NAME-338

SHIP DESIGN PROJECT AND PRESENTATION

A REPORT ON

A DESIGN OF 1500 TEUs SEA-GOING CONTAINER VESSEL

Under the Supervision of

Dr. Md. Shahidul Islam

Professor, Department of NAME, BUET

Submitted by

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Date of Submission: 01-03-2022

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FORWARDING LETTER

7/21/2023
To,
The Course Supervisor,
Dr. Md. Shahidul Islam
Professor,
Department of Naval Architecture & Marine Engineering, BUET

Subject: Submission of report on a design of 1500 TEUs sea-going Container vessel.

Dear Sir,
I hope this letter finds you in good health and high spirits. I am writing to formally submit my academic project titled **"A DESIGN OF 1500 TEUs SEA-GOING CONTAINER VESSEL"** as part of the requirements for Course -338 (Ship Design Project and Presentation). It is with great pleasure that I present this comprehensive document which represents years of research, data collection and analysis, calculations, and cost-effective choices for the ship. We took support from different report books, rulebooks, respected teachers of our department, and the internet.

I would like to express my sincere gratitude to you for providing valuable time, guidance, and support throughout this project. Your valuable insights, constructive feedback, and mentorship have played a pivotal role in shaping the outcome of this report. I have endeavoured to incorporate your suggestions and recommendations to enhance the quality and clarity of the content.

Sincerely yours,

Md. Irtesum Nasrat
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PREFACE

Ship designing is an assiduous task that requires a firm grasp of a lot of information to ensure proper execution. However, theoretical knowledge alone is not sufficient; staying updated with practical know-how is equally essential. Recognizing this fact, the Department of Naval Architecture and Marine Engineering at Bangladesh University of Engineering and Technology has introduced a course named "NAME-338," also known as "Ship Design Project and Presentation." This course aims to familiarize students with the basics of ship designing processes.

Under the guidance of Professor Dr. Md. Shahidul Islam, we have completed our project. We express our sincerest gratitude to him for his wholehearted cooperation throughout the journey of our project completion. From the project's inception to its conclusion, he supported us with constructive suggestions and ideas, and at every step of the designing process, he provided invaluable assistance in rectifying our mistakes and offered endless encouragement to ensure the successful completion of our work.

We would also like to extend our appreciation to all the teachers of the Department of Naval Architecture and Marine Engineering for their valuable suggestions and the necessary information they provided during the preparation and presentation of the project. Throughout this project, we acquired valuable knowledge of various software and information that would not have been possible without the unwavering support and guidance of our respected teachers.

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1 OBJECTIVE

The course outline dictated that we are to design a ship and present it in front of our respected teachers. For our assignment, we were to design a **1500 TEU container ship** that would transport from Chittagong to Singapore at a speed of **20 knots**. In this respect, we have completed the following tasks.

- Principal particulars
- General Arrangement
- Lines Plan
- Hydrostatic Calculations
- Scantling Calculations
- Midship Section Scantling
- Longitudinal Construction
- Shell Expansion Drawing
- Weight Calculation
- Stability Calculation
- Trim Calculation
- Resistance Calculation
- Power Calculation
- Propeller Design
- Rudder Design
- Steering Gear Arrangement
- Engine Selection
- Engine Foundation
- Propeller Shaft Design

2 Owner's Requirement

The essential logical specification of the ship required by the owner must be provided in the Design. It could be flexible to a very small degree but any drastic change must be avoided in the design. For our project, we considered the owners' requirements as follows:

Container Holding Capacity	:	1500 TEUs (minimum)
Service Speed	:	20 knots
Route	:	Chittagong Port to Tuas Port (Singapore)
Type	:	Full/Box Container Ship
Compatibility	:	Compatible with the Major Canals.
		Ex: Suez Canal, Panama Canal

3 Route Details

The proposed route is Chittagong Sea Port to the Singapore Sea Port.

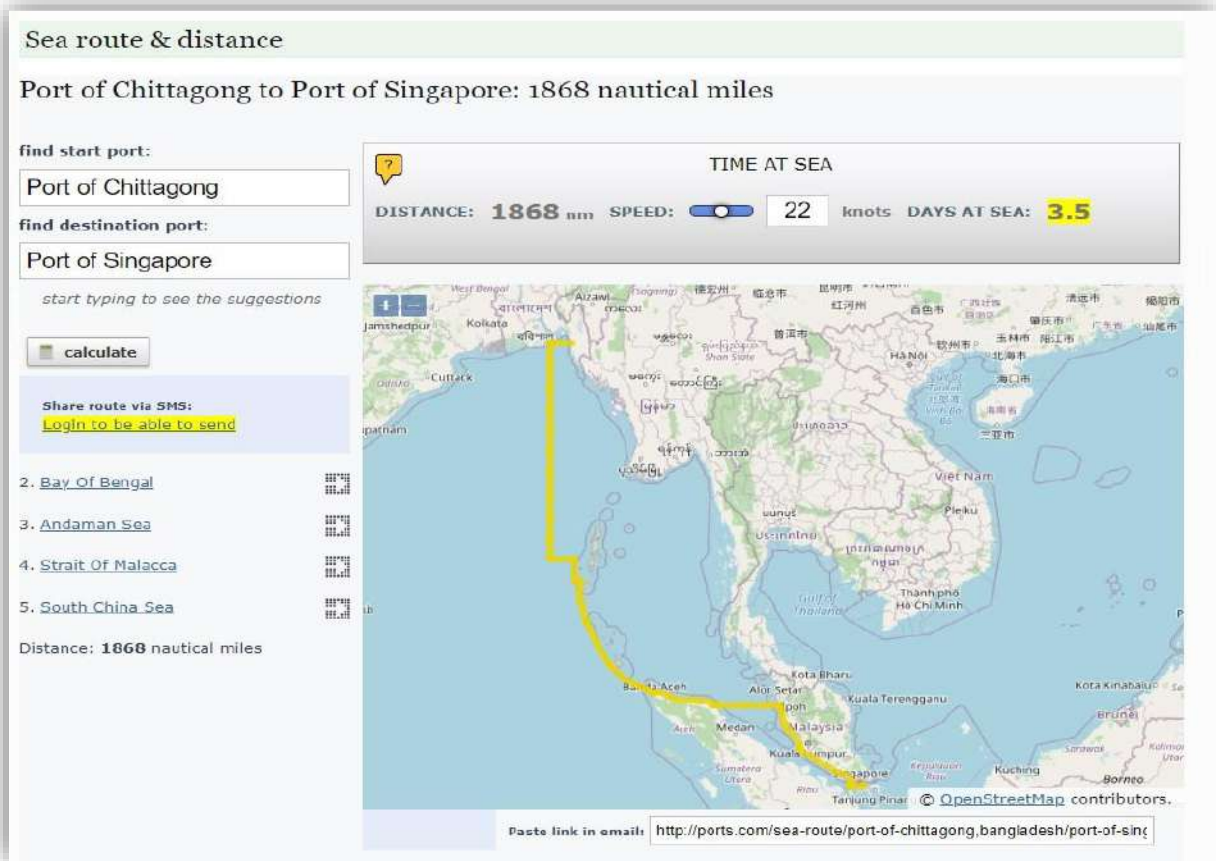


Figure 1: Root details

3.1 The reason behind choosing this sea route

- ✓ Yearly TEUs: 36.6 million (2018)
- ✓ Currently one of the World's 10 largest seaports
- ✓ Tuas Port to be the world's largest fully automated terminal when completed in 2040
- ✓ Adequate Quay-Side and Overhead Cranes since our vessel is a feeder type and has no on-board crane.

4 Reasonings

4.1 Why Container Vessel?

- ⇨ Fast transportation at a low cost.
- ⇨ A secure means of cargo transport with low energy consumption.
- ⇨ A versatile, highly flexible means of transport.

4.2 Why 1500 TEUs?

- ⇨ The target demographic of Merchant Ships being built in Bangladesh: European countries.
- ⇨ Europe produces 90% of the world's passenger liners and 60% of superyachts.
- ⇨ China, Japan, and Korea are not interested in producing small merchant vessels. So, countries like Bangladesh, India, and Sri Lanka have a chance to enter the market.

5 Principal Particulars

5.1 Procedures used to determine optimum Principal Particulars

- The preliminary calculation for principal particulars is carried out using Munro-Smith's Elements of Ship Design and using iterative methods of container arrangement.
- The dimensions obtained are then cross-validated using a research paper named "Statistical Analysis and Determination of Regression Formulas for Main Dimensions of Container Ships based on IHS Fair Play Data" published under the University of Southern Denmark.
- A basic ship is collected from a reputable ship design firm "Khun E. Hansen" located in Elsinore, Denmark.

5.2 Container Arrangement

Number of Containers on Deck(N_d): **975**

Tiers	5
Bays	18
Rows	7(N_b)

Number of Containers inside Hold (N_c): **525**

Tiers	5(N_t)
Bays	22
Rows	7

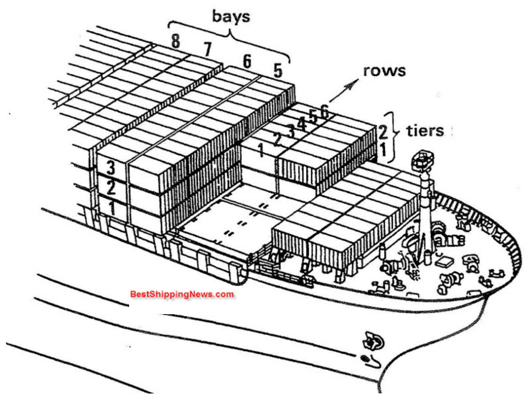


Figure 2: A sample illustration of how Containers are Loaded on a Full Container Ship

"The container arrangement on deck is done such that is MARPOL and IMO Criteria for visibility is satisfied."

