $C_B = 0.82$

Speed of the ship V= 9 knot

Nominal upper yield strength of forged steel $R_{eH} = 280\ N/mm^2$

Material factor $k_R = \left(\frac{235}{R_{eH}}\right)^{0.75}$ in case of $R_{eH} \geq 235\ N/mm^2$

$$= \left(\frac{235}{280}\right)^{0.75}$$

$$= \mathbf{0.88}$$

RUDDER AREA:

- According to Germanischer Lloyd the size of movable rudder area is recommended to be not less than,

$$A = c_1 \times c_2 \times c_3 \times c_4 \times \frac{1.75 \times LT}{100}$$

Where,

c_1 = Factor for the ship type = 1.0 (in general)

c_2 = Factor for the rudder type = 1.0 (in general)

c_3 = Factor for the rudder profile = 1.0 (for NACA profile and plate rudder)

c_4 = Factor for the rudder arrangement = 1.0 (for rudders in the propeller jet)

So we have,

$$A = c_1 \times c_2 \times c_3 \times c_4 \times \frac{1.75 \times LT}{100}$$

$$= 1.0 \times 1.0 \times 1.0 \times 1..0 \times \frac{1.75 \times 50.13 \times 3.63}{100}$$

$$= 3.311\ m^2$$

So we take the rudder area as $3.311m^2$

Aspect ratio:

Aspect ratio $\mathbf{a} = \frac{\textbf{Mean height of rudder b}}{\textbf{Mean breadth of rudder c}}$ =1.6

Let, Aspect ratio, a = h^2/A_t =1.6

Where

Rudder area A=3.311 m^2

Mean height of rudder h=2.323 m

Mean Breadth of rudder b= 1.455 m

RUDDER FORCE & TORQUE:

- From the Germanischer Lloyd the rudder force is to be determined form the following formula,

$$C_R = 132 \times Av^2 \times \kappa_1 \times \kappa_2 \times \kappa_3 \times \kappa_t$$

Where,

C_R = Normal force acting on rudder

κ_1 = Coefficient depending on the aspect ratio

$= \frac{1.6+2}{3}$

$= 1.2$

κ_2 = Coefficient depending on the type of the rudder and rudder profile

$= 1.1$ (For NACA profile and ahead condition)

=1.4 for astern condition

κ_3 = Coefficient depending on the location of the rudder

$= 1.0$ (For rudders including those within the propeller jet)

κ_4 = Coefficient depending on the thrust coefficient

$= 1.0$ (Normally)

v = Ship speed (kn) = 9 kn for ahead condition

= 7 kn for astern condition

A = Movable rudder area

So we have,

$$C_R = 132 \times Av^2 \times \kappa_1 \times \kappa_2 \times \kappa_3 \times \kappa_t$$

$$= 132 \times 3.31 \times (9)^2 \times 1.2 \times 1.1 \times 1.0 \times 1.0$$

$= 46715\ N$ (ahead)

$$C_R = 132 \times Av^2 \times \kappa_1 \times \kappa_2 \times \kappa_3 \times \kappa_t$$

$$= 132 \times 3.7 \times (7)^2 \times 1.2 \times 1.4 \times 1.0 \times 1.0$$

$= 28260\ N$ (astern)

The distance of centre of pressure from the turning axis is given by,

$$r = b(\alpha - k_b)$$

Where,

$\alpha = 0.33$ (For ahead condition) and

= 0.66 (for astern condition)

k_b = Balance factor

$= A_f/A = 0.25$

$b =$ Mean breadth of rudder

So we have,

Ahead condition $r = b(\alpha - k_b)$

$= 1.57(0.33 - 0.25)$

$= 0.1256\, m$

but, $r_{min} = (0.1 \times b)$ for ahead condition.

so, $r = 0.1 \times 1.57 = 0.157m$

So we take r as 0.157m for ahead condition

Astern condition $r = b(\alpha - k_b)$

$= 1.57(0.66 - 0.25)$

$= 0.6437\, m$

The torque on rudder is to be determined by using this formula,

$$Q_R = C_R \times r$$

$$= 46715 \times 0.1256$$

$$= \mathbf{5868}\ Nm \text{ (ahead)}$$

$$Q_R = C_R \times r$$

$$= 28260 \times 0.6437$$

$$= \mathbf{18190}\ Nm \text{ (astern)}$$

The load on rudder is to be calculated by,

$$p_R = \frac{C_R}{10^3 \times h}$$

$$= \frac{18190}{10^3 \times 5.1}$$

$$= \mathbf{5.072}\ kN/m^2$$

RUDDER STOCK:

- According to Germanischer Lloyd the diameter of rudder stock for transmitting the rudder torque is not to be less than,

$$D_t = 4.2 \times \sqrt[3]{Q_R \times k_R}$$

Where,

$k_R =$ Material factor for rudder

$= 0.88$

So we have,

$$D_t = 4.2 \times \sqrt[3]{Q_R \times k_R}$$

$$= 4.2 \times \sqrt[3]{18190 \times .88}$$

$$= 105.84\ mm$$

We take diameter of the rudder stock as $D_t = 110\ mm$

RUDDER COUPLINGS:

- The diameter of horizontal coupling bolts is not to be less than,

$$d_b = 0.62 \times \sqrt{\frac{D^3 \times k_b}{k_R \times n \times e}}$$

Where,

$D =$ Rudder stock diameter

$n =$ Total number of bolts

$= 6$

k_R = Material factor for rudder

$= 0.88$

k_b = Material factor for bolt

$= k_R$

$= 1$

e = Mean distance of the bolt axis form the centre of bolt system

= Rudder stock radius + distance of bolt axis from outer surface of rudder stock

$= (61 + 150)$

$= 211\ mm$

So we have,

$$d_b = 0.62 \times \sqrt{\frac{D^3 \times k_b}{k_R \times n \times e}}$$

$$= 0.62 \times \sqrt{\frac{(110)^3 \times 1}{1 \times 6 \times 211}}$$

$$= 20.103\ mm$$

So we take the diameter of horizontal coupling bolts as $d_b = 21\ mm$

- ♣ The thickness of coupling flanges is not to be less than, $0.9d_b$

So we take the thickness of coupling flanges as $t_f = \mathbf{20}\ mm$

RUDDER FRAMES:

- According to NKK rules for construction of ships, the standard spacing of horizontal rudder frames is to be obtained from the following formula,

$$a_h = 0.2 \times \frac{L}{100} + 0.4$$

$$= 0.2 \times \frac{50.13}{100} + 0.4$$

$$= 0.5022\ m$$

$$= 502\ mm$$

So we take the spacing of horizontal rudder frames $a_h = \mathbf{505}\ mm$

- The standard distance from the vertical rudder frame forming the rudder main piece to the adjacent vertical frame is to be obtained by,

$$a_v = 1.5 \times a_h$$

$$= 1.5 \times 505$$

$$= 757mm$$

So, we take the spacing of horizontal rudder frames $a_v = \mathbf{760}\ mm$

RUDDER PLATES & WEB:

- According to Germanischer Lloyd, the thickness of rudder plating is to determined from the following formula,

$$t_p = 1.74 \times a \times \sqrt{p_R \times k} + 2.5$$

Where,

$a =$ Smaller unsupported width of a plate panel

$= 1\ m$

$p_R = 10T + \frac{C_R}{10^3 \times A}$

$= 10 \times 3.63 + \frac{46715}{1000 \times 3.311}$

$= 17.71\ kN/m^2$

$k =$ Material factor $= \mathbf{1}$

So we have,

$$t_p = 1.74 \times a \times \sqrt{p_R \times k} + 2.5$$

$$= 1.74 \times 1 \times \sqrt{17.81 \times 1} + 2.5$$

$$= 9.48\ mm$$

Hence we take the thickness of rudder plating as $t_p = \mathbf{10}\ mm$

- ♣ The thickness of the webs is not to be less than,

$$t_w = 0.7 \times t_p$$

$$= 0.7 \times 10$$

$$= 7\ mm$$

So, we take thickness of webs as $t_w = \mathbf{7}\ mm$

PINTLE:

We take, d = 110 mm

The diameter of pintle is not to be less than,

$$d_p = 0.35 \times \sqrt{B_1 \times k_R}$$

Where,

$B_1 =$ Support reaction at the pintle

$= C_R \times b/c$

$= 46715 \times 1.6 = 74744\ N$

$k_R =$ Material factor

$= 1$

So we have,

$$d_p = 0.35 \times \sqrt{B_1 \times k_R}$$

$$= 0.35 \times \sqrt{74744 \times 1}$$

$$= 95.687\ mm$$

we take pintle diameter as $\boldsymbol{d_p = 100}\ mm$

BEARING:

In way of bearings liners and bushes are to be fitted. Their minimum thickness is given as,

$$\boldsymbol{t_{min} = 22}\ mm \quad \text{(for lignum materials)}$$

So we take thickness of liner, $\boldsymbol{t_l = 22\ mm}$

Thickness of bush not be less than,

$$d = 0.01\sqrt{B_1}$$

$where,\ B_1 = C_R \times \frac{b}{c}$

$= 74744$ N

And, $d = 0.01\sqrt{B_1}$

$= .01 \times \sqrt{74744}$

$= 2.733\ mm$

d = 3 mm

The projected bearing surface at the neck bearing,

$$\mathrm{A_b} = \frac{\mathrm{B}}{\mathrm{q}}$$

Where,

B= Support reaction at neck bearing and carrier bearing = $C_R - B_1$

$= 46715 - 74744$ N

= -28029 N

q = Permissible surface pressure

$= 2.5\ N/mm^2$ (For lignum vitae)

So we have,

$$A_b = \frac{B}{q} = \frac{28029}{2.5} = 11212\ mm^2$$

Again,

$\boldsymbol{A_b = bearing\ height \times external\ diameter\ of\ liner}$

External diameter of liner, $= (51 + 44)\ mm$

$= 95\ mm$

So we have, Bearing height,

$$h_b = \frac{11212}{95}$$

$$= 118.021\ mm$$

So we take bearing height as, $\boldsymbol{h_b = 120\ mm}$

Spacing of Rudder Frame: (According to NKK rule)

Horizontal Spacing:

=0.2(L/100) +0.4

=0.2(50.13/100) +0.4 = 0.5022m = 502 mm

Vertical Spacing:

= Horizontal Spacing x 1.5

= 0.753 m

= 760 mm

Sleeve:

Thickness = 8 mm , for metallic sleeve

Steering Arrangement:

