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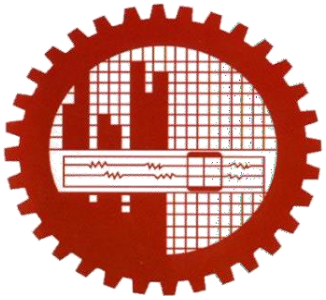


NAME 338

Ship Design Project & Presentation

A report on,

Design of an Inland Bulk Carrier of 2300 Tonnes Capacity

Under the Supervision of,

Professor Dr. N.M. Golam Zakaria
Department of Naval Architecture & Marine Engineering,
Bangladesh University of Engineering & Technology,
Dhaka.

Submitted by,

Group: N
Touseef Hasan (1812044)
Mehedi Hasan (1712046)

Contents

Forwarding Letter

To
Professor Dr. N.M. Golam Zakaria
Department of Naval Architecture & Marine Engineering,
Bangladesh University of Engineering & Technology,
Dhaka.

Subject: The design of a bulk carrier of 2300 tonnes capacity.

Respected Sir,

It is of immense pleasure to us to submit the draft of the report on the design project of an inland bulk carrier of 2300 tonnes capacity for operation in waterways of Bangladesh. We would also like to express our sincere gratitude to you for the support, encouragement, and overall guidance you have provided us throughout the entire timeline of the project.

We would like to convey our special thanks to Baytech Ship Builders and Bashundhara Steel & Engineering Ltd. for helping us with necessary data that has also made a significant difference to the validity of the project.

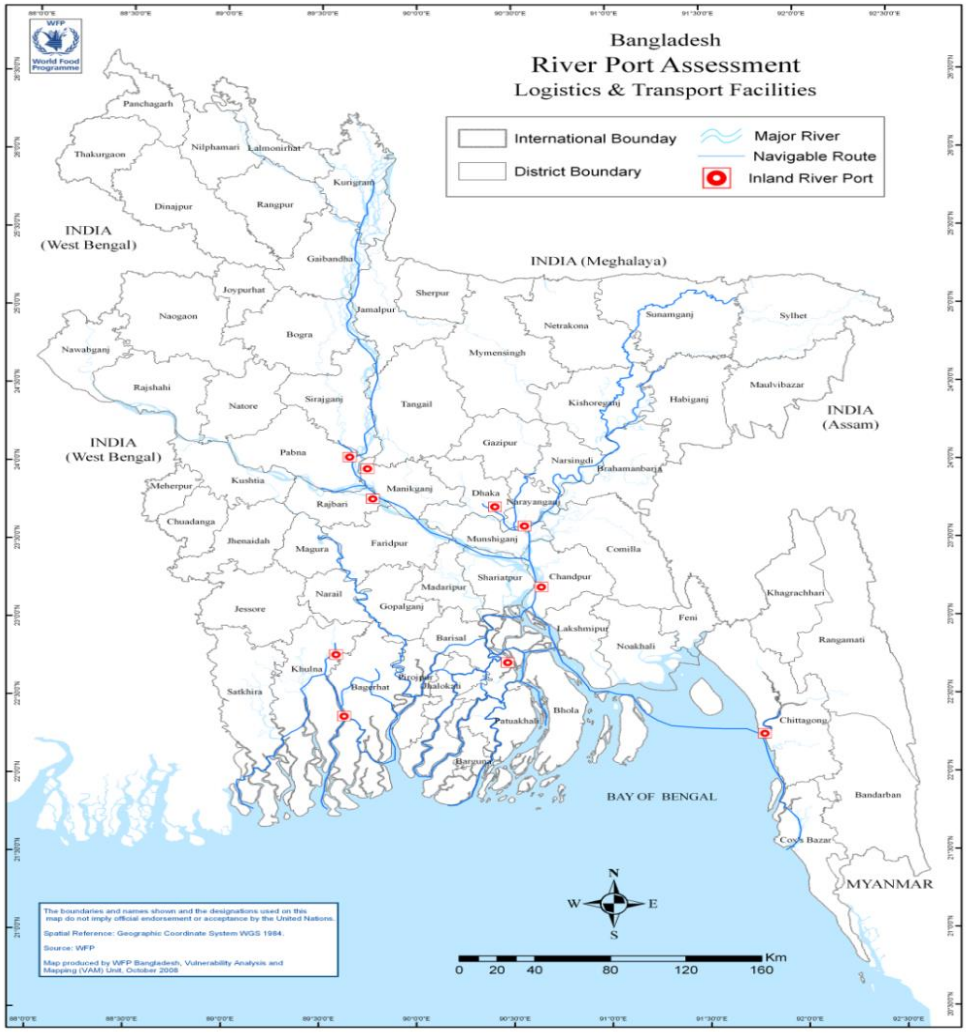
Sincerely yours,
Touseef Hasan (Student ID: 1812044)
Mehedi Hasan (Student ID: 1712046)

1. Owner's Requirements:

- Type of Ship : Bulk Carrier
- Capacity : 2300 tonnes
- Speed : 10 knots
- Route : Dhaka to Chittagong (Inland)

2. Route Specification:

- Route Distance: 315 Kilometers / 174 Nautical Miles
- Maximum Draft: 4.0 m
- Maximum Length: 76.0 m
- Maximum Breadth: 15.0 m



3. Determination of Principal Particulars

Selection of Basis Ship:

We are required to design an inland bulk carrier that has a capacity of 2300 tonnes.

After careful observation, we decided to choose an inland coal carrier that has a capacity of 2000 tonnes and operates in the Dhaka-Khulna route.

Particulars of Basis Ship:

LOA	63.2	m
LBP	61.5	m
B mld.	10.2	m
D mld.	4.6	m
T	3.5	m
Engine Power	522*2	kW
Service Speed	10	knots
Cb	0.79	
Cd	0.76	

Finding Principal Particulars of Required Ship:

LOA/LBP	= 1.027642		
LBP/B	= 6.029412		
B/D	= 2.217391		
B/T	= 2.914286		
Cb	= 1–0.19*(V/√L)	= 0.79	
∇	= LBP*B*T*Cb	1734.4845	m^3
		= 1734.485	tonnes
DWT	= ∇*Cd	1318.2086	tonnes

Admiralty Coefficient =	$\frac{\Delta\text{^}(2/3) * V\text{^}3}{P\_b}$	185.3565

Using Cubic Root Formula and from L/B, B/D, D/T ratio,

LBP	74.33752586	m	LOA	76.4	m
	74.4	m			
B	13.5398	m			
	13.54	m			
T	4.10102595	m	D	5.1	m
	3.85	m			
Cb	0.789799				
	0.79				

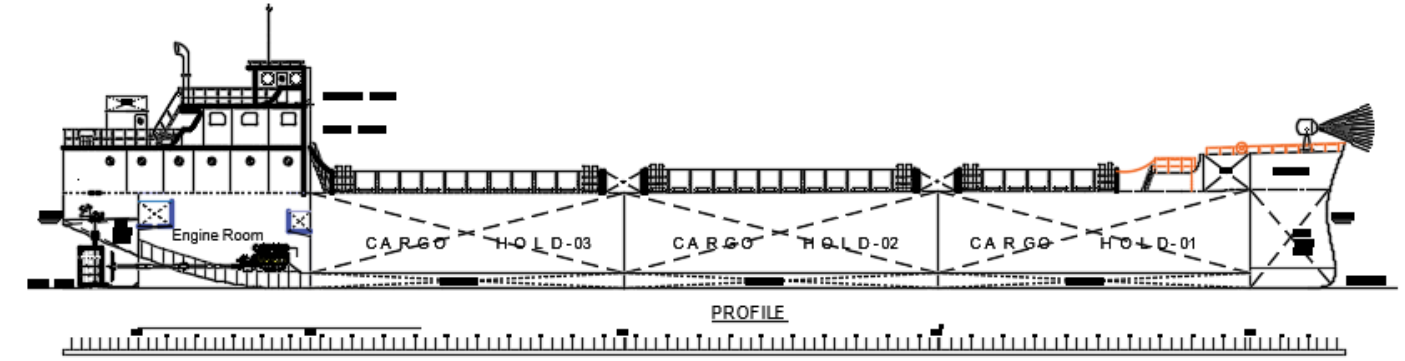
Final Principal Particulars of Required Ship:

LOA	76.4	m
LBP	74.4	m
B mld.	13.54	m
D mld.	5.1	m
T	3.85	m
Service Speed	10	knots
Cb	0.79	
Deadweight	2328	tonnes
Displacement	3063	tonnes

Manning:

Master	(Class 1)	1
	(Class 2)	1
Sailor		8
Driver	(Class 1)	1
	(Class 2)	1
Geezer		3
Total Crew:		**15**

4. General Arrangement



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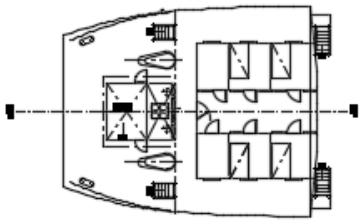
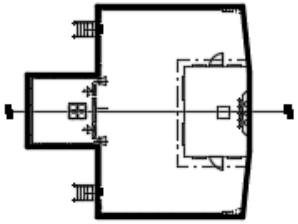
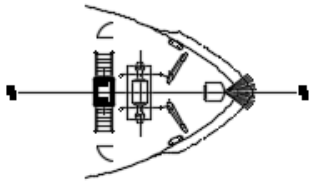


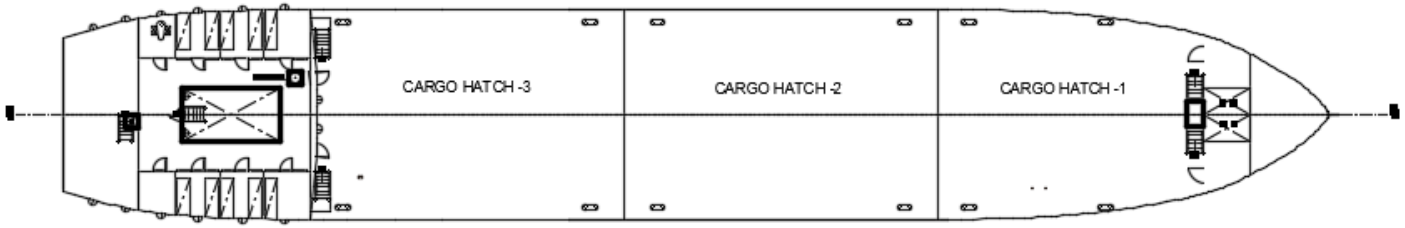
POOP DECK



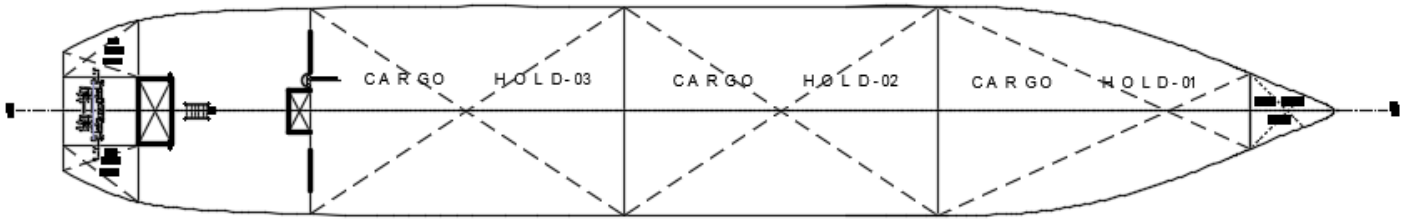
NAVIGATION DECK



FORECASTLE DECK



MAIN DECK



UNDER DECK

Principal Particulars

Length Overall, LOA	76.4 m
Length between Perpendiculars, LBP	74.4 m
Breadth, B	13.54 m
Draft, T	3.85 m
Depth, D	5.1 m
Frame Spacing	550 mm

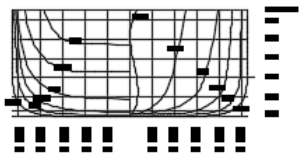
General Arrangement Drawing

Name	Student ID
Touseef Hasan	1812044
Mehedi Hasan	1712046

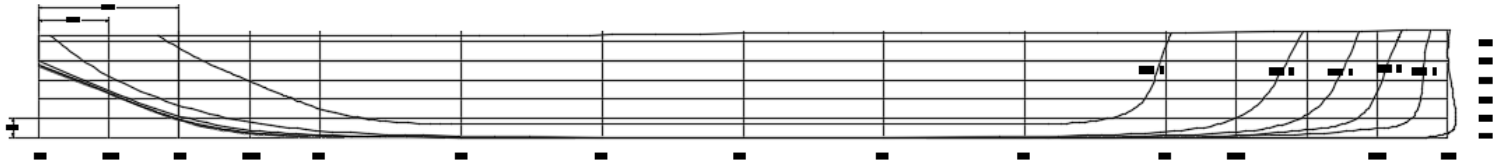
5. Lines Plan

Offset Table:

	Half Breadth (mm)							Height above Base Line (mm)					
Station	**Keel**	**WL1**	**WL2**	**WL3**	**WL4**	**WL5**	**Deck At Side**	**Keel**	**BTK1**	**BTK2**	**BTK3**	**BTK4**	**BTK5**
0	0	-	-	-	3854	4721	4943	4121	4141	4191	4430	3543	-
0.5	0	-	-	4936	5664	5964	6046	2530	2554	2564	2687	1858	-
1	0	3200	5913	6052	6292	6447	6515	981	1016	1050	1236	874	5353
1.5	0	5453	6125	6349	6456	6544	6592	207	244	292	417	377	4066
2	0	6113	6471	6547	6603	6659	6699	56	68	89	129	71	1922
3	0	6623	6760	6765	6765	6765	6765	0	0	4	6	71	742
4	0	6623	6760	6765	6765	6765	6765	0	0	4	6	71	742
5	0	6623	6760	6765	6765	6765	6765	0	0	4	6	71	742
6	0	6623	6760	6765	6765	6765	6765	0	0	4	6	71	742
7	0	6623	6760	6765	6765	6765	6765	0	0	4	6	71	742
8	0	6060	6340	6376	6397	6415	6424	0	25	56	102	310	5139
8.5	0	5118	5549	5699	5794	5862	5890	25	81	139	313	1135	-
9	0	3678	4314	4584	4803	4981	5076	43	193	492	1306	-	-
9.5	0	1890	2389	2660	2916	3140	3246	60	495	2921	-	-	-
10	0	440	385	163	-	191	385	148	-	-	-	-	-



BODY PLAN



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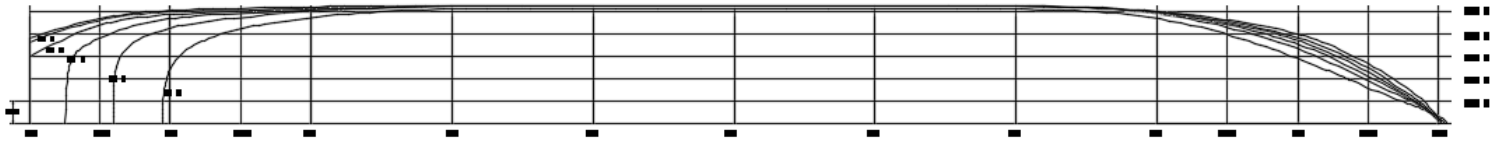


HALF BREADTH PLAN

Principal Particulars

Length Overall, LOA	76.4 m
Length between Perpendiculars, LBP	74.4 m
Breadth, B	13.54 m
Draft, T	3.85 m
Depth, D	5.1 m
Frame Spacing	550 mm
Station Spacing	8.134 mm
Waterline Spacing	1.1 mm
Buttock Spacing	1.285 mm

Lines Plan

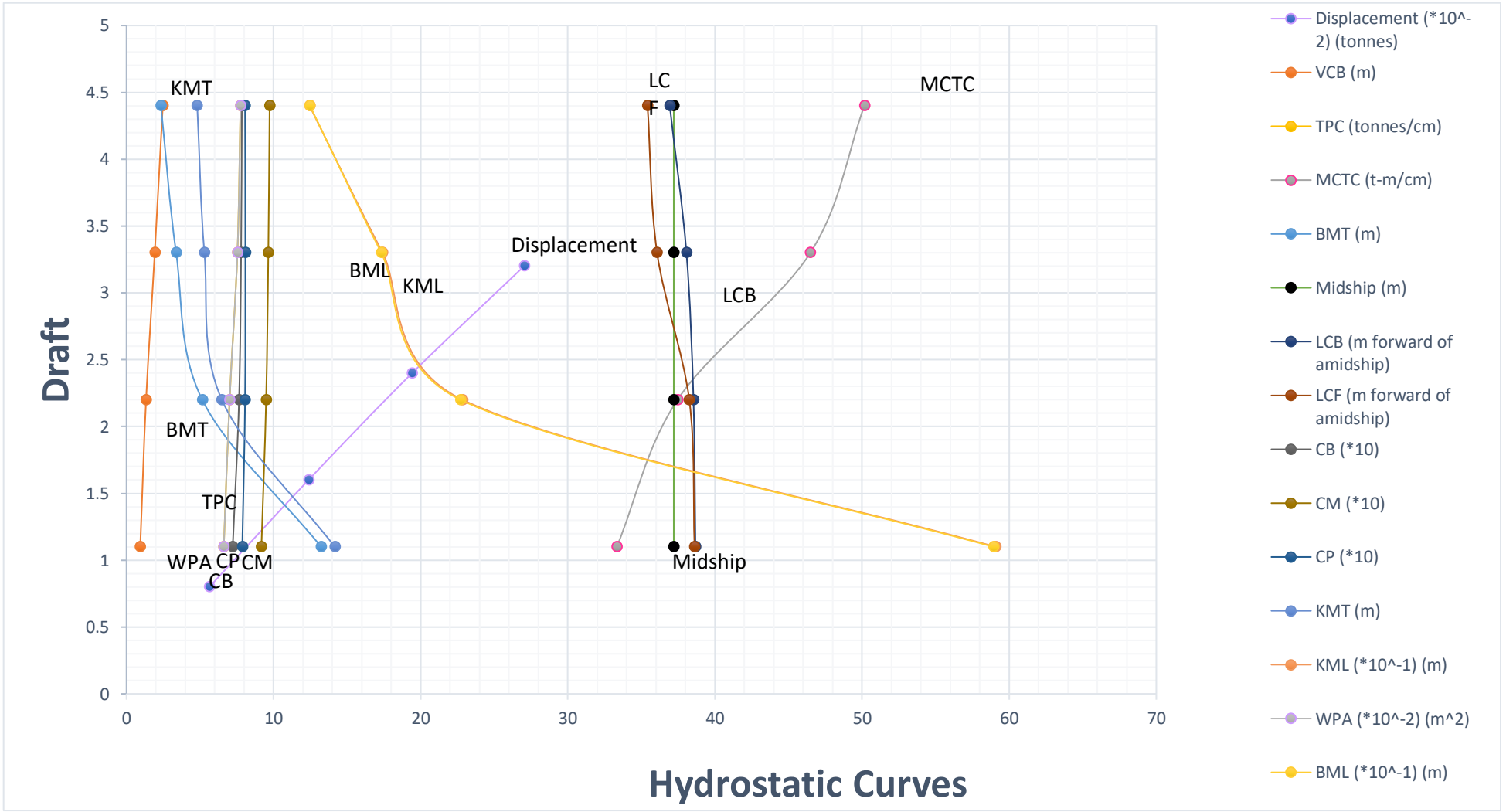
Name	Student ID
Touseef Hasan	1812044
Mehedi Hasan	1712046

6. Hydrostatic Calculations

Summary of Hydrostatic Calculations

Waterline	Position of Waterline (m)	Displacement (ton)	VCB (m)	LCB (m from amidship)	TPC (tonnes/cm)	BM_T (m)	BM_L (m)	LCF (m from amidship)	MCTC (t-m/cm)	CB	CP	CM	KML (m)	KMT (m)
1.000	1.100	420.737	0.932	1.469	6.613	13.230	589.317	1.414	33.326	0.722	0.787	0.917	590.786	14.162
2.000	2.200	1226.901	1.330	1.339	7.008	5.149	227.121	1.055	37.454	0.765	0.806	0.949	228.460	6.480
3.000	3.300	1996.590	1.920	0.861	7.539	3.374	173.229	-1.135	46.487	0.779	0.808	0.964	174.090	5.294
4.000	4.400	2993.128	2.467	-0.274	7.751	2.339	124.685	-1.784	50.161	0.784	0.806	0.973	124.412	4.806

Hydrostatic Curves



7. Scantling Calculations

Rule Book Used: Germanischer Lloyd 2013

Principal Particulars

LWL	76.4	m
L	74.4	m
B	13.54	m
D	5.1	m
T	3.8	m
Cb	5	
v_0	0.79	kn
	10	
	5.1	
	44	m/s

Higher strength hull structural steels

Higher strength hull structural steel is a hull structural steel, the yield and tensile properties of which exceed those of normal strength hull structural steel. According to the GL Rules for Metallic Materials (II-1), for three groups of higher strength hull structural steels the yield strength R_{eH} has been fixed at 315, 355 and 390 N / mm^2 respectively.

k	0.78		[Chapter-1, Section-2, A.2.1]
R_{eH}	315	N/mm^2	

$k = 0.78$ for $R_{eH} = 315\ N / mm^2$

Design Loads

[Chapter-1, Section-4]

F	0.127
m	1
m_0	1.627
a_v	0.127
c_L	0.909
c_{RW}	1

F : coefficient, defined as:

$$F = 0.11 \cdot \frac{v_0}{\sqrt{L}}$$

m_0 : coefficient, defined as:

$$m_0 = 1.5 + F$$

a_v : acceleration addition, defined as:

$$a_v = F \cdot m$$

c_L : length coefficient, defined as:

$$c_L = \sqrt{\frac{L}{90}} \quad \text{for } L < 90 \text{ m}$$

$$c_L = 1.0 \quad \text{for } L \geq 90 \text{ m}$$

c_{RW} : service range coefficient, defined as:

$$c_{RW} = 1.00 \quad \text{for unlimited service range}$$

c_0	7.076	
f	1 0.75 0.6	
p_0	15.09 8	kN/mm ^2
p_L	28.08 96	kN
z	3	
c_F	1	

c_0 : wave coefficient, defined as:

$$c_0 = \left[\frac{\mathbf{L}}{25} + 4.1\right] \cdot c_{RW} \qquad \text{for } \mathbf{L} < 90 \text{ m}$$

f : probability factor, defined as:

$f = 1.00$	for plate panels of the outer hull (shell plating, weather decks)
$f = 0.75$	for secondary stiffening members of the outer hull (frames, deck beams), but not less than f_Q as defined in Section 5, D.2.3
$f = 0.60$	for girders and girder systems of the outer hull (web frames, stringers, grillage systems), but not less than $f_Q / 1.25$

p_0 : basic external dynamic load $[kN / mm^2]$ for wave directions with or against the ship's heading, defined as:

$$p_0 = 2.1 \cdot (C_B + 0.7) \cdot c_0 \cdot c_L \cdot f$$

C.1.3 The loads P_L due to single forces P (e.g. in case of containers) are to be determined by following formula:

$$P_L = P \cdot (1 + a_v) \quad [kN]$$

P : single force [kN] acting on cargo deck

c_D	1		

External Sea Loads

Load on weather decks	p_D	24.912 62	kN/m^2
Load on the ship's bottom	p_B	53.598 02	kN/m^2
Load on the ship's sides	p_S	35.362 7	kN/m^2

B External Sea Loads

B.1 Load on weather decks

The load p_D on weather decks is to be determined by the following formula:

$$p_D = p_0 \cdot \frac{20 \cdot \mathbf{T}}{(10 + z - \mathbf{T}) \cdot \mathbf{H}} \cdot c_D \quad [kN/m^2] \qquad \text{with } p_D \geq p_{D,min}$$

B.5 Load on the ship's bottom

The load p_B on the ship's bottom is to be determined by the following formula:

$$p_B = 10 \cdot \mathbf{T} + p_0 \cdot c_F \quad [kN/m^2]$$

B.2 Load on ship's sides

The loads p_S and p_{SI} on the ship's sides are to be determined by the following formulae:

For elements having the load centre located below the load waterline:

$$p_S = 10 \cdot (\mathbf{T} - z) + p_0 \cdot c_F \cdot \left(1 + \frac{z}{\mathbf{T}}\right) \quad [kN/m^2]$$

for wave directions with or against the ship's heading

Shell Structures [Chapter-1, Section-6]

Permissible design stress		284.6496	N/mm^2				
		285	N/mm^2	σ_{perm}	: permissible design stress [N / mm^2], defined as:		
					$\sigma_{perm} = \left(0.8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k}$		for $\mathbf{L} < 90$ m
Minimum plate thickness	t_{min}	10.11787	mm	c_1	1	m	[*L>50 m]*
		11	mm	t_K	2.5	m	*[Corrosion Addition]*

B.2 Minimum plate thickness

At no point the thickness t_B of the bottom shell plating is to be less than t_{min} determined by the following formulae:

$$t_{min} = c_1 \cdot \sqrt{\mathbf{L} \cdot k} + t_K \quad [mm] \qquad \text{with } t_{min} \leq 16 \text{ mm}$$

c_1 : coefficient, defined as:

$$c_1 = (1.5 - 0.01 \cdot \mathbf{L}) \qquad \text{for } \mathbf{L} < 50 \text{ m}$$

$$c_1 = 1.00 \qquad \text{for } \mathbf{L} \geq 50 \text{ m}$$

Plate thickness

Thickness of bottom shell plating	t_{B1}	$t = c_1 * \sqrt{L * k} + t_k$	10.117	m			0.8		[*Longitudinal framing system] [Frame spacing]*
			87	m		nf	3		
				m			55	m	
			11	m		a	0	m	
							0.5		
							5	m	
	t_{B2}	$t = 1.9 * n_f * a * \sqrt{L * k} + t_k$	9.1073	m					
			63	m					
				m					
			10	m					
Thus,	t_B	10	mm						

B.1 Plate thickness

The thickness t_B of the bottom shell plating is not to be less than determined by the following formulae:

For ships without proven longitudinal strength:

$t_B = t_{Bl}$ within 0.4 **L** amidships

$t_B = \max[t_{Bl} ; t_{B2}]$ within 0.1 **L** forward of the aft end of the length **L** and within 0.05 **L** aft of **F.P.**

$t_{Bl} = 1.9 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{p_B \cdot k} + t_K$ [mm]

$t_{B2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p_B \cdot k} + t_K$ [mm]

Bilge Strake

Minimum width of bilge strake	b	1172	mm
		1200	mm

B.3.2 If according to Section 2, B. a higher steel grade than A / AH is required for the bilge strake, the width of the bilge strake is not to be less than determined by the following formulae:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}]$$

Minimum thickness of bilge strake	t	10.117	
		87	mm
		11	mm

The thickness of these plate fields is not to be less than the thickness determined according to from B.1, B.2 and C.1 respectively.

Flat Plate
Keel

Minimum width of flat plate keel	b	1172 1200	mm mm
Thickness of flat plate keel	t_{FK}	12	mm

B.4 Flat plate keel and garboard strake

B.4.1 The width b of the flat plate keel is not to be less than determined by the following formula:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}]$$

The thickness t_{FK} of the flat plate keel is not to be less than be determined by the following formulae:

$t_{FK} = t_B + 2.0$ [mm] within $0.7\,\mathbf{L}$ amidships and in way of the engine seating

$t_{FK} = t_B$ [mm] otherwise

t_B : thickness of the bottom plating according to B.1 and B.2

Side Shell Plating

Thickness of side shell plating		7.0552		
	t_{S1}	73	mm	
		8	mm	
		5.9951		
	t_{S2}	68	mm	
		6	mm	
	t	11	mm	*[Minimum plate thickness]*

C Side Shell Plating

C.1 Plate thickness

The thickness t_S of the side shell plating is not to be less than determined by the following formulae:

For ships without proven longitudinal strength:

$t_S = t_{S1}$ within 0.4 **L** amidships

$t_S = \max\left[t_{S1} ; t_{S2}\right]$ within 0.1 **L** forward of the aft end of the length **L** and within 0.05 **L** aft of **F.P.**

$$t_{S1} = 1.9 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{p_S \cdot k} + t_K \quad [mm]$$

$$t_{S2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

C.2 Minimum plate thickness

At no point the thickness t_S of the side shell plating is to be less than t_{min} determined according to B.2.

Sheerstrake

Width of the sheerstrake	b	1172	mm
		1200	mm
Maximum width of the sheerstrake	b_{max}	1800	mm

C.3 Sheerstrake

C.3.1 The width b of the sheerstrake is not to be less than determined by the following formula:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}] \qquad \text{with } b \le b_{max}$$

b_{max} : maximum width of the sheerstake [mm], defined as:

$$b_{max} = 1\,800$$

Thickness of the sheerstrake	t	9.5	mm

C.3.2 The thickness t of the sheerstrake is, in general, not to be less than determined by the following formula:

$$t = 0.5 \cdot (t_D + t_S) \quad [\text{mm}] \qquad \text{with } t \ge t_s$$

Bulwark

Thickness of bulwark plating	t	1.4640 52 2	 mm mm

I Bulwark

I.1 The thickness t of bulwark plating is not to be less than determined by the following formulae:

$$t = \left(0.75 - \frac{L}{1000}\right) \cdot \sqrt{L} \quad [mm] \qquad \text{for } L \leq 100 \text{ m}$$

Minimum vertical bulwark height		1000 1	mm m

I.2 The vertical bulwark height or height of guard rail is not to be less than 1.0 m.

Decks

[Chapter-1, Section-7]

Minimum plate thickness	t_{min}	5.3318	
		88	mm
		8	mm

The plate thickness t is not to be less than determined by the following formula:

$$t = 1.1 \cdot \mathbf{a} \cdot \sqrt{p_L \cdot k} + t_K \quad [mm] \qquad \text{with } t \geq t_{min}$$

Bottom Structures [Chapter-1, Section-8]

Longitudinal Girder System

Plate thickness of the longitudinal girders	t	4.5178	m	
		87	m	
			m	
		6	m	*[Minimum thickness]*
Minimum plate thickness	tmin	5.2990	m	
		57	m	
			m	
		6	m	

C.6.4.2 The plate thickness t of the longitudinal girders is not to be less than determined by the following formula:

$$t = (5.0 + 0.03 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [mm] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum plate thickness [mm], defined as:

$$t_{min} = 6.0 \cdot \sqrt{k}$$

Center Girder

Depth of the center girder	h	523.25	mm	
		600	mm	*[Minimum depth]*
Minimum depth	h_{min}	600	mm	

C.2.2.1 The depth h of the centre girder is not to be less than determined by the following formula:

$$h = 350 + 45 \cdot \ell \quad [mm] \qquad \text{with } h \geq h_{min}$$

h_{min} : minimum depth [mm], defined as:

$$h_{min} = 600$$

Thickness of the center girder	t_m	6.1822		
		33	mm	
		7	mm	

C.2.2.2 The thickness t_m of the centre girder is not to be less than determined by the following formulae:

$$t_m = \frac{h}{h_a} \cdot \left(\frac{h}{100} + 1.0 \right) \cdot \sqrt{k} \quad [mm] \qquad \text{for } h \leq 1\,200 \text{ mm}$$

Side Girders

Thickness of the side girders	t_m	4.4158		
		8	mm	
		6	mm	*[Minimum thickness]*

The thickness t_m of the side girders is not to be less than determined by the following formula:

$$t_m = \frac{h^2}{120 \cdot h_a} \cdot \sqrt{k} \quad [mm] \qquad \text{with } t_m \geq t$$

Inner Bottom Plating

Thickness of the inner bottom plating	t	5.6774		
		26	mm	
		6	mm	

C.4.1 The thickness t of the inner bottom plating is not to be less than determined by the following formula:

$$t = 1.1 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

Plate Floors

Thickness of plate floors	tpf	5.2336	
		48	mm
		6	mm

C.5.2.1 The thickness t_{pf} of plate floors is not to be less than determined by the following formula:

$$t_{pf} = t_m - 2.0 \cdot \sqrt{k} \quad [mm] \qquad \text{with} \quad t_{pf} \le 16 \text{ mm}$$

t_m : thickness of centre girder according to C.2.2.2

Floor thickness	t	6.3	mm	P	650	HP
		7	mm		484.9	kW
				c	1.0045 7	
					1.05	*[minimum]*

D.3.1 Plate floors

Plate floors are to be fitted at every frame. The floor thickness t is to be determined by the following formula:

$$t = c \cdot t_{pf} \quad [mm]$$

c : coefficient, defined as:

$$c = 1.0 + \left(3.6 + \frac{P}{500}\right) \cdot 10^{-3} \qquad \text{with } 1.05 \le c \le 1.15$$

P : single engine output [kW]

t_{pf} : thickness of floor plates according to B.5.2.1

Longitudinal Girder System

Plate thickness of longitudinal girders	t	6.3871	
		29	mm
		7	mm

C.6.4.2 The plate thickness t of the longitudinal girders is not to be less than determined by the following formula:

$$t = (5.0 + 0.03 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [mm] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum plate thickness [mm], defined as:

$$t_{min} = 6.0 \cdot \sqrt{k}$$

Thickness of longitudinal girders	t	11.685	
		65	mm
		12	mm

D.4.2.1 The thickness t of the longitudinal girders above the inner bottom is not to be less than determined by the following formula:

$$t = \sqrt{\frac{P}{15}} + 6 \quad [mm] \qquad \text{for } P < 1\,500 \text{ kW}$$

Watertight Bulkheads [Chapter-1, Section-10]

Bulkhead
Plating

Thickness of collision bulkhead plating	t	6.4118 03	mm	f	0.78	
					0.9714	*[collision*
		7	mm	cp	94	*bulkhead]*
					0.7948	*[other*
					58	*s]*
Thickness of other bulkhead plating	t	5.7005 66	mm			
		6	mm			

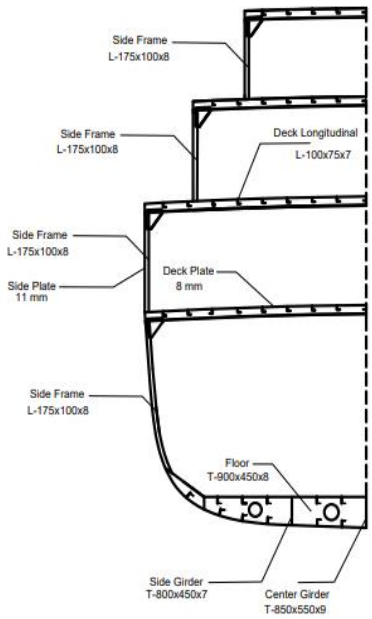
Structural element	Coefficient	Boundary Condition	Collision bulkhead	Other bulk-heads
Plating	c_p	-	$1.1 \cdot \sqrt{f}$	$0.9 \cdot \sqrt{f}$

Scantling Summary

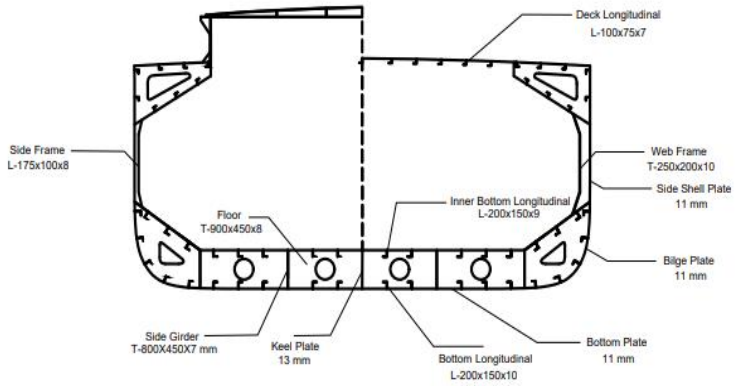
Items	Property	Value
	Plating	
Bottom Shell Plate	Thickness (mm)	11
Bilge Strake	Thickness (mm)	10
	Width (mm)	1200
Flat Keel Plate	Thickness (mm)	13
	Width (mm)	1200
Side Shell Plate	Thickness (mm)	11
Sheer Strake	Thickness (mm)	8.5
	Width (mm)	1200
Bulwark Plate	Thickness (mm)	2
Deck Plate	Thickness (mm)	8
	Bottom Structure	
Bottom Longitudinal	Dimension	L-200x150x10
Bottom Center Girder	Dimension	T-850x550x9
Bottom Side Girder	Dimension	T-800x450x7
Inner Bottom Longitudinal	Dimension	L-200x150x9
Floor	Dimension	T-900x450x8
	Side Structure	
Main Frame	Dimension	L-175x100x8
Web Frame	Dimension	T-250x200x10
Side Longitudinal	Dimension	L-150x75x8
	Deck Structure	
Deck Longitudinal	Dimension	L-100x75x7
Deck Web	Dimension	T-200x100x10

	Watertight Bulkheads	
Plate	Thickness (mm)	9
Web	Dimension	T-200x100x9
Vertical Stiffeners	Dimension	L-75x50x9
Transverse Stiffeners	Dimension	L-90x65x7
	Superstructure	
Top Plate	Thickness (mm)	7
Side Plate	Thickness (mm)	9
Side Frame	Dimension	L-125x75x7
Web Frame	Dimension	T-250x175x9
Deck Longitudinal	Dimension	L-100x75x7

8. Midship Section (Drawing)



Frame No. 21



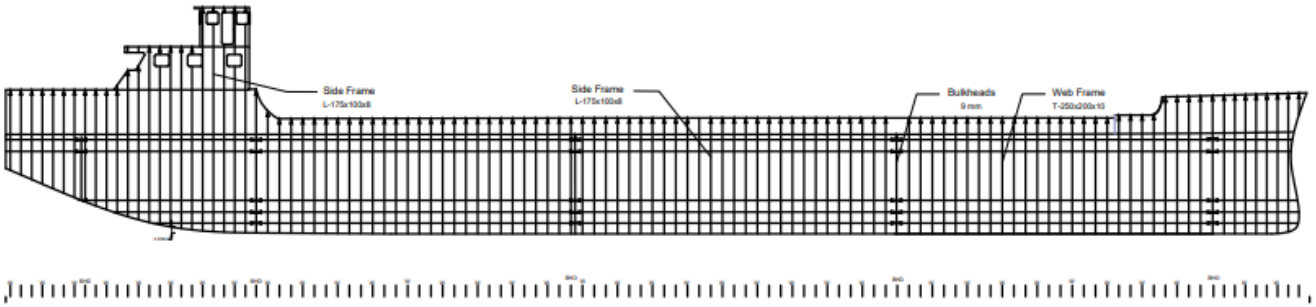
Frame No. 60 Frame No. 52

Principal Particulars	
Length Overall, LOA	76.4 m
Length between Perpendiculars, LBP	74.4 m
Breadth, B	13.54 m
Draft, T	3.85 m
Depth, D	5.1 m
Frame Spacing	550 mm

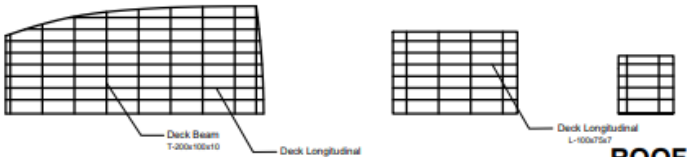
Midship Section Drawing	
Name	Student ID
Touseef Hasan	1812044
Mehedi Hasan	1712046

9. Longitudinal Construction (Drawing)

Principal Particulars	
Length Overall, LOA	76.4 m
Length between Perpendiculars, LBP	74.4 m
Breadth, B	13.54 m
Draft, T	3.85 m
Depth, D	5.1 m
Frame Spacing	550 mm



ELEVATION

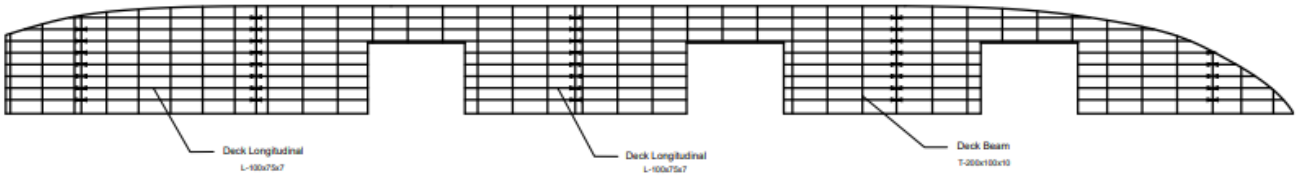


POOP DECK

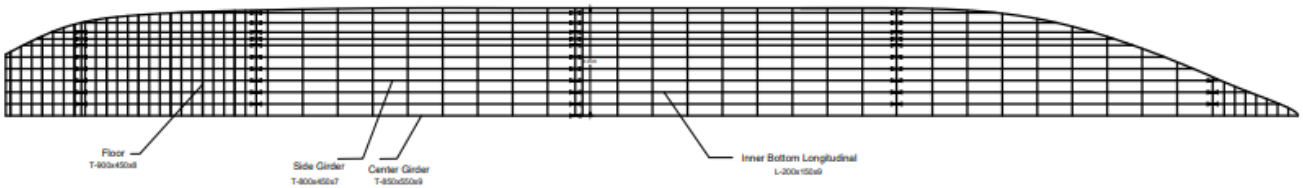
BRIDGE DECK

ROOF

FORECASTLE DECK



MAIN DECK



BOTTOM

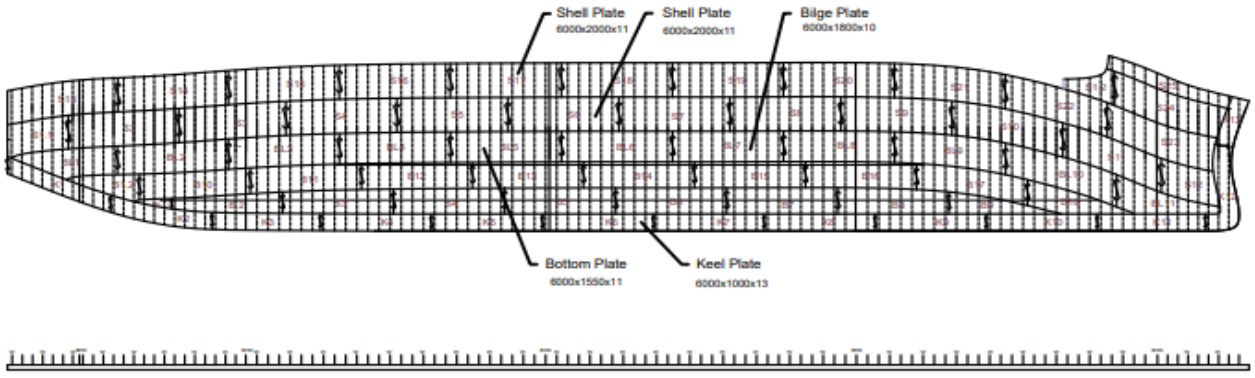
Longitudinal Construction Drawing	
Name	Student ID
Touseef Hasan	1812044
Mehedi Hasan	1712046

10. Shell Expansion (Drawing)

Plate Type, Dimension and Number:

Type of Plate	Dimension	Plate Number
Keel Plate	K1 - K12: 6000x1000x13 K13: 2630x1000x13	13
Bottom Shell Plate	B1 - B18: 6000x1550x11	18
Bilge Plate	BL1: 3145x520x10 BL2 - BL3: 6000x970x10	3
Shell Plate	S1 - S24: 6000x2000x11 S25: 6000x850x11	25

Principal Particulars	
Length Overall, LOA	76.4 m
Length between Perpendiculars, LBP	74.4 m
Breadth, B	13.54 m
Draft, T	3.85 m
Depth, D	5.1 m
Frame Spacing	550 mm



SHELL EXPANSION

Shell Expansion Drawing	
Name	Student ID
Touseef Hasan	1812044
Mehedi Hasan	1712046

11. Resistance & Power Calculation

Resistance Calculation (According to Holtrop & Mennen's Method)

$$R_{Total} = R_F(1+k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A$$

where:

R_F = frictional resistance according to the ITTC-1957 formula

$1+k_1$ = form factor of the hull

R_{APP} = appendage resistance

R_W = wave resistance

R_B = additional pressure resistance of bulbous bow near the water surface

R_{TR} = additional pressure resistance due to transom immersion

R_A = model-ship correlation resistance.