5.3 Details of the container, TEU(m)

Parameter	:	Value
Length (l)	:	6.05 m
Width (w)	:	2.43 m
Height (h)	:	2.59 m
Usable capacity (m^3)	:	30.75 m^3
Gross Weight (Tonnes)	:	10.1605 tonnes

5.4 Clearances

Parameter	:	Value
From one bay to another	:	1.5 m
Allowance for clearance and cross-tie across the ship	:	0.14 m
The length required for each container	:	7.55 m
Width required for each container	:	2.57 m

5.5 Length of our container Ship

The number of cells in length inside holds (bays), $n = \frac{N_c}{N_t \cdot N_b} = 16$.

Due to the shape of the ship forward and aft, not all sets of cells will satisfy this equation. Therefore, we assume a 10% loss.

Hence, the number of bays along the length inside the hold (rounded), $N_{bh} = 18$.

Now,

Parameter	:	Value
Cargo length	:	135.9 m
Aft peak tank (0.035LBP)	:	6 m (Preliminary)
Engine Room	:	25 m (Preliminary)
Fore End Space	:	7 m (Preliminary)
Fore Peak Tank (0.05LBP)	:	7 m (Preliminary)
LBP	:	180.9 m (Preliminary)

5.6 The breadth of our Container Ship

Containers have a standard width of 2.43 m. However, each container requires an allowance for clearance, guides, etc., of about 240 mm, making each container require a width of 2.67 m.

Thus, the number n of cells located transversely in the ship requires 2.67 m. Since the width available for the containers is about 80% of the ship's breadth (B), then $0.8B = 2.67n$.

So, $B = 3.34n$. In our ship, $n = Nb = 7$.

Hence, the Breadth of the container ship is $3.34 \times 7 = \mathbf{23.38\ m}$ (Preliminary).

5.7 Depth of our container ship

Parameter	:	Value
Number of tiers of containers inside the hold (N_t)	:	5 TEU
Depth of the Double Bottom (D_b)	:	1.5 m (Preliminary)
Depth, ($N_t \times h + D_b$)	:	14.45 m (Preliminary)
Draught	:	8.257 m (Preliminary)

5.8 Block Co-efficient

From CBB and Alexander's Research, the block coefficient is given by

$$\text{CB} = 1 - 0.265\frac{V}{\sqrt{L}}$$

where $V = 20$ knots is the service speed and $L = 180.9$ m is the LBP.

So, CB $= 0.6$.

The displacement is calculated as follows:

$$\text{Displacement} = \text{LBP} \times B \times H \times \text{CB} \times 1.025 = \mathbf{22630\ tonnes.}$$

5.9 Iterative process for optimum hull shape

- An offset table for a similar vessel is collected from the departmental library.
- The line plan is drawn in AutoCAD and modified to meet our dimensional and hull-form requirements. The changes are saved in the offset table.
- 3D Control Points are generated using the new offset table, saved as a .csv file, and exported to Rhinoceros to generate the hull surface.

- The hull surface is checked for naked, rough edges, and other imperfections, and corrected accordingly.
- Then the model is exported to Maxsurf as .iges, and the hull form coefficient is checked.
- If the requirements are not met and the results seem unsatisfactory, then we start again by modifying the last lines plan in AutoCAD.
- The whole procedure is repeated about 15 times.
- Finally, the final particulars are validated by the research paper named "Statistical Analysis and Determination of Regression Formulas for Main Dimensions of Container Ships based on IHS Fairplay Data," published at the University of Southern Denmark.

5.10 Expectations regarding the Hull Form of our ship

⇨ The **block coefficient** must stay in the range of 0.6-0.7. This ensures less resistance and faster speeds and as a result, ensures fast transportation of goods at a lower cost.

⇨ The **prismatic Coefficient** should stay near the **Block Coefficient**.

⇨ **Midship Coefficient** is anticipated to be in the range of 0.95-0.98. It is to carry the greatest number of containers possible transversely and ensure efficient use of space.

⇨ A good **geometric similarity** is maintained with our basis ship.

⇨ **Displacement** should be in the range of 21,000-23,000 Tones and Draught should not exceed 9 m as per our numeric calculations.

5.11 Final Principal Particulars

Parameter	**:**	**Value**
LOA (Length Overall)	:	188.8 m
LBP (Length Between Perpendiculars)	:	178 m
LWL (Length Waterline)	:	183.9 m
Draft	:	8.3 m
Breadth	:	23.5 m
Depth	:	14.5 m

5.12 Final Hull-Form Coefficients

Parameter	**:**	**Value**
Block Coefficient	:	0.6
Prismatic Coefficient	:	0.613
Midship Area Coefficient	:	0.97
WP Area Coefficient	:	0.72
Displacement (m^3)	:	21560
Displacement (t)	:	22099

6 Basis Ship

1467 TEU Container Vessel (KEH MARK X)

General: Two vessels have been delivered to this design. Both were built by Ørskov Christensen Shipyard, Denmark: M/S Kirsten Sif (hull No. 180) and M/S Helene Sif (hull No. 181).

Main Particulars:

Length o.a. (approx.)	165.60 m
Length p.p.	153.00 m
Breadth moulded	27.20 m
Depth	12.00 m
Draught	8.50 m
Scantling draught	8.95 m
DWT at design draught (approx.)	15,500 t
DWT at scantling draught (approx.)	17,000 t

Capacity:

Container capacity:	Hold:	Deck:	Total:
20' TEU	474	993	1,467
40' FEU + 20' TEU	221+32	471+51	692+83

Homogeneously loaded with TEU of 14 t (0.45 % C.g.) stability for:

No. of holds	4
At design draught (approx.)	1,000 units
At scantling draught (approx.)	1,060 units

Speed: Service speed (90 % MCR and 15 % sea margin) (approx.) 20.00 kn

Machinery and Equipment:

Diesel	
Main engine	1 x 14,800 kW
Propeller	CP-propeller, 5.6 m diameter, 127 rpm
Aux. engines	3 x approx. 700 kW at 1,800 rpm

Miscellaneous:

Classification Norske Veritas + 1A1, Container carrier, EO	
IMO number Kirsten Sif	9086796
IMO number Helene Sif	9086801

Scope of Work: Complete design developed together with the shipyard, including:
Initial Design
Basic Design

Ref. No.: KEH 93075

KNUD E. HANSEN
SHIP DESIGN SINCE 1937

7 Preliminary Power Calculation

7.1 Basis Ship Data

The principal data for our basis ship, 'KEH MARK X,' used for preliminary power calculation and manning requirement, is shown below.

Parameter	**:**	**Value**
Capacity	:	1467 TEUs
Length overall, LOA	:	165.60 m
Length between perpendicular, LBP	:	153.00 m
Breadth molded, B_{mld}	:	27.20 m
Depth, D	:	12 m
Draft, T	:	8.95 m
Engine	:	1 x 14,800 kW
Speed, V	:	20 knots
Route	:	International
Block Co-efficient, C_b	:	0.64
Deadweight Co-efficient, C_d	:	0.75

The necessary geometric ratios are shown below.

Parameter	**:**	**Value**
LBP/B_{mld}	:	5.625
B_{mld}/T	:	8.95
B_{mld}/D	:	2.2667

7.2 Calculation of Displacement & Deadweight of Basis Ship

$$\begin{aligned}\text{Displacement} &= L_{BP} \times B \times T \times C_b \\ &= 153 \times 27.2 \times 8.95 \times 0.64 \text{ m}^3 \\ &= 23837.6448 \text{ m}^3\end{aligned}$$

As it is a seagoing vessel, the density of water is 1.05 tonnes/m ^{3}. Therefore, the displacement in weight, Δ, is

$$\begin{aligned}&= 23837.6448 \times 1.05 \text{ tonnes} \\ &= 25029.52704 \text{ tonnes}\end{aligned}$$

Now, Deadweight Coefficient,

$$CD = 0.75 = \frac{DWT}{\Delta}$$

Or,

$$0.75 = \frac{DWT}{25029.52704}$$

Therefore, Deadweight,

$$DWT = \mathbf{18772.145\ tonnes}$$

7.3 Admiralty Coefficient Calculation

Parameter	**:**	**Value**
Displacement	:	18772.145 tonnes
Speed, V	:	20 knots
Power	:	14,800 kW

$$\begin{aligned}\text{Admiralty Coefficient, A}_c &= \frac{\text{Displacement}^{2/3}}{\text{Power}} \times V^4 \\ &= \frac{18772.145^{\frac{2}{3}}}{14800} \times 20^4 \\ &= \mathbf{381.80}\end{aligned}$$

7.4 Power Calculation for New Ship

The capacity of the new ship is approximately 1500 TEUs.
The route is from Chittagong Port to Singapore Port.

Since our ship carries cargo of almost similar capacity at a maximum speed of 20 knots (compared to 22 knots of the basis ship), but we are using a finer hull, we can opt for an engine of the same capacity.

Therefore, we have selected the preliminary main engine power as 14,400 kW.
The preliminary engine we have chosen is the VM 43 C Propulsion Engine of the 16M 43 C type.

The catalog is given below.