From NKK Rulebook, sectional Area of the tiller

$$A_t = 0.4 \times {d_u}^2$$

Here,

d_u = Diameter of the upper stock in cm

= **7.6 cm**

So we have,

$$A_t = 0.4 \times {d_u}^2$$

$$= 0.4 \times 7.6^2$$

$$= 23.104$$

If diameter of the tiller is d then,

$$d = \sqrt{\frac{A_t \times 4}{\pi}}$$

$$= \sqrt{\frac{23.104 \times 4}{\pi}}$$

$$= 5.4237\ cm$$

$$= 54.237 mm$$

So we take diameter of tiller as $d = 55\ mm$

Diameter of the link chain

$$d_c = 0.38\sqrt{\frac{{d_u}^3}{R}}$$

Where,

d_u = Diameter of the upper stock in mm =76 mm

R = Length of the chain in mm = B⁄2 = 5500 mm

So, we have,

$$d_c = 0.38\sqrt{\frac{{d_u}^3}{R}}$$

$$= 0.38\sqrt{\frac{76^3}{5500}}$$

$$= 3.394mm$$

So, diameter of link chain $\boldsymbol{d_c = 4\ mm}$

Diameter of the steering rod,

$$d_s = 1.25 \times d_c$$

$$= 1.25 \times 4$$

$$= 5\ mm$$

So we take diameter of steering rod $\boldsymbol{d_s = 5\ m}$

Various rudder components and their corresponding dimensions

Items	Dimensions	Material
Rudder stock	Diameter 110 mm	Forged steel
Coupling bolts	Diameter 20 mm	Forged steel
Coupling flanges	Thickness 20 mm	Forged steel
Horizontal web	Spacing 502 mm	Forged steel
Vertical web	Spacing 760 mm	Forged steel
Web plate	Thickness 7 mm	Forged steel
Rudder plate	Thickness 7 mm	Forged steel
Pintle	Diameter 100 mm	Forged steel
Liner	Thickness 22 mm	Bronze
Neck bearing	Height 95 mm	Forged steel
Carrier bearing	Height 95 mm	Forged steel
Tiller	Diameter 55 mm	Forged steel
Link chain	Diameter 4 mm	Forged steel
Steering rod	Diameter 5 mm	Forged steel
Bush	Thickness 2 mm	Lignum vitae

Principle Particulars:

Length of ship, L=50.13 m

Breadth of ship, B=10.78 m

Draft $T = 3.63\ m$

Block coefficient $C_B = 0.82$

Ship Speed $V = 9$ Knots

Displacement Δ = 1612 tonnes

Calculation for Steering Gear:

Rudder Torque= = **18190 N-m**

From NKK Rulebook, sectional Area of the tiller

$$A_t = 0.4 \times {d_u}^2$$

Here,

d_u = Diameter of the upper stock in cm

= 7.6 cm

So we have,

$$A_t = 0.4 \times {d_u}^2$$

$$= 0.4 \times 7.6\text{^}2$$

$$= 23.104\ \text{cm}^2$$

If diameter of the tiller is d then,

$$d = \sqrt{\frac{A_t \times 4}{\pi}}$$

$$= \sqrt{\frac{23.104 \times 4}{\pi}}$$

$$= \mathbf{5.4237\ cm}$$

$$= \mathbf{54.237 mm}$$

So we take diameter of tiller as $\boldsymbol{d = 55\ mm}$

Diameter of the link chain

$$d_c = 0.38\sqrt{\frac{{d_u}^3}{R}}$$

Where,

d_u = Diameter of the upper stock in mm =76 mm

R = Length of the chain in mm = B⁄2 = 5500mm

So, we have,

$$d_c = 0.38\sqrt{\frac{{d_u}^3}{R}}$$

$$= 0.38\sqrt{\frac{76^3}{5500}}$$

$$= 3.394mm$$

So, diameter of link chain $\boldsymbol{d_c = 4\ mm}$

Diameter of the steering rod,

$$d_s = 1.25 \times d_c$$

$$= 1.25 \times 4$$

$$= 5\ mm$$

So we take diameter of steering rod $\boldsymbol{d_s = 5\ mm}$

Selected Steering Gear: MS25-35

Maker: Hydrostar

Piston type steering gear
with constant delivery pumps

working torques

6,3 ÷ 320 kNm

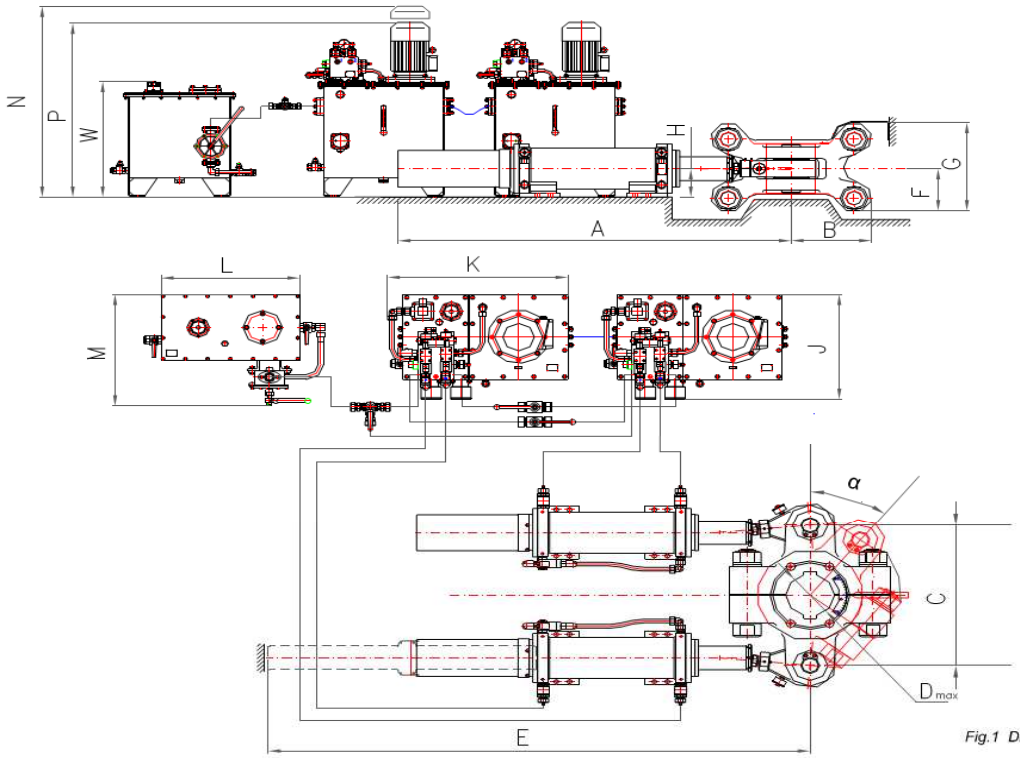


Fig.1 Dimensional sketch.

Type	Dimensions [mm]														
	A	B	C	D_{max}	E	F	G	H	J	K	L	M	N	P	W
MS 25-35	1048	160	600	140	1600	75	150	80	400	830	750	520	990	1080	500
MS 32-35	1133	228	700	170	1600	140	280	97	400	830	750	520	990	1080	680
MS 50-35	1283	298	800	220	1800	183	366	109	400	830	750	520	1045	1150	680
MS 80-35	1590	333	950	250	2200	198	396	125	660	385	840	610	1050	1150	700
MS 125-35	1744	374	1100	290	2450	215	430	150	475	750	840	610	1110	1200	1000
MS 200-35	2025	435	1250	340	2800	256	512	170	475	750	1230	680	1392	1510	840
MS 320-35	2462	500	1575	400	3360	283	566	185	620	1200	1230	680	1285	1645	1120

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MS series steering gear technical specification with rudder deflection angle ±35.

Parameter	Symbol	Unit	MS20-35	MS32-35	MS50-35	MS80-35	MS125-35	MS200-35	MS320-35
Working torque at working pressure p_{nom} and rudder deflection angle α=35˚	**M_r**	**[kNm]**	20	32	50	80	125	200	320
Design torque at open safety valve pressure pmax and rudder deflection angle α=35˚	**M_k**	**[kNm]**	25	40	62,5	100	156	250	400
Maximal tiller turn angle limited by rudder actuator design	**α_{max}**	**[deg]**	±38						
Rudder putting over time from α=-35˚ to α=+30˚	**t_1**	**[s]**	≤28						
	t_2	**[s]**	~ 0,5 t_1						
Electric motors supply voltage	**U_1**	**[V], [f]**	3x380, 50						
	U_2	**[V], [f]**	3x440, 60						
Directional proportional valves supply voltage[1]	**U**	**[V]**	24 DC						
Power of solenoid	**N**	**[W]**	30						
Ambient temperature during steering gear operation	**T_o**	**[K]/[˚C]**	273 ÷ 318K (0˚C ÷ +45˚C)						
Ambient temperature permissible for idle steering gear	**T_{od}**	**[K]/[˚C]**	248 ÷ 343K (-25˚C ÷ +70˚C)						
Hydraulic oil operating temperature	**T_{pr}**	**[K]/[˚C]**	273 ÷ 353K (0˚C÷ +80˚C)						
Hydraulic oil high temperature signalling	**T_s**	**[K]/[˚C]**	≥ 343K (+70˚C)						
Working medium			hydraulic mineral oils of kinematic viscosity v=68mm²/s (68 cSt) at T=40˚C and viscosity index W≥95						

[1] Pump directional proportional valves cooperating with remote control system

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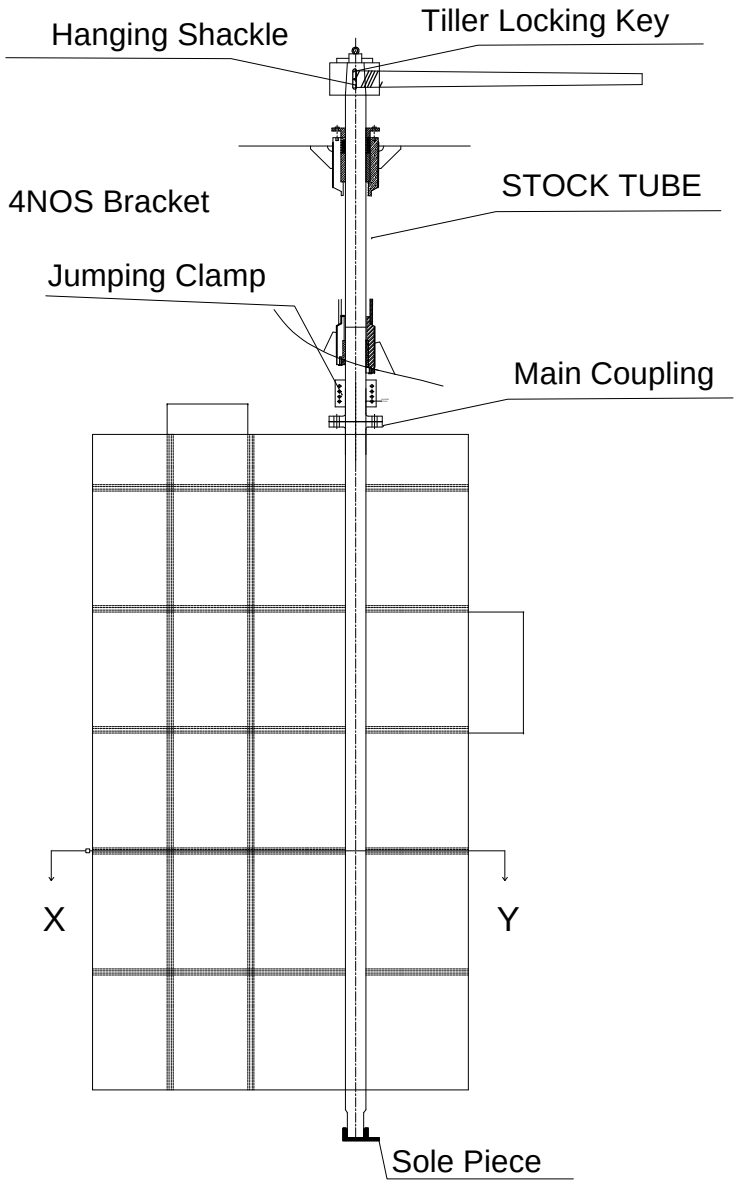
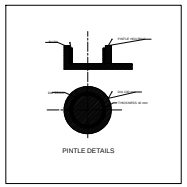
PRINCIPAL PARTICULARS	
LENGTH BP	50.13 m
BREADTH MLD	10.78 m
DEPTH MLD	4.07 m