Principal Particulars

L (LWL)	76.400	m
L_{PP}	74.400	m
LCB	-0.223	m
B	13.540	m
H	5.100	m
T	3.850	m
∇	3063.934	m^3
C_B	0.790	
C_{PR}	0.814	
C_X	0.973	
C_S	0.894	
Fn	0.1-0.8	

L/LPP	1.027
LCB	0.223
B/LPP	0.182
H/LPP	0.069
T/L	0.052
B/T	3.517

L/B	5.495
L/T	19.325
B/L	0.182
$L/\Delta^{1/3}$	5.122

Coefficient accounts for specific shape of afterbody	**C_{13}**	$1 + 0.003C_{stern}$	1.030	(For U Shape C_{strern}=+10)	
Coefficient	**C_{12}**	(T/L)^0.2228446	0.517	(When T/L > 0.05)	
Longitudinal centre of buoyancy	**L_{CB}**	1.5% of Length aft of amidship	-0.223		
Parameter reflecting the length of the run	**L_R**	$L \{1 - C_P + 0.06\, C_P\, L_{CB}/(4C_P - 1) \}$	12.010		
Form factor	**$1+k_1$**	$C_{13} \{ 0.93 + C_{12} (B/L_R)^{0.92497} (0.95 - C_P)^{-0.521448} (1 - C_P + 0.0225L_{CB})^{0.6906} \}$	1.350		
Waterplane area co-efficient	**C_{WP}**	$2/3\, C_B + 1/3$	0.860		
Wetted area of the hull	**S**	$L(2T+B)\sqrt{C_M}(0.453+0.4425C_B-0.2862C_M-0.003467\, B/T+0.3696C_{WP})+2.38A_{BT}/C_B$	1298.050		
Coefficient	**C_7**	B/L	0.182	(For .11< B/L <.25)	
Half angle of entrance	**i_E**	$1 + 89 \exp \{-(L/B)^{0.80856}(1-C_{WP})^{0.30484}(1-C_P-$	45.465	48.000	

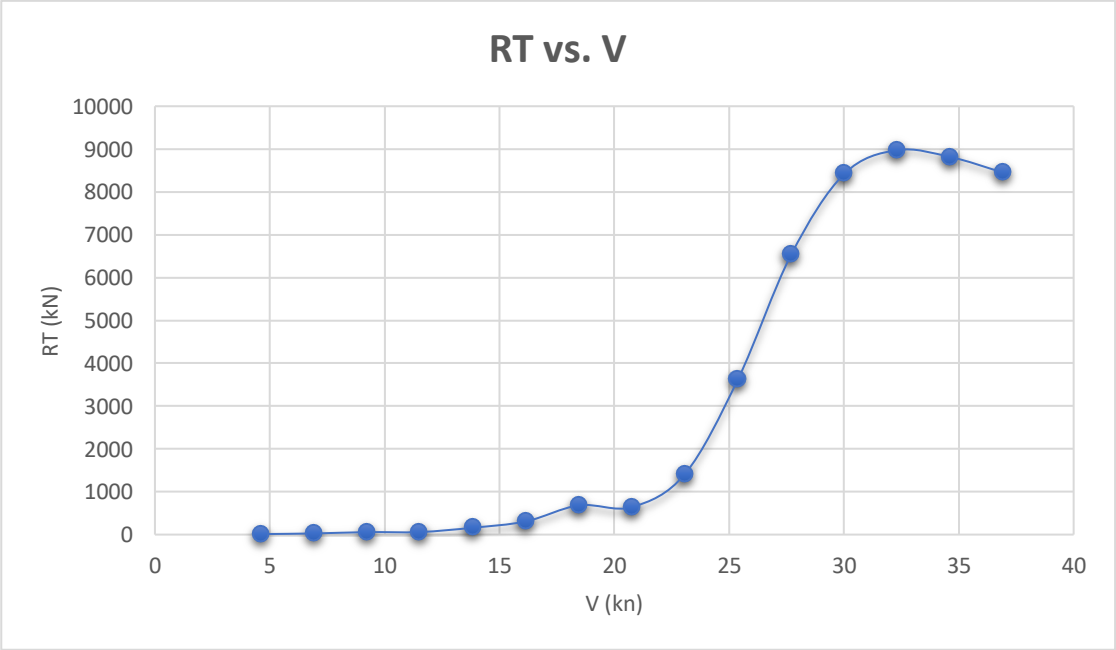
		$0.0225L_{CB})^{0.6367}(L_R/B)^{0.34574}(100\nabla/L^3)^{0.16302}\}$		
Coefficient	$\mathbf{C_1}$	$2223105\ c_7{}^{3.78613}\ (T/B)^{1.07961}(90\text{-}i_E)^{-1.37656}$	5.263	
A parameter which expresses the influence of a transom stern on the wave resistance	$\mathbf{C_5}$	$1\text{-}0.8\ A_T/(BTC_M)$	0.988	
A parameter which accounts for the reduction of the wave resistance due to the action of bulbous bow	$\mathbf{C_2}$	$\exp(-1.89\sqrt{c_3})$	1.000	(Since C_3 = 0 due to A_{BT}=0)
Parameter	$\mathbf{m_1}$	$0.0140407\ L/T - 1.75254\ \nabla^{1/3}/L - 4.79323B/L - c_{16}$	-2.098	
Coefficient	$\mathbf{C_{16}}$	1.73014-0.7067*Cp	1.155	(For Cp > 0.8)
Coefficient	$\mathbf{C_{15}}$	$-1.69385+(L/\nabla^{1/3}\text{-}8.0)/2.36$	-1.698	(For L^3/∇ <512)
Parameter reflecting the length of the run	$\boldsymbol{\lambda}$	$1.446C_P\text{-}0.03\ L/B$	1.012	(For L/B <12)
The wetted area of the appendages	$\mathbf{S_{APP}}$	2% of S	25.961	

The equivalent appendage resistance factor	$(1+k_2)_{eq}$	$\{\Sigma(1+k_2)S_{APP}\}/\Sigma S_{APP}$	12.200	
Increase in the correlation allowance coefficient	ΔC_A	$(0.105k_s^{1/3}-0.005579)/L^{1/3}$	-0.001	
Coefficient	C_4		0.052	
The correlation allowance coefficient	C_A	$0.006\,(L+100)^{-0.16} - 0.00205 + 0.003\sqrt{L/7.5}\,C_B^4 c_2\,(0.04 - c_4)$	0.001	

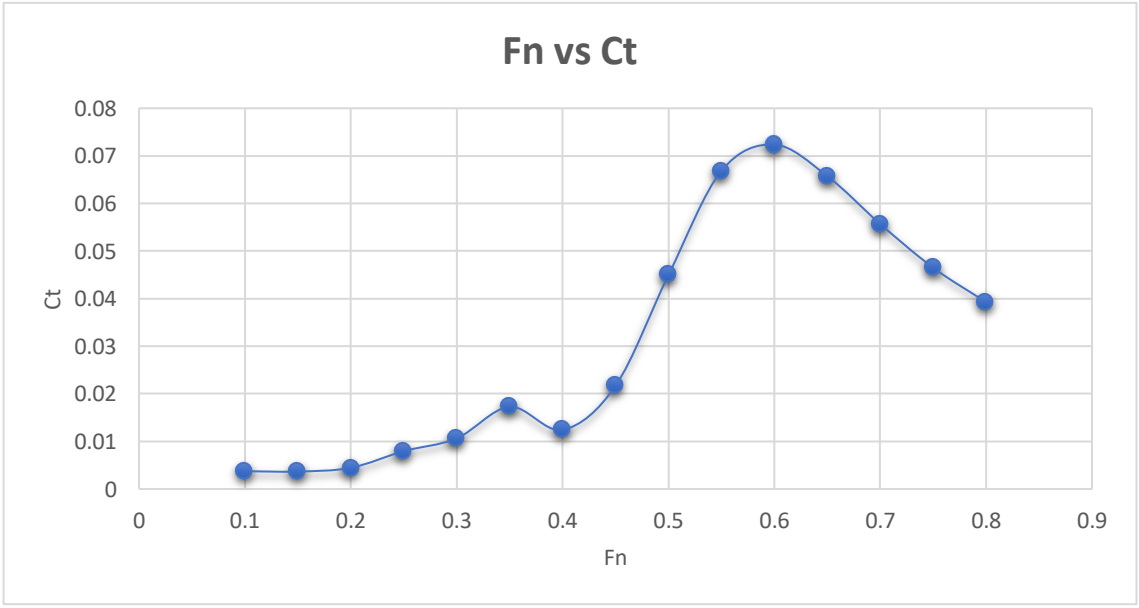
We take appendage as			$1 + k_2$	$(1 + k_2)S_{APP}$
	Rudder behind Stern		1.400	36.345
	Twin Screw Balance Rudder		2.800	72.691
	Shaft Bracket		3.000	77.883
	Strut Bossing		3.000	77.883
	Shaft		2.000	51.922
	Sum			316.724

F_n^{-2}	$\sin(F_n^{-2})$	$\cos(F_n^{-2})$	logRn - 2
100.000	-0.506	0.862	6.353
44.444	0.446	0.895	6.529
25.000	-0.132	0.991	6.654
24.483	-0.605	0.796	6.658
16.000	-0.288	-0.958	6.751
11.111	-0.993	0.115	6.830
8.163	0.953	-0.304	6.897
6.250	-0.033	0.999	6.955
4.938	-0.975	0.224	7.006
4.000	-0.757	-0.654	7.052
3.306	-0.163	-0.987	7.093
2.778	0.356	-0.935	7.131
2.367	0.700	-0.715	7.166
2.041	0.892	-0.453	7.198
1.778	0.979	-0.206	7.228
1.563	1.000	0.008	7.256

V (kn)	R_T (kN)
4.897	17.370
7.345	38.269
9.793	81.674
12.242	84.552
14.690	227.300
17.138	431.821
19.587	1065.992
22.035	966.196
24.483	2075.280
26.932	5442.389
29.380	10158.953
31.828	13449.688
34.277	14566.810
36.725	14419.048
39.173	13867.668



F_n	C_T
0.100	0.004
0.150	0.004
0.200	0.004
0.250	0.008
0.300	0.010
0.350	0.018
0.400	0.013
0.450	0.022
0.500	0.046
0.550	0.071
0.600	0.079
0.650	0.073
0.700	0.062
0.750	0.052
0.800	0.044



Power Calculation

C_F		R_F	m_2
$0.075/(\log Rn-2)^2$	F(nT)	$\rho SV^2C_F/2$	$c_{15}C_P{}^2 \exp(-0.1Fn^{-2})$
		(N)	
0.002	0.189	28489.593	-0.098

	R_W	R_{APP}		R_A	R_T
	$c_1c_2c_5\Delta\rho g \exp\{m_1Fn^{-9}+m_2\cos(\lambda Fn^{-2})\}$	$0.5\rho V^2S_{APP}(1+k_2)_{eq}C_F$		$0.5\rho V^2SC_A$	$R_F(1+k_1)+R_W+R_{APP}+R_A+R_B+R_{TR}$
	(N)	(N)		(N)	(kN)
	15896.371	5923.249		8428.246	58.381

Total Resistance, RT	**58.381**	**kN**
Effective Power, PE	**300.312**	**kW**

Based on the analysis in Appendix G, following corrected formulas for calculation of the wake fraction and the thrust deduction fraction for tankers and bulk carriers have been derived:

$$w_{Corrected} = 0.7 \cdot w_{Harvald} - 0.45 + 0.08 \cdot M$$

$$t_{Corrected} = t_{Harvald} - 0.26 + 0.04 \cdot M$$

The updated values of the hull efficiency according to the new formulas are also shown in Appendix G. The mean value of model test generated hull efficiencies is identical with the mean value of the corresponding hull efficiency calculated by using the corrected w and t formulas.

- *M*: Length-displacement ratio $M = \frac{L_{WL}}{\nabla^{1/3}}$
- C_P: Prismatic coefficient $C_P = \frac{C_B}{C_M}$
- *Fn*: Froude number

$$w_T = [0.71 - 2.39C_B + 2.33C_B^2] + [0.12C_B^4(6.5 - L/B)], \qquad (8.21)$$

suitable for C_B range 0.525–0.675 and L/B range 6.0–7.0.

Twin screw ships

$$t = 0.325\,C_B - 0.1885\,D/\sqrt{BT} \qquad \text{(A4.27)}$$

Twin screw ships

$$\eta_R = 0.9737 + 0.111\,(C_P - 0.0225\,LCB) - 0.06325\,P/D \qquad \text{(A4.35)}$$

Wake Function, Wt		**0.323**
	Wt (corrected)	0.186

	D/(BT)^0.5		0.224
Thrust Deduction Factor, t		**0.215**	
		0.159	

P/D	0.910

Relative Rotative Efficiency, ηR			**1.006**	
	Hull Efficiency, ηH		**0.965**	**(twin screw)**
	Thrust Power, Pt		**311.251**	**kW**

To calculate Open Water Efficiency,

$T=R_T(1-t)=$ 552.6214 kN

h=D/2+0.2 (height of shaft centre-line above base)

$$\frac{A_E}{A_0} = \frac{(1.3 + 0.3Z)T}{(P_0 - P_V)D^2} + K$$ Keller's formula

	Rt	**58.381**	**kN**
	T	**37.163**	**kN**
	P atm	**101.325**	**kPa**
	h	**1.009**	**m**
	H=T-h	**2.842**	**m**
	Pv	**1.646**	**kPa**
Po=P(atm)+PgH		**129.868**	**kPa**
	K	**0.100**	
	Z	**3.000**	
	Ae/Ao	**0.344**	
	Va	**8.141**	**knots**
		4.188	m/s
	Do	1.702	m
ηD =		0.534	
Pd= PE/ηD		562.569	kw

$P_D = P_E/\eta_D$

$V_A = V_{S(trial)}(1\text{-}w)$

$B_p = 1.158(NxP_D^{1/2}/V_A^{2.5})$

$\delta = 3.2808(NxD_0/V_A)$

BP	47.498
	247.500
Do	1.878
DB	1.784

OPTIMUM	
N	327.000
ηo	0.550
ηd	0.534

P_D		562.569	kW
Shaft efficiency	shaft loss 3.5%	0.965	
P_S		582.974	kW
Engine Efficiency	gear box loss 5%	0.950	
P_I		613.656	kW
sea margin	Considering 15% sea margin	0.150	
80% MCR operation		705.705	kW
Total engine break power		830.241	kW

415.120	**kW (for each engine)**	
556.462	**bhp (for each engine)**	

Engine and Gear Box Selection

Selected Engine: (Weichai Marine Engine)

General Specifications

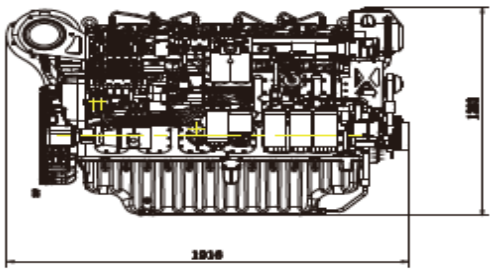
Configuration - In line,4-stroke diesel Aspiration ---------- TA
Fuel system ---- Mechanical Pump Bore & Stroke ------- 150×185 mm
Displacement ---------- 19.6L Min. fuel consumption - 198g/(kW.h)

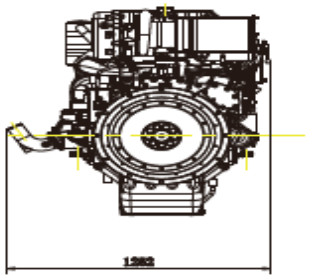
Model list

Model	HP	kW	RPM	Rating	Certificated
6M33C500-15	500	368	1500	P1	CCS, BV, RS, LR, GL, VR, RINA
6M33C550-15	550	405	1500	P1	
6M33C600-15	600	441	1500	P1	
6M33C650-15	650	478	1500	P2	
6M33C600-18	600	441	1800	P1	
6M33C650-18	650	478	1800	P1	
6M33C700-18	700	515	1800	P1	
6M33C750-18	750	551	1800	P2	
6M33C800-18	800	588	1800	P2	

Products Dimensions(mm)and Net Weight(kg)

Model	L	W	H	H*	Net Weight
6M33	1916	1252	1383	1000	2390

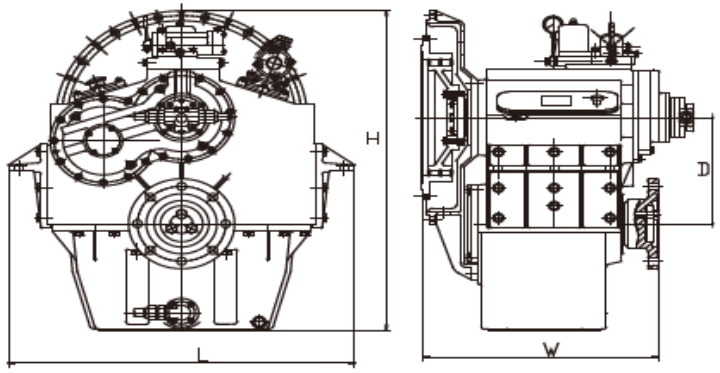




Selected Gear Box: (Weichai Marine Engine)

Marine Gearbox

Model	Input speed r/min	Ratio	kW/r/min	Rated thrust kN	Net Weight kg	Center distance mm	L mm	W mm	H mm
WHG300	750-2500	2,2.5	0.257	50	720	264	930	807	890
		3	0.243						
		3.5	0.221						
		4,4.5	0.184						
		5	0.147						
		5.5	0.125						
WHG300	750-2500	2,2.5,3	0.282	60	722	264	980	770	1066
		3.5,4	0.257						
		4.5	0.243						
		5	0.221						
		5.5,6	0.184						
		6.5,7	0.147						
		7.5	0.125						
	750-2300	6,6.5,7	0.243	70	1120		980	772	1106
		7.5,8	0.221						



Resistance Summary

Frictional Resistance	R_F	28.489	kN
Resistance of Appendages	R_{APP}	5.923	kN
Wave Making and Wave Breaking Resistance	R_W	15.896	kN
Additional Resistance due to Bulbous Bow	R(B)	0	kN
Resistance of Immersed Transom Stern	R(TR)	0.25	kN
Model Ship Correlation Resistance	R_A	8.428	kN
Total Resistance	R_T	58.381	kN

Power Summary

Effective Power	300.312	kW
ηo	0.55	
ηd (QPC)	0.534	
Delivered Power	562.569	kW
Shaft Power *(considering shaft loss of 3.5%)*	582.974	kW
Power *(considering gear box loss of 5%)*	613.656	kW
Power *(considering sea margin of 15%)*	705.704	kW
Total Brake Power *(considering 85% MCR)*	830.241	kW
Per Engine Brake Power	415.121	kW

12. Rudder Arrangement

Key Particulars

L_{PP}	76.40	m
L (LWL)	74.40	m
LCB	0.22	m
B	13.54	m
H	5.10	m
T	3.85	m
V	10.00	knots (Ahead)
	6.00	knots (Astern) (i.e. 60% of Ahead)

Rudder Area Calculation

A = $c_1.c_2.c_3.c_4$. $1.75 \cdot L \cdot T / 100$

5.013 m^2

A = $L \cdot T / 60$

4.774 m^2

For ship type, c_1	1.000	In general
For ruddder type, c_2	1.000	In general
For ruddder profile, c_3	1.000	For NACA- profiles and plate rudder
For rudder arrangement, c_4	1.000	For rudders in the propeller jet

A = $T \cdot L \{ 1 + 25 (B/L)^2 \} / 100$

5.114 m^2

A = 5.114 m^2

Each rudder will thus have an area of,

A = 2.557 m^2

Assuming,		
Clearance for rudder	0.700	m
Allowable height	2.572	m
Mean height of rudder, b	1.872	m
Aspect Ratio, $\Lambda = b^2/A$	1.371	
Mean breadth of rudder, c = A/b	1.366	m

Material Selection

Used material, (High Strength Steel) **GL F-40**

Yield strength, R_{eH}	390.0	Mpa
Tensile strength, R_m	660.0	Mpa

$k_r = (235/R_{eH})^{0.75}$ ($R_{eh} > 235$)

0.684

Rudder Force & Torque

Rudder Force

C_R = $132 \cdot A \cdot v^2 \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_t$

41710.948 (Ahead) N

10920.684 (Astern) N

Rudder Torque

For ahead condition

r c (α - k_b)

0.109 < r = 0.1c

Q_R = $C_R \cdot r$ (r = 0.1c)

5696.909 Nm

For astern condition

r c (α - k_b)

0.560 > r = 0.1c

Q_R = $C_R \cdot r$

6115.373 14.677 kNm

$k_1 = (\Lambda + 2) / 3$	1.124	
k_2 (Ahead)=	00 1.1	For NACA-00 series Gottingen profiles
k_2 (Astern)=	00 0.8	For NACA-profiles and plate rudder
k_3	00 1.0	
k_t	00 1.0	In general
Ship speed, v	000 10.	knots (Ahead)
	00 6.0	knots (Ahead)

α	0.330
c	1.366
r = 0.1c	0.137
$k_b = A_f/A$	0.250

α	0.660
c	1.366
r = 0.1c	0.137
$k_b = A_f/A$	0.250

Rudder Stock Diameter

D_t	$4.2\ \sqrt[3]{(\ Q_R \cdot k_r\ )}$		
		67.669	mm
taking		**70**	**mm**

Rudder Coupling

Minimum diameter for coupling bolts,

d_b	$0.62\ \sqrt{(\ D^3 \cdot k_b / k_r \cdot n \cdot e\ )}$		
		16.079	mm
		≈ **20**	**mm**

Coupling flange thickness,

t_f	$0.62\ \sqrt{(\ D^3 \cdot k_f / k_r \cdot n \cdot e\ )}$		
		16.079	mm
		≈ **20**	**mm**

Minimum thickness for coupling flanges,

$t_{f,min}$	$0.9\ d_b$		
		14.471	mm

Minimum thickness clear of the bolts,

	$0.6\ t_f$		
		9.647	mm

w	0.081	rads^-1
p	0.991	kw
p	1.329	hp

$D = D_t$	70.000	mm
Material factor, k_b	0.684	
k_r	0.684	
Bolt number, n	6.000	
Mean distance of the bolts from axes, e	85.000	mm

Minimum width of material outside the bolt holes,

$0.67\ d_b$

10.773 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 $0.2\ L / 100 + 0.4$

0.549

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

a_v $1.5\ a_h$

0.823

Rudder Plating

Design stress, p_R $10\ T + C_R / 10^3 A$

54.814 kN/mm^2

T	3.850	m	
A	2.557	m^2	
C_R	41710.948		

Plate thickness, t		1.74 a √(p_R · k) + 2.5			
		7.827	**mm**		
		8	mm		
Web thickness					
	70% of plate thickness	5.479	mm		
	or, t_{min} = 8√k	**6.616**	**mm**	k	0.684
		7	**mm**		