Type	Output Range		Speed	Bore	Stroke	Specific Fuel Consumption(g/kwh)	
	Kw	MHP	RPM	mm	mm	100%	85%
16 M 43 C	14400	19580	514	430	610	176	175

8 Manning Information

According to the "Merchant Shipping (Safe Manning) Regulations, 2022" published by "MARINECARE Consultant Bangladesh Ltd.," all seagoing ships registered under the Bangladesh flag, except for fishing vessels and pleasure crafts not engaged in trade, and with a gross tonnage (GT) ranging from 500 to 3000GT, must have safe manning as follows:

8.1 Deck

Category	**:**	**Person**
Master	:	01
Chief Mate	:	01
Officer in Charge of Navigation Watch	:	01
Navigation Watch Rating	:	03
Able Seafarer Deck	:	03
Deck Cadets	:	02

8.2 Engine

Category	:	Person
Chief Engineer	:	01
Second Officer	:	01
Officer in charge of the Engineering watch	:	02
Engine Cadet	:	02
Able Seafarer (Engine)	:	03
Engine Watch Rating	:	03
Chef/Cook	:	02
Total	**:**	**25**

9 Preliminary Deadweight Calculation

9.1 Heavy Fuel Oil weight

$$W_{HFO} = SFOC \cdot BHP \cdot \text{time to voyage} \cdot \text{constant addition of fuel}$$

Here,
SFOC: 176 g/ kWh (100% power)
Constant addition of fuel: 1.3
Therefore,

$$W_{HFO} = 176\text{ g/kWh} \cdot 14400 \cdot 85\text{ h} \cdot 1.3 = \mathbf{280\ tonnes}$$

9.2 Diesel oil (DO) weight

$$\begin{aligned} W_{DO} &= 20\% \text{ of } W_{HFO} \\ &= 20\% \times 280 \text{ tonnes} \\ &= \mathbf{56\ tones} \end{aligned}$$

9.3 Lube Oil (LO) weight

$$W_{LO} = SLOC \cdot BHP \cdot \text{time of voyage} \cdot \text{constant addition of fuel}$$

Here,
SLOC: 0.6 g/kWh
Constant addition of fuel: 1.3
Therefore,

$$W_{LO} = 0.60\text{ g/kWh} \cdot 14400\text{ kW} \cdot 85\text{ h} \cdot 1.3 = \mathbf{0.955\ tonnes}$$

9.4 Fresh Water weight

- ⇨ Consumption for crew = 10 kg/person/day
- ⇨ Bath & laundry = 50 kg/person/day
- ⇨ Cooking = 5 kg/person/day

Necessary fresh water per person per day = (10 + 50 + 5) = 65kg/person/day

Now, in terms of the Manning aspect, it has been determined that a minimum of 25 persons must be considered for the safe and efficient operation of the ship. This number of personnel is essential to ensure the vessel's smooth functioning, adherence to safety protocols, and effective navigation during its operations. By maintaining an adequate crew complement, the ship can operate proficiently, respond to various situations, and meet regulatory requirements for safe manning.

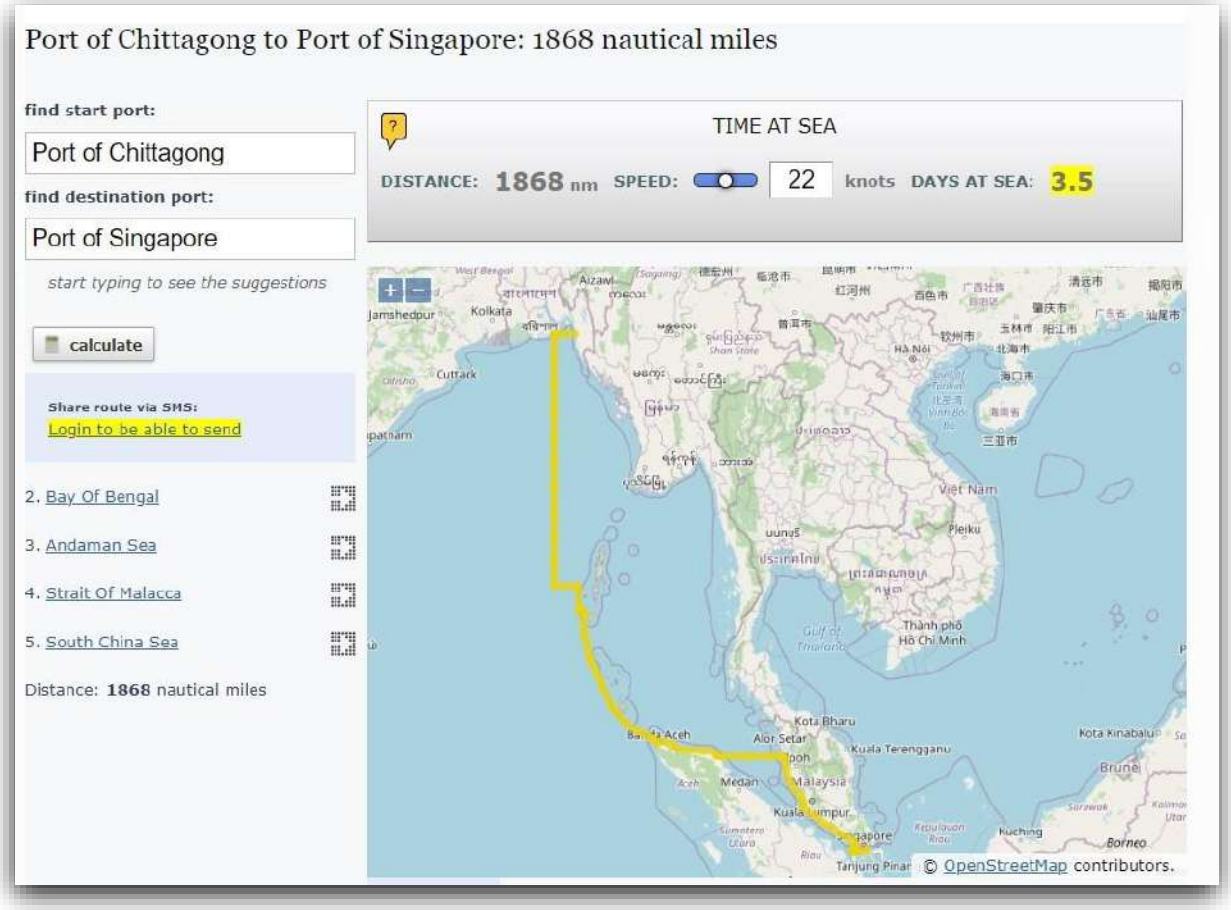


Figure 3: Chittagong Port to Singapore Port

The distance from Chittagong Port to Singapore Port Internal Container Terminal is 1868 knots.

Speed is 22 kn/hr

Cruising time = 1868/22 hours = 84.90 hours ~~3.5 days (Approximate)

So, Freshwater weight for manning = 65 kg/person/day×3.5 days×25 persons

$= \mathbf{5.69\ tonnes}$

9.5 Weight for Manning

The average weight of a man $= 75$ kg

So, total weight for manning $= 75\ \text{kg} \times 25$

$= \mathbf{1.875\ tonnes}$

9.6 Necessary fresh water for engines

For main engine $= 25$ g/kWh

$= 100 \times 10^{-3}\ \text{g/kWh} \times 14{,}400 \times 85\ \text{h}$

$= \mathbf{8.568\ tonnes}$

For auxiliary engine $=$ 0.2 of the main engine's fresh water

$= 0.2 \times 8.568$ tonnes

$= \mathbf{1.71\ tonnes}$

9.7 Provision weight

Average provision needs $= 5$ kg/person/day

$= 5\ \text{kg/person/day} \times 25\ \text{person} \times 3.5\text{days}$

$= \mathbf{0.4375\ tonnes}$

9.8 Capacity weight:

The capacity of our ship $= 1500$ TEUs

The average capacity of a container $= 10$ tonnes

Capacity $= 1500 \times 11$ tonnes

$= \mathbf{16500\ tonnes}$

9.9 Final Summary

Component	:	Weight
Heavy Fuel Oil	:	280
Diesel Oil	:	56
Lube Oil	:	0.955
Fresh Water Weight	:	5.69
Manning	:	1.875
Fresh Water for engines (Main)	:	8.568
Fresh Water for engines (Auxiliary)	:	1.71
Provision Weight	:	0.4375
Capacity Weight	:	16500
Total Deadweight	:	19799.35

Therefore, the Deadweight Coefficient will be:

$$C_D = \frac{\text{DWT}}{\nabla} = \frac{19799.35}{21517.72 \times 1.05} = \mathbf{0.7435}$$

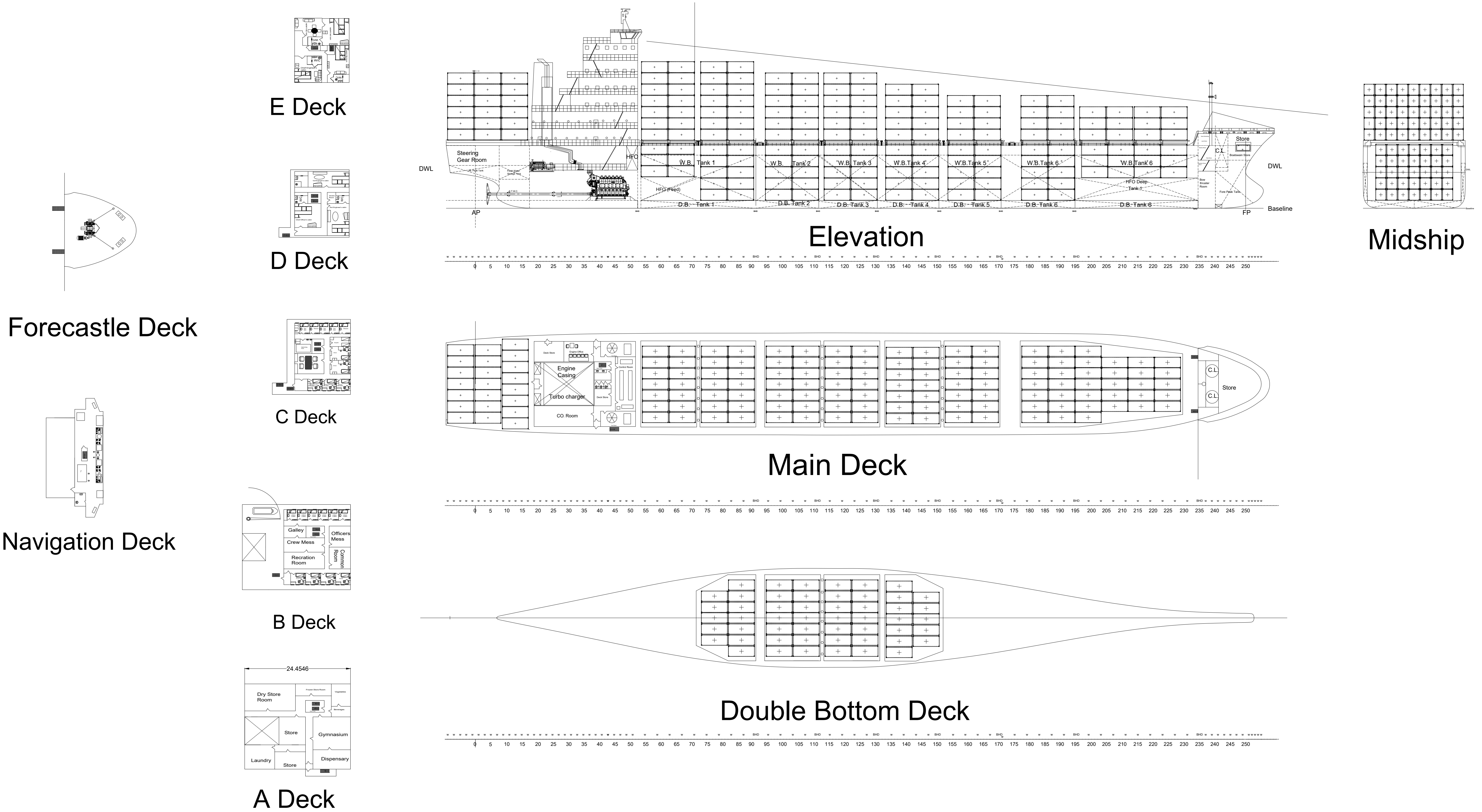
10 General Arrangement

The General Arrangement Plan provides details of each deck's components. As a container ship, we must be cautious about the Container Arrangement to ensure it doesn't hinder navigation from the navigation deck. This is indicated in the elevation plan, which emphasizes visibility.