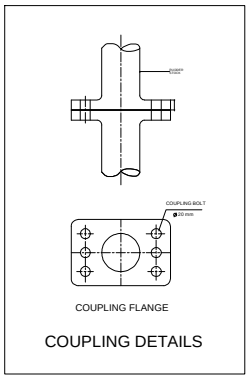


RUDDER DESIGN

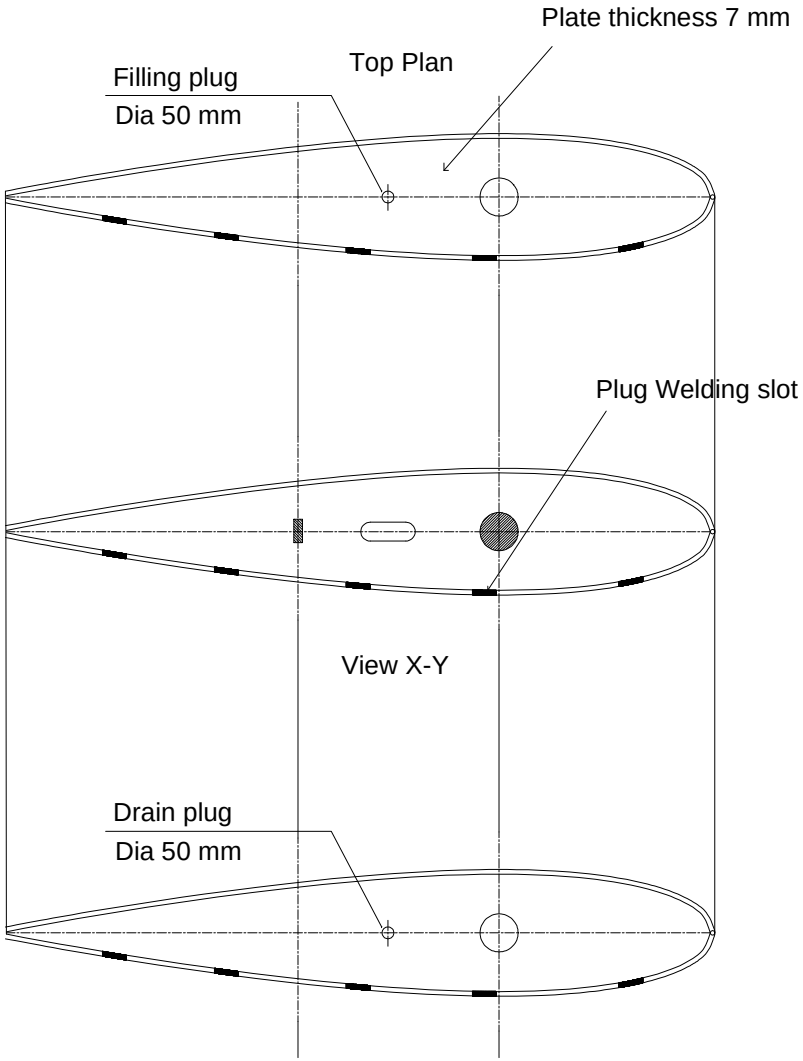
Various rudder components		
Item	Particulars	Material
Rudder Stock	Diameter 110.000mm	Forged steel
	Diameter 110.000mm	Forged steel
Coupling Bolt	Diameter 20.000mm	Forged steel
Horizontal Web	Spacing 502.000mm	Forged steel
Vertical Web	Spacing 760.000mm	Forged steel
Rudder Plate	Thickness 7.000mm	Forged steel
Pintle	Diameter 100.000mm	Forged steel
Tiller	Diameter 55.000mm	Forged steel
Bush	Thickness 2.000mm	Lignum vitae
Height of Bearing	95.000mm	Forged steel
Link Chain	Diameter 4.000mm	Forged steel
Steering Rod	Diameter 5.000mm	Forged steel
Coupling Flange	Thickness 20.000mm	Forged steel
Web Plate	Thickness 7.000mm	Forged steel
Liner	Thickness 22 mm	Bronze

Group: D
Rudder Design
Course No. NAME 338
Designed by-
Md. Khalikujjaman (1312024)
ASM Arman (1312038)

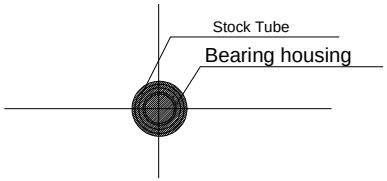




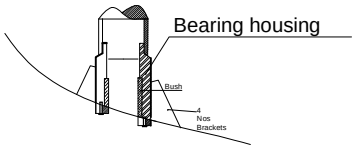
NACA PROFILE DRAWING



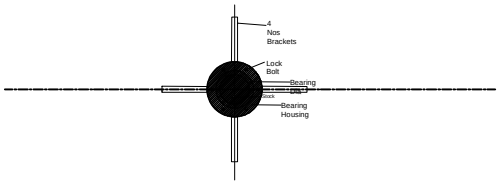
RUDDER BODY DETAIL



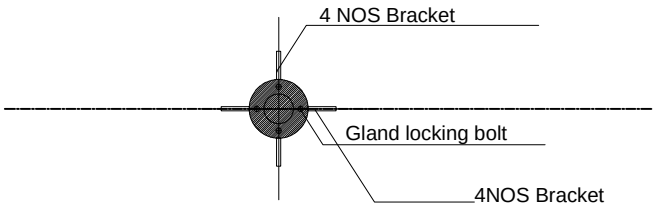
Top View (lower bearing)



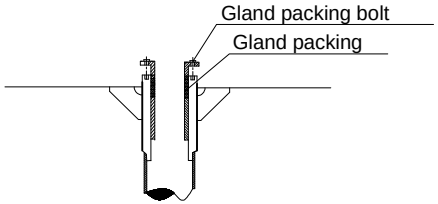
Lower Bearing Details



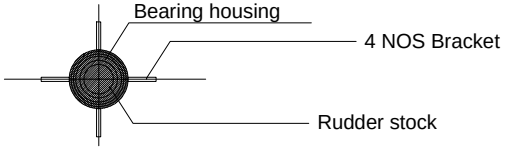
Bottom View (lower bearing)



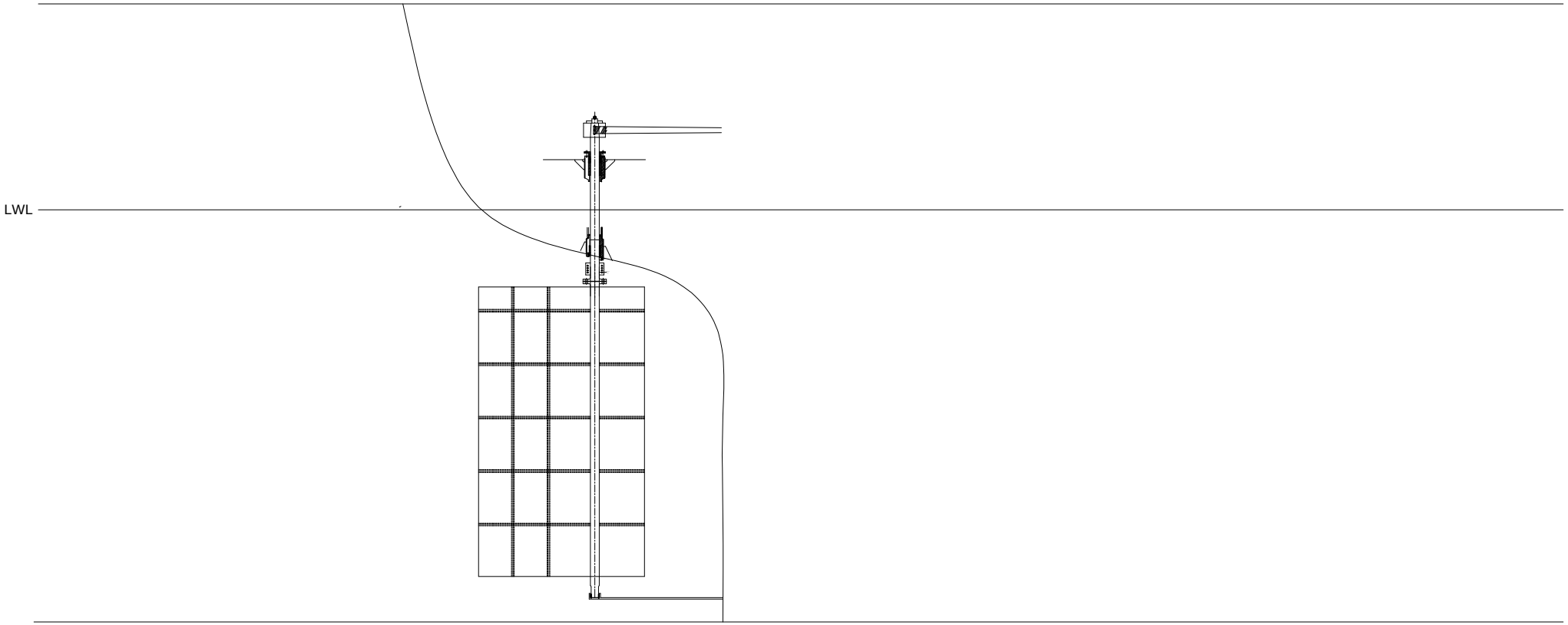
Top View (upper bearing)



Upper Bearing Details



Bottom View (upper bearing)