Plate thickness in way of the coupling,

	t + 25% of t	9.783	mm

Rudder Bearing

Minimum thickness for bearing liners and brushes,

t_{min} 8 mm

For Spade Rudder,

B_1	C_R / 2		
	83421.895	N	
B_2	C_R / 2		
	83421.895	N	

Clearance	d_b / 1000 + 1 or 1.5 mm		
		1.016	mm
	or	**1.5**	**mm**

Pintle

Pintle diameter,

d_p $0.35 \sqrt{(B_1 \cdot k_r)}$

	83.601	mm
	≈ 84	**mm**

For Taper 1:10,
Diameter at the end

	75.241	mm
	76	**mm**

Thickness of any liner or bush

t $0.01 \sqrt{B_1}$

	2.888	mm

Wall thickness

d $0.25\ d_p$

20.900	mm	
21	**mm**	

Pintle Height = 120% of Diameter

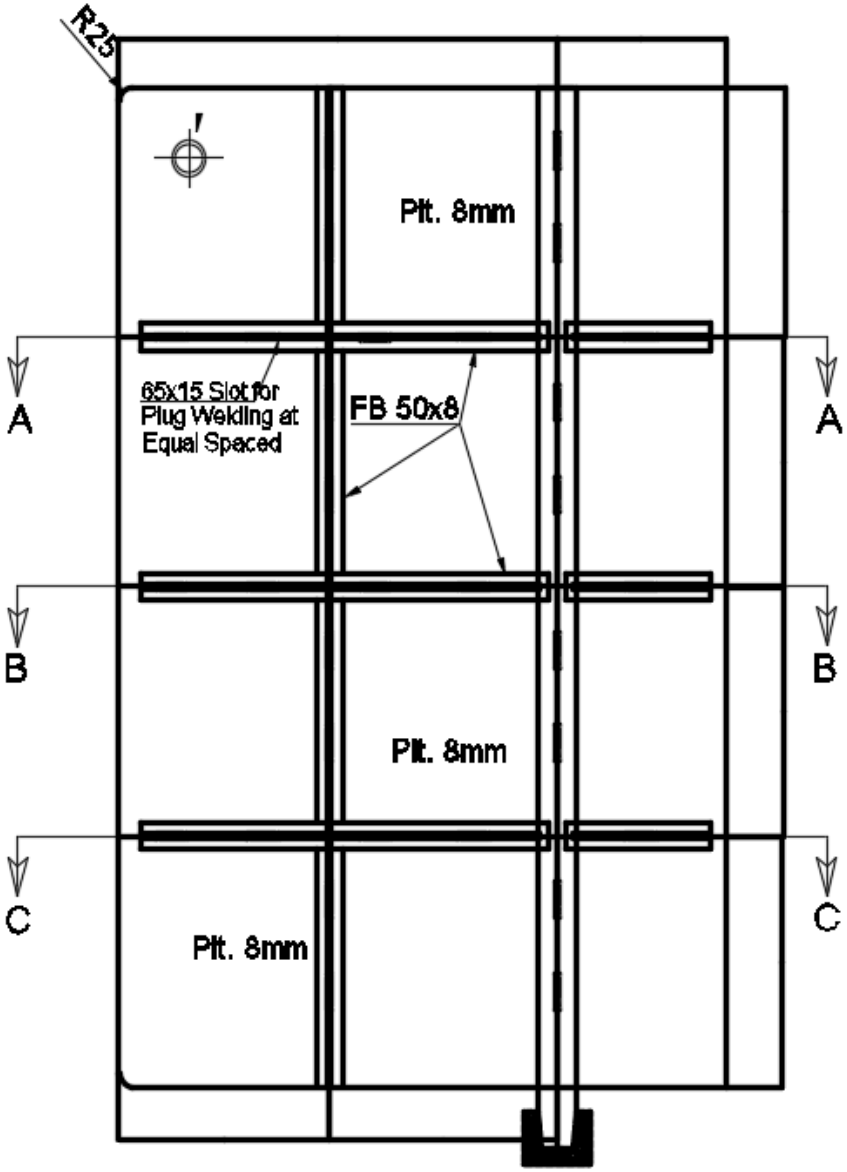
100.321	mm	
101	**mm**	

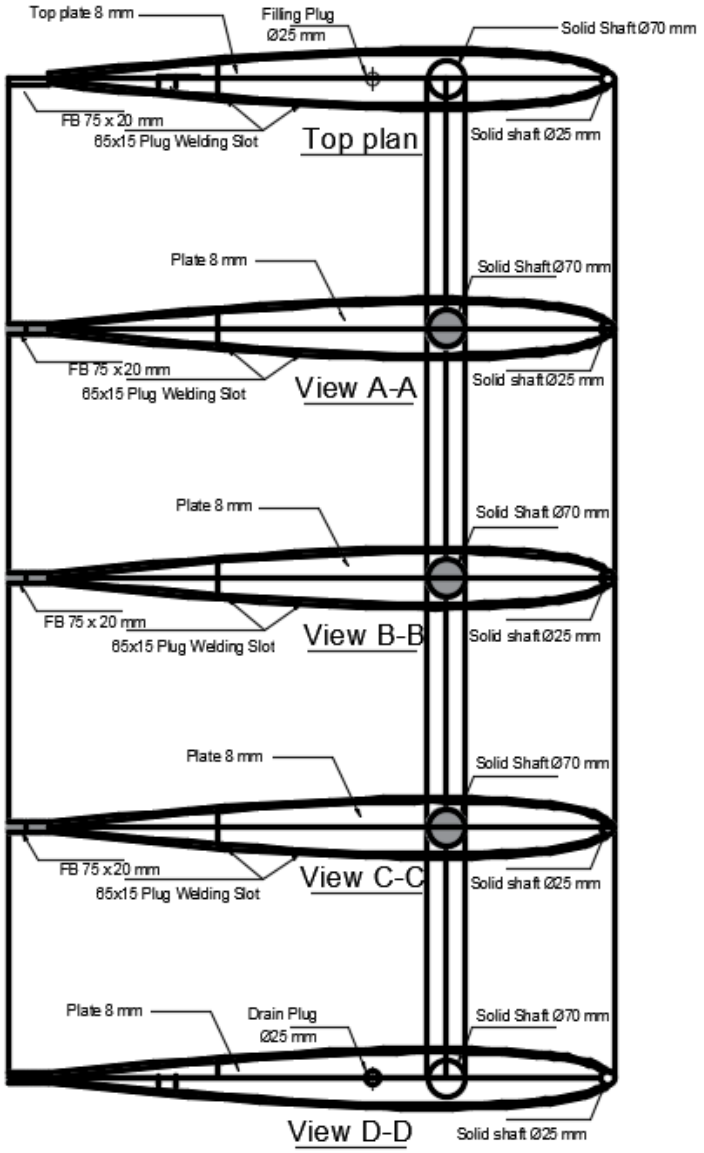
NACA 0010

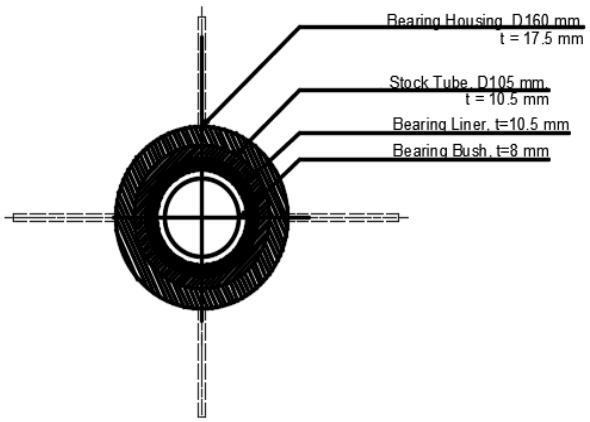
		x	y
1.000	0.001	1365.807	1.434
0.950	0.007	1297.516	9.178
0.900	0.012	1229.226	16.485
0.800	0.022	1092.645	29.870
0.700	0.031	956.065	41.698
0.600	0.038	819.484	51.942
0.500	0.044	682.903	60.259
0.400	0.048	546.323	66.064
3.000	0.050	4097.420	68.318
0.250	0.050	341.452	67.635
0.200	0.048	273.161	65.313
0.150	0.045	204.871	60.847
0.100	0.039	136.581	53.294
0.070	0.035	95.606	47.803
0.050	0.030	68.290	40.455
0.025	0.022	34.145	29.747
0.013	0.016	17.073	21.552
0.000	0.000	0.000	0.000

Rudder Calculation Summary

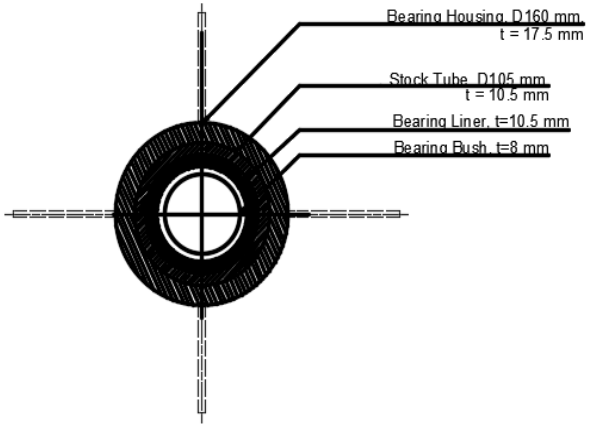
Used Material	HLS GL F-40	
Rudder Area *(each)*	2.557	m^2
Mean height	1.872	m
Mean breadth	1.366	m
Aspect ratio	1.371	
Rudder Force	41.71	kN *(ahead)*
	10.92	kN *(astern)*
Rudder Torque	5.696	kNm *(ahead)*
	6.115	kNm *(astern)*
Rudder Stock Diameter	70	mm
Coupling Bolt Diameter	20	mm
Coupling Flange Thickness	20	mm
Rudder Plate Thickness	8	mm
Rudder Web Thickness	7	mm
Pintle Diameter	84	mm
Bearing liners	8	mm
NACA Section	0010	


R25
Plt. 8mm
65x15 Slot for
Plug Welding at
Equal Spaced
FB 50x8
A
A
B
B
Plt. 8mm
C
C
Plt. 8mm

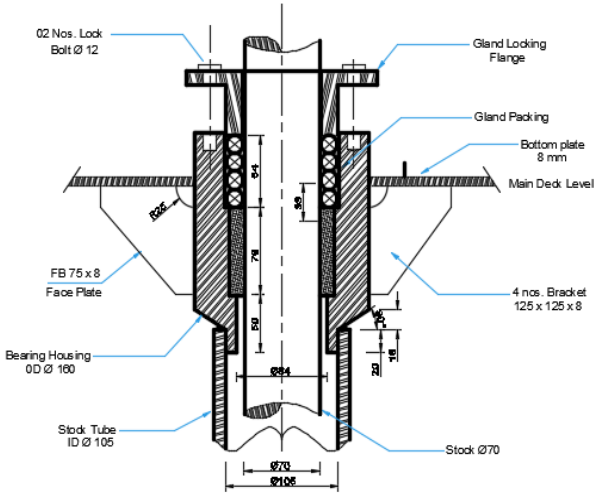

Top plate 8 mm
Filling Plug
Ø25 mm
Solid Shaft Ø70 mm
FB 75 x 20 mm
65x15 Plug Welding Slot
Top plan
Solid shaft Ø25 mm
Plate 8 mm
Solid Shaft Ø70 mm
FB 75 x 20 mm
65x15 Plug Welding Slot
View A-A
Solid shaft Ø25 mm
Plate 8 mm
Solid Shaft Ø70 mm
FB 75 x 20 mm
65x15 Plug Welding Slot
View B-B
Solid shaft Ø25 mm
Plate 8 mm
Solid Shaft Ø70 mm
FB 75 x 20 mm
65x15 Plug Welding Slot
View C-C
Solid shaft Ø25 mm
Plate 8 mm
Drain Plug
Ø25 mm
Solid Shaft Ø70 mm
View D-D
Solid shaft Ø25 mm



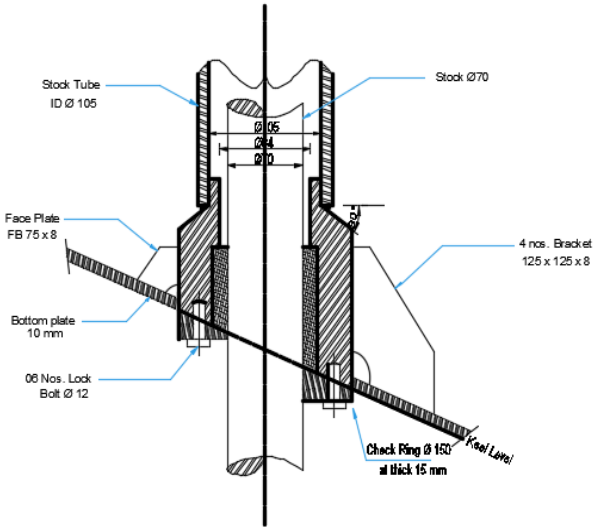
Upper Bearing (Top View)



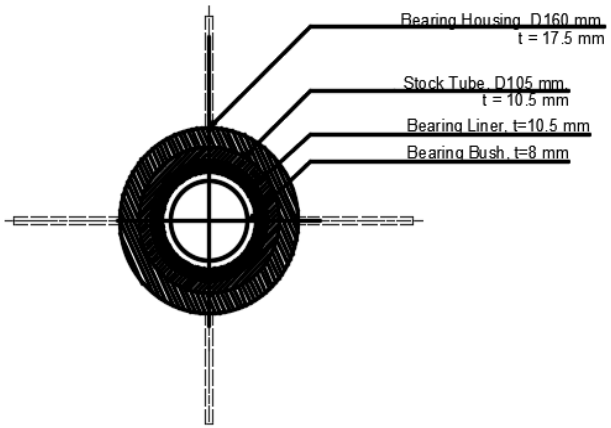
Lower Bearing (Top View)



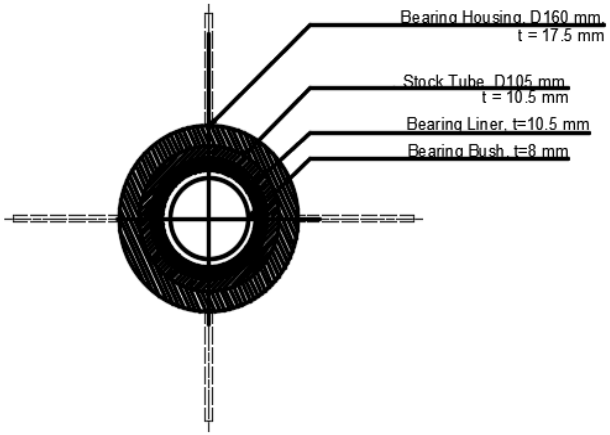
Upper Bearing



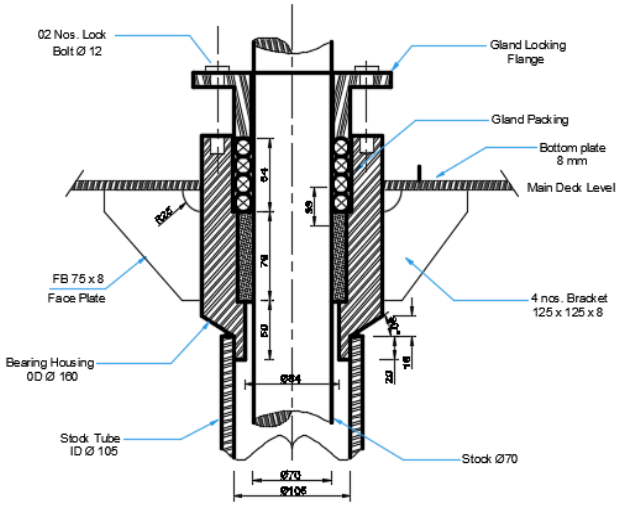
Lower Bearing



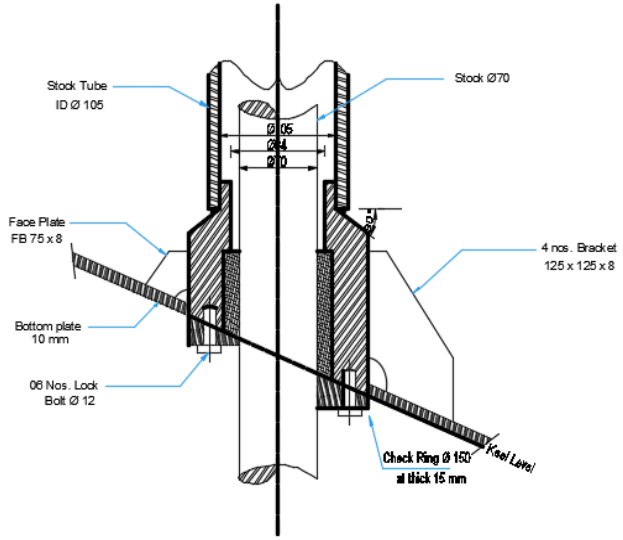
Upper Bearing (Top View)



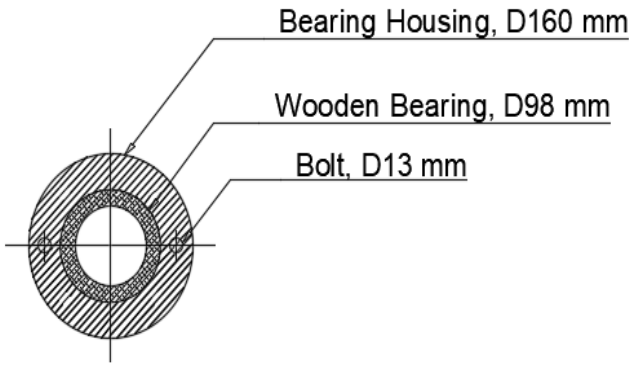
Lower Bearing (Top View)



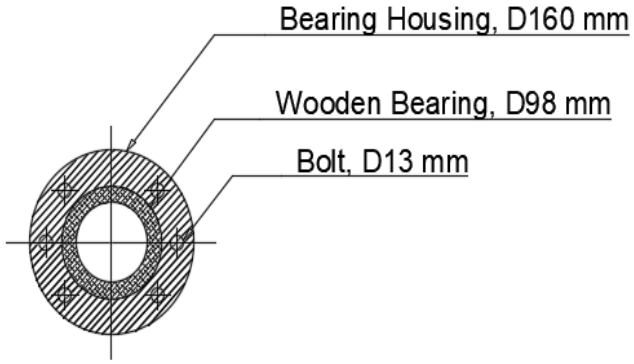
Upper Bearing



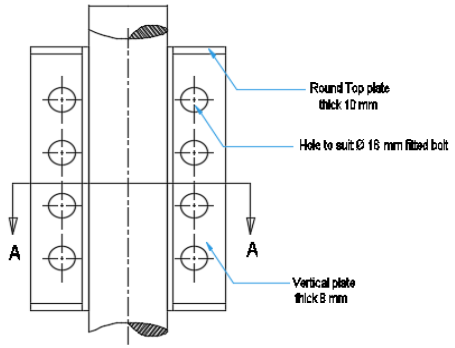
Lower Bearing



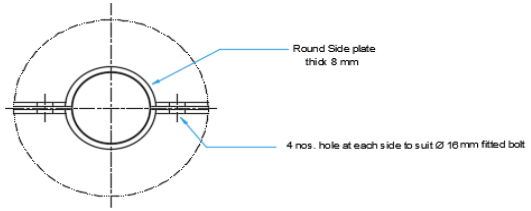
Upper Bearing (Bottom View)



Lower Bearing (Bottom View)



Jumping Clamp



Detail of View A-A

13. Steering Gear Arrangement

Type		050
Torque at maximum working oil pressure	t-m	5
	kN-m	49
Rudder turning speed	deg/sec	
Normal tiller radius	mm	
Diameter of ram	mm	
Maximum working oil pressure	kgf/cm²	140
	Mpa	13.7
Safety valve pressure (Design pressure)	kgf/cm²	175
	Mpa	17.2

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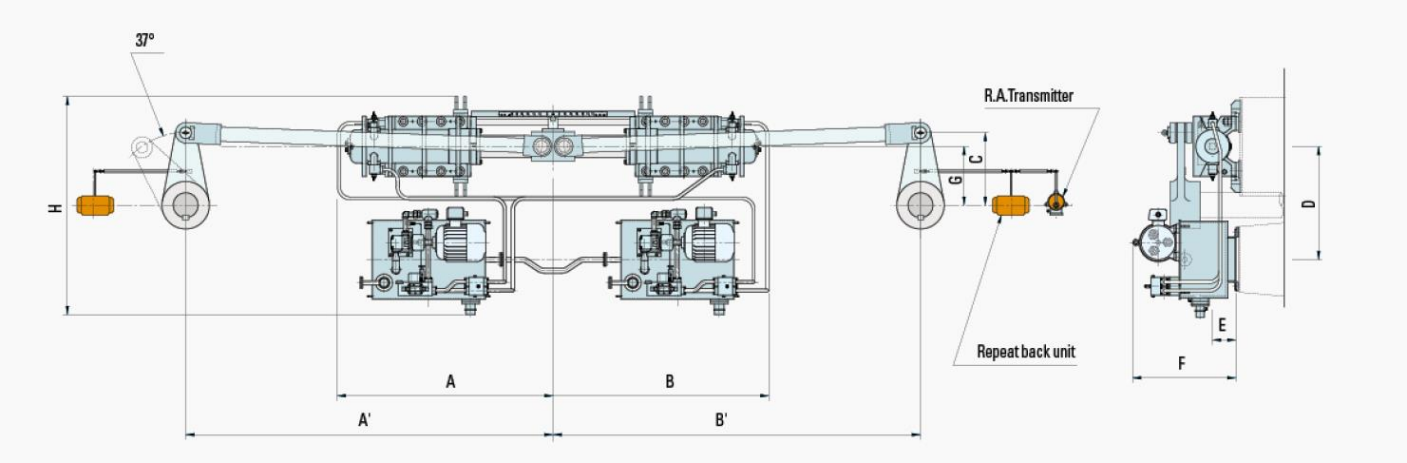
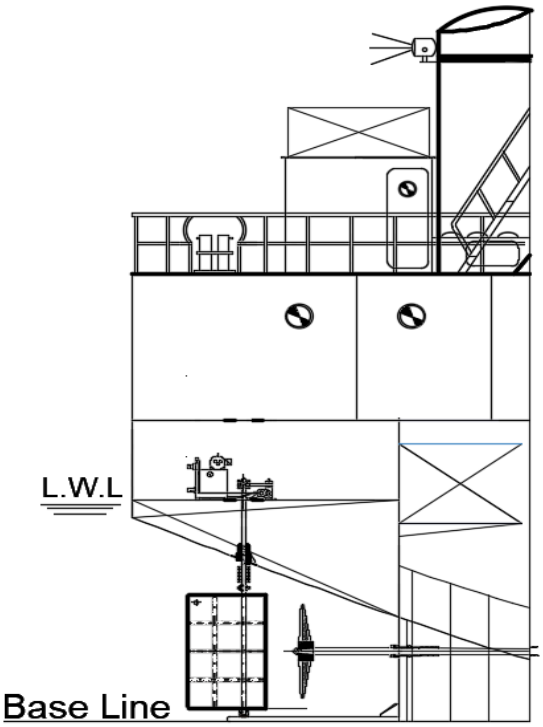
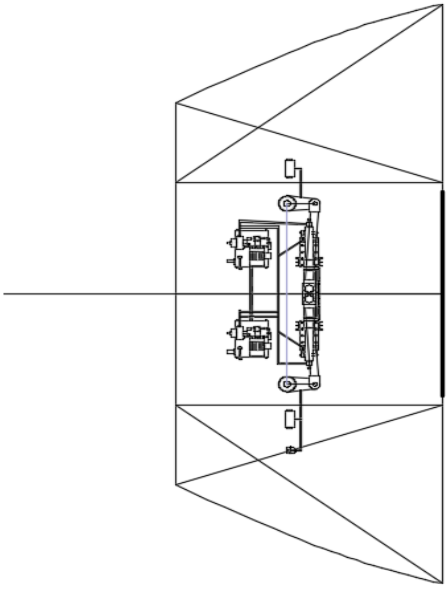
Dimensions	mm	A	1230
		B	1230
		C	400
		D	750
		E	160
		F	720
		G	320
		H	1370