Since our ship is a seagoing container vessel, it consists of several decks, with the main deck and double bottom deck being the primary ones. The additional decks include A-Deck, B-Deck, C-Deck, D-Deck, E-Deck, Navigation Deck, and Forecastle Deck.

To finalize the General Arrangement, we utilize the "AutoCAD" software, which aids in creating detailed and accurate plans.

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



11 Offset Table and Lines Plan

First, the Offset table is generated using the "Maxsurf" software, which involves creating a detailed mesh of our hull. The Offset table contains essential data that defines the three-dimensional shape of the ship's hull.

Next, using the information from the Offset table, the lines plan is meticulously drawn in the "AutoCAD" software. The lines plan is a two-dimensional representation of the hull's shape, and it plays a crucial role in ship design and naval architecture.

Drawing the lines plan in "AutoCAD" allows for precise and accurate representations of the hull's contours, sections, and waterlines. This process ensures that the ship's dimensions and hydrodynamic characteristics are appropriately captured and analyzed during the design phase.

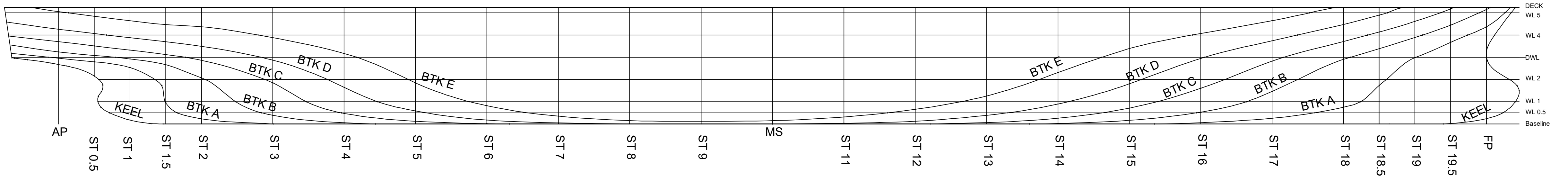
The combination of the Offset table from "Maxsurf" and the lines plan from "AutoCAD" provides a comprehensive representation of the ship's hull design. This detailed and accurate information serves as the foundation for further analyses, calculations, and evaluations in the ship design process. It aids naval architects and engineers in assessing the ship's stability, resistance, and overall performance in various operating conditions.

Offset Table

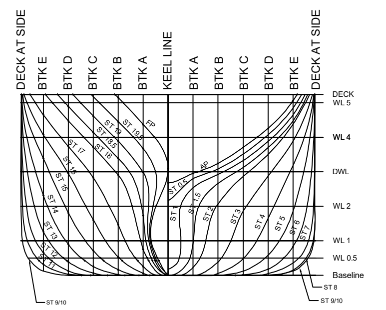
	Half Breadth								Hight Above Base line					
ST	WL-0	WL-0.5	WL-1	WL-2	WL-3	WL-4	WL-5	Main Deck	Keel	BTK-A	BTK-B	BTK-C	BTK-D	BTK-E
AP	--	--	--	--	2.362	7.130	9.893	10.344	7.409	8.180	8.960	10.245	11.762	13.986
0.5	--	--	--	--	3.446	7.778	10.289	10.691	6.004	7.737	8.520	9.706	11.251	13.401
1	--	0.895	1.027	0.988	4.416	8.386	10.628	10.976	0.466	7.032	8.089	9.190	10.729	12.839
1.5	0.096	1.743	2.015	2.442	5.465	8.892	10.877	11.181	0.000	2.627	7.379	8.638	10.227	12.359
2	0.901	2.589	3.044	3.879	6.465	9.256	11.011	11.350	0.000	0.619	5.707	7.921	9.668	12.103
3	2.000	4.282	5.038	6.264	8.279	10.182	11.369	11.577	0.000	0.001	1.059	5.123	7.956	10.747
4	3.369	6.076	7.107	8.481	9.781	10.931	11.591	11.661	0.000	0.000	0.149	1.305	4.542	8.761
5	4.524	7.779	8.924	10.137	10.874	11.366	11.684	11.737	0.000	0.000	0.000	0.319	1.596	5.085
6	5.639	9.297	10.302	11.137	11.489	11.675	11.750	11.753	0.000	0.000	0.000	0.043	0.474	2.265
7	6.842	10.485	11.247	11.650	11.746	11.749	11.748	11.749	0.000	0.000	0.000	0.000	0.282	1.451
8	7.597	11.088	11.628	11.746	11.752	11.755	11.754	11.753	0.000	0.000	0.000	0.000	0.010	0.409
9	7.938	11.294	11.699	11.794	11.815	11.803	11.778	11.771	0.000	0.000	0.000	0.000	0.000	0.312
10	7.693	11.109	11.622	11.774	11.793	11.785	11.769	11.764	0.000	0.000	0.000	0.000	0.001	0.386
11	7.004	10.567	11.287	11.677	11.761	11.768	11.760	11.758	0.000	0.000	0.000	0.000	0.088	0.858
12	6.209	9.593	10.652	11.373	11.630	11.739	11.751	11.750	0.000	0.000	0.000	0.000	0.336	1.813
13	4.869	8.413	9.588	10.739	11.283	11.617	11.746	11.742	0.000	0.000	0.000	0.171	1.062	3.453
14	3.467	6.971	8.221	9.686	10.634	11.345	11.705	11.721	0.000	0.000	0.059	0.713	2.469	6.373
15	2.335	5.431	6.643	8.270	9.536	10.771	11.571	11.650	0.000	0.000	0.426	1.971	4.987	9.371
16	1.469	3.924	5.008	6.609	8.076	9.882	11.318	11.563	0.000	0.151	1.462	4.419	8.170	11.252
17	0.785	2.630	3.457	4.717	6.341	8.618	10.663	11.076	0.000	0.699	4.025	7.826	10.337	12.840
18	0.311	1.688	2.202	2.882	4.231	6.780	9.289	9.853	0.000	2.074	8.054	10.251	12.367	--
18.5	--	1.373	1.791	2.129	3.116	5.625	8.271	8.871	0.000	4.799	9.375	11.441	13.535	--
19	--	1.149	1.556	1.570	2.032	4.306	7.020	7.644	0.000	8.252	10.757	12.763	--	--
19.5	--	1.014	1.440	1.209	1.015	2.779	5.505	6.177	0.031	10.162	12.306	14.326	--	--
FP	--	0.858	1.362	0.977	0.005	1.081	3.594	4.313	0.64, 8.59	12.084	14.237	--	--	--
Transom	--	--	--	--	0.357	6.164	8.995	9.522	8.217	8.778	9.591	10.966	12.686	14.500

BTK Spacing	2.000
Station Spacing	8.900
Waterline Spacing	2.767
LWL	178
Scale	meters

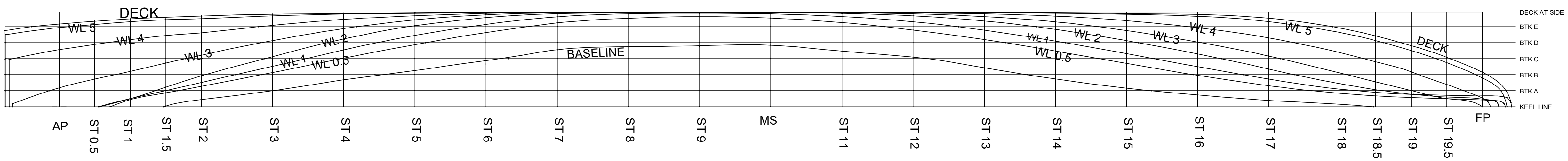
Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



PROFILE



BODY PLAN



HALF-BREADTH PLAN

12 Hydrostatic Calculation

12.1 Hydrostatic Particulars

- ✓ Water Plane Area
- ✓ Displacement
- ✓ KB
- ✓ KM_L
- ✓ MCTC
- ✓ KM_T
- ✓ BM_T
- ✓ Longitudinal Centre of Buoyancy
- ✓ Vertical Centre of Buoyancy
- ✓ Centre of Flotation

12.2 Methods Used in Hydrostatic Calculation

12.2.1 Water plane area

In our lines plan, we have a total of 20 stations. By multiplying the half ordinate of each station with the multipliers used in Simpson's rule, we can calculate the total product of the area.

12.2.2 Displacement:

In our lines plan, we consider a total of 5 water lines. To calculate the volume up to different water lines, we utilize the 5,8,-1 rule, Simpson's first rule, and Simpson's second rule after determining the various water plane areas.