POSITION OF RUDDER IN SHIP

PROPELLER DESIGN AND DRAWING

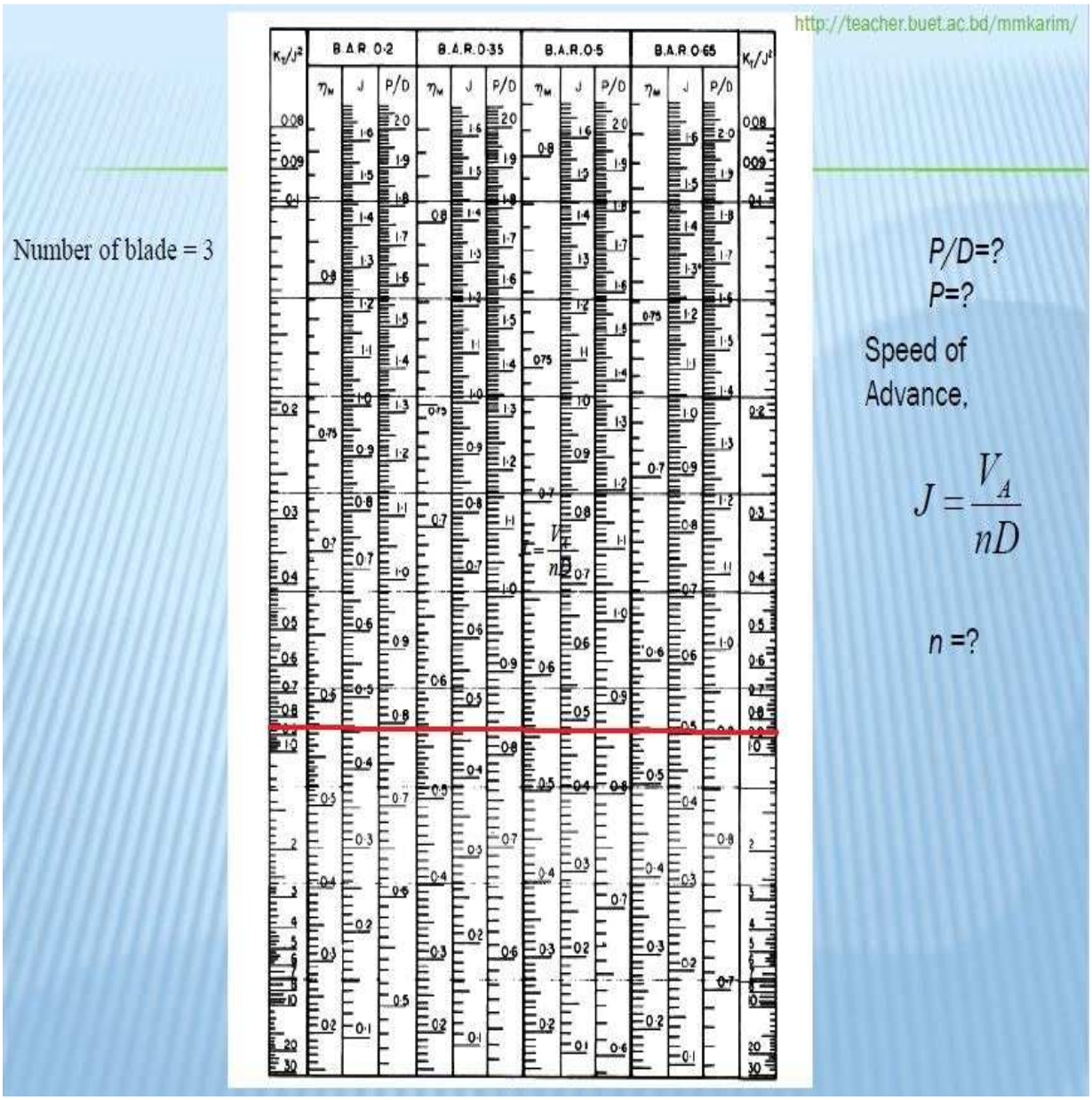
PROPELLER CALCULATION

Particulars:

Length of ship $L = 50.13\ m$
Breadth of ship $B = 10.78m$
Draft $T = 3.3m$
Depth$H = 4.07m$
Block coefficient $C_B = 0.82$
Break power of Engine $P_B = 365\ kW$
Speed of the vessel $V_s = 9\ knots$
No of blades of propeller $Z = 3$
Shaft immersion, h= D/2+0.2 =1.31 m
t=0.2009 w=0.268
B.A. R=0.35 (Assumed)
H=T-h= 3.63-1.31 =2.32 m

Total Resistance, R= 40.23 KN

Thrust, T = R/(1-t) = 50.87 KN
$V_a=V_s(1-w)$
= 9(1-0.268)
= 6.588 knot
= 3.389 m/s
KT/J^2 = T/(ρD^2*Va^2) =0.899



From chart these values are found

η_m=0.56 J=0.455 P/D=0.80

J= $\frac{V_a}{nD}$

n= $\frac{V_a}{JD}$ = 3.224 r.p.s = 194 r.p.m

Now, cross check the value using B_p-δ chart

Effective power, $P =$ 490 HP

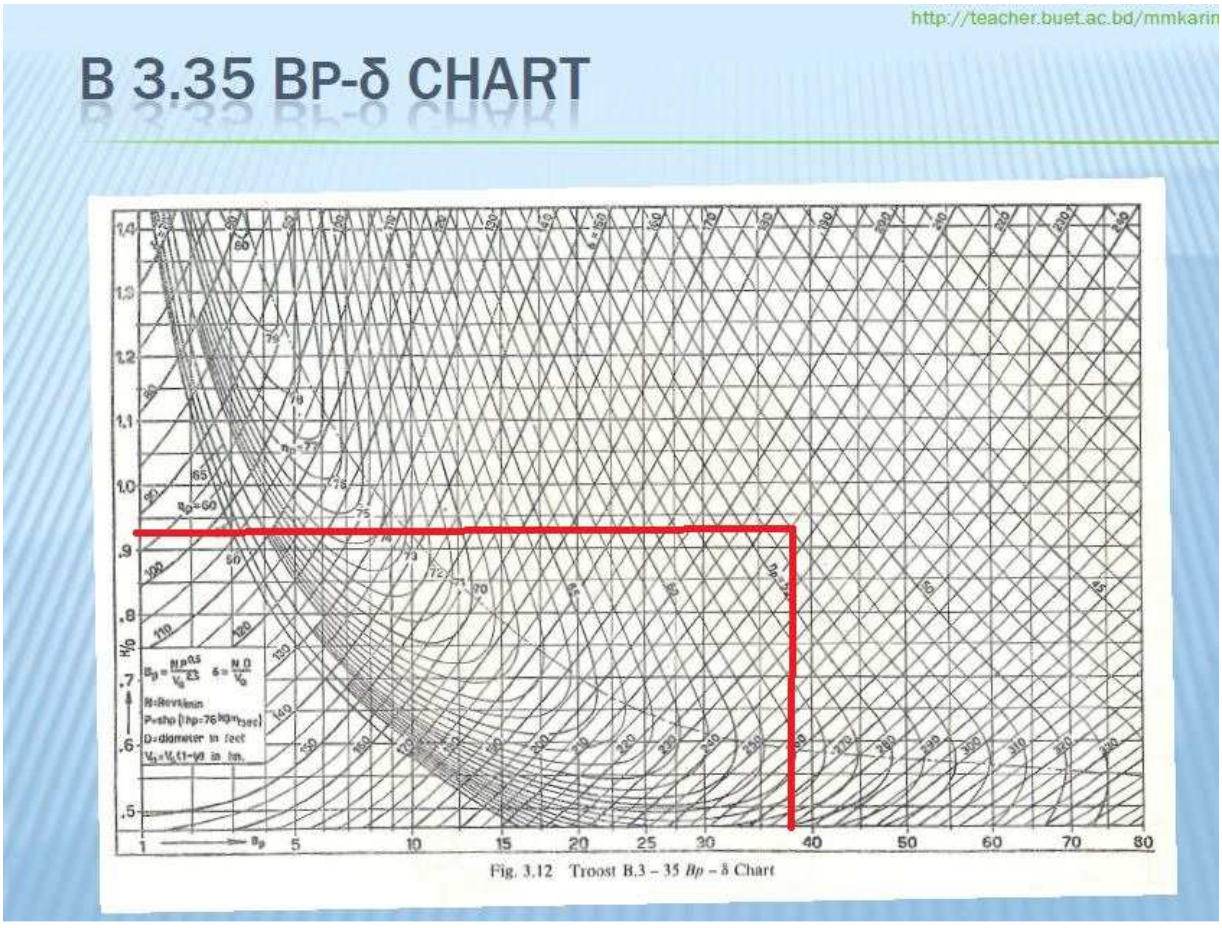
Velocity of advance, $V_A = 6.588\ knots$

Now,

$$B_p = \frac{N\sqrt{P}}{V_A^{2.5}} = \frac{194\sqrt{490}}{6.588^{2.5}} = 38.734$$

Now,

$$\delta = \frac{ND}{V_A} = 194 \times \frac{7.28}{6.588} = 214.378$$

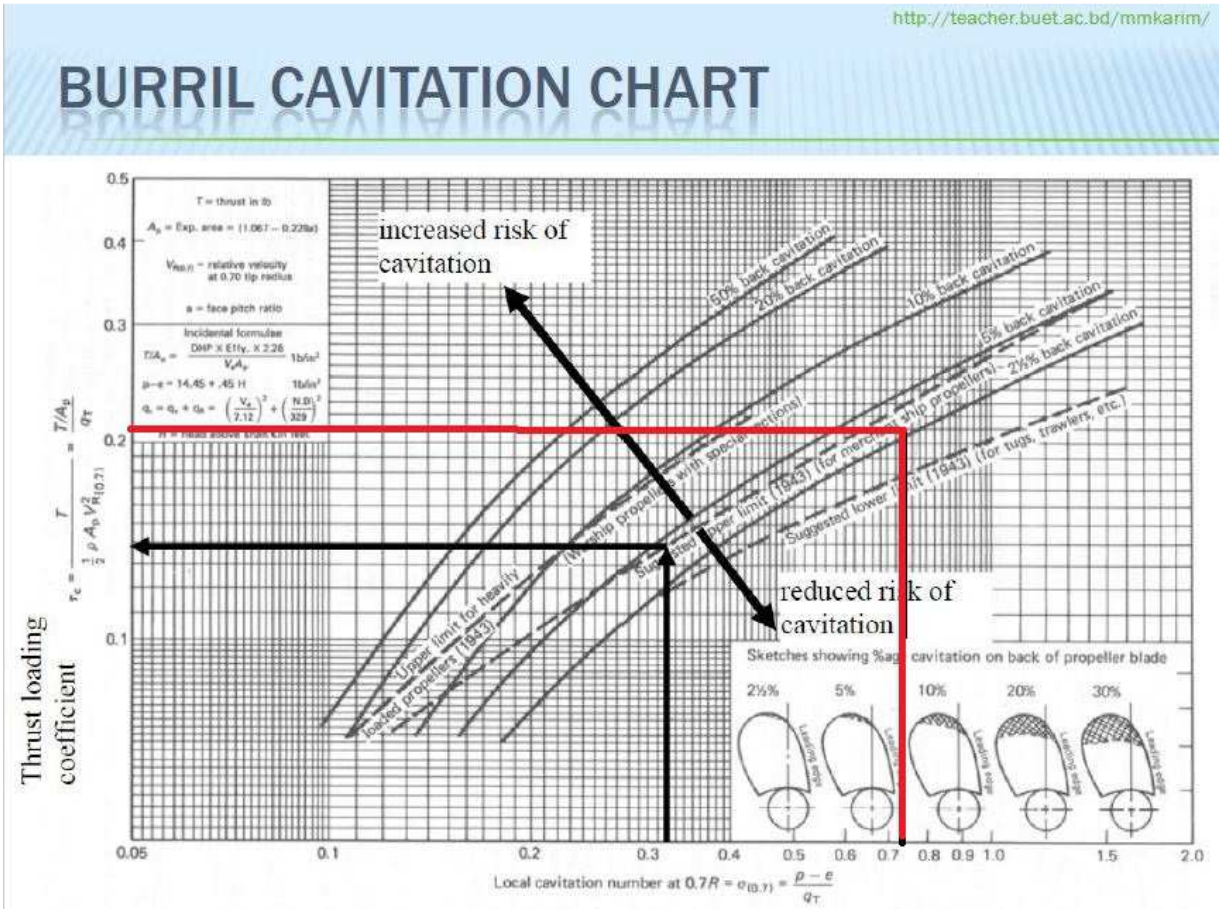


From this graph, $\eta = 0.53$, $\frac{P}{D} = 0.91$ So, P= 0.91 × 2.22 = 2.072 m

Cavitation Check:

$\sigma_{0.7R} = \frac{188.2+19.62h}{Va^2+4.836\times n^2\times D\text{^}2} = \frac{188.2+19.62*1.375}{3.389^2+4.836\times 3.224^2\times 2.224\text{^}2} = 0.748$

$T_C = 0.031+0.3886\,\sigma_{0.7R} - 0.1984\,(\sigma_{0.7R})\text{^}2 + 0.0501\,(\sigma_{0.7R}\text{^}3) = 0.2327$



So, from this chart , Cavitation is lower than safe limit.
There is no need for cavitation correction

PROPELLER SPECICATION

Number of Blade	3
RPM	194
Propeller Diameter	2.22 m
Pitch	2.072
BAR	0.35
Efficiency, η	0.53

r/R	(d/D)*(Z/BAR)	a/c	b/c	Ar	Br	c	a	b	T (max)		y	a,y		-(c-a)	-(c-a),y
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.2