Profile View



Top View

14. Propeller Blade Calculation & Drawing

Propeller Calculation

	Rt	58.831	kN		
	T	37.163	kN		
	P (atm)	101.325	kPa		
	h	0.965	m		
				D	1.53m
	H=T-h	2.683	m		
	Pv	1.646	kPa		
Po=P(atm)+PgH		128.276	kPa		
	K	0.1			
	Z	3			
	Ae/Ao	0.381			
	Va	8.275	knots		
		4.25666	m/s		
	Do	1.614	m		

$\frac{K_T}{J^2}$ $\frac{T}{\rho D^2 V_a{}^2}$

=

0.854803

	For BAR 0.35	*For BAR 0.5*	*For BAR 0.6*	*For BAR 0.8*	*For BAR 0.7*
ηo =	0.57	0.56	0.55	0.553	0.522
J =	0.47	0.49	0.51	0.503	0.477
$\frac{P}{D}$	0.83	0.87	0.91	0.896	0.893

For BAR 0.7

from $\frac{K_T}{J^2}$ chart,

η_H = 0.522

J = 0.477

0.893

$\frac{P}{D}$

$\frac{V_a}{nD}$ n 5.832559

J=

349.9535

V_R^2 =

(0.7 $\times 3.1416 \times n \times D$)^2

$$A_E = \frac{A_P}{1.067 - 0.229\,P/D}$$

385.1226

$V0.7_R^2$

= 403.2418

$$\frac{A_E}{A_O} = \frac{A_E}{\pi D^2/4}$$

$$\sigma_{0.7R} = \frac{p_A + \rho g h - p_V}{\frac{1}{2}\rho V_{0.7R}^2}$$

0.61274

A_P = 0.864546

Ae 1.002369

$$\tau_C = \frac{\frac{T}{A_P}}{\frac{1}{2}\rho V_{0.7R}^2}$$

τ_C = 0.61 [Burril Cavitation Chart]

Cross Check

To reduce cavitation the necessary expanded BAR are to be at least,

BAR =

$$\frac{T}{Ao\left(1.067-\frac{0.229P}{D}\right)(0.3\,\sigma 0.7R^{0.5}-0.03)\,q0.7R}$$

0.553626

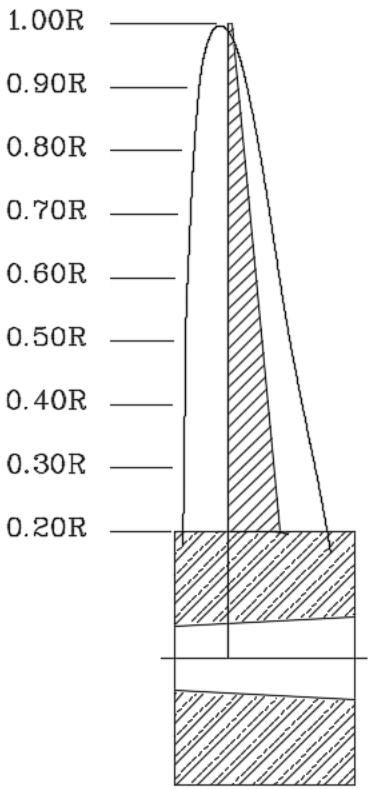
Propeller Blade

BAR	0.65	***D***	1533							
r/R	**(c/D)*(Z/BAR)**	**a/c**	**b/c**	**Ar**	**Br**	**c**	**a**	**b**	**T (max)**	**c-b**
0.2	1.633	0.616	0.35	0.0526	0.004	542.401	334.119	189.8403	62.2398	352.5606
0.3	1.832	0.611	0.35	0.0464	0.0035	608.4988	371.7928	212.9746	55.0347	395.5242
0.4	2	0.599	0.351	0.0402	0.003	664.3	397.9157	233.1693	47.8296	431.1307
0.5	2.12	0.583	0.355	0.034	0.0025	704.158	410.5241	249.9761	40.6245	454.1819
0.6	2.186	0.558	0.389	0.0278	0.002	726.0799	405.1526	282.4451	33.4194	443.6348
0.7	2.168	0.526	0.442	0.0216	0.0015	720.1012	378.7732	318.2847	26.2143	401.8165
0.8	2.127	0.481	0.478	0.0154	0.001	706.4831	339.8183	337.6989	19.0092	368.7842
0.85	1.892	0.4405	0.489	0.0123	0.00075	628.4278	276.8224	307.3012	15.40665	321.1266
0.9	1.657	0.4	0.5	0.0092	0.0005	550.3726	220.149	275.1863	11.8041	275.1863
1	0	0	0	0.003	0	0	0	0	4.599	0

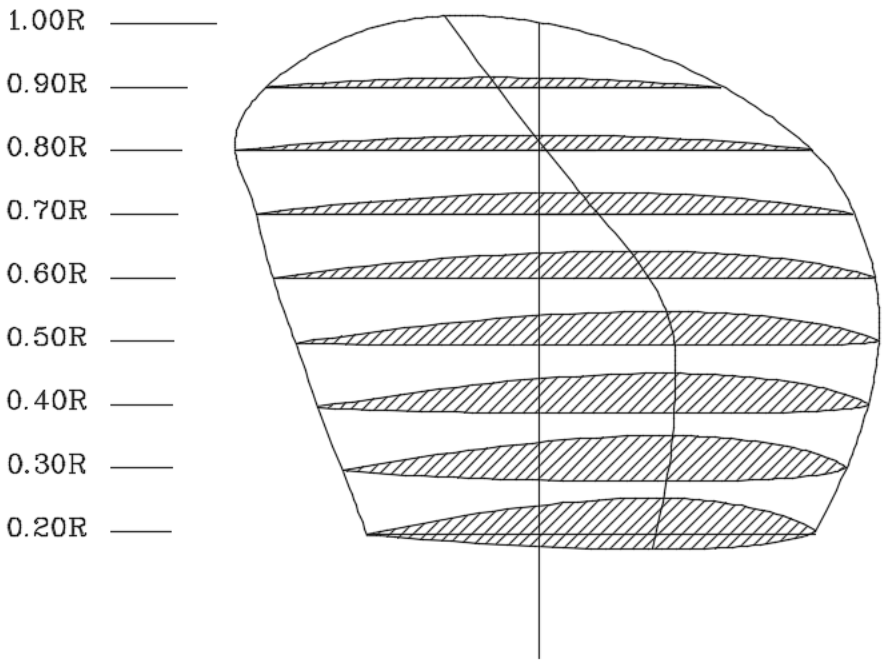
Propeller Blade Calculation Summary

Number of propellers	2	
Number of blades	3	
BAR	0.65	
Diameter, D	1.533	m
P/D	0.91	
Efficiency	0.55	
Propeller speed	327	rpm
Pitch, P	1.395	m

BAR	0.65
Open water efficiency	0.55
P/D	0.91
J	0.51
Min. BAR (for cavitation)	0.598



Profile View



Expanded View

15. Shafting Arrangement

Shafting Arrangement Calculation

LBP	74.4
B	13.54
T	3.85
Cb	0.79

Engine power	484
Engine speed	1800
Gear ratio	5
Propeller RPM	350

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

12.03209 kNm

Here, τ = 120 N/mm^2

C = d/2

J = $\pi d^4/32$

Stress, τ = $\frac{TC}{J}$

79.930 mm

taking **100 mm**

Twisting Angle :

G	83000000000	N/m^2
J	4.00718E-06	m^4
L	6.8	m

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

0.245998509

14.09464339

Considering twisting angle 1 degree

L	0.482452788	m

Shaft Liners :

Minimum wall thickness , $t = \frac{75\ x\ d}{d\ +1000}$

5.551052 mm

Taking 6 mm

Coupling :

Thickness of coupling flanges, s = 0.20 x d

15.98599 mm

Taking **18 mm**

Shaft bearing :

$$I_{max} = K_1 \; x \; \sqrt{d}$$

Maximum permissible distance between the bearing

,

mm

Where ,

K_1 = 280

2503.3 mm

Taking **2.5 m**

Stern Tube bearing :

Length of after stern tube bearing = 2.5 x d	199.8249	mm
	220	**mm**
Length of forward stern tube bearing = 1 x d	79.92996	mm
	90	**mm**

· Diameter of Flange coupling bolt:

According to the formula

$$d_f$$

$$16 \; x \; \sqrt{\frac{10^6 \, . \, P_w}{n \, Z \, D \, R_m}}$$

=

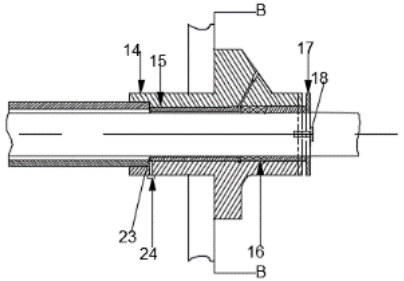
62.30562 mm

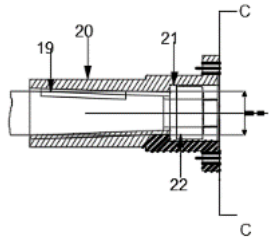
Shafting Arrangement Summary

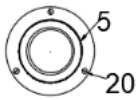
SL. NO	DESCRIPTION	MATERIALS	NUMBER OF COMPONENT
1	Cone nut	M.B. BS	**1**
2	Cone nut securing screw	M.B. BS	**2**
3	Propeller key	M.B. BS	**1**
4	Propeller dia X pitch	M.B. BS	**1**
5	Aft Brg securing screw	M.B. BS	**3**
6	Cover plate securing screw	STEEL BS	**3**
7	Aft locking ring	STEEL BS	**1**
8	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**

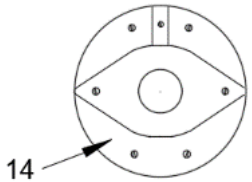
Shaft Speed	327	rpm
Torque	16	kNm
Stress	120	Nm^-2
Shaft Diameter	100	mm
Twisting angle	4.75	degrees
Shaft liners	6	mm
Coupling	18	mm
Shaft bearing max. distance	2.6	m
Stern tube bearing (fwd.)	90	mm
Stern tube bearing (aft)	220	mm
Flange coupling bolt diameter	38	mm



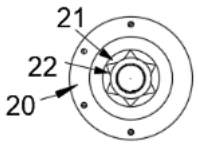




Section : A-A



Section : B-B



Section : C-C

16. Engine Room Foundation Calculation & Drawing

Rule Book Used: Germanischer Lloyd-2013

(Pt-1, Ch-1, Sec-8)

Depth of the center girder, h

$h = 350 + 45l$

959.3 mm

l	13.54	m

We are taking the depth of the center girder

960 mm

Thickness of the center girder, t_m

$t_m = h/h_a(h/100 + 1)\sqrt{k}$

9.349 mm

h_a	960	mm
h	959.3	mm
k	0.78	

Thickness of the side girders, t_m	$t_m=(h^2/120h_a) * \sqrt{k}$	7.055	mm			
Thickness of plate floors	$t_{pf} = t_m - 2.0\sqrt{k}$	7.582	mm			
(Pt-1, Ch-1, Sec-8, C.5.2.1)						
				P	484	kw
Thickness of plate floors at Engine Room	$t=c\ t_{pf}$	7.961	mm	c	1.00457	
				taking	1.05	
(Pt-1, Ch-1, Sec-8, D.3.1)	**taking**	**8**	**mm**			
Thickness of the longitudinal girders, t	$t=\sqrt{(P/15)} +6$	11.680	mm	P	484	kW
(Pt-1, Ch-1, Sec-8, D.4.2.1)		**12**	mm			
	taking	**8**	**mm**			
Taking,						
Thickness of side girder	t	11.680	mm			
		12	mm			
	taking	**8**	**mm**			

Thickness of inner bottom plating	$t = 1.1 \cdot a \cdot \sqrt{(p \cdot k)} + t_K$	4.931	mm	
		5	mm	

p	41.24	kN/m^2
t_k	1.5	mm
a	0.55	

Between the foundation girders, thickness of inner bottom plating	6.931	mm	
	7	mm	
The thickness of top plate should approximately be equal to the diameter of the fitted-in bolts. So, thickness of the top plate	**23**	mm	
The cross sectional area of the top plate $A_t = P/15 + 30$	**62.267**	cm^2	
The width of the plate A_t*100/t	**270.725**	mm	
	295	mm	

Center Girder:

C.2.2.1 The depth h of the centre girder is not to be less than determined by the following formula:

$h = 350 + 45 \cdot \ell$ [mm] with $h \geq h_{min}$

h_{min} : minimum depth [mm], defined as:

$h_{min} = 600$

ℓ : unsupported span [m] of the floor plates, defined as:

$\ell = \mathbf{B}$ in general

However, $\ell \geq 0.8 \cdot \mathbf{B}$

In case of additional longitudinal bulkheads, the unsupported span can be shortened accordingly.

$$h = 350 + 45l = 1099.16\ mm$$

$h_{min} = 600$

C.2.2.2 The thickness t_m of the centre girder is not to be less than determined by the following formulae:

$$t_m = \frac{h}{h_a} \cdot \left(\frac{h}{120} + 3.0 \right) \cdot \sqrt{k} \quad [mm]$$

h : depth of the centre girder according to C.2.2.1

h_a : depth [mm] of centre girder as built

C.5.2.1 The thickness t_{pf} of plate floors is not to be less than determined by the following formula:

$$t_{pf} = t_m - 2.0 \cdot \sqrt{k} \quad [mm] \qquad \text{with} \quad t_{pf} \leq 16 \text{ mm}$$

t_m : thickness of centre girder according to C.2.2.2

D.3.2 Side girders

D.3.2.1 The thickness of side girders under an engine foundation top plate inserted into the inner bottom is to be equal to the thickness of side girders above the inner bottom according to D.4.2.1.

D.3.2.2 Side girders with the thickness of longitudinal girders according to D.4.2.1 are to be fitted under the foundation girders in full height of the double bottom. Where two side girders are fitted on either side of the engine, one may be a half-height girder under the inner bottom for engines up to 3 000 kW.

D.3.2.3 Side girders under foundation girders are to be extended into the adjacent spaces and to be connected to the bottom structure. This extension abaft and forward of the engine room bulkheads is to be two to four frame spacings, if practicable.

D.3.2.4 No centre girder is required in way of the engine seating (see D.2.4).

D.3.3 Inner bottom

Between the foundation girders, the thickness of the inner bottom plating required according to C.4.1 is to be increased by 2 mm. The strengthened plate is to be extended beyond the engine seating by three to five frame spacings.

C.4 Inner bottom

C.4.1 The thickness t of the inner bottom plating is not to be less than determined by the following formula:

$$t = 1.1 \cdot a \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

p : design pressure [kN/m2], defined as:

$$p = \max\left[p_I \; ; \; p_{T1} \; ; \; p_{T2} \; ; \; p_{f} \right] \qquad \text{as applicable}$$

D.4.2 Longitudinal girders

D.4.2.1 The thickness t of the longitudinal girders above the inner bottom is not to be less than determined by the following formula:

$$t = \sqrt{\frac{P}{15}} + 6 \quad [mm] \qquad \text{for } P < 1\,500 \text{ kW}$$

$$t = \frac{P}{750} + 14 \quad [mm] \qquad \text{for } 1\,500 \le P < 7\,500 \text{ kW}$$

$$t = \frac{P}{1\,875} + 20 \quad [mm] \qquad \text{for } 7\,500 \text{ kW} \le P$$

P : single engine output [kW]

D.4.2.2 Where two longitudinal girders are fitted on either side of the engine, their thickness required according to D.4.2.1 may be reduced by 4 mm.

D.4.2.3 The sizes of the top plate (width and thickness) are to be sufficient to attain efficient attachment and seating of the engine and - depending on seating height and type of engine - adequate transverse rigidity.

The thickness of the top plate is approximately to be equal to the diameter of the fitted-in bolts. The cross sectional area A_T of the top plate is not to be less than determined by the following formulae:

$$A_T = \frac{P}{15} + 30 \quad [cm^2] \qquad \text{for } P \le 750 \text{ kW}$$

$$A_T = \frac{P}{75} + 70 \quad [cm^2] \qquad \text{for } P > 750 \text{ kW}$$

Where twin engines are fitted, a continuous top plate is to be arranged in general if the engines are coupled to one propeller shaft.

The section modulus of web frame **94.632** cm3 **(Pt-1, Ch-1, Sec-9)**

T - 250X175X10 mm

The foundation bolts for fastening the engine at the seating shall be spaced no more apart than, S = 3×D
Where, d = diameter of the foundation bolt

S=3×D	69.000 mm

B.6 Web frames in machinery spaces

B.6.1 Arrangement

B.6.1.1 In the engine room, web frames are to be fitted. Generally, they should extend up to the uppermost continuous deck. They are to be spaced not more than 5 times the frame spacing in the engine room.

B.6.1.2 For combustion engines, web frames are generally to be fitted at the forward and aft ends of the engine. The web frames are to be evenly distributed along the length of the engine.

B.6.1.3 Where combustion engines are fitted aft, stringers spaced 2.6 m apart are to be fitted in the engine room, in alignment with the stringers in the after peak, if any. Otherwise the main frames are to be adequately strengthened. The scantlings of the stringers are to be similar to those of the web frames. At least one stringer is required where the depth up to the lowest deck is less than 4 m.

B.6.2 Scantlings

B.6.2.1 The section modulus W and moment of inertia I of web frames are not to be less than determined by the following formulae:

$$W = 0.8 \cdot e \cdot \ell^2 \cdot p_S \cdot k \quad [cm^3]$$

Thickness of Brackets

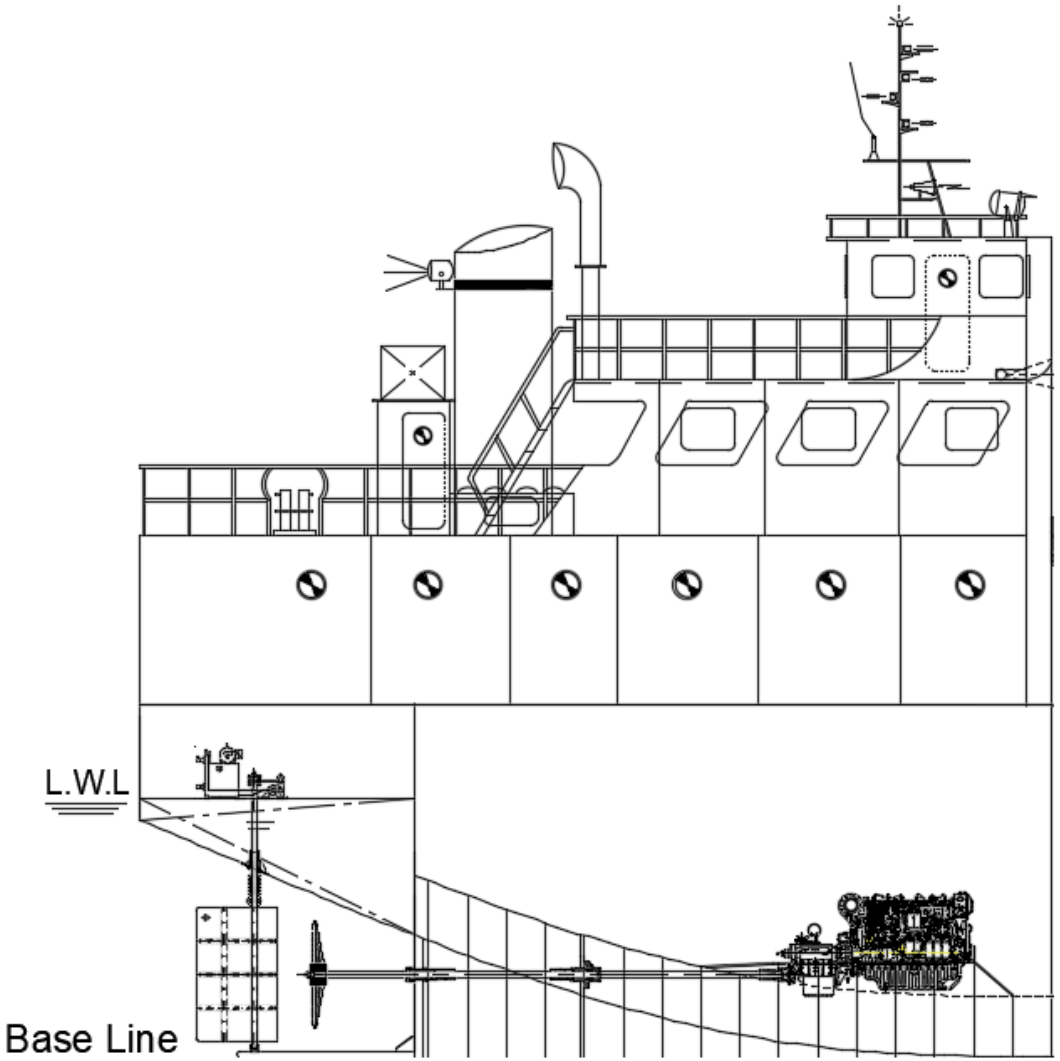
3.5+.25*√Z	5.932					
	6.5	mm				
a	216	mm		300	l	270
b	216	mm		300		

Bracket	Thickness, in mm	Limits	
		Minimum	Maximum
With edge stiffened:			
(a) in dry spaces	$3,5+0,25\sqrt{Z}$	6,5	12,5
(b) in tanks	$4,5+0,25\sqrt{Z}$	7,5	13,5