The volume up to water line 1 is obtained using the 5,8,-1 rule:
Volume up to water line 1 = 1/12 * h * Total product for Volume (Using 5,8,-1 rule)

The volume up to water line 2 is calculated using Simpson's first rule:
Volume up to the water line 2 = 1/3 * h * Total product for volume (Using Simpson's First rule)

For water line 3, we employ Simpson's second rule:
Volume up to water line 3 = 3/8 * h * Total product for volume (Using Simpson's 2nd rule)

The volume up to water line 4 is obtained using Simpson's first rule:

Volume up to the water line 4 = 1/3 * h * Total product for volume (Using Simpson's First rule)

Finally, for water line 5, we use Simpson's second rule:
Volume up to water line 5 = 3/8 * h * Total product for volume (Using Simpson's 2nd rule)
Additionally, we determine the positions of buoyancy above the keel (KB):
KB is the Moment of Volume displacement above the base divided by the Volume up to the corresponding waterline.
These calculations are essential for understanding the vessel's stability and performance, aiding in the design and safe operation of the ship.

12.2.3 Positions of longitudinal metacenter above the base (KM_L)

$$KM_L = KB + BM_L$$

Where BM_L is the moment of inertia about the center of flotation (I_L) divided by the Displacement of Volume.

12.2.4 Moment to change trim per cm (MCTC)

The formula for determining MCTC is:

$$\text{MCTC} = \frac{I_L \cdot \text{displacement in tons}}{\text{LBP} \cdot \text{displacement in volume}}$$

12.2.5 Positions of Transverse Metacenter above the base (KM_T)

$$KM_T = KB + BM_T$$

Where BM_T is the Transverse moment of inertia divided by the moment of volume.

12.2.6 Block Coefficient (C_B)

The formula for determining C_B is:

$$C_B = \frac{\text{displacement in volume}}{\text{LBP} \cdot \text{B} \cdot \text{draught at corresponding water plane}}$$

12.2.7 Midship area coefficient (C_M)

The formula for determining C_M is:

$$C_M = \frac{\text{Midship section area}}{B \cdot \text{draught at corresponding water plane}}$$

12.2.8 Prismatic coefficient (C_P)

The formula for determining C_P is:

$$C_P = \frac{C_B}{C_M}$$

Displacement Calculation at WL 1

No. of ord.	SM	Water Lines WL 0		WL 0.5		WL 1		F. of ord.	F. of Vol.	Lever	Prod. Of Mom.
		SM 0.5		2		0.5					
0	0.5	--	--	--	--	--	--				
		--		--		--		0.000	0.000	0	0.000
0.5	2	--	--	--	--	--	--				
		--		--		--		0.000	0.000	0.5	0.000
1	1	--	--	0.895	0.895	1.027	1.027				
		--		1.790		0.514		2.304	2.304	1	2.304
1.5	2	0.096	0.192	1.743	3.486	2.015	4.030				
		0.048		3.486		1.008		4.542	9.083	1.5	13.625
2	1.5	0.901	1.351	2.589	3.884	3.044	4.566				
		0.450		5.178		1.522		7.150	10.726	2	21.451
3	4	2.000	8.000	4.282	17.128	5.038	20.152				
		1.000		8.564		2.519		12.083	48.332	3	144.996
4	2	3.369	6.738	6.076	12.152	7.107	14.214				
		1.685		12.152		3.554		17.390	34.780	4	139.121
5	4	4.524	18.095	7.779	31.116	8.924	35.696				
		2.262		15.558		4.462		22.282	89.128	5	445.638
6	2	5.639	11.278	9.297	18.594	10.302	20.604				
		2.820		18.594		5.151		26.565	53.129	6	318.774
7	4	6.842	27.369	10.485	41.940	11.247	44.988				
		3.421		20.970		5.624		30.015	120.058	7	840.409
8	2	7.597	15.193	11.088	22.176	11.628	23.256				
		3.798		22.176		5.814		31.788	63.577	8	508.613
9	4	7.938	31.753	11.294	45.176	11.699	46.796				
		3.969		22.588		5.850		32.407	129.626	9	1166.638
10	2	7.693	15.387	11.109	22.218	11.622	23.244				
		3.847		22.218		5.811		31.876	63.751	10	637.514
11	4	7.004	28.015	10.567	42.268	11.287	45.148				
		3.502		21.134		5.644		30.279	121.117	11	1332.291
12	2	6.209	12.417	9.593	19.186	10.652	21.304				
		3.104		19.186		5.326		27.616	55.233	12	662.792
13	4	4.869	19.474	8.413	33.652	9.588	38.352				
		2.434		16.826		4.794		24.054	96.217	13	1250.824
14	2	3.467	6.934	6.971	13.942	8.221	16.442				
		1.734		13.942		4.111		19.786	39.572	14	554.009
15	4	2.335	9.339	5.431	21.724	6.643	26.572				
		1.167		10.862		3.322		15.351	61.404	15	921.054
16	2	1.469	2.937	3.924	7.848	5.008	10.016				
		0.734		7.848		2.504		11.086	22.173	16	354.762
17	4	0.785	3.140	2.630	10.520	3.457	13.828				
		0.392		5.260		1.729		7.381	29.524	17	501.905
18	1.5	0.311	0.466	1.688	2.532	2.202	3.303				
		0.155		3.376		1.101		4.632	6.949	18	125.073
18.5	2	--	--	1.373	2.746	1.791	3.582				
		--		2.746		0.896		3.642	7.283	18.5	134.736
19	1	--	--	1.149	1.149	1.556	1.556				
		--		2.298		0.778		3.076	3.076	19	58.444
19.5	2	--	--	1.014	2.028	1.440	2.880				
		--		2.028		0.720		2.748	5.496	19.5	107.172
20	0.5	--	--	0.858	0.429	1.362	0.681				
		--		1.716		0.681		2.397	1.199	20	23.970
F. of WL			218.079		376.789		422.237		॥		10266.113
SM			0.5		2		0.5		1073.735		
F. of Vol.			109.040		753.577		211.119	=	1073.735		
Lever			0		0.5		1				
P. of Mom.			0.000		376.789		211.119	=	587.907		

Displacement=⅓×ST spacing× ⅓× WL spacing× Sum of F. of Volume×2×Density	=	**6022.2021 Tones**
Vertical CB above Keel = Momments about keel/Vol.	=	**1.514845492 (m)**
Longitudinal CB from aft= Moments about Aft/Vol.	=	**85.09399567 (m)**

Metacenter Calculation at WL 1

No. of Ord.	SM	Metacenter							
		Ord. of WL 1	Transverse		Longitudinal				
			Cubes	F. Cubes	F. ord.	Multiplier	F. of CF	Multiplier	F. of MI
0	0.5	--	--	--	--	10	--	10	--
0.5	2	--	--	--	--	9.5	--	9.5	--
1	1	1.027	1.083	1.083	1.027	9	9.243	9	83.19
1.5	2	2.015	8.181	16.363	4.03	8.5	34.255	8.5	291.17
2	1.5	3.044	28.206	42.308	4.566	8	36.528	8	292.22
3	4	5.038	127.872	511.487	20.152	7	141.064	7	987.45
4	2	7.107	358.971	717.941	14.214	6	85.284	6	511.70
5	4	8.924	710.688	2842.750	35.696	5	178.480	5	892.40
6	2	10.302	1093.364	2186.727	20.604	4	82.416	4	329.66
7	4	11.247	1422.689	5690.757	44.988	3	134.964	3	404.89
8	2	11.628	1572.226	3144.453	23.256	2	46.512	2	93.02
9	4	11.699	1601.202	6404.809	46.796	1	46.796	1	46.80
10	2	11.622	1569.794	3139.588	23.244	0	0.000	0	0.00
11	4	11.287	1437.923	5751.691	45.148	-1	-45.148	-1	45.15
12	2	10.652	1208.630	2417.261	21.304	-2	-42.608	-2	85.22
13	4	9.588	881.422	3525.690	38.352	-3	-115.056	-3	345.17
14	2	8.221	555.615	1111.230	16.442	-4	-65.768	-4	263.07
15	4	6.643	293.152	1172.608	26.572	-5	-132.860	-5	664.30
16	2	5.008	125.601	251.202	10.016	-6	-60.096	-6	360.58
17	4	3.457	41.314	165.256	13.828	-7	-96.796	-7	677.57
18	1.5	2.202	10.677	16.016	3.303	-8	-26.424	-8	211.39
18.5	2	1.791	5.745	11.490	3.582	-8.5	-30.447	-8.5	258.80
19	1	1.556	3.767	3.767	1.556	-9	-14.004	-9	126.04
19.5	2	1.440	2.986	5.972	2.88	-9.5	-27.360	-9.5	259.92
20	0.5	1.362	2.527	1.263	0.681	-10	-6.810	-10	68.10
				39131.712	422.237		132.165		7297.81

Transverse BM=⅓×⅔×ST spacing× Sum of F. cubes/Displacement = 12.8514171 (m)	**Longitudinal Inertia about Amidship=** **⅓×2×Sum of F. of MI×(ST spacing)^3=** 3429818 (m^4)
Area of WL 5 = ⅓×2× Sum of F. of Ord.×ST spacing = 2505.27287 (sq. m)	**I(CF)=I(midship)+Ax^2=** 3449260.65 (m^4)
	Longitudinal BM=I(CF)/Displacement= 572.757372
CF abaft midship= (CI×F. of. CF)/F. of ord = 2.78580158 (m)	**MCTC=(Disp.×Long. BM)/(100×total length)=** 198.623155
TPC = (Density×WL area)/1000 = 25.67904688	