T (max) Corresponding to r/R =	90.13		a=	260.54	b=	148.03	(c-a)=	-162.41			c=	422.95		(c-b)	274.92

T(te)	1.80264
T(le)	0.90132

Table of V1

P (-)	V1	P (+)	V1
-1	0.2826	1	0.356
-0.95	0.263	0.95	0.2821
-0.9	0.24	0.9	0.2353
-0.8	0.1967	0.8	0.1685
-0.7	0.157	0.7	0.118
-0.6	0.1207	0.6	0.0804
-0.5	0.088	0.5	0.052
-0.4	0.0592	0.4	0.0304
-0.2	0.0172	0.2	0.0049
0	0	0	0

Table of V2

P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.064	0.95	0.156
-0.9	0.1455	0.9	0.284
-0.8	0.306	0.8	0.4777
-0.7	0.4535	0.7	0.619
-0.6	0.5842	0.6	0.7277
-0.5	0.6995	0.5	0.817
-0.4	0.7984	0.4	0.8875
-0.2	0.9446	0.2	0.975
0	1	0	1

for P<0	
Yface	Yback
24.96188	26.76452
23.23062	30.68634
21.19905	35.85361
17.37439	46.20581
13.86771	55.72771
10.66135	64.06601
7.772984	71.36201
5.229098	77.5539
1.519265	86.75782
0	90.132

for P>0	
Yface	Yback
31.76612	32.66744
25.17197	39.99328
20.99598	47.23881
15.03537	58.56219
10.52922	66.66433
7.174147	73.00863
4.639995	78.44278
2.712613	82.80616
0.43723	88.33846
0	90.132

P<0		
	x,y	x,y
-274.92	-274.91555,24.961877136	-274.91555,26.764517136
-261.17	-261.1697725,23.23062168	-261.1697725,30.68634072
-247.42	-247.423995,21.1990464	-247.423995,35.85360828
-219.93	-219.93244,17.374385112	-219.93244,46.205809272
-192.44	-192.440885,13.86770952	-192.440885,55.72771428
-164.95	-164.94933,10.661353752	-164.94933,64.066005864
-137.46	-137.457775,7.77298368	-137.457775,71.362011
-109.97	-109.96622,5.229098112	-109.96622,77.553899136
-54.98	-54.98311,1.519264992	-54.98311,86.757818448
0.00	0,0	0,90.132

P>0		
	x,y	x,y
148.03	148.03145,31.76612	148.03145,32.66744208
140.63	140.62987,25.17197	140.62987,39.99328993280908
133.23	133.22830,20.99598	133.22830,47.23812124
118.43	118.42516,15.03537	118.42516,58.562185416
103.62	103.62201,10.52922	103.62201,66.66433116
88.82	88.81887,7.174147	88.81887,73.008632508
74.02	74.01572,4.639995	74.01572,78.44278092
59.21	59.21258,2.712613	59.21258,82.806161172
29.61	29.60629,0.43723	29.60629,88.338463332
0.00	0,0	0,90.132

r/R	(c/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

	r/R=0.3													
T (max) Corresponding to r/R =	79.70		a=	289.91	b=	166.07	(c-a)=	-184.58			c=	474.49	(c-b)	308.42

T(te)	1.59396
T(le)	0.79698

Table of V1			
P (-)	V1	P (+)	V1
-1	0.2306	1	0.2923
-0.95	0.204	0.95	0.2186
-0.9	0.179	0.9	0.176
-0.8	0.1333	0.8	0.1191
-0.7	0.0943	0.7	0.079
-0.6	0.0623	0.6	0.0503
-0.5	0.0376	0.5	0.03
-0.4	0.0202	0.4	0.0148
-0.2	0.0033	0.2	0.0027
0	0	0	0

Table of V2			
P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.08	0.95	0.189
-0.9	0.167	0.9	0.3197
-0.8	0.336	0.8	0.513
-0.7	0.4885	0.7	0.6505
-0.6	0.6195	0.6	0.752
-0.5	0.7335	0.5	0.8315
-0.4	0.8265	0.4	0.802
-0.2	0.9583	0.2	0.975
0	1	0	1

for P<0	
Yface	Yback
18.01079	19.60475
15.93322	23.77551
13.98062	28.61796
10.41127	38.24819
7.365211	47.11299
4.865882	54.84529
2.936712	61.81999
1.577702	67.72465
0.257743	76.6988
0	79.698

for P>0	
Yface	Yback
23.06277	23.85975
17.24776	32.95704
13.88658	39.90822
9.397111	50.67031
6.233181	58.35527
3.968721	64.09927
2.367031	68.77021
1.167735	65.24333
0.213033	77.93851
0	79.698

P<0		
	x,y	x,y
-308.42	-308.4172,1	0.604751624
-293.00	-292.99634,	23.77550736
-277.58	-277.57548,	28.61795784
-246.73	-246.73376,	38.248185972
-215.89	-215.89204,	47.112994512
-185.05	-185.05032,	54.845294472
-154.21	-154.2086,2	61.819985244
-123.37	-123.36688,	67.724650668
-61.68	-61.68344,0	76.698804864
0.00	0,0	0,79.698

P>0		
	x,y	x,y
166.07	166.0708,23.0627	08,23.859748146
157.77	157.76726,17.247	32.957035752
149.46	149.46372,13.886	39.908215614
132.86	132.85664,9.3971	50.67031474
116.25	116.24956,6.2331	58.35527409
99.64	99.64248,3.9687	64.099268346
83.04	83.0354,2.367030	68.77020873
66.43	66.42832,1.1677	65.243333136
33.21	33.21416,0.2130	77.938507254
0.00	0,0	0,79.698

r/R	(d/D)*(Z/BAR)	a/c	b/c	Ar	Br	c	a	b	T (max)		y	a,y		-(c-a)	-(c-a),y
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.4

T (max) Corresponding to r/R =	69.26		a=	310.28	b=	181.30	(c-a)=	-207.72			c=	518.00		(c-b)	336.70

T(te)	1.38528
T(le)	0.69264

Table of V1			
P (-)	V1	P (+)	V1
-1	0.1467	1	0.2181
-0.95	0.12	0.95	0.1467
-0.9	0.0972	0.9	0.1088
-0.8	0.063	0.8	0.0637
-0.7	0.0395	0.7	0.0357
-0.6	0.0214	0.6	0.0189
-0.5	0.0116	0.5	0.009
-0.4	0.0044	0.4	0.0033
-0.2	0	0.2	0
0	0	0	0

Table of V2			
P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0905	0.95	0.1935
-0.9	0.181	0.9	0.3235
-0.8	0.35	0.8	0.522
-0.7	0.504	0.7	0.659
-0.6	0.6353	0.6	0.7593
-0.5	0.7525	0.5	0.8345
-0.4	0.8415	0.4	0.8933
-0.2	0.9645	0.2	0.9725
0	1	0	1

for P<0	
Yface	Yback
9.957808	11.34309
8.145446	15.67375
6.597812	20.26914
4.276359	29.41919
2.681209	38.27736
1.452605	45.96124
0.787393	53.25141
0.298666	58.80389
0	66.85431
0	69.264

for P>0	
Yface	Yback
14.95541	15.64805
10.05942	24.02062
7.460564	30.33604
4.367996	40.85489
2.447998	48.32916
1.295999	54.05487
0.617142	58.53258
0.226285	62.17372
0	67.37829
0	69.264

P<0		
	x,y	x,y
-336.70	-336.7,9.95	7808724,1.343088224
-319.87	-319.865,8.1	3454865,15.67375056
-303.03	-303.03,6.5	9781582,20.269139904
-269.36	-269.36,4.2	2645962,29.41919136
-235.69	-235.69,2.6	8250004,38.27736432
-202.02	-202.02,1.4	5260008,45.961235424
-168.35	-168.35,0.7	6583152,58.251409952
-134.68	-134.68,0.2	9666368,58.803889248
-67.34	-67.34,0	-67.34,66.85430544
0.00	0,0	0,69.264

P>0		
	x,y	x,y
181.30	181.3,14.9	5841365,1.343088224
172.24	172.235,10	0594318,15.67375056
163.17	163.17,7.4	3661958,30.33604
145.04	145.04,4.3	3749632,40.85489
126.91	126.91,2.4	4769152,48.32916
108.78	108.78,1.2	5698304,54.05487
90.65	90.65,0.61	7041424,58.53258
72.52	72.52,0.22	5254592,62.17372
36.26	36.26,0	36.26,67.37829
0.00	0,0	0,69.264

r/R	(d/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
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0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.5

T (max) Corresponding to r/R =	58.83		a=	320.11	b=	194.92	(c-a)=	228.9664			c=	549.08		(c-b)	354.16

T(te)	1.1766
T(le)	0.5883

Table of V1			
P (-)	V1	P (+)	V1
-1	0.0522	1	0.1278
-0.95	0.042	0.95	0.0778
-0.9	0.033	0.9	0.05
-0.8	0.019	0.8	0.0211
-0.7	0.01	0.7	0.0085
-0.6	0.004	0.6	0.0034
-0.5	0.0012	0.5	0.0008
-0.4	0	0.4	0
-0.2	0	0.2	0
0	0	0	0

Table of V2			
P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0965	0.95	0.1485
-0.9	0.1885	0.9	0.272
-0.8	0.3585	0.8	0.462
-0.7	0.511	0.7	0.606
-0.6	0.6415	0.6	0.72
-0.5	0.753	0.5	0.809
-0.4	0.8426	0.4	0.879
-0.2	0.9613	0.2	0.969
0	1	0	1

for P<0	
Yface	Yback
3.009507	4.186107
2.421443	9.161596
1.902562	13.94683
1.095415	22.94076
0.576534	31.21402
0.230614	38.39187
0.069184	44.65879
0	49.75535
0	56.59881
0	58.83

for P>0	
Yface	Yback
7.443289	8.031589
4.531204	13.7684
2.912085	19.34213
1.2289	28.72487
0.495054	36.37782
0.198022	42.72035
0.046593	47.75243
0	51.78275
0	57.02451
0	58.83

P<0		
	x,y	x,y
-354.16	-354.1566,3	4.18610748
-336.45	-336.4487,7	9.1615959
-318.74	-318.7409,1	13.9468281
-283.33	-283.3252,2	22.9407585
-247.91	-247.9096,2	31.2140214
-212.49	-212.4939,2	38.3918697
-177.08	-177.0783,3	44.6587943
-141.66	-141.6626,4	49.7553548
-70.83	-70.83132,9	56.5988134
0.00	0,0	0,58.83

P>0		
	x,y	x,y
194.92	194.9234,7	8.03158926
185.18	185.1772,3	13.7683967
175.43	175.4310,6	19.3421274
155.94	155.9387,2	28.7248653
136.45	136.4463,8	36.3778247
116.95	116.9540,4	42.7203458
97.46	97.4617,0	47.7524287
77.97	77.96936,0	51.7827543
38.98	38.98468,0	57.0245073
0.00	0,0	0,58.83

r/R	(d/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.6

T (max) Corresponding to r/R =	48.40		a=	315.93	b=	220.24	(c-a)=	250.2489

T(te)	0.96792
T(le)	0.48396

Table of V1

P (-)	V1	P (+)	V1
-1	0	1	0.0382
-0.95	0	0.95	0.0169
-0.9	0	0.9	0.0067
-0.8	0	0.8	0.006
-0.7	0	0.7	0
-0.6	0	0.6	0
-0.5	0	0.5	0
-0.4	0	0.4	0
-0.2	0	0.2	0
0	0	0	0