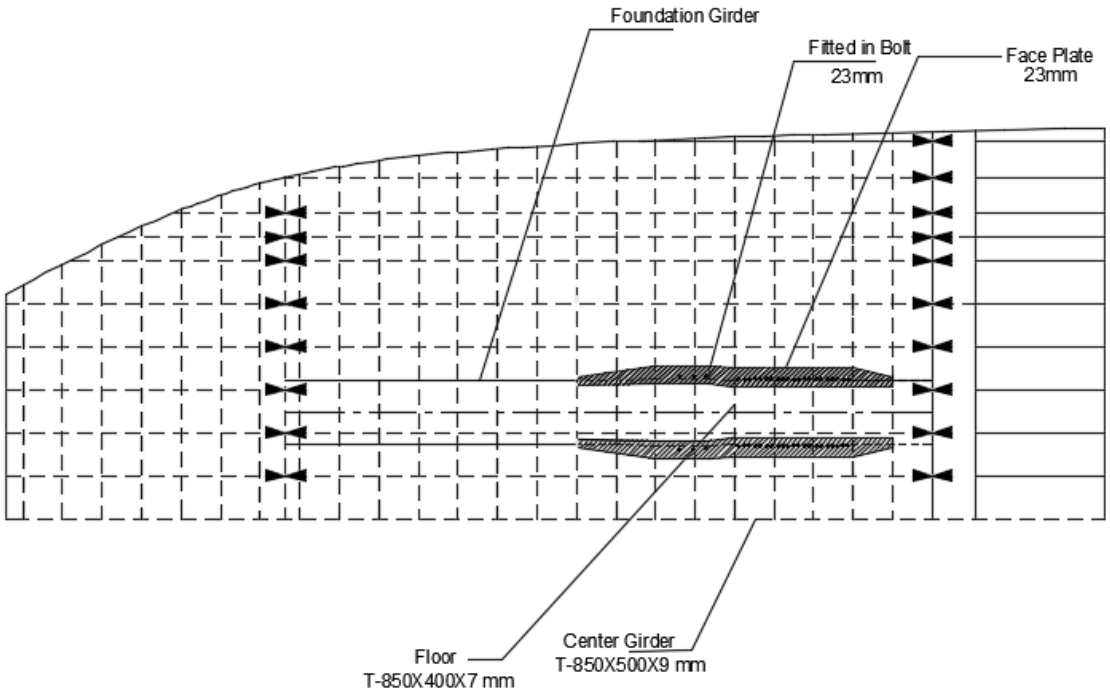
Engine Room Scantling Summary

Plate Floor	8	mm
Longitudinal Girder	8	mm
Side Girder	8	mm
Inner Bottom Plate	7	mm
Top Plate (Thickness)	23	mm
Top Plate (Width)	270	mm
Bottom Plate	10	mm
Web Frame	T-200x100x12	mm
Foundation Bolt (Diameter)	3	mm
Foundation Bolt (Spacing)	70	mm

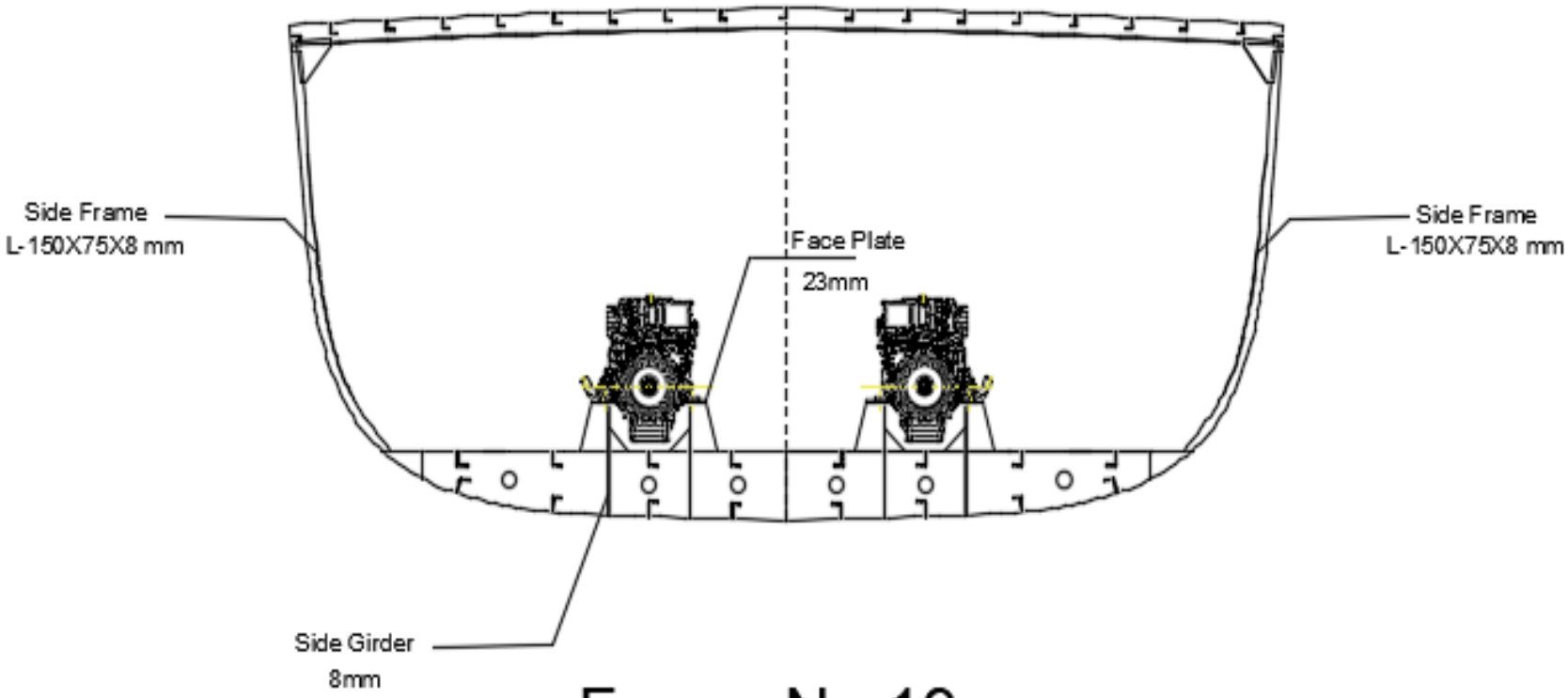
Profile View



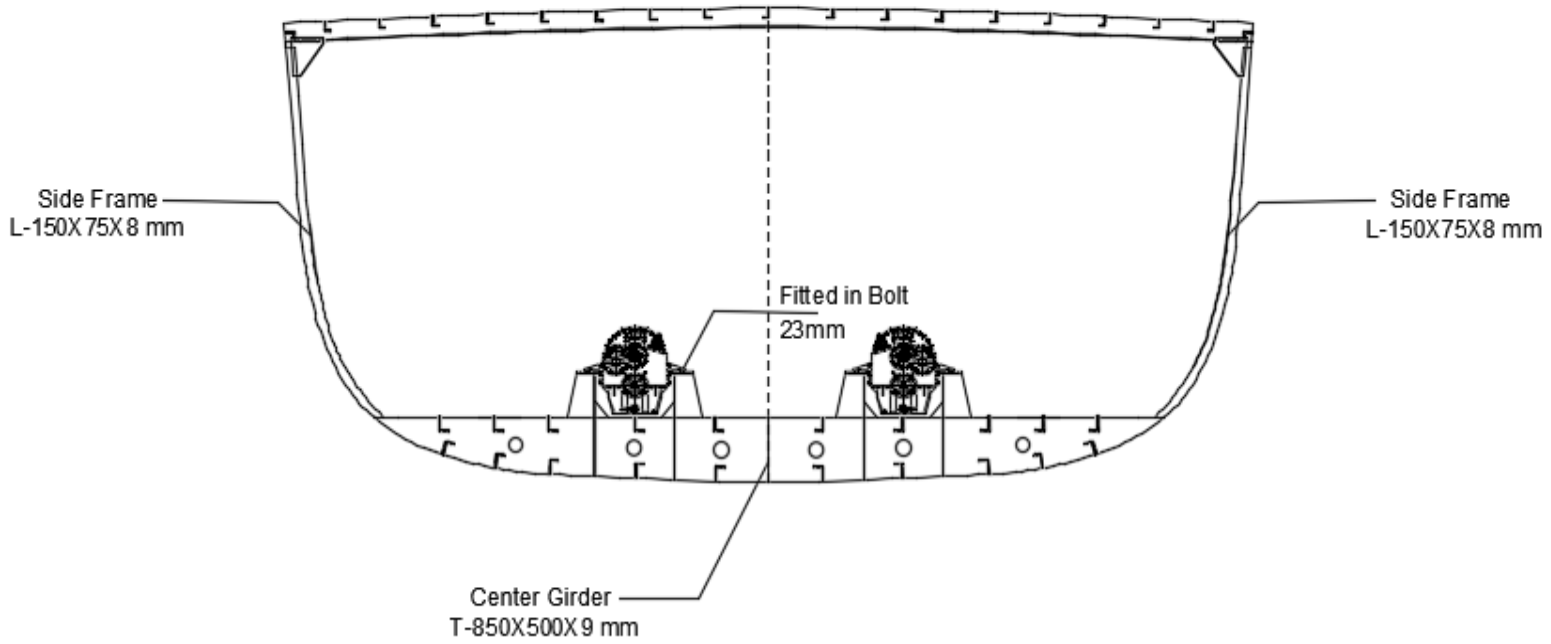
Plan View


Foundation Girder
Fitted in Bolt
23mm
Face Plate
23mm
Floor
T-850X400X7 mm
Center Girder
T-850X500X9 mm

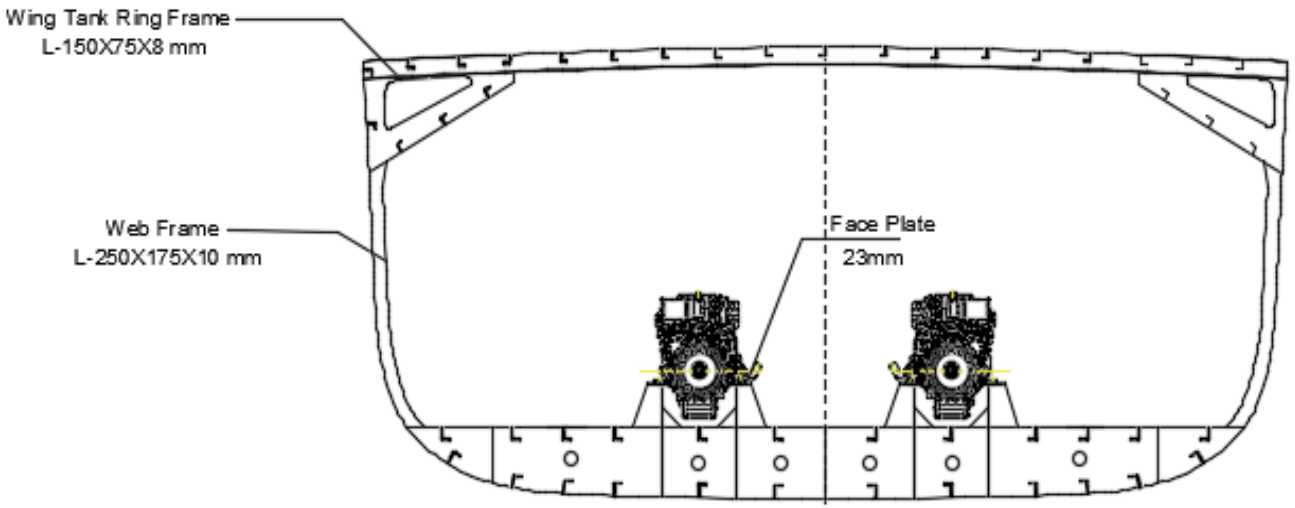

W
W
W
BHD
W
W
W
W
W
W
BHD
W
W


Side Frame
L-150X75X8 mm
Face Plate
23mm
Side Frame
L-150X75X8 mm
Side Girder
8mm

Frame No.19


Side Frame
L-150X75X8 mm
Side Frame
L-150X75X8 mm
Fitted in Bolt
23mm
Center Girder
T-850X500X9 mm

Frame No.16


Wing Tank Ring Frame
L-150X75X8 mm
Web Frame
L-250X175X10 mm
Face Plate
23mm

Frame No.25

17. Detailed Weight Calculation

	Dimension	Area (m^2)	Length	Weight	LCG	Moment LCG	VCG	Moment VCG
Floor								
Floor 1		0.010	3.250	0.512	0.235	0.120	3.595	1.839
Floor 2		0.010	3.540	0.557	0.835	0.465	3.575	1.992
Floor 3		0.010	3.810	0.600	1.435	0.861	3.425	2.054
Floor 4		0.010	4.070	0.641	2.035	1.304	2.935	1.880
Floor 5		0.010	4.300	0.677	2.635	1.783	2.725	1.844
Floor 6		0.010	4.500	0.708	3.235	2.291	2.525	1.788
Floor 7		0.010	4.670	0.735	3.835	2.819	2.235	1.643
Floor 8		0.010	4.800	0.756	4.435	3.351	2.125	1.605
Floor 9		0.010	4.900	0.771	5.035	3.883	2.025	1.562
Floor 10		0.010	4.980	0.784	5.635	4.417	1.425	1.117
Floor 11		0.010	5.000	0.787	6.235	4.907	1.225	0.964
Floor 12		0.010	5.100	0.803	6.835	5.487	1.102	0.885
Floor 13		0.010	5.300	0.834	7.435	6.202	1.025	0.855
Floor 14		0.010	5.500	0.866	8.035	6.956	0.925	0.801
Floor 15		0.010	5.500	0.866	8.635	7.475	0.739	0.640
Floor 16		0.010	5.500	0.866	9.235	7.995	0.625	0.541
Floor 17		0.010	5.500	0.866	9.835	8.514	0.425	0.368
Floor 18		0.010	5.500	0.866	10.435	9.034	0.425	0.368
Floor 19		0.010	5.500	0.866	11.035	9.553	0.425	0.368
Floor 20		0.010	5.500	0.866	11.635	10.072	0.425	0.368
Floor 21		0.010	5.500	0.866	12.235	10.592	0.425	0.368
Floor 22		0.010	5.500	0.866	12.835	11.111	0.425	0.368
Floor 23		0.010	5.500	0.866	13.435	11.631	0.425	0.368
Floor 24		0.010	5.500	0.866	14.035	12.150	0.425	0.368

Floor 25	0.010	5.500	0.866	15.835	13.708	0.425	0.368
Floor 26	0.010	5.500	0.866	17.635	15.267	0.425	0.368
Floor 27	0.010	5.500	0.866	19.435	16.825	0.425	0.368
Floor 28	0.010	5.500	0.866	21.235	18.383	0.425	0.368
Floor 29	0.010	5.500	0.866	23.035	19.941	0.425	0.368
Floor 30	0.010	5.500	0.866	24.835	21.500	0.425	0.368
Floor 31	0.010	5.500	0.866	26.635	23.058	0.425	0.368
Floor 32	0.010	5.500	0.866	28.435	24.616	0.425	0.368
Floor 33	0.010	5.500	0.866	30.235	26.174	0.425	0.368
Floor 34	0.010	5.500	0.866	32.035	27.733	0.425	0.368
Floor 35	0.010	5.500	0.866	33.835	29.291	0.425	0.368
Floor 36	0.010	5.500	0.866	35.635	30.849	0.425	0.368
Floor 37	0.010	5.500	0.866	37.435	32.407	0.425	0.368
Floor 38	0.010	5.500	0.866	39.235	33.966	0.425	0.368
Floor 39	0.010	5.500	0.866	41.035	35.524	0.425	0.368
Floor 40	0.010	5.500	0.866	42.835	37.082	0.425	0.368
Floor 41	0.010	5.500	0.866	44.635	38.641	0.425	0.368
Floor 42	0.010	5.500	0.866	46.435	40.199	0.425	0.368
Floor 43	0.010	5.500	0.866	48.235	41.757	0.425	0.368
Floor 44	0.010	5.500	0.866	50.035	43.315	0.425	0.368
Floor 45	0.010	5.000	0.787	51.835	40.794	0.425	0.334
Floor 46	0.010	4.800	0.756	53.635	40.522	0.425	0.321
Floor 47	0.010	4.500	0.708	55.435	39.265	0.425	0.301
Floor 48	0.010	4.200	0.661	57.235	37.837	0.425	0.281
Floor 49	0.010	4.000	0.630	59.035	37.168	0.425	0.268
Floor 50	0.010	3.500	0.551	60.835	33.514	0.425	0.234
Floor 51	0.010	3.000	0.472	61.435	29.010	0.425	0.201
Floor 52	0.010	2.900	0.456	62.035	28.316	0.425	0.194
Floor 53	0.010	2.800	0.441	62.635	27.604	0.425	0.187
Floor 54	0.010	2.600	0.409	63.235	25.878	0.425	0.174
Floor 55	0.010	2.000	0.315	63.835	20.095	0.425	0.134
Floor 56	0.010	1.500	0.236	64.435	15.213	0.425	0.100

Floor 57		0.010	1.000	0.157	65.035	10.237	0.425	0.067
				42.580		**1098.664**		35.108
				LCG	**25.802**		**0.825**	**VCG**

	Dimension	Area (m^2)	Length	Weight	LCG	Moment LCG	VCG	Moment VCG
Floor								
Floor 1		0.010	3.250	0.512	0.235	0.120	3.595	1.839
Floor 2		0.010	3.540	0.557	0.835	0.465	3.575	1.992
Floor 3		0.010	3.810	0.600	1.435	0.861	3.425	2.054
Floor 4		0.010	4.070	0.641	2.035	1.304	2.935	1.880
Floor 5		0.010	4.300	0.677	2.635	1.783	2.725	1.844
Floor 6		0.010	4.500	0.708	3.235	2.291	2.525	1.788
Floor 7		0.010	4.670	0.735	3.835	2.819	2.235	1.643
Floor 8		0.010	4.800	0.756	4.435	3.351	2.125	1.605
Floor 9		0.010	4.900	0.771	5.035	3.883	2.025	1.562
Floor 10		0.010	4.980	0.784	5.635	4.417	1.425	1.117
Floor 11		0.010	5.000	0.787	6.235	4.907	1.225	0.964
Floor 12		0.010	5.100	0.803	6.835	5.487	1.102	0.885
Floor 13		0.010	5.300	0.834	7.435	6.202	1.025	0.855
Floor 14		0.010	5.500	0.866	8.035	6.956	0.925	0.801
Floor 15		0.010	5.500	0.866	8.635	7.475	0.739	0.640
Floor 16		0.010	5.500	0.866	9.235	7.995	0.625	0.541

Floor 17	0.010	5.500	0.866	9.835	8.514	0.425	0.368
Floor 18	0.010	5.500	0.866	10.435	9.034	0.425	0.368
Floor 19	0.010	5.500	0.866	11.035	9.553	0.425	0.368
Floor 20	0.010	5.500	0.866	11.635	10.072	0.425	0.368
Floor 21	0.010	5.500	0.866	12.235	10.592	0.425	0.368
Floor 22	0.010	5.500	0.866	12.835	11.111	0.425	0.368
Floor 23	0.010	5.500	0.866	13.435	11.631	0.425	0.368
Floor 24	0.010	5.500	0.866	14.035	12.150	0.425	0.368
Floor 25	0.010	5.500	0.866	15.835	13.708	0.425	0.368
Floor 26	0.010	5.500	0.866	17.635	15.267	0.425	0.368
Floor 27	0.010	5.500	0.866	19.435	16.825	0.425	0.368
Floor 28	0.010	5.500	0.866	21.235	18.383	0.425	0.368
Floor 29	0.010	5.500	0.866	23.035	19.941	0.425	0.368
Floor 30	0.010	5.500	0.866	24.835	21.500	0.425	0.368
Floor 31	0.010	5.500	0.866	26.635	23.058	0.425	0.368
Floor 32	0.010	5.500	0.866	28.435	24.616	0.425	0.368
Floor 33	0.010	5.500	0.866	30.235	26.174	0.425	0.368
Floor 34	0.010	5.500	0.866	32.035	27.733	0.425	0.368
Floor 35	0.010	5.500	0.866	33.835	29.291	0.425	0.368
Floor 36	0.010	5.500	0.866	35.635	30.849	0.425	0.368
Floor 37	0.010	5.500	0.866	37.435	32.407	0.425	0.368
Floor 38	0.010	5.500	0.866	39.235	33.966	0.425	0.368
Floor 39	0.010	5.500	0.866	41.035	35.524	0.425	0.368
Floor 40	0.010	5.500	0.866	42.835	37.082	0.425	0.368
Floor 41	0.010	5.500	0.866	44.635	38.641	0.425	0.368
Floor 42	0.010	5.500	0.866	46.435	40.199	0.425	0.368
Floor 43	0.010	5.500	0.866	48.235	41.757	0.425	0.368
Floor 44	0.010	5.500	0.866	50.035	43.315	0.425	0.368
Floor 45	0.010	5.000	0.787	51.835	40.794	0.425	0.334
Floor 46	0.010	4.800	0.756	53.635	40.522	0.425	0.321
Floor 47	0.010	4.500	0.708	55.435	39.265	0.425	0.301
Floor 48	0.010	4.200	0.661	57.235	37.837	0.425	0.281

Floor 49	0.010	4.000	0.630	59.035	37.168	0.425	0.268
Floor 50	0.010	3.500	0.551	60.835	33.514	0.425	0.234
Floor 51	0.010	3.000	0.472	61.435	29.010	0.425	0.201
Floor 52	0.010	2.900	0.456	62.035	28.316	0.425	0.194
Floor 53	0.010	2.800	0.441	62.635	27.604	0.425	0.187
Floor 54	0.010	2.600	0.409	63.235	25.878	0.425	0.174
Floor 55	0.010	2.000	0.315	63.835	20.095	0.425	0.134
Floor 56	0.010	1.500	0.236	64.435	15.213	0.425	0.100
Floor 57	0.010	1.000	0.157	65.035	10.237	0.425	0.067
			42.580		**1098.664**		35.108
			LCG	**25.802**		**0.825**	**VCG**

Web Frame

WF 1	34.600	4.110	0.284	0.234	0.067	5.225	1.486
WF 2	34.600	4.820	0.334	1.884	0.628	4.920	1.641
WF 3	34.600	5.500	0.381	3.534	1.345	4.560	1.736
WF 4	34.600	6.120	0.424	5.184	2.195	4.250	1.800
WF 5	34.600	7.870	0.545	6.834	3.722	4.612	2.512
WF 6	34.600	9.210	0.637	8.484	5.407	4.605	2.935
WF 7	34.600	11.420	0.790	10.134	8.009	5.710	4.512
WF 8	34.600	8.500	0.588	11.784	6.931	4.250	2.500
WF 9	34.600	6.230	0.431	13.584	5.856	3.115	1.343
WF 10	34.600	5.860	0.406	15.384	6.238	2.930	1.188