Displacement Calculation at WL 2

No. of ord.	SM	Water Lines WL 0		WL 1		WL 2		F. of ord.	F. of Vol.	Lever	Prod. Of Mom.
		1		SM 4		1					
0	0.5	--	--	--	--	--	--				
		--		--		--		0.000	0.000	0	0.000
0.5	2	--	--	--	--	--	--				
		--		--		--		0.000	0.000	0.5	0.000
1	1	--	--	1.027	1.027	0.988	0.988				
		--		4.108		0.988		5.096	5.096	1	5.096
1.5	2	0.096	0.192	2.015	4.030	2.442	4.884				
		0.096		8.060		2.442		10.598	21.196	1.5	31.794
2	1.5	0.901	1.351	3.044	4.566	3.879	5.819				
		0.901		12.176		3.879		16.956	25.434	2	50.867
3	4	2.000	8.000	5.038	20.152	6.264	25.056				
		2.000		20.152		6.264		28.416	113.664	3	340.992
4	2	3.369	6.738	7.107	14.214	8.481	16.962				
		3.369		28.428		8.481		40.278	80.556	4	322.226
5	4	4.524	18.095	8.924	35.696	10.137	40.548				
		4.524		35.696		10.137		50.357	201.427	5	1007.136
6	2	5.639	11.278	10.302	20.604	11.137	22.274				
		5.639		41.208		11.137		57.984	115.968	6	695.808
7	4	6.842	27.369	11.247	44.988	11.650	46.600				
		6.842		44.988		11.650		63.480	253.921	7	1777.446
8	2	7.597	15.193	11.628	23.256	11.746	23.492				
		7.597		46.512		11.746		65.855	131.709	8	1053.674
9	4	7.938	31.753	11.699	46.796	11.794	47.176				
		7.938		46.796		11.794		66.528	266.113	9	2395.015
10	2	7.693	15.387	11.622	23.244	11.774	23.548				
		7.693		46.488		11.774		65.955	131.911	10	1319.108
11	4	7.004	28.015	11.287	45.148	11.677	46.708				
		7.004		45.148		11.677		63.829	255.315	11	2808.463
12	2	6.209	12.417	10.652	21.304	11.373	22.746				
		6.209		42.608		11.373		60.190	120.379	12	1444.553
13	4	4.869	19.474	9.588	38.352	10.739	42.956				
		4.869		38.352		10.739		53.960	215.838	13	2805.899
14	2	3.467	6.934	8.221	16.442	9.686	19.372				
		3.467		32.884		9.686		46.037	92.074	14	1289.039
15	4	2.335	9.339	6.643	26.572	8.270	33.080				
		2.335		26.572		8.270		37.177	148.707	15	2230.608
16	2	1.469	2.937	5.008	10.016	6.609	13.218				
		1.469		20.032		6.609		28.110	56.219	16	899.507
17	4	0.785	3.140	3.457	13.828	4.717	18.868				
		0.785		13.828		4.717		19.330	77.320	17	1314.433
18	1.5	0.311	0.466	2.202	3.303	2.882	4.323				
		0.311		8.808		2.882		12.001	18.001	18	324.019
18.5	2	--	--	1.791	3.582	2.129	4.258				
		--		7.164		2.129		9.293	18.586	18.5	343.841
19	1	--	--	1.556	1.556	1.570	1.570				
		--		6.224		1.570		7.794	7.794	19	148.086
19.5	2	--	--	1.440	2.880	1.209	2.418				
		--		5.760		1.209		6.969	13.938	19.5	271.791
20	0.5	--	--	1.362	0.681	0.977	0.489				
		--		5.448		0.977		6.425	3.213	20	64.250
F. of WL			218.079		422.237		467.352		॥		22943.650
SM			1		4		1		2374.379		
F. of Vol.			218.079		1688.948		467.352	=	2374.379		
Lever			0		1		2				
P. of Mom.			0.000		1688.948		934.704	=	2623.652		

Displacement=⅓×ST spacing× ⅓× WL spacing× Sum of F. of Volume×2×Density	=	**13317 Tones**
Vertical CB above Keel = Momments about keel/Vol.	=	**3.0571 (m)**
Longitudinal CB from aft= Moments about Aft/Vol.	=	**86.001 (m)**

Metacenter Calculation at WL 2

No. of Ord.	SM	Metacenter							
		Ord. of WL 2	Transverse		Longitudinal				
			Cubes	F. Cubes	F. ord.	Multiplier	F. of CF	Multiplier	F. of MI
0	0.5	--	--	--	--	10	--	10	--
0.5	2	--	--	--	--	9.5	--	9.5	--
1	1	0.988	0.964	0.964	0.988	9	8.892	9	80.03
1.5	2	2.442	14.563	29.125	4.884	8.5	41.514	8.5	352.87
2	1.5	3.879	58.366	87.549	5.8185	8	46.548	8	372.38
3	4	6.264	245.785	983.140	25.056	7	175.392	7	1227.74
4	2	8.481	610.016	1220.032	16.962	6	101.772	6	610.63
5	4	10.137	1041.666	4166.663	40.548	5	202.740	5	1013.70
6	2	11.137	1381.353	2762.706	22.274	4	89.096	4	356.38
7	4	11.650	1581.167	6324.669	46.6	3	139.800	3	419.40
8	2	11.746	1620.578	3241.156	23.492	2	46.984	2	93.97
9	4	11.794	1640.527	6562.108	47.176	1	47.176	1	47.18
10	2	11.774	1632.195	3264.390	23.548	0	0.000	0	0.00
11	4	11.677	1592.186	6368.745	46.708	-1	-46.708	-1	46.71
12	2	11.373	1471.042	2942.084	22.746	-2	-45.492	-2	90.98
13	4	10.739	1238.487	4953.949	42.956	-3	-128.868	-3	386.60
14	2	9.686	908.727	1817.454	19.372	-4	-77.488	-4	309.95
15	4	8.270	565.609	2262.437	33.08	-5	-165.400	-5	827.00
16	2	6.609	288.674	577.347	13.218	-6	-79.308	-6	475.85
17	4	4.717	104.954	419.815	18.868	-7	-132.076	-7	924.53
18	1.5	2.882	23.938	35.907	4.323	-8	-34.584	-8	276.67
18.5	2	2.129	9.650	19.300	4.258	-8.5	-36.193	-8.5	307.64
19	1	1.570	3.870	3.870	1.57	-9	-14.130	-9	127.17
19.5	2	1.209	1.767	3.534	2.418	-9.5	-22.971	-9.5	218.22
20	0.5	0.977	0.933	0.466	0.4885	-10	-4.885	-10	48.85
				48047.409	467.352		111.811		8614.47

Transverse BM=⅓×⅔×ST spacing× Sum of F. cubes/Displacement = 7.1357432 (m)	**Longitudinal Inertia about Amidship=** **⅓×2×Sum of F. of MI×(ST spacing)^3=** 4048622.87 (m^4)
Area of WL 5 = ⅓×2× Sum of F. of Ord.×ST spacing = 2772.9552 (sq. m)	**I(CF)=I(midship)+Ax^2=** 4061194.85 (m^4) **Longitudinal BM=I(CF)/Displacement=** 304.96189
CF abaft midship= (CI×F. of. CF)/F. of ord = 2.12926852 (m)	**MCTC=(Disp.×Long. BM)/(100×total length)=** 233.860939
TPC = (Density×WL area)/1000 = 28.4227908	

Displacement Calculation at WL 3

No. of ord.	SM	WL 0		WL 0.5		Water Lines WL 1 SM		WL 2		WL 3		F. of ord.	F. of Vol.	Lever	Prod. Of Mom.
		0.5		2		1.5		4		1					
0	0.5	--	--	--	--	--	--	--	--	2.362	1.181				
		--		--		--		--		2.362		2.362	1.181	0	0.000
0.5	2	--	--	--	--	--	--	--	--	3.446	6.892				
		--		--		--		--		3.446		3.446	6.892	0.5	3.446
1	1	--	--	0.895	0.895	1.027	1.027	0.988	0.988	4.416	4.416				
		--		1.790		1.541		3.952		4.416		11.699	11.699	1	11.699
1.5	2	0.096	0.192	1.743	3.486	2.015	4.030	2.442	4.884	5.465	10.930				
		0.048		3.486		3.023		9.768		5.465		21.790	43.579	1.5	65.369
2	1.5	0.901	1.351	2.589	3.884	3.044	4.566	3.879	5.819	6.465	9.698				
		0.450		5.178		4.566		15.516		6.465		32.175	48.263	2	96.526
3	4	2.000	8.000	4.282	17.128	5.038	20.152	6.264	25.056	8.279	33.116				
		1.000		8.564		7.557		25.056		8.279		50.456	201.824	3	605.472
4	2	3.369	6.738	6.076	12.152	7.107	14.214	8.481	16.962	9.781	19.562				
		1.685		12.152		10.661		33.924		9.781		68.202	136.404	4	545.617
5	4	4.524	18.095	7.779	31.116	8.924	35.696	10.137	40.548	10.874	43.496				
		2.262		15.558		13.386		40.548		10.874		82.628	330.512	5	1652.558
6	2	5.639	11.278	9.297	18.594	10.302	20.604	11.137	22.274	11.489	22.978				
		2.820		18.594		15.453		44.548		11.489		92.904	185.807	6	1114.842
7	4	6.842	27.369	10.485	41.940	11.247	44.988	11.650	46.600	11.746	46.984				
		3.421		20.970		16.871		46.600		11.746		99.608	398.430	7	2789.013
8	2	7.597	15.193	11.088	22.176	11.628	23.256	11.746	23.492	11.752	23.504				
		3.798		22.176		17.442		46.984		11.752		102.152	204.305	8	1634.437
9	4	7.938	31.753	11.294	45.176	11.699	46.796	11.794	47.176	11.815	47.260				
		3.969		22.588		17.549		47.176		11.815		103.097	412.386	9	3711.478
10	2	7.693	15.387	11.109	22.218	11.622	23.244	11.774	23.548	11.793	23.586				
		3.847		22.218		17.433		47.096		11.793		102.387	204.773	10	2047.734
11	4	7.004	28.015	10.567	42.268	11.287	45.148	11.677	46.708	11.761	47.044				
		3.502		21.134		16.931		46.708		11.761		100.035	400.141	11	4401.555
12	2	6.209	12.417	9.593	19.186	10.652	21.304	11.373	22.746	11.630	23.260				
		3.104		19.186		15.978		45.492		11.630		95.390	190.781	12	2289.368
13	4	4.869	19.474	8.413	33.652	9.588	38.352	10.739	42.956	11.283	45.132				
		2.434		16.826		14.382		42.956		11.283		87.881	351.525	13	4569.828
14	2	3.467	6.934	6.971	13.942	8.221	16.442	9.686	19.372	10.634	21.268				
		1.734		13.942		12.332		38.744		10.634		77.385	154.770	14	2166.781
15	4	2.335	9.339	5.431	21.724	6.643	26.572	8.270	33.080	9.536	38.144				
		1.167		10.862		9.965		33.080		9.536		64.610	258.440	15	3876.594
16	2	1.469	2.937	3.924	7.848	5.008	10.016	6.609	13.218	8.076	16.152				
		0.734		7.848		7.512		26.436		8.076		50.606	101.213	16	1619.402
17	4	0.785	3.140	2.630	10.520	3.457	13.828	4.717	18.868	6.341	25.364				
		0.392		5.260		5.186		18.868		6.341		36.047	144.188	17	2451.193
18	1.5	0.311	0.466	1.688	2.532	2.202	3.303	2.882	4.323	4.231	6.347				
		0.155		3.376		3.303		11.528		4.231		22.593	33.890	18	610.020
18.5	2	--	--	1.373	2.746	1.791	3.582	2.129	4.258	3.116	6.232				
		--		2.746		2.687		8.516		3.116		17.065	34.129	18.5	631.387
19	1	--	--	1.149	1.149	1.556	1.556	1.570	1.570	2.032	2.032				
		--		2.298		2.334		6.280		2.032		12.944	12.944	19	245.936
19.5	2	--	--	1.014	2.028	1.440	2.880	1.209	2.418	1.015	2.030				
		--		2.028		2.160		4.836		1.015		10.039	20.078	19.5	391.521
20	0.5	--	--	0.858	0.429	1.362	0.681	0.977	0.489	0.005	0.003				
		--		1.716		2.043		3.908		0.005		7.672	3.836	20	76.720
F. of WL			218.079		376.789		422.237		467.352		526.610		=		37608.494
SM			0.5		2		1.5		4		1		3891.990		
F. of Vol.			109.040		753.577		633.356		1869.408		526.610	=	3891.990		
Lever			0		0.5		1		2		3				
P. of Mom.			0.000		376.789		633.356		3738.816		1579.829	=	6328.789		