Table of V2

P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0965	0.95	0.1485
-0.9	0.1885	0.9	0.272
-0.8	0.3585	0.8	0.462
-0.7	0.511	0.7	0.606
-0.6	0.6415	0.6	0.72
-0.5	0.753	0.5	0.809
-0.4	0.8426	0.4	0.879
-0.2	0.9613	0.2	0.969
0	1	0	1

for P<0	
Yface	Yback
0	0.96792
0	5.54473
0	9.908113
0	17.97089
0	25.20367
0	31.39303
0	36.68126
0	40.93082
0	46.56053
0	48.396

for P>0	
Yface	Yback
1.83024	2.3142
0.809713	8.408611
0.321011	13.83705
0.287472	22.90679
0	29.51866
0	34.98063
0	39.2448
0	42.59864
0	46.91073
0	48.396

P<0		
	x,y	x,y
-345.93	-345.932314	-345.932314,0.96792
-328.64	-328.6356983	-328.6356983,5.54472972
-311.34	-311.3390826	-311.3390826,9.90811308
-276.75	-276.7458512	-276.7458512,17.97088668
-242.15	-242.1526198	-242.1526198,25.20366888
-207.56	-207.5593884	-207.5593884,31.39303332
-172.97	-172.966157	-172.966157,36.68126424
-138.37	-138.3729256	-138.3729256,40.930820208
-69.19	-69.18646256	-69.1864628,46.560533304
0.00	0,0	0,48.396

P>0		
	x,y	x,y
220.24	220.2416852	220.2416852,2.3142314199928
209.23	209.2296017	209.2296017,8.408611416
198.22	198.2175174	198.2175174,13.837045548
176.19	176.1933438	176.1933438,22.90679472
154.17	154.1691802	154.1691802,29.51865624
132.15	132.1450116	132.1450116,34.9806288
110.12	110.120843	110.120843,39.24480036
88.10	88.0966744	88.0966744,42.59864316
44.05	44.0483372	44.0483372,46.91072676
0.00	0,0	0,48.396

r/R	(d/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.7

T (max) Corresponding to r/R =	37.96		a=	295.36	b=	248.19	(c-a)=	266.1567

T(te)	0.75924
T(le)	0.37962

Table of V1

P (-)	V1	P (+)	V1
-1	0	1	0
-0.95	0	0.95	0
-0.9	0	0.9	0
-0.8	0	0.8	0
-0.7	0	0.7	0
-0.6	0	0.6	0
-0.5	0	0.5	0
-0.4	0	0.4	0
-0.2	0	0.2	0
0	0	0	0

Table of V2

P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0975	0.95	0.124
-0.9	0.19	0.9	0.2337
-0.8	0.36	0.8	0.414
-0.7	0.51	0.7	0.5615
-0.6	0.64	0.6	0.684
-0.5	0.75	0.5	0.785
-0.4	0.84	0.4	0.866
-0.2	0.96	0.2	0.9675
0	1	0	1

for P<0	
Yface	Yback
0	0.75924
0	4.386509
0	7.827764
0	14.15223
0	19.73265
0	24.56901
0	28.66131
0	32.00956
0	36.47389
0	37.962

for P>0	
Yface	Yback
0	0.37962
0	5.039835
0	9.162622
0	15.93873
0	21.48213
0	26.08597
0	29.88179
0	32.92596
0	36.74057
0	37.962

P<0		
	x,y	x,y
-313.32	-313.323696,0	313.323696,0.75924
-297.66	-297.6575112,0	297.6575112,4.3865091
-281.99	-281.9913264,0	281.9913264,7.8277644
-250.66	-250.6589568,0	250.6589568,14.1522336
-219.33	-219.3265872,0	219.3265872,19.7326476
-187.99	-187.9942176,0	187.9942176,24.5690064
-156.66	-156.661848,0	156.661848,28.66131
-125.33	-125.3294784,0	125.3294784,32.0095584
-62.66	-62.66473952,0	62.6647392,36.4738896
0.00	0,0	0,37.962

P>0		
	x,y	x,y
248.19	248.188304,0	248.188304,0.37962
235.78	235.7788832,0	235.7788888,5.03983512
223.37	223.3694736,0	223.3694736,9.162622206
198.55	198.5506432,0	198.5506432,15.93872532
173.73	173.7318128,0	173.7318128,21.48212637
148.91	148.9129824,0	148.9129824,26.08596792
124.09	124.094152,0	124.094152,29.8817883
99.28	99.27532160,0	99.2753216,32.92596108
49.64	49.63766080,0	49.6376608,36.74057265
0.00	0,0	0,37.962

r/R	(c/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.8

T (max) Corresponding to r/R =	27.53		a=	264.98	b=	263.33	(c-a)=	285.9135

T(te)	0.55056
T(le)	0.27528

Table of V1

P (-)	V1	P (+)	V1
-1	0	1	0
-0.95	0	0.95	0
-0.9	0	0.9	0
-0.8	0	0.8	0
-0.7	0	0.7	0
-0.6	0	0.6	0
-0.5	0	0.5	0
-0.4	0	0.4	0
-0.2	0	0.2	0
0	0	0	0

Table of V2

P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0975	0.95	0.105
-0.9	0.19	0.9	0.2028
-0.8	0.36	0.8	0.3765
-0.7	0.51	0.7	0.5265
-0.6	0.64	0.6	0.6545
-0.5	0.75	0.5	0.7635
-0.4	0.84	0.4	0.852
-0.2	0.96	0.2	0.9635
0	1	0	1

for P<0	
Yface	Yback
0	0.55056
0	3.18086
0	5.676274
0	10.26244
0	14.30905
0	17.81612
0	20.78364
0	23.21161
0	26.4489
0	27.528

for P>0	
Yface	Yback
0	0.27528
0	3.136816
0	5.802132
0	10.53593
0	14.62384
0	18.11219
0	21.08273
0	23.4946
0	26.53328
0	27.528

P<0		
	x,y	x,y
-287.57	-287.566146,27	87.566146,0.55056
-273.19	-273.1878387,2	73.1878387,3.1808604
-258.81	-258.8095314,2	58.8095314,5.6762736
-230.05	-230.0529168,2	30.0529168,10.2624384
-201.30	-201.2963022,2	01.2963022,14.3090544
-172.54	-172.5396876,1	72.5396876,17.8161216
-143.78	-143.783073,19	43.783073,20.78364
-115.03	-115.0264584,1	15.0264584,23.2116096
-57.51	-57.51322925,	57.5132292,26.4489024
0.00	0,0	0,27.528

P>0		
	x,y	x,y
263.33	263.3268542,	263.326854,0.27528
250.16	250.1605112,	250.1605113,3.1368156
236.99	236.9941629,	236.9941686,5.802131616
210.66	210.6614832,	210.6614832,10.53592908
184.33	184.3287978,	184.3287978,14.62383708
158.00	157.9961124,	157.9961124,18.11218524
131.66	131.6634271,	131.663427,21.08273172
105.33	105.3307416,	105.3307416,23.49459744
52.67	52.66537082,	52.6653708,26.53327572
0.00	0,0	0,27.528

r/R	(c/D)*(Z/BAR)	a/c	b/c	Ar	Br	**c**	**a**	**b**	**T (max)**		**y**	**a,y**		**-(c-a)**	**-(c-a),y**
0.2	1.633	0.616	0.35	0.0526	0.004	422.95	260.54	148.03	90.13		222	260.535352,222		-162.412	-162.411648,222
0.3	1.832	0.611	0.35	0.0464	0.0035	474.49	289.91	166.07	79.70		333	289.912168,333		-184.576	-184.575832,333
0.4	2	0.599	0.35	0.0402	0.003	518.00	310.28	181.30	69.26		444	310.282,444		-207.718	-207.718,444
0.5	2.12	0.583	0.355	0.034	0.0025	549.08	320.11	194.92	58.83		555	320.11364,555		-228.966	-228.96636,555
0.6	2.186	0.558	0.389	0.0278	0.002	566.17	315.93	220.24	48.40		666	315.925092,666		-250.249	-250.248908,666
0.7	2.168	0.526	0.442	0.0216	0.0015	561.51	295.36	248.19	37.96		777	295.355312,777		-266.157	-266.156688,777
0.8	2.127	0.481	0.478	0.0154	0.001	550.89	264.98	263.33	27.53		888	264.979533,888		-285.913	-285.913467,888
0.9	1.657	0.4	0.5	0.0092	0.0005	429.16	171.67	214.58	17.09		999	171.6652,999		-257.498	-257.4978,999
1	0	0	0	0.003	0	0.00	0.00	0.00	6.66		1110	0,1110		0	0,1110

D	2220
BAR	0.35

r/R=0.9

T (max) Corresponding to r/R =	17.09		a=	171.67	b=	214.58	(c-a)=	257.4978

T(te)	0.34188
T(le)	0.17094

Table of V1			
P (-)	V1	P (+)	V1
-1	0	1	0
-0.95	0	0.95	0
-0.9	0	0.9	0
-0.8	0	0.8	0
-0.7	0	0.7	0
-0.6	0	0.6	0
-0.5	0	0.5	0
-0.4	0	0.4	0
-0.2	0	0.2	0
0	0	0	0

Table of V2			
P (-)	V2	P (+)	V2
-1	0	1	0
-0.95	0.0975	0.95	0.0975
-0.9	0.19	0.9	0.19
-0.8	0.36	0.8	0.366
-0.7	0.51	0.7	0.51
-0.6	0.64	0.6	0.64
-0.5	0.75	0.5	0.75
-0.4	0.84	0.4	0.84
-0.2	0.96	0.2	0.96
0	1	0	1