WF 11	34.600	5.860	0.406	17.184	6.968	2.930	1.188
WF 12	34.600	5.860	0.406	18.984	7.698	2.930	1.188
WF 13	34.600	5.860	0.406	20.784	8.428	2.930	1.188
WF 14	34.600	5.860	0.406	22.584	9.158	2.930	1.188
WF 15	34.600	5.860	0.406	24.384	9.888	2.930	1.188
WF 16	34.600	5.860	0.406	26.184	10.618	2.930	1.188
WF 17	34.600	5.860	0.406	27.984	11.348	2.930	1.188
WF 18	34.600	5.860	0.406	29.784	12.078	2.930	1.188
WF 19	34.600	5.860	0.406	31.584	12.808	2.930	1.188
WF 20	34.600	5.860	0.406	33.384	13.538	2.930	1.188
WF 21	34.600	5.860	0.406	35.184	14.268	2.930	1.188
WF 22	34.600	5.860	0.406	36.984	14.997	2.930	1.188
WF 23	34.600	5.860	0.406	38.784	15.727	2.930	1.188
WF 24	34.600	5.860	0.406	40.584	16.457	2.930	1.188
WF 25	34.600	5.860	0.406	42.384	17.187	2.930	1.188
WF 26	34.600	5.860	0.406	44.184	17.917	2.930	1.188
WF 27	34.600	5.860	0.406	45.984	18.647	2.930	1.188
WF 28	34.600	5.860	0.406	47.784	19.377	2.930	1.188
WF 29	34.600	5.860	0.406	49.584	20.107	2.930	1.188
WF 30	34.600	5.860	0.406	51.384	20.837	2.930	1.188
WF 31	34.600	5.860	0.406	53.184	21.567	2.930	1.188
WF 32	34.600	5.860	0.406	54.984	22.297	2.930	1.188
WF 33	34.600	5.860	0.406	56.784	23.027	2.930	1.188
WF 34	34.600	7.010	0.485	58.434	28.346	3.505	1.700
WF 35	34.600	7.110	0.492	60.084	29.562	3.555	1.749
WF 36	34.600	7.140	0.494	61.734	30.502	3.570	1.764
			15.617		**473.750**		**54.193**
			LCG	**30.335**		**3.470**	**VCG**

Web Frame (Main Deck)

WF 1	24.900	4.090	0.204	0.234	0.048	5.000	1.018
WF 2	24.900	4.570	0.228	1.884	0.429	5.000	1.138
WF 3	24.900	5.190	0.258	3.534	0.913	5.000	1.292
WF 4	24.900	5.340	0.266	5.184	1.379	5.000	1.330
WF 5	24.900	5.430	0.270	6.834	1.848	5.000	1.352
WF 6	24.900	5.470	0.272	8.484	2.311	5.000	1.362
WF 7	24.900	5.500	0.274	10.134	2.776	5.000	1.370
WF 8	24.900	5.500	0.274	11.784	3.228	5.000	1.370
WF 9	24.900	5.500	0.274	13.584	3.721	5.000	1.370
WF 10	24.900	5.500	0.274	15.384	4.214	5.000	1.370
WF 11	24.900	5.500	0.274	17.184	4.707	5.000	1.370
WF 12	24.900	1.860	0.093	18.984	1.758	5.000	0.463
WF 13	24.900	1.860	0.093	20.784	1.925	5.000	0.463
WF 14	24.900	1.860	0.093	22.584	2.092	5.000	0.463
WF 15	24.900	5.500	0.274	24.384	6.679	5.000	1.370
WF 16	24.900	5.500	0.274	26.184	7.172	5.000	1.370
WF 17	24.900	5.500	0.274	27.984	7.665	5.000	1.370
WF 18	24.900	5.500	0.274	29.784	8.158	5.000	1.370
WF 19	24.900	5.500	0.274	31.584	8.651	5.000	1.370
WF 20	24.900	5.500	0.274	33.384	9.144	5.000	1.370
WF 21	24.900	1.860	0.093	35.184	3.259	5.000	0.463
WF 22	24.900	1.860	0.093	36.984	3.426	5.000	0.463
WF 23	24.900	1.860	0.093	38.784	3.592	5.000	0.463
WF 24	24.900	5.500	0.274	40.584	11.116	5.000	1.370
WF 25	24.900	5.500	0.274	42.384	11.609	5.000	1.370
WF 26	24.900	5.500	0.274	44.184	12.102	5.000	1.370
WF 27	24.900	5.500	0.274	45.984	12.595	5.000	1.370
WF 28	24.900	5.500	0.274	47.784	13.088	5.000	1.370
WF 29	24.900	4.770	0.238	49.584	11.778	5.000	1.188

WF 30	24.900	4.450	0.222	51.384	11.387	5.000	1.108
WF 31	24.900	3.960	0.197	53.034	10.459	5.000	0.986
WF 32	24.900	2.360	0.118	54.684	6.427	5.000	0.588
WF 33	24.900	1.214	0.060	56.334	3.406	5.000	0.302
			7.271		**193.060**		**36.355**
			LCG	**26.552**		**5.000**	**VCG**

Web Frame (Poop Deck)

WF 1	24.900	4.090	0.204	0.234	0.048	7.320	1.491
WF 2	24.900	4.570	0.228	1.884	0.429	7.320	1.666
WF 3	24.900	5.190	0.258	3.534	0.913	7.320	1.892
WF 4	24.900	5.340	0.266	5.184	1.379	7.320	1.947
WF 5	24.900	5.430	0.270	6.834	1.848	7.320	1.979
WF 6	24.900	5.470	0.272	8.484	2.311	7.320	1.994
WF 7	24.900	5.500	0.274	10.134	2.776	7.320	2.005
WF 8	24.900	5.500	0.274	11.784	3.228	7.320	2.005
WF	24.900	4.180	0.208	6.834	1.423	9.520	1.982
	24.900	4.180	0.208	8.484	1.766	9.520	1.982
	24.900	4.180	0.208	10.134	2.110	9.520	1.982
	24.900	4.180	0.208	11.784	2.453	9.520	1.982

	24.900	2.930	0.146	10.134	1.479	11.520	1.681
	24.900	2.930	0.146	11.784	1.719	11.520	1.681
			3.171		**23.880**		**26.268**
			LCG	**7.531**		**8.284**	**VCG**

Main Frame

Frame 1	13.800	4.350	0.120	0.785	0.094	5.325	0.639
Frame 2	13.800	4.580	0.126	1.335	0.169	5.390	0.681
Frame 3	13.800	5.050	0.139	2.435	0.339	4.825	0.673
Frame 4	13.800	5.280	0.146	2.985	0.435	4.640	0.676
Frame 5	13.800	5.720	0.158	4.085	0.645	4.360	0.688
Frame 6	13.800	5.920	0.163	4.635	0.757	4.260	0.696
Frame 7	13.800	6.550	0.181	5.735	1.037	4.275	0.773
Frame 8	13.800	7.480	0.206	6.285	1.298	4.540	0.937
Frame 9	13.800	8.980	0.248	7.385	1.830	4.990	1.237
Frame 10	13.800	8.100	0.224	7.935	1.774	4.350	0.972
Frame 11	13.800	9.290	0.256	9.035	2.317	4.895	1.255
Frame 12	13.800	8.360	0.231	9.585	2.212	4.180	0.964
Frame 13	13.800	10.600	0.293	10.685	3.126	5.300	1.551
Frame 14	13.800	9.600	0.265	11.235	2.977	4.800	1.272
Frame 15	13.800	10.660	0.294	12.335	3.629	5.330	1.568
Frame 16	13.800	5.920	0.163	12.935	2.113	2.960	0.484
Frame 17	13.800	5.920	0.163	14.135	2.310	2.960	0.484

Frame 18	13.800	5.920	0.163	14.735	2.408	2.960	0.484
Frame 19	13.800	5.920	0.163	15.935	2.604	2.960	0.484
Frame 20	13.800	5.920	0.163	16.535	2.702	2.960	0.484
Frame 21	13.800	5.920	0.163	17.735	2.898	2.960	0.484
Frame 22	13.800	5.920	0.163	18.335	2.996	2.960	0.484
Frame 23	13.800	5.920	0.163	19.535	3.192	2.960	0.484
Frame 24	13.800	5.920	0.163	20.135	3.290	2.960	0.484
Frame 25	13.800	5.920	0.163	21.335	3.486	2.960	0.484
Frame 26	13.800	5.920	0.163	21.935	3.584	2.960	0.484
Frame 27	13.800	5.920	0.163	23.135	3.780	2.960	0.484
Frame 28	13.800	5.920	0.163	23.735	3.878	2.960	0.484
Frame 29	13.800	5.920	0.163	24.935	4.074	2.960	0.484
Frame 30	13.800	5.920	0.163	25.535	4.172	2.960	0.484
Frame 31	13.800	5.920	0.163	26.735	4.368	2.960	0.484
Frame 32	13.800	5.920	0.163	27.335	4.466	2.960	0.484
Frame 33	13.800	5.920	0.163	28.535	4.662	2.960	0.484
Frame 34	13.800	5.920	0.163	29.135	4.760	2.960	0.484
Frame 35	13.800	5.920	0.163	30.335	4.956	2.960	0.484
Frame 36	13.800	5.920	0.163	30.935	5.055	2.960	0.484
Frame 37	13.800	5.920	0.163	32.135	5.251	2.960	0.484
Frame 38	13.800	5.920	0.163	32.735	5.349	2.960	0.484
Frame 39	13.800	5.920	0.163	33.935	5.545	2.960	0.484
Frame 40	13.800	5.920	0.163	34.535	5.643	2.960	0.484
Frame 41	13.800	5.920	0.163	35.735	5.839	2.960	0.484
Frame 42	13.800	5.920	0.163	36.335	5.937	2.960	0.484
Frame 43	13.800	5.920	0.163	37.535	6.133	2.960	0.484
Frame 44	13.800	5.920	0.163	38.135	6.231	2.960	0.484
Frame 45	13.800	5.920	0.163	39.335	6.427	2.960	0.484
Frame 46	13.800	5.920	0.163	39.935	6.525	2.960	0.484
Frame 47	13.800	5.920	0.163	41.135	6.721	2.960	0.484
Frame 48	13.800	5.920	0.163	41.735	6.819	2.960	0.484
Frame 49	13.800	5.920	0.163	42.935	7.015	2.960	0.484

Frame 50	13.800	5.920	0.163	43.535	7.113	2.960	0.484
Frame 51	13.800	5.920	0.163	44.735	7.309	2.960	0.484
Frame 52	13.800	5.920	0.163	45.335	7.407	2.960	0.484
Frame 53	13.800	5.920	0.163	46.535	7.603	2.960	0.484
Frame 54	13.800	5.920	0.163	47.135	7.701	2.960	0.484
Frame 55	13.800	5.920	0.163	48.335	7.898	2.960	0.484
Frame 56	13.800	5.920	0.163	48.935	7.996	2.960	0.484
Frame 57	13.800	5.920	0.163	50.135	8.192	2.960	0.484
Frame 58	13.800	5.920	0.163	50.735	8.290	2.960	0.484
Frame 59	13.800	5.920	0.163	51.935	8.486	2.960	0.484
Frame 60	13.800	5.920	0.163	52.535	8.584	2.960	0.484
Frame 61	13.800	5.920	0.163	53.735	8.780	2.960	0.484
Frame 62	13.800	5.920	0.163	54.335	8.878	2.960	0.484
Frame 63	13.800	5.920	0.163	55.535	9.074	2.960	0.484
Frame 64	13.800	5.920	0.163	56.135	9.172	2.960	0.484
Frame 65	13.800	5.920	0.163	57.335	9.368	2.960	0.484
Frame 66	13.800	5.920	0.163	57.935	9.466	2.960	0.484
Frame 67	13.800	7.100	0.196	59.135	11.588	3.550	0.696
Frame 68	13.800	7.100	0.196	59.735	11.706	3.550	0.696
Frame 69	13.800	7.100	0.196	60.935	11.941	3.550	0.696
Frame 70	13.800	7.100	0.196	61.535	12.058	3.550	0.696
Frame 71	13.800	7.100	0.196	62.635	12.274	3.550	0.696
Frame 72	13.800	7.100	0.196	63.185	12.382	3.550	0.696
Frame 73	13.800	7.100	0.196	64.285	12.597	3.550	0.696
Frame 74	13.800	7.100	0.196	64.835	12.705	3.550	0.696
Frame 75	13.800	1.100	0.030	65.935	2.002	6.620	0.201
			12.981		**418.396**		**45.015**
			LCG	**32.230**		**3.468**	**VCG**

Steel Weight

No.	Item	Total Weight (tonnes)	LCG (m)	Moment (t-m) (from aft)	VCG (m)	Moment (t-m) (from keel)
1	Keel	14.096	36.821	519.040	0.636	8.968
2	Bottom Inner Bottom	49.737	31.911	1587.148	0.476	23.692
3	Bilge	16.829	33.000	555.364	0.633	10.648
4	Side Shell	41.521	36.109	1499.262	3.017	125.284
6	Deck Plate (Strength Deck)	26.908	28.062	755.105	5.000	134.542
7	Forecastle Deck Plate	4.533	58.700	266.094	6.100	27.652
9	Side Longitudinal	1.230	33.080	40.695	4.000	4.921
	Side Longitudinal	1.230	33.080	40.695	3.400	4.183
	Side Longitudinal	10.385	33.000	342.715	1.500	15.578
	Tank Longitudinal	3.236	33.000	106.801	4.000	12.946
	Tank Longitudinal	5.916	33.000	195.228	1.000	5.916
10	Main Frame	14.981	32.230	482.857	3.468	51.950
11	Side Web Frame	18.617	30.335	564.757	3.470	64.604
13	Center Girder	6.390	33.250	212.459	0.425	2.716
14	Side Girder (A)	17.908	31.500	564.110	0.425	7.611
	Side Girder (B)	15.902	30.000	477.055	0.425	6.758
15	Bottom Longitudinals	11.682	33.000	385.492	0.100	1.168

16	Inner Bottom Longitudinals	10.513	33.000	346.943	0.950	9.988
18	Floors	42.580	25.802	1098.664	0.825	35.108
19	Main Deck to Poop Deck	16.399	7.594	124.525	6.802	111.550
	Poop Deck to Bridge Deck	9.693	9.236	89.521	8.943	86.686
20	Bridge Deck to Roof	3.601	11.570	41.660	10.565	38.043
21	Hopper Tank Plate	16.885	37.000	624.733	0.815	13.761
22	Wing Tank Plate	21.616	37.000	799.803	4.487	96.993
23	Transom Stern Plate	1.002	0.000	0.000	4.120	4.129
24	Deck Beam	10.442	20.776	216.940	5.997	62.623
25	Deck Longitudinals	9.109	31.500	286.939	5.000	45.546
26	Deck Longitudinals	2.006	6.630	13.302	7.320	14.686
		0.774	8.000	6.190	9.520	7.366
27	Side Girder for Engine Room	3.085	8.380	25.855	0.605	1.867
28	Face Plate	0.828	10.130	8.391	1.210	1.002
29	Hatch Cover 1	4.806	21.110	101.456	5.000	24.030
	Hatch Cover 2					
	Hatch Cover 3	4.806	37.470	180.083	5.000	24.030
		4.806	52.660	253.087	5.000	24.030
	Bulkhead 1					
	Plate	2.389	3.880	9.271	3.450	8.243
	Vertical Stiffener	0.234	3.880	0.908	3.450	0.807
	Transverse Stiffener	0.218	3.880	0.844	3.450	0.750
	Bulkhead 2					

Plate	5.688	12.880	73.257	3.650	20.760
Vertical Stiffener	1.175	12.880	15.131	3.650	4.288
Transverse Stiffener	0.867	12.880	11.161	3.650	3.163
Bulkhead 3					
Plate	3.896	29.310	114.182	2.264	8.820
Vertical Stiffener	0.805	29.310	23.584	2.428	1.954
Transverse Stiffener	0.477	29.310	13.969	2.428	1.157
Bulkhead 4					
Plate	3.896	45.840	178.577	2.264	8.820
Vertical Stiffener	0.805	45.840	36.884	2.428	1.954
Transverse Stiffener	0.477	45.840	21.848	2.144	1.022
Collision Bulkhead					
Plate	2.479	22.917	56.812	2.909	7.212
Vertical Stiffener	0.379	22.917	8.679	3.043	1.152
Transverse Stiffener	0.383	22.917	8.772	2.140	0.819
	582.680		13386.847		1181.495

Steel Weight	**640.950**	tonnes	(with 10% increase)
LCG (from aft)	22.975	m	
	1.843	m	

VCG (from keel)

Item	Total Weight (tonnes)	LCG (m)	Moment (t-m) (from aft)	VCG (m)	Moment (t-m) (from keel)
Keel Plate	1.133	3.000	3.400	2.074	2.350
	1.133	9.000	10.200	0.456	0.517
	1.133	15.000	16.999	0.006	0.007
	1.133	21.000	23.799	0.006	0.007
	1.133	27.000	30.599	0.006	0.007
	1.133	33.000	37.398	0.006	0.007
	1.133	39.000	44.198	0.006	0.007
	1.133	45.000	50.998	0.006	0.007
	1.133	51.000	57.797	0.006	0.007
	1.133	57.000	64.597	0.006	0.007
	1.133	63.000	71.397	0.006	0.007
	1.133	66.000	74.796	2.720	3.083
	0.497	66.130	32.863	5.950	2.957
	14.096		519.040		8.968

Bottom Plate

1.464	5.738	8.399	2.070	3.030
1.464	11.738	17.182	0.454	0.664
1.464	17.738	25.965	0.005	0.007
1.464	23.738	34.748	0.005	0.007
1.464	29.738	43.531	0.005	0.007
1.464	35.738	52.314	0.005	0.007
1.464	41.738	61.097	0.005	0.007
1.464	47.738	69.880	0.005	0.007
1.464	53.270	77.978	0.005	0.007
1.464	10.135	14.836	0.005	0.007
1.464	16.135	23.619	0.005	0.007
1.464	22.135	32.402	0.005	0.007
1.464	28.135	41.185	0.005	0.007
1.464	34.135	49.967	0.005	0.007
1.464	40.135	58.750	0.005	0.007
1.464	46.135	67.533	0.005	0.007
1.464	52.135	76.316	0.005	0.007
1.464	58.135	85.099	0.005	0.007
26.349		840.802		3.811

31.911	m
0.145	m

Bilge Plate

1.530	3.000	4.590	0.700	1.071

1.530	9.000	13.769	0.626	0.958
1.530	15.000	22.949	0.626	0.958
1.530	21.000	32.128	0.626	0.958
1.530	27.000	41.308	0.626	0.958
1.530	33.000	50.488	0.626	0.958
1.530	39.000	59.667	0.626	0.958
1.530	45.000	68.847	0.626	0.958
1.530	51.000	78.026	0.626	0.958
1.530	57.000	87.206	0.626	0.958
1.530	63.000	96.385	0.626	0.958
16.829		555.364		10.648

33.000	m
0.633	m

Side Shell Plate

1.700	3.000	5.100	2.000	3.400
1.700	9.000	15.299	2.000	3.400
1.700	15.000	25.499	2.000	3.400
1.700	21.000	35.698	2.000	3.400
1.700	27.000	45.898	2.000	3.400
1.700	33.000	56.097	2.000	3.400
1.700	39.000	66.297	2.000	3.400
1.700	45.000	76.496	2.000	3.400
1.700	51.000	86.696	2.000	3.400
1.700	57.000	96.895	2.000	3.400
1.700	63.000	107.095	2.000	3.400
1.700	64.310	109.322	2.000	3.400
1.700	3.000	5.100	4.000	6.800

1.700	9.000	15.299	4.000	6.800
1.700	15.000	25.499	4.000	6.800
1.700	21.000	35.698	4.000	6.800
1.700	27.000	45.898	4.000	6.800
1.700	33.000	56.097	4.000	6.800
1.700	39.000	66.297	4.000	6.800
1.700	45.000	76.496	4.000	6.800
1.700	51.000	86.696	4.000	6.800
1.700	57.000	96.895	4.000	6.800
1.700	63.000	107.095	4.000	6.800
1.700	64.310	109.322	4.000	6.800
0.722	64.330	46.476	4.000	2.890
41.521		1499.262		125.284

LCG 36.109
VCG 3.017

		S.M	Ord.	Func.
	1.465	1.000	5.500	5.500
	2.051	4.000	5.490	21.960
(Opening)	2.051	2.000	5.427	10.854
	2.051	4.000	5.358	21.432
	2.051	2.000	5.248	10.496
	2.051	4.000	5.088	20.352
	2.051	2.000	5.088	10.176
	2.051	4.000	4.880	19.520

2.051	2.000	4.646	9.292
2.051	4.000	4.352	17.409
2.051	2.000	3.937	7.874
2.051	4.000	3.308	13.232
2.051	2.000	2.521	5.042
2.051	4.000	1.158	4.632
2.051	1.000	0.000	0.000
			177.771
		A4	173.623

1.288	1.000	4.019	4.019
	4.000	4.408	17.632
	2.000	4.754	9.508
	4.000	5.018	20.072
	2.000	5.194	10.388
	4.000	5.311	21.244
	2.000	5.390	10.780
	4.000	5.440	21.760
	2.000	5.470	10.940
	4.000	5.490	21.960
	1.000	5.500	5.500
			153.803
		A1	132.107

	427.390	m^2		
8.317	7.700	64.044	5.000	41.587
6.344	21.150	134.186	5.000	31.722
6.344	37.520	238.045	5.000	31.722
5.902	54.020	318.830	5.000	29.510
26.908		755.105		134.542

LCG	28.062	m
VCG	5.000	m

8.758	7.700	67.438	7.360	64.460
4.426	7.300	32.310	6.163	27.277
1.347	0.000	0.000	6.163	8.305
1.867	13.270	24.778	6.163	11.508
16.399		124.525		111.550

7.594	m
6.802	m

4.418	8.830	39.009	9.520	42.058
2.112	8.830	18.645	8.460	17.864
1.441	6.250	9.006	8.460	12.191
1.723	13.270	22.860	8.460	14.574
9.693	tonnes	89.521		86.686
	LCG	9.236		
	VCG	8.943		

1.047	11.430	11.962	10.830	11.334
0.801	11.430	9.158	10.457	8.378
0.832	10.000	8.321	10.457	8.701
0.921	13.270	12.219	10.457	9.629
3.601		41.660		38.043
	LCG	11.570		
	VCG	10.565		

3.473	21.140	73.414	0.815	2.830
1.078	13.270	14.302	0.815	0.878
1.078	29.000	31.255	0.815	0.878
3.473	37.510	130.263	0.815	2.830
1.078	29.300	31.578	0.815	0.878
1.078	45.000	48.499	0.815	0.878
3.473	52.700	183.014	0.815	2.830
1.078	45.300	48.822	0.815	0.878
1.078	59.000	63.587	0.815	0.878

16.885		624.733		13.761

LCG	37.000	m
VCG	0.815	m

4.446	21.140	93.987	4.487	19.949
1.380	13.270	18.310	4.487	6.191
1.380	29.000	40.013	4.487	6.191
4.446	37.510	166.766	4.487	19.949
1.380	29.300	40.427	4.487	6.191
1.380	45.000	62.090	4.487	6.191
4.446	52.700	234.300	4.487	19.949
1.380	45.300	62.504	4.487	6.191
1.380	59.000	81.406	4.487	6.191
21.616		799.803		96.993