Displacement=⅓×ST spacing× ⅓× WL spacing× Sum of F. of Volume×2×Density	=	**21828.8 Tones**
Vertical CB above Keel = Momments about keel/Vol.	=	**4.49889 (m)**
Longitudinal CB from aft= Moments about Aft/Vol.	=	**86.0012 (m)**

Metacenter Calculation at WL 3

No. of Ord.	SM	Metacenter							
		Ord. of WL 3	Transverse		Longitudinal				
			Cubes	F. Cubes	F. ord.	Multiplier	F. of CF	Multiplier	F. of MI
0	0.5	2.362	--	--	--	10	--	10	--
0.5	2	3.446	40.921	81.842	6.892	9.5	65.474	9.5	622.00
1	1	4.416	86.117	86.117	4.416	9	39.744	9	357.70
1.5	2	5.465	163.219	326.438	10.93	8.5	92.905	8.5	789.69
2	1.5	6.465	270.213	405.319	9.6975	8	77.580	8	620.64
3	4	8.279	567.458	2269.832	33.116	7	231.812	7	1622.68
4	2	9.781	935.728	1871.457	19.562	6	117.372	6	704.23
5	4	10.874	1285.784	5143.136	43.496	5	217.480	5	1087.40
6	2	11.489	1516.515	3033.030	22.978	4	91.912	4	367.65
7	4	11.746	1620.578	6482.313	46.984	3	140.952	3	422.86
8	2	11.752	1623.063	3246.126	23.504	2	47.008	2	94.02
9	4	11.815	1649.306	6597.223	47.26	1	47.260	1	47.26
10	2	11.793	1640.110	3280.219	23.586	0	0.000	0	0.00
11	4	11.761	1626.795	6507.179	47.044	-1	-47.044	-1	47.04
12	2	11.630	1573.038	3146.075	23.26	-2	-46.520	-2	93.04
13	4	11.283	1436.395	5745.578	45.132	-3	-135.396	-3	406.19
14	2	10.634	1202.514	2405.027	21.268	-4	-85.072	-4	340.29
15	4	9.536	867.159	3468.636	38.144	-5	-190.720	-5	953.60
16	2	8.076	526.731	1053.462	16.152	-6	-96.912	-6	581.47
17	4	6.341	254.961	1019.843	25.364	-7	-177.548	-7	1242.84
18	1.5	4.231	75.741	113.611	6.3465	-8	-50.772	-8	406.18
18.5	2	3.116	30.255	60.509	6.232	-8.5	-52.972	-8.5	450.26
19	1	2.032	8.390	8.390	2.032	-9	-18.288	-9	164.59
19.5	2	1.015	1.046	2.091	2.03	-9.5	-19.285	-9.5	183.21
20	0.5	0.005	0.000	0.000	0.0025	-10	-0.025	-10	0.25
				56353.453	525.4285		248.945		11605.08

Transverse BM=⅓×⅔×ST spacing× Sum of F. cubes/Displacement = 5.10585127 (m)	**Longitudinal Inertia about Amidship=** **⅓×2×Sum of F. of MI×(ST spacing)^3=** 5454149.17 (m^4)
Area of WL 5 = ⅓×2× Sum of F. of Ord.×ST spacing = 3117.54243 (sq. m)	**I(CF)=I(midship)+Ax^2=** 5509582.63 (m^4)
	Longitudinal BM=I(CF)/Displacement= 252.399703
CF abaft midship= (CI×F. of. CF)/F. of ord = 4.21676879 (m)	**MCTC=(Disp.×Long. BM)/(100×total length)=** 317.265292
TPC = (Density×WL area)/1000 = 31.95480994	

Displacement Calculation at WL 4

No. of ord.	SM	Water Lines WL 0		WL 1		WL 2		WL 3		WL 4		F. of ord.	F. of Vol.	Lever	Prod. Of Mom.
		SM 1		4		2		4		1					
0	0.5	--	--	--	--	--	--	--	--	7.130	3.565				
		--		--		--		--		7.130		7.130	3.565	0	0.00
0.5	2	--	--	--	--	--	--	--	--	7.778	15.556				
		--		--		--		--		7.778		7.778	15.556	0.5	7.78
1	1	--	--	1.027	1.027	0.988	0.988	4.416	4.416	8.386	8.386				
		--		4.108		1.976		17.664		8.386		32.134	32.134	1	32.13
1.5	2	0.096	0.192	2.015	4.030	2.442	4.884	5.465	10.930	8.892	17.784				
		0.096		8.060		4.884		21.860		8.892		43.792	87.584	1.5	131.38
2	1.5	0.901	1.351	3.044	4.566	3.879	5.819	6.465	9.698	9.256	13.884				
		0.901		12.176		7.758		25.860		9.256		55.951	83.926	2	167.85
3	4	2.000	8.000	5.038	20.152	6.264	25.056	8.279	33.116	10.182	40.728				
		2.000		20.152		12.528		33.116		10.182		77.978	311.912	3	935.74
4	2	3.369	6.738	7.107	14.214	8.481	16.962	9.781	19.562	10.931	21.862				
		3.369		28.428		16.962		39.124		10.931		98.814	197.628	4	790.51
5	4	4.524	18.095	8.924	35.696	10.137	40.548	10.874	43.496	11.366	45.464				
		4.524		35.696		20.274		43.496		11.366		115.356	461.423	5	2307.12
6	2	5.639	11.278	10.302	20.604	11.137	22.274	11.489	22.978	11.675	23.350				
		5.639		41.208		22.274		45.956		11.675		126.752	253.504	6	1521.02
7	4	6.842	27.369	11.247	44.988	11.650	46.600	11.746	46.984	11.749	46.996				
		6.842		44.988		23.300		46.984		11.749		133.863	535.453	7	3748.17
8	2	7.597	15.193	11.628	23.256	11.746	23.492	11.752	23.504	11.755	23.510				
		7.597		46.512		23.492		47.008		11.755		136.364	272.727	8	2181.82
9	4	7.938	31.753	11.699	46.796	11.794	47.176	11.815	47.260	11.803	47.212				
		7.938		46.796		23.588		47.260		11.803		137.385	549.541	9	4945.87
10	2	7.693	15.387	11.622	23.244	11.774	23.548	11.793	23.586	11.785	23.570				
		7.693		46.488		23.548		47.172		11.785		136.686	273.373	10	2733.73
11	4	7.004	28.015	11.287	45.148	11.677	46.708	11.761	47.044	11.768	47.072				
		7.004		45.148		23.354		47.044		11.768		134.318	537.271	11	5909.98
12	2	6.209	12.417	10.652	21.304	11.373	22.746	11.630	23.260	11.739	23.478				
		6.209		42.608		22.746		46.520		11.739		129.822	259.643	12	3115.72
13	4	4.869	19.474	9.588	38.352	10.739	42.956	11.283	45.132	11.617	46.468				
		4.869		38.352		21.478		45.132		11.617		121.448	485.790	13	6315.28
14	2	3.467	6.934	8.221	16.442	9.686	19.372	10.634	21.268	11.345	22.690				
		3.467		32.884		19.372		42.536		11.345		109.604	219.208	14	3068.91
15	4	2.335	9.339	6.643	26.572	8.270	33.080	9.536	38.144	10.771	43.084				
		2.335		26.572		16.540		38.144		10.771		94.362	377.447	15	5661.71
16	2	1.469	2.937	5.008	10.016	6.609	13.218	8.076	16.152	9.882	19.764				
		1.469		20.032		13.218		32.304		9.882		76.905	153.809	16	2460.95
17	4	0.785	3.140	3.457	13.828	4.717	18.868	6.341	25.364	8.618	34.472				
		0.785		13.828		9.434		25.364		8.618		58.029	232.116	17	3945.97
18	1.5	0.311	0.466	2.202	3.303	2.882	4.323	4.231	6.347	6.780	10.170				
		0.311		8.808		5.764		16.924		6.780		38.587	57.880	18	1041.84
18.5	2	--	--	1.791	3.582	2.129	4.258	3.116	6.232	5.625	11.250				
		--		7.164		4.258		12.464		5.625		29.511	59.022	18.5	1091.91
19	1	--	--	1.556	1.556	1.570	1.570	2.032	2.032	4.306	4.306				
		--		6.224		3.140		8.128		4.306		21.798	21.798	19	414.16
19.5	2	--	--	1.440	2.880	1.209	2.418	1.015	2.030	2.779	5.558				
		--		5.760		2.418		4.060		2.779		15.017	30.034	19.5	585.66
20	0.5	--	--	1.362	0.681	0.977	0.489	0.005	0.003	1.081	0.541				
		--		5.448		1.954		0.020		1.081		8.503	4.252	20	85.03
F. of WL			218.079		422.237		467.352		518.537		600.720		=		53200.2
SM			1		4		2		4		1		5516.6		
F. of Vol.			218.079		1688.95		934.704		2074.15		600.720	=	5516.6		
Lever			0		1		2		3		4				
P. of Mom.			0.0		1688.9		1869.4		6222.4		2402.9	=	12183.7		