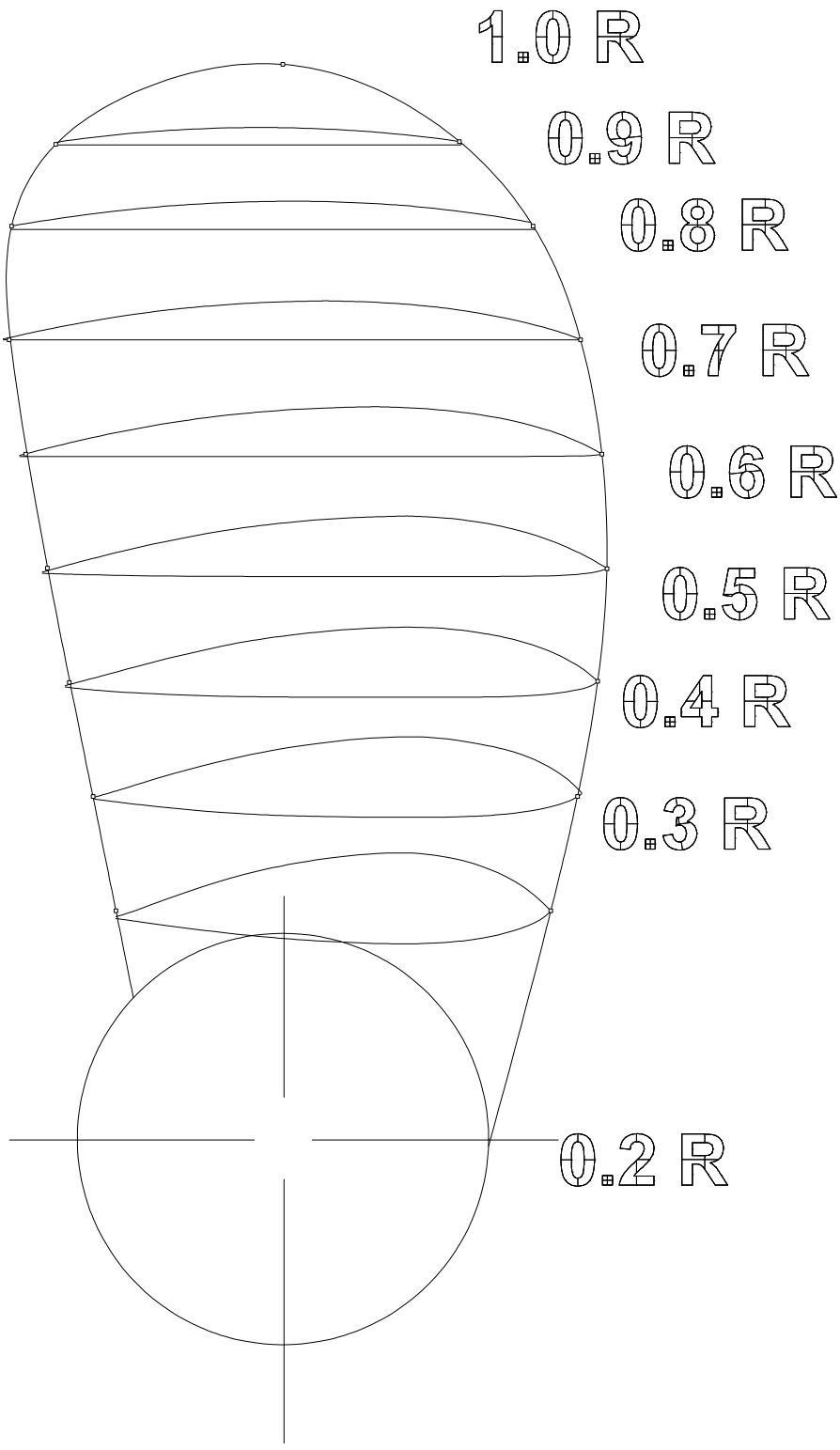
for P<0	
Yface	Yback
0	0.34188
0	1.975212
0	3.524783
0	6.372643
0	8.885461
0	11.06324
0	12.90597
0	14.41366
0	16.42392
0	17.094

for P>0	
Yface	Yback
0	0.17094
0	1.820938
0	3.386321
0	6.36478
0	8.801701
0	11.0017
0	12.86324
0	14.38631
0	16.41708
0	17.094

P<0		
	x,y	x,y
-214.58	-214.5815,0	-214.5815,0.34188
-203.85	-203.852425,0	-203.852425,1.9752117
-193.12	-193.12335,0	-193.12335,3.5247828
-171.67	-171.6652,0	-171.6652,6.3726432
-150.21	-150.20705,0	-150.20705,8.8854612
-128.75	-128.7489,0	-128.7489,11.0632368
-107.29	-107.29075,0	-107.29075,12.90597
-85.83	-85.8326,0	-85.8326,14.4136608
-42.92	-42.9163,0	-42.9163,16.4239152
0.00	0,0	0,17.094

P>0		
	x,y	x,y
214.58	214.5815,0	214.5815,0.17094
203.85	203.852425,0	203.852425,1.82093835
193.12	193.12335,0	193.12335,3.3863214
171.67	171.6652,0	171.6652,6.36477996
150.21	150.20705,0	150.20705,8.8017006
128.75	128.7489,0	128.7489,11.0016984
107.29	107.29075,0	107.29075,12.863235
85.83	85.8326,0	85.8326,14.3863104
42.92	42.9163,0	42.9163,16.4170776
0.00	0,0	0,17.094

PROPELLER BLADE DRAWING



Propeller Design

(Expanded View)

Propeller Shafting Arrangement

Principal Particulars
Length, L_{OA}= 58.98 m
Length, L_{BP}= 50.13 m
Breadth, B_{MLD}= 10.78 m
Depth, D = 4.07 m
Draught, T= 3.63 m

Calculation:

Engine power, P = 365 kw

From propeller calculation we get,

Shaft speed, f=194 rpm

We know,

Shaft speed, $f = \frac{\text{Engine speed}}{\text{Gear ratio (Z)}}$

Engine Speed= 1350 rpm

So,

Gear Ratio= 1350/194 = 6.96

Calculation for Shaft Diameter (Theoretical Formula)

[Strength of Materials, by Ferdinand L.Singer et. al]

Torque at shaft, $T = P \times \frac{60}{2\pi f}$

$= \frac{365\times1000\times60}{2\times\pi\times194}$ = 17966 Nm

Stress, $\tau = \frac{16T}{\pi d^3}$

Here, τ = 60N/mm^2

= 60×10^6 N/m^2

T =17966 N-m

Then, $60\times10^6 = \frac{16 \text{ x } 17966}{\pi \, d^3}$

d= $\sqrt[3]{(\frac{17966\times 16}{\pi\times60000000})}$

= 115.10 mm

So we take shaft diameter = 120 mm

Calculation for Shaft Diameter *[Chapter 2, Page 4–2, GL 2013]*

(Using GL Rule Book-2013)

Shaft Diameter:

According to GL rule,

Minimum shaft diameter, $d = F \times K \times \sqrt[3]{\frac{P_W}{n\times\left[1-\left\{\frac{d_i}{d_a}\right\}^4\right]}}\times C_W$

Where,

d = Required outside diameter of shaft

d_i =Actual diameter of shaft bore, where present.

d_a =Actual shaft diameter

The expression $1-\left\{\frac{d_i}{d_a}\right\}^4$ can be taken as equal to1

P_w =Power transmitted by shaft

= 0.97 x 365 kW

= 354.05 kW

f = Shaft speed= 194 rpm

Here,

R_m =Tensile strength of shaft material (Forged steel)

$= 600$ N/mm

C_w =Material factor

$= \frac{560}{R_m + 160}$

$= \frac{560}{600+160} =$ 0.737

$\mathrm{F} =$ Factor for type of propulsion installation = 100

$\mathrm{k} =$ Factor for shaft type

$= 1.40$ (Intermediate propeller shaft)

So we have, $\mathrm{d} = \mathrm{F} \times \mathrm{k} \times \sqrt[3]{\frac{\mathrm{P_W}}{\mathrm{f} \times \left[1 - \left\{\frac{\mathrm{d_i}}{\mathrm{d_a}}\right\}^4\right]}} \times \mathrm{C_w}$

$$= 100 \times 1.4 \times \sqrt[3]{\frac{354}{194 \times 1}} \times 0.737$$

$= 126.08$ mm

From two methods,we take the shaft diameter = 130 **mm**

Angle of Twist:

$$\theta = \frac{TL}{GJ}$$

Here length of the shaft, L= 4.5 m

Angular moment of inertia, J = $\frac{\pi d^4}{32}$ = 3.26 x 10^{-4} m^4

Modulus of rigidity, G = $83\ GPa$= 8.3 x 10^{10} Nm^{-2}

So, angle of twist, $\theta = \frac{17966 \times 4.5}{(8.3 \times 10^{10}) \times (3.26\ x\ 10^{-4})}$rad.

= 0.0031 rad.

= 0.18^0

Minimum Liner Thickness: *[Chapter 2, Page 4–4]*

s =0.03 × d + 4.5 mm

=0.03 × 120+4.5 mm

= 8.1 mm

= 9 mm(taken)

COUPLING: *[Chapter 2, Page 4–4]*

The thickness of coupling flanges must be equal to at least 20 % of the calculated diameter of the shaft.

Thickness of coupling flange $=0.20 \times 120=$ **24 mm**

Thickness of coupling flange $S_{fl} = 370 \sqrt{\frac{P(kw) x Cw}{n \; x \; D}}$

$= 27$ mm

we take Thickness of coupling flange = 30 **mm**

Shaft Bearings: *[Chapter 2, Page 4–6]*

$l_{max} = K_1 \cdot \sqrt{d}$ (for n < 350 rpm)

Where,

l_{max} = Maximum permissible distance between bearings

d = Diameter of shaft between bearings (mm) = 120 mm

k_1 = 280-350 (for water lubricated rubber bearing in stern tubes and shaft bracket)

So, $\mathbf{l_{max}} = K_1.\sqrt{d} = 280 \times \sqrt{120} = 3067.24$ mm = 3.06 m

Stern tube bearing:

For water lubricated aft and forward rubber bearings inside stern tube,

Length of after stern tube bearing = 4d

Length of forward stern tube bearing= 1.5d

So,

Length of after stern tube bearing = 4 x 120=480 mm

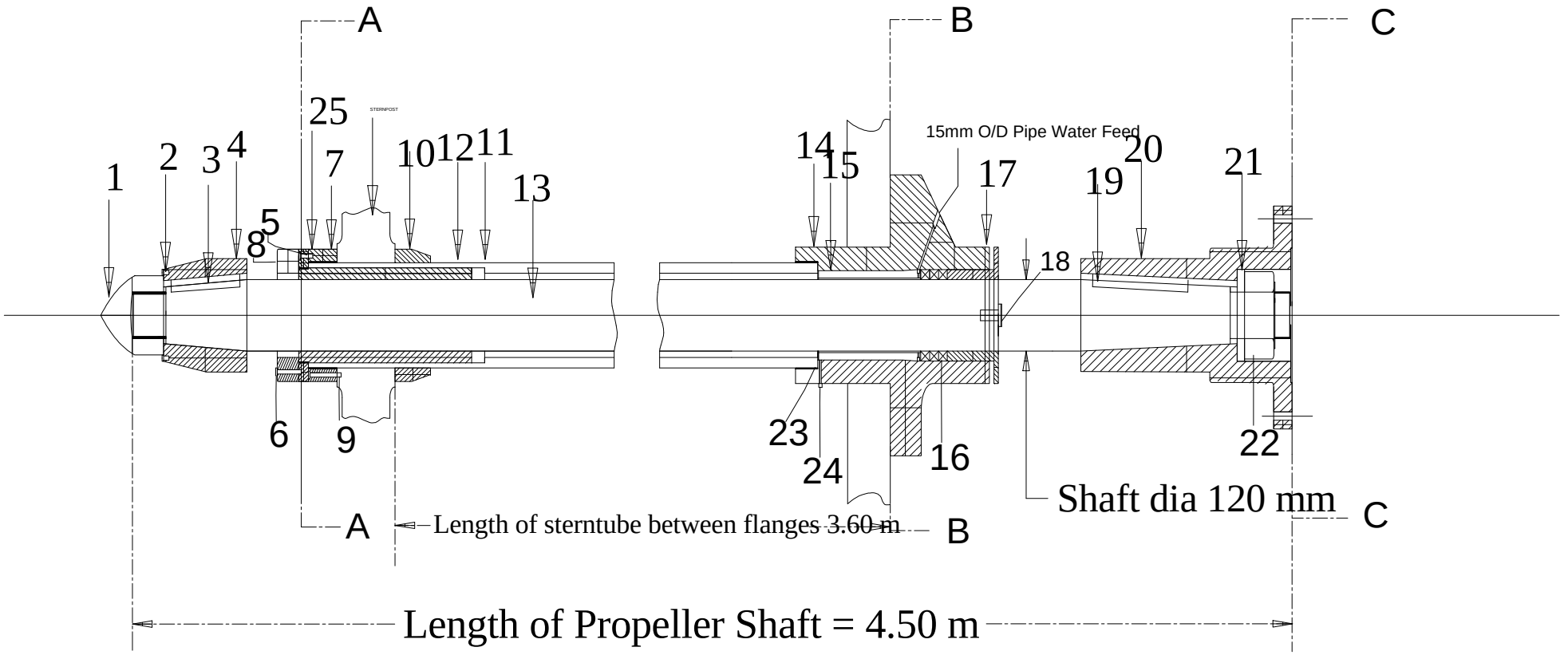
Length of forward stern tube bearing = 1.5 x 120 = 180 mm