LCG	37.000	m
VCG	4.487	m

Inner Bottom

1	1.000	3.134	3.134
2	4.000	4.610	18.440

3	2.000	5.130	10.260		
4	4.000	5.300	21.200		
5	2.000	5.390	10.780		
6	4.000	5.460	21.840		
7	2.000	5.490	10.980		
8	4.000	5.500	22.000		
9	2.000	5.500	11.000		
10	4.000	5.500	22.000		
11	2.000	5.500	11.000		
12	4.000	5.500	22.000		
13	2.000	5.500	11.000		
14	4.000	5.500	22.000		
15	2.000	5.490	10.980	0.476	
16	4.000	5.350	21.400		
17	2.000	4.930	9.860		
18	4.000	4.090	16.360		
19	2.000	2.920	5.840		
20	4.000	1.525	6.100		
21	1.000	0.000	0.000		
			288.174		
			638.786	40.218	
				23.389	tonnes
				LCG	31.911
				VCG	0.850

Wood & Outfit Weight

Item	Weight (kg)	Total Weight (tonnes)	LCG (m)	Moment (t-m) (about amidship)	VCG (m)	Moment (t-m) (about keel)	
Control Panel	850.00	0.85	10.11	8.59	7.31	6.21	
Wing Control Panel (Starboard)	50.00	0.05	11.00	0.55	7.31	0.37	
Wing Control Panel (Port Side)	50.00	0.05	11.00	0.55	7.31	0.37	
Cabinet	50.00	0.05	9.00	0.45	7.31	0.37	
Chart Table	50.00	0.05	10.50	0.53	7.31	0.37	
Chart Table & Chair	15.00	0.02	10.50	0.16	7.31	0.11	
Map Table	40.00	0.04	10.50	0.42	7.31	0.29	
Map Table & Chair	20.00	0.02	10.50	0.21	7.31	0.15	
Control Panel Chair	20.00	0.02	11.00	0.22	7.31	0.15	
Radio Instrument Table	75.00	0.08	11.00	0.83	7.31	0.55	
Radio Operator's Chair	20.00	0.02	11.00	0.22	7.31	0.15	
Sofa	80.00	0.08	11.00	0.88	7.31	0.58	
Wash cabin item	40.00	0.04	7.77	0.31	6.50	0.26	
Bath House	20.00	0.02	4.77	0.10	5.10	0.10	
2nd Class Driver	35.00	0.04	11.85	0.41	5.10	0.18	
	30.00	0.03	11.94	0.36	5.10	0.15	
	15.00	0.02	11.94	0.18	5.10	0.08	

3rd Class Driver	35.00	0.04	11.94	0.42	5.10	0.18
	30.00	0.03	11.94	0.36	5.10	0.15
	15.00	0.02	11.94	0.18	5.10	0.08
2nd Class Master	35.00	0.04	11.85	0.41	7.31	0.26
	35.00	0.04	11.85	0.41	7.31	0.26
	20.00	0.02	11.88	0.24	7.31	0.15
	15.00	0.02	11.85	0.18	7.31	0.11
	100.00	0.06	11.85	0.71	7.31	0.44
	85.00	0.09	11.85	1.01	7.31	0.62
Inspector	35.00	0.04	11.85	0.41	7.31	0.26
	35.00	0.04	11.85	0.41	7.31	0.26
	15.00	0.02	11.88	0.18	7.31	0.11
	10.00	0.01	11.85	0.12	7.31	0.07
	100.00	0.10	11.85	1.19	7.31	0.73
	55.00	0.06	11.85	0.65	7.31	0.40
Owner	35.00	0.04	9.36	0.33	7.31	0.26
	25.00	0.03	9.30	0.23	7.31	0.18
	15.00	0.02	9.30	0.14	7.31	0.11
	10.00	0.01	9.30	0.09	7.31	0.07
	30.00	0.03	9.30	0.28	7.31	0.22
	35.00	0.04	9.30	0.33	7.31	0.26
	50.00	0.05	9.30	0.47	7.31	0.37
	15.00	0.02	9.30	0.14	7.31	0.11
	150.00	0.15	9.30	1.40	7.31	1.10
Sailor 1	35.00	0.04	6.28	0.22	5.10	0.18
	20.00	0.02	6.25	0.13	5.10	0.10

	15.00	0.02	6.28	0.09	5.10	0.08
Sailor 2	35.00	0.04	7.75	0.27	5.00	0.18
	20.00	0.02	7.75	0.16	5.10	0.10
	15.00	0.02	7.75	0.12	5.10	0.08
Sailor 3	35.00	0.04	8.57	0.30	5.00	0.18
	20.00	0.02	8.57	0.17	5.10	0.10
	15.00	0.02	8.57	0.13	5.10	0.08
Sailor 4	35.00	0.04	10.04	0.35	5.00	0.18
	20.00	0.02	10.04	0.20	5.10	0.10
	15.00	0.02	10.04	0.15	5.10	0.08
Sailor 5	35.00	0.04	6.28	0.22	5.00	0.18
	20.00	0.02	6.28	0.13	5.10	0.10
	15.00	0.02	6.28	0.09	5.10	0.08
Geezer 1	35.00	0.04	7.75	0.27	4.70	0.16
	25.00	0.03	7.75	0.19	4.70	0.12
	40.00	0.04	7.75	0.31	4.72	0.19
Geezer 2	35.00	0.04	8.57	0.30	5.10	0.18
	25.00	0.03	8.57	0.21	5.10	0.13
	40.00	0.04	8.57	0.34	5.10	0.20
Geezer 3	35.00	0.04	10.04	0.35	5.10	0.18
	25.00	0.03	10.04	0.25	5.10	0.13
	40.00	0.04	10.04	0.40	5.10	0.20

Cook	35.00	0.04	8.57	0.30	5.10	0.18
	25.00	0.03	8.57	0.21	5.10	0.13
	15.00	0.02	8.57	0.13	5.10	0.08
Store-1	75.00	0.08	10.50	0.79	7.31	0.55
Deck Store	75.00	0.08	10.50	0.79	7.31	0.55
Engine Office	40.00	0.04	10.50	0.42	7.31	0.29
Engine Control Room	400.00	0.40	10.50	4.20	7.31	2.92
Deck Workshop	75.00	0.08	10.50	0.79	7.31	0.55
Radio Operator's Room	35.00	0.04	7.80	0.27	7.31	0.26
	25.00	0.03	7.80	0.20	7.31	0.18
	45.00	0.09	7.80	0.70	7.31	0.66
	30.00	0.03	7.80	0.23	7.31	0.22
	100.00	0.10	7.80	0.78	7.31	0.73
Fan Room	50.00	0.05	10.60	0.53	6.50	0.33
			10.60			
Deck Store 2	35.00	0.04	10.60	0.37	8.20	0.29
Lush Storage	50.00	0.05	10.60	0.53	7.00	0.35
Deck Workshop	80.00	0.08	10.60	0.85	8.20	0.66
Store	600.00	0.60	10.60	6.36	7.00	4.20
Electric Room	350.00	0.35	10.60	3.71	7.50	2.63

Boatswain/Bosun Store	150.00	0.15	10.60	1.59	5.50	0.83
Paint Store	250.00	0.25	10.60	2.65	5.50	1.38
Funnel		2.40	6.42	15.41	10.15	24.36
	Total	**10.44**		72.40		62.71

11.49	**tonnes**	(10% increase)
6.30	**m**	
5.46	**m**	

Machinery Weight

	Item	Total weight (tonnes)	LCG (m)	Moment (about amidship)	VCG (m)	Moment (about keel)
1	Main Engine	4.78	10.8	51.62	1.65	7.89
2	Gear Box	1.44	10.6	15.26	1.6	2.30
3	Generator	0.93	8.39	7.80	1.5	1.40
4	Pump	0.63	8.15	5.13	1.2	0.76
5	Exhaust and Chimney	1.25	8.17	10.21	6	7.50
6	Engine Control Room Equipment	3.00	8	24.00	7.31	21.93
7	Rudder & Steering Arrangement	3.92	1.62	6.35	3.63	14.23
8	Anchor & Chain	9.18	61.6	565.49	5.5	50.49
9	Bollard, Capstan and other Fittings	4.00	61.68	246.72	5.5	22.00
10	Propeller, Propeller Shaft	2.41	1.5	3.61	0.85	2.05
11	Complete Electrical System	3.00	7	21.00	5	15.00
12	Hatch Coaming Girder	3.00	34	102.00	4.5	13.50
13	Complete Piping	2.00	33.5	67.00	4.3	8.60
14	Windlass	1.00	32	32.00	4.3	4.30
15	Mooring Rope	1.00	62.5	62.50	5.7	5.70
		52.69		**1158.21**		**171.94**

57.96 **tonnes** (10% increase)

25.97 **m**

3.86 **m**

	Item	Weight (tonnes)	LCG (m)	Moment (t-m) (about aft)	VCG (m)	Moment (t-m) (about keel)
1	Steel Weight	640.95	29.87	19143.08	2.40	1535.94
2	Wood & Outfit Weight	11.49	8.19	94.07	7.09	81.47
3	Machinery Weight	57.96	25.97	1505.37	3.86	223.48
Total Lightship Weight		**710.40**	**29.20**	20742.52	**2.59**	1840.88

Fully Loaded Departure Condition

No.	Item	Weight (tonnes)	LCG (m)	Moment (t-m) (about aft)	VCG (m)	Moment (t-m) (about keel)
1	Light Ship	710.40	29.20	20742.52	2.59	1840.88
2	Crew (13)	0.975	8.75	8.53	5.50	5.36
3	Fuel Oil	8.85	12.34	109.21	3.07	27.17
4	Lub Oil	0.07	4.60	0.32	3.00	0.21
7	Fresh Water	5	64.00	320.00	2.80	14.00
9	Cargo Hold 1	450	52.67	23701.50	2.92	1314.00
10	Cargo Hold 2	568	37.54	21322.72	2.92	1658.56
11	Cargo Hold 3	568	21.13	12001.84	2.92	1658.56
Total Weight		**2311.30**	**33.84**	78206.64	**2.82**	6518.74

Fully Loaded Arrival Condition

No.	Item	Weight (tonnes)	LCG (m)	Moment (t-m) (about aft)	VCG (m)	Moment (t-m) (about keel)
1	Light Ship	710.40	29.20	20742.52	2.59	1840.88
2	Crew (13)	0.975	8.75	8.53	5.50	5.36
3	Fuel Oil (10%)	0.885	12.34	10.92	3.07	2.72
4	Lub Oil (10%)	0.007	4.60	0.03	3.00	0.02
7	Fresh Water (10%)	0.5	64.00	32.00	2.80	1.40
9	Cargo Hold 1	450	52.67	23701.50	2.92	1314.00
10	Cargo Hold 2	568	37.54	21322.72	2.92	1658.56
11	Cargo Hold 3	568	21.13	12001.84	2.92	1658.56
Total Weight		**2298.77**	**33.85**	77820.06	**2.82**	6481.50

Ballast Arrival Condition

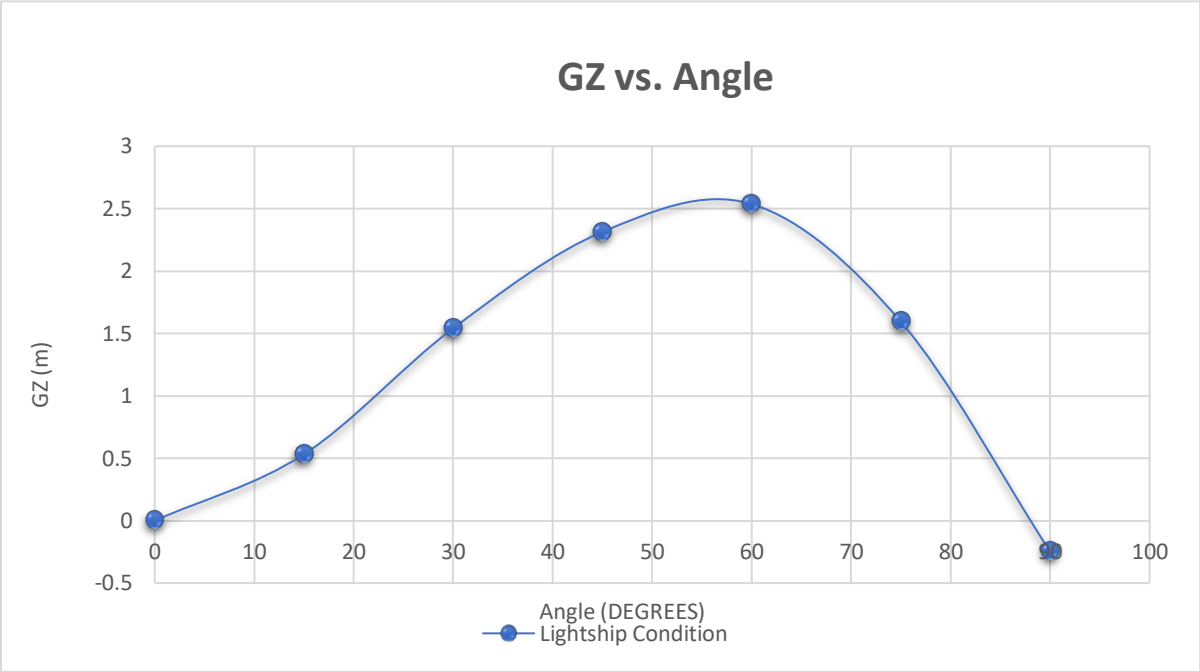
No.	Item	Weight (tonnes)	LCG (m)	Moment (t-m) (about aft)	VCG (m)	Moment (t-m) (about keel)
1	Light Ship	710.40	29.20	20742.52	2.59	1840.88
2	Crew (13)	0.975	8.75	8.53	5.50	5.36
3	Reserved Fuel Oil	1	4.60	4.60	3.07	3.07
4	Service Fuel Oil (Engine)	1.5	12.34	18.51	3.07	4.61
5	Service Fuel Oil (Generator)	1	12.34	12.34	3.07	3.07

6	Lub Oil	0.007	4.60	0.03	3.00	0.02
7	Reserved Fresh Water	0.5	64.00	32.00	2.80	1.40
8	Service Fresh Water	1	2.60	2.60	3.57	3.57
9	Ballast Water	346.43975	40.74	14112.54	0.96	332.98
Total Weight		**1062.82**	**32.87**	34933.67	**2.07**	2194.95

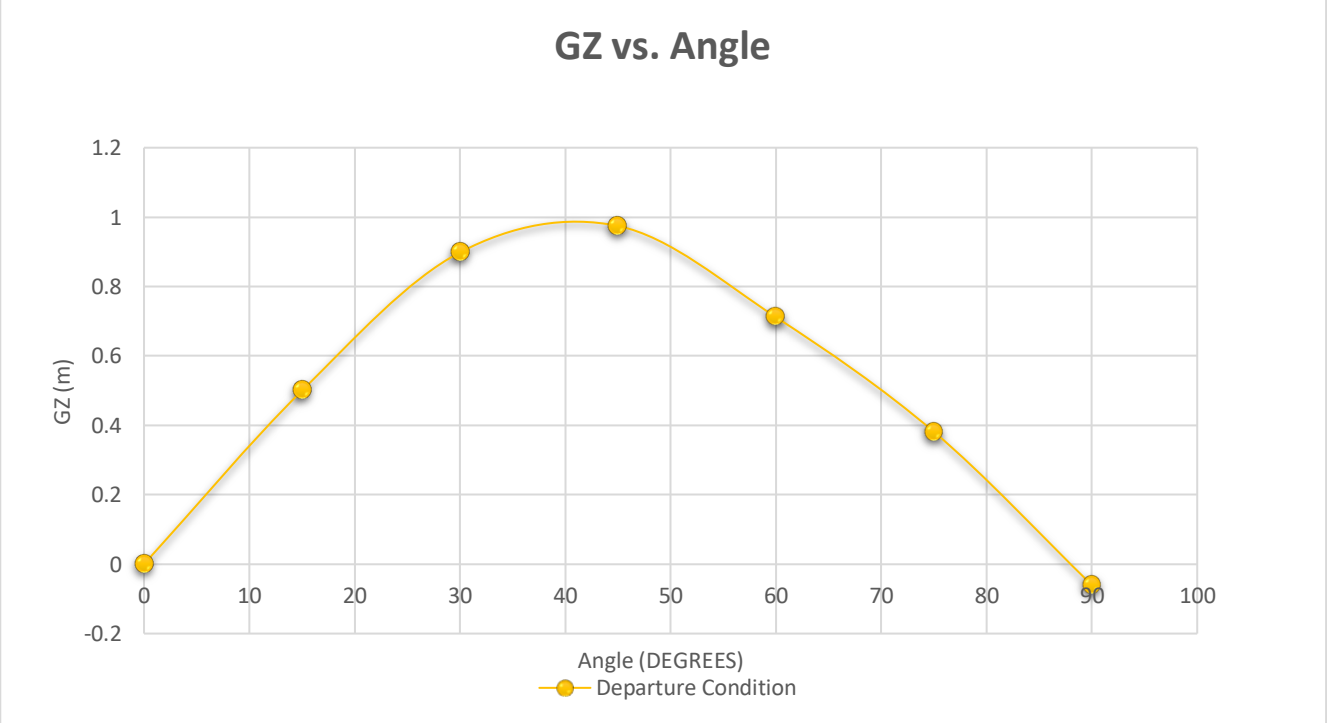
18. Stability Calculation

Condition	Lightship Condition	Arrival Condition	Departure Condition
Angle	**GZ(m)**	**GZ(m)**	**GZ(m)**
0	0.000	0.000	0.000
15	0.532	0.335	0.500
30	1.541	0.569	0.898
45	2.313	0.703	0.974
60	2.536	0.669	0.712
75	1.594	0.328	0.381
90	-0.248	-0.040	-0.060

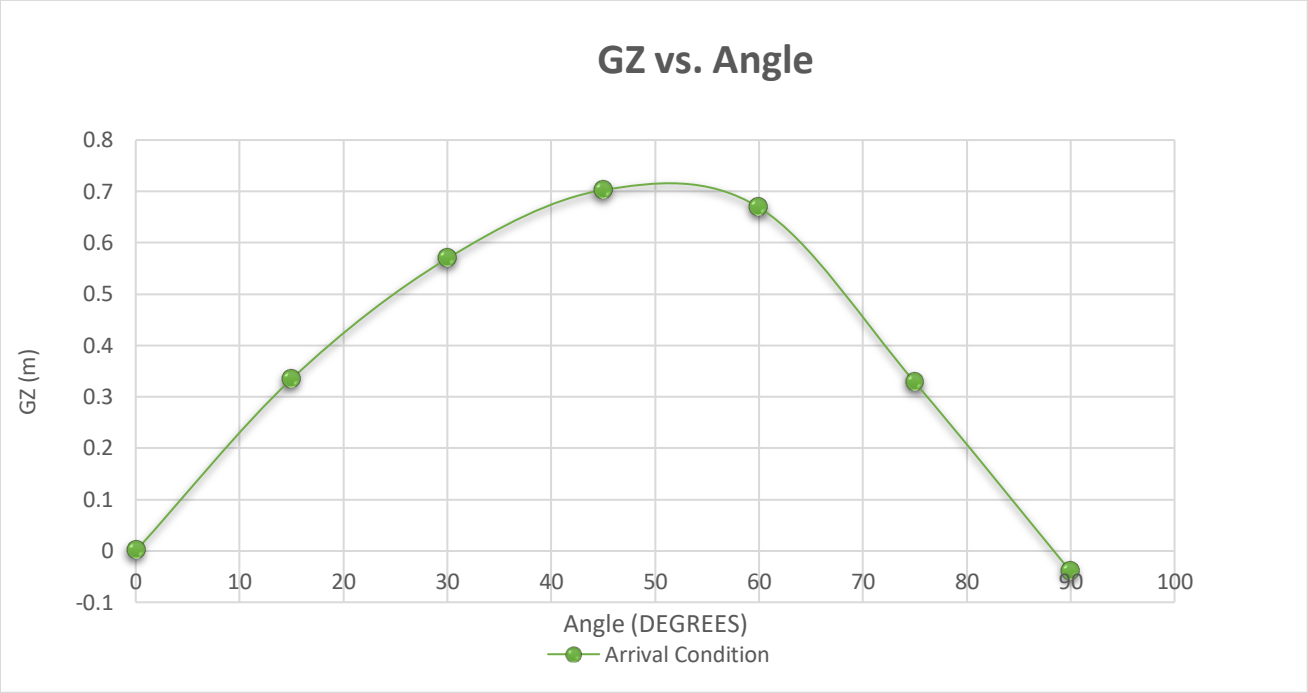
Lightship Condition



Fully Loaded Departure Condition



Fully Loaded Arrival Condition



IMO Criteria Check:

Properties	IMO value	Lightship Condition	Arrival Condition	Departure Condition	Comment
Area up to 30 degree (m-rad)	≥ 0.055	0.3201	0.1665	0.2529	Satisfied
Area up to 40˚ (m-rad)	≥ 0.09	0.7450	0.3093	0.4740	Satisfied
Area up to 30˚ - 40˚ (m-rad)	≥ 0.03	0.4250	0.1428	0.2210	Satisfied
GZ at 30 degree (m)	≥ 0.2	1.5410	0.5693	0.8984	Satisfied
Max. GZ at (degree)	≥ 30 (preferable) but not ≤ 25	45	52	42	Satisfied
Initial Metacentric Height (m)	Should not be ≤ 0.15	2.3	1.4	1.9	Satisfied

19. Trim Calculation

Fully Loaded Departure Condition

Final Draft of Vessel			
	Draft (aft)	Draft (fore)	Comment
Mean Draft (m)	3.65	3.65	
Change in Draft (m)	0.05	0.05	***Trim by Stern***
Final Draft (m)	3.70	3.60	

Fully Loaded Arrival Condition

Final Draft of Vessel			
	Draft (aft)	Draft (fore)	Comment
Mean Draft (m)	3.65	3.65	
Change in Draft (m)	0.16	0.17	***Trim by Stern***
Final Draft (m)	3.81	3.48	

Lightship Condition

Final Draft of Vessel			
	Draft (aft)	Draft (fore)	Comment
Mean Draft (m)	3.65	3.65	
Change in Draft (m)	0.77	0.72	***Trim by Stern***
Final Draft (m)	4.42	2.93	

1. Germanischer Lloyd, 13th Edition (GL-13)

2. Illustration of Hull Structures (English/Japanese),

Dr. Hirohiko Emi (Author/Illustrator)

3. ISO-2001

4. DNV-GL 2016

5. Weichai Marine Engines Catalogue