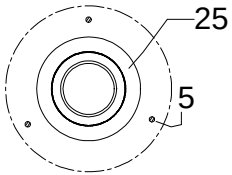
Shaft details:

Details of the elements are given in the following table according to their serial number in CAD drawing

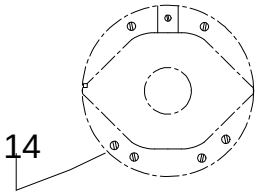
SL. NO	DESCRIPTION	MATERIALS	NUMBER OF COMPONENT
1	CONE NUT	M.B. BS	1
2	CONE NUT SECURING SCREW	M.B. BS	2
3	PROPELLER KEY	M.B. BS	1
4	PROPELLER DIA X PITCH	M.B. BS	1
5	AFT BRG SECURING SCREW	M.B. BS	3
6	COVER PLATE SECURING SCREW	STEEL BS	3
7	AFT LOCKING RING	STEEL BS	1
8	COVER PLATE	STEEL BS	1
9	LOCK RING SECURING SCREW	STEEL BS	3
10	FWD LOCKING RING	STEEL BS	1
11	RUBBER BEARING		
12	STERNTUBE	STEEL BS	1
13	TAILSHAFT		1
14	GLAND HOUSING	G.M. BS	1
15	FWD BEARING	G.M. BS	1
16	GREASY PACKING	GRAPHITED ASBESTOS	3 turns
17	GLAND RING	G.M. BS	1
18	GLAND STUDS AND NUTS	M.B. BS	2
19	COUPLING KEY	STEEL BS	1
20	HALF COUPLING	STEEL BS	1
21	BACKING WASHER	STEEL BS	1
22	LOCKING NUT	STEEL En7 BS	1
23	SEALING RING	BS	1
24	FWD BRG SECURING SCREW	M.B. BS	1
25	BEARING LOCK RING	STEEL BS	1

PROPELLER SHAFT ARRANGEMENT





SECTION:A-A



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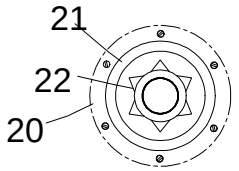


SECTION:C-C

ENGINE AND GEAR BOX SELECTION

YANMAR 6EY17W MARINE ENGINE

Engine specification Information

Engine Name	YANMAR 6EY17W
Power	374KW
Speed	1350 rpm
Number of Cylinder	6
Mean Effective Pressure	1.06 Mpa
Weight	3880 Kg
Fuel Consumption	
Bore X Stroke	170 x 230

Gearbox Specific Information

Name	YXH-500
Gear Ratio	6:1
Offset	Offset
Weight	700 Kg

ENGINE AND GEAR BOX FOUNDATION

Particulars

Length of ship L= 50.13 m

Breadth of ship B= 10.78 m

Draft T= 3.63 m

Height H= 4.07 m

Block coefficient =0.82

Frame spacing a=0.6 m

Web frame spacing e= 2.4 m

Engine output P=365 KW

The foundation shall be constructed for the proper transmission of forces in the transverse and longitudinal directions. Longitudinal girders forming seating's of the engine, the gearbox and the thrust block shall therefore extend to the engine room bulkheads and are to be supported transversely by floors, web frames or wing bulkheads. Floors in the engine room are generally to be fitted at every frame. Additional intermediate frames may be appropriate.

Floor plate thickness(gl_i-2-2_e-8.3.1)

The floor thickness is to be increased as follows,

Here,

t_f = Floor thickness =9 mm

$$t_{fe} = t_f + t_f\left(3.6 + \frac{P}{500}\right)\%$$

$$= 9.39 \text{ mm}$$

So we take floor plate thickness as in way of engine **10 mm**

Inner Bottom Plating

Between the foundation girders, the thickness of the inner bottom plating required is to
be increased by 2 mm.

$\boldsymbol{t_b}$ = Thickness of inner bottom plating in other place = 6 mm

So the thickness of inner bottom plating will be,

$\boldsymbol{t_{be}} = \boldsymbol{t_b} + \mathbf{2}$= 8 m

So we take the thickness of inner bottom plating in way of engine as **8 mm**

Bottom Plating (gl_i-2-2_e-8.4)

The thickness of bottom plating will be, $t_{be} = t_0 + 2.3* P/ n_r$

= 10.68 mm ≈ **11 mm**

t_0 = net thickness of the bottom plating [mm] in the central part.

Longitudinal girders

The thickness of longitudinal girders above the inner bottom is not to be less than, for
P < 1500 kW

$$\mathbf{t} = \sqrt{(\frac{\mathbf{P}}{\mathbf{15}}) + \mathbf{6})}$$

$$= \sqrt{\frac{\mathbf{365}}{\mathbf{15}} + \mathbf{6}}$$

$$= \mathbf{10.953\ mm}$$

So we take the thickness of longitudinal girder as $\boldsymbol{t} = \mathbf{11}\ \boldsymbol{mm}$

Foundation bolts

The foundation bolts for fastening the engine at the seating shall be spaced no more than apart,

$$\boldsymbol{s = 3 \times d}$$

From the longitudinal foundation girder. Where the distance of the foundation bolts from the longitudinal foundation girder is greater, proof of equivalence is to be provided.
Where,

$\boldsymbol{d}$ = diameter of the foundation bolt =25 mm

So we have

$\boldsymbol{s = 3 \times d}$=75 mm

So we take the spacing of foundation bolt from the foundation girder 75 mm

Face plate dimension

Sectional area of the face plate should not be less than, (gl_i-2-2_e-8.2)

$$\boldsymbol{A_T = \frac{P}{Nr} * 23 + 40\ cm^2}$$

$$\boldsymbol{= \frac{365}{1350} * 23 + 40}$$

$$\boldsymbol{= 46.86\ cm^2 \approx 47\ cm^2}$$

Thickness (min) = 18+2.3 $\boldsymbol{P/Nr}$= 18.63 mm ≈ 20 mm

So the width of face plate will be,

$$\boldsymbol{b_T = \frac{A_T \times 100}{20}}$$

$$\boldsymbol{= \frac{47 \times 100}{20}}$$

$$\boldsymbol{= 235\ mm}$$

So we take width of face plate as $\boldsymbol{b_T = 235\ mm}$

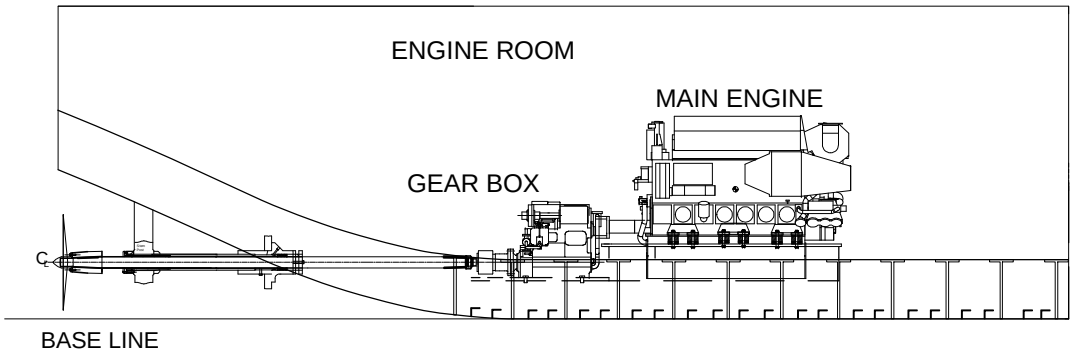
Web frame

The longitudinal girders of the engine seating are to be supported transversely by means of web frames. The scantlings of web frames are to be taken as before. Hence the dimension of the web frame T -section is $\mathbf{360} \times \mathbf{190} \times \mathbf{7}\,\boldsymbol{mm}$

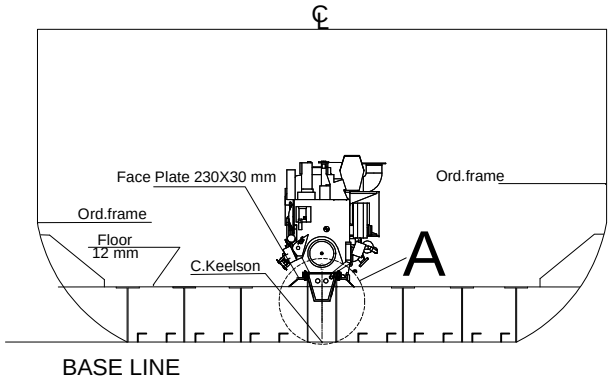
SUMMARY:

ITEMS	DIMENSIONS
FLOOR PLATE	10 mm (Thickness)
INNER BOTTOM PLATING	8 mm (Thickness)
Longitudinal girders	11 mm (Thickness)
Foundation bolts	25 mm (Diameter)
Face Plate Thickness	20 mm
Top plate dimension	235 mm (width)
Web Frame	360 × 190 × 7

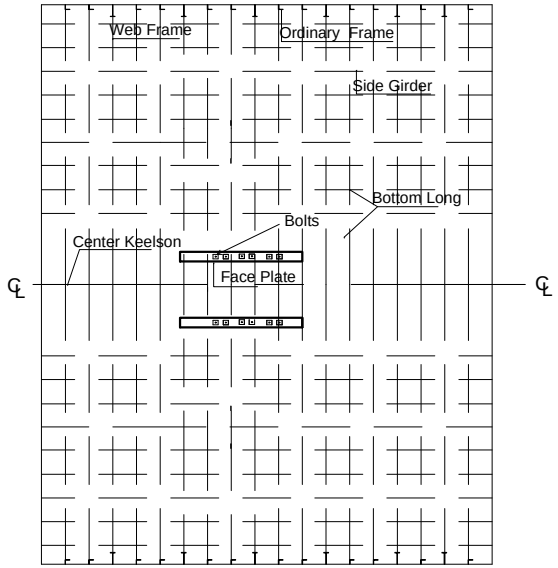
ENGINE FOUNDATION DRAWING



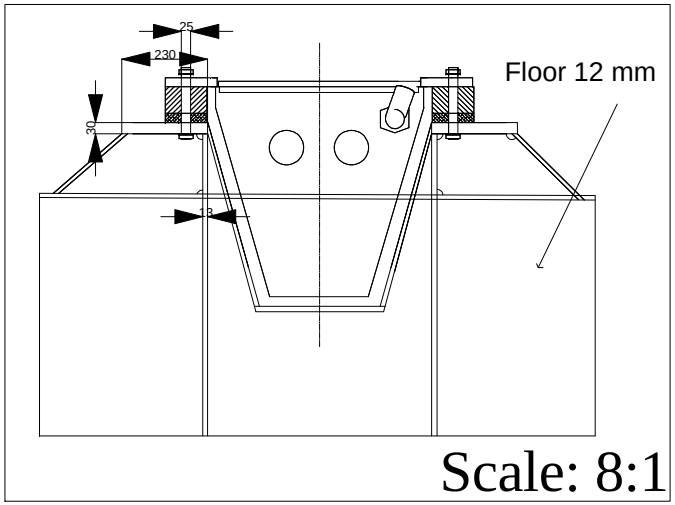
Side View



Section At Frame No-13



Top View



Detail A

Title: Engine Room Foundation
Course No. NAME 338
Designed by-
Mohammad Khalikujjaman
Abu Saleh Mohammad Arman

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