Displacement=⅓×ST spacing× ⅓× WL spacing× Sum of F. of Volume×2×Densi	=	**30941 Tones**
Vertical CB above Keel = Momments about keel/Vol.	=	**6.11032 (m)**
Longitudinal CB from aft= Moments about Aft/Vol.	=	**85.8286 (m)**

Metacenter Calculation at WL 4

No. of Ord.	SM	Metacenter							
		Ord. of WL 4	Transverse		Longitudinal				
			Cubes	F. Cubes	F. ord.	Multiplier	F. of CF	Multiplier	F. of MI
0	0.5	7.130	--	--	--	10	--	10	--
0.5	2	7.778	470.548	941.096	15.556	9.5	147.782	9.5	1403.93
1	1	8.386	589.745	589.745	8.386	9	75.474	9	679.27
1.5	2	8.892	703.070	1406.139	17.784	8.5	151.164	8.5	1284.89
2	1.5	9.256	792.994	1189.491	13.884	8	111.072	8	888.58
3	4	10.182	1055.600	4222.399	40.728	7	285.096	7	1995.67
4	2	10.931	1306.110	2612.220	21.862	6	131.172	6	787.03
5	4	11.366	1468.328	5873.310	45.464	5	227.320	5	1136.60
6	2	11.675	1591.368	3182.736	23.35	4	93.400	4	373.60
7	4	11.749	1621.820	6487.281	46.996	3	140.988	3	422.96
8	2	11.755	1624.306	3248.612	23.51	2	47.020	2	94.04
9	4	11.803	1644.285	6577.142	47.212	1	47.212	1	47.21
10	2	11.785	1636.774	3273.548	23.57	0	0.000	0	0.00
11	4	11.768	1629.701	6518.805	47.072	-1	-47.072	-1	47.07
12	2	11.739	1617.683	3235.365	23.478	-2	-46.956	-2	93.91
13	4	11.617	1567.769	6271.074	46.468	-3	-139.404	-3	418.21
14	2	11.345	1460.204	2920.408	22.69	-4	-90.760	-4	363.04
15	4	10.771	1249.592	4998.366	43.084	-5	-215.420	-5	1077.10
16	2	9.882	965.016	1930.032	19.764	-6	-118.584	-6	711.50
17	4	8.618	640.058	2560.233	34.472	-7	-241.304	-7	1689.13
18	1.5	6.780	311.666	467.499	10.17	-8	-81.360	-8	650.88
18.5	2	5.625	177.979	355.957	11.25	-8.5	-95.625	-8.5	812.81
19	1	4.306	79.840	79.840	4.306	-9	-38.754	-9	348.79
19.5	2	2.779	21.462	42.924	5.558	-9.5	-52.801	-9.5	501.61
20	0.5	1.081	1.263	0.632	0.5405	-10	-5.405	-10	54.05
				68984.855	597.1545		284.255		15881.89

Transverse BM=⅓×⅔×ST spacing× Sum of F. cubes/Displacement = 4.4096267 (m)	**Longitudinal Inertia about Amidship=** **⅓×2×Sum of F. of MI×(ST spacing)^3=** 7464160.54 (m^4)
Area of WL 5 = ⅓×2× Sum of F. of Ord.×ST spacing = 3543.1167 (sq. m)	**I(CF)=I(midship)+Ax^2=** 7527753.39 (m^4) **Longitudinal BM=I(CF)/Displacement=** 243.296555
CF abaft midship= (CI×F. of. CF)/F. of ord = 4.23654096 (m)	**MCTC=(Disp.×Long. BM)/(100×total length)=** 433.480181
TPC = (Density×WL area)/1000 = 36.31694618	

Displacement Calculation at WL 1

No. of ord.	SM	Water Lines 5 Displacement Calculation														F. of ord.	F. of Vol.	Lever	Prod. Of Mom.
		WL 0		WL 0.5		WL 1		WL 2 SM		WL 3		WL 4		WL 5					
			0.5		2		1.5		4		2		4		1				
0	0.5	--	--	--	--	--	--	--	--	2.362	1.181	7.130	3.565	9.893	4.947				
		--		--		--		--		4.724		28.520		9.893		43.137	21.569	0	0.00
0.5	2	--	--	--	--	--	--	--	--	3.446	6.892	7.778	15.556	10.289	20.578				
		--		--		--		--		6.892		31.112		10.289		48.293	96.586	0.5	48.29
1	1	--	--	0.895	0.895	1.027	1.027	0.988	0.988	4.416	4.416	8.386	8.386	10.628	10.628				
		--		1.790		1.541		3.952		8.832		33.544		10.628		60.287	60.287	1	60.29
1.5	2	0.096	0.192	1.743	3.486	2.015	4.030	2.442	4.884	5.465	10.930	8.892	17.784	10.877	21.754				
		0.048		3.486		3.023		9.768		10.930		35.568		10.877		73.700	147.399	1.5	221.10
2	1.5	0.901	1.351	2.589	3.884	3.044	4.566	3.879	5.819	6.465	9.698	9.256	13.884	11.011	16.517				
		0.450		5.178		4.566		15.516		12.930		37.024		11.011		86.675	130.013	2	260.03
3	4	2.000	8.000	4.282	17.128	5.038	20.152	6.264	25.056	8.279	33.116	10.182	40.728	11.369	45.476				
		1.000		8.564		7.557		25.056		16.558		40.728		11.369		110.832	443.328	3	1329.98
4	2	3.369	6.738	6.076	12.152	7.107	14.214	8.481	16.962	9.781	19.562	10.931	21.862	11.591	23.182				
		1.685		12.152		10.661		33.924		19.562		43.724		11.591		133.298	266.596	4	1066.38
5	4	4.524	18.095	7.779	31.116	8.924	35.696	10.137	40.548	10.874	43.496	11.366	45.464	11.684	46.736				
		2.262		15.558		13.386		40.548		21.748		45.464		11.684		150.650	602.600	5	3013.00
6	2	5.639	11.278	9.297	18.594	10.302	20.604	11.137	22.274	11.489	22.978	11.675	23.350	11.750	23.500				
		2.820		18.594		15.453		44.548		22.978		46.700		11.750		162.843	325.685	6	1954.11
7	4	6.842	27.369	10.485	41.940	11.247	44.988	11.650	46.600	11.746	46.984	11.749	46.996	11.748	46.992				
		3.421		20.970		16.871		46.600		23.492		46.996		11.748		170.098	680.390	7	4762.73
8	2	7.597	15.193	11.088	22.176	11.628	23.256	11.746	23.492	11.752	23.504	11.755	23.510	11.754	23.508				
		3.798		22.176		17.442		46.984		23.504		47.020		11.754		172.678	345.357	8	2762.85
9	4	7.938	31.753	11.294	45.176	11.699	46.796	11.794	47.176	11.815	47.260	11.803	47.212	11.778	47.112				
		3.969		22.588		17.549		47.176		23.630		47.212		11.778		173.902	695.606	9	6260.46
10	2	7.693	15.387	11.109	22.218	11.622	23.244	11.774	23.548	11.793	23.586	11.785	23.570	11.769	23.538				
		3.847		22.218		17.433		47.096		23.586		47.140		11.769		173.089	346.177	10	3461.77
11	4	7.004	28.015	10.567	42.268	11.287	45.148	11.677	46.708	11.761	47.044	11.768	47.072	11.760	47.040				
		3.502		21.134		16.931		46.708		23.522		47.072		11.760		170.628	682.513	11	7507.65
12	2	6.209	12.417	9.593	19.186	10.652	21.304	11.373	22.746	11.630	23.260	11.739	23.478	11.751	23.502				
		3.104		19.186		15.978		45.492		23.260		46.956		11.751		165.727	331.455	12	3977.46
13	4	4.869	19.474	8.413	33.652	9.588	38.352	10.739	42.956	11.283	45.132	11.617	46.468	11.746	46.984				
		2.434		16.826		14.382		42.956		22.566		46.468		11.746		157.378	629.513	13	8183.67
14	2	3.467	6.934	6.971	13.942	8.221	16.442	9.686	19.372	10.634	21.268	11.345	22.690	11.705	23.410				
		1.734		13.942		12.332		38.744		21.268		45.380		11.705		145.104	290.208	14	4062.91
15	4	2.335	9.339	5.431	21.724	6.643	26.572	8.270	33.080	9.536	38.144	10.771	43.084	11.571	46.284				
		1.167		10.862		9.965		33.080		19.072		43.084		11.571		128.801	515.204	15	7728.05
16	2	1.469	2.937	3.924	7.848	5.008	10.016	6.609	13.218	8.076	16.152	9.882	19.764	11.318	22.636				
		0.734		7.848		7.512		26.436		16.152		39.528		11.318		109.528	219.057	16	3504.91
17	4	0.785	3.140	2.630	10.520	3.457	13.828	4.717	18.868	6.341	25.364	8.618	34.472	10.663	42.652				
		0.392		5.260		5.186		18.868		12.682		34.472		10.663		87.523	350.092	17	5951.56
18	1.5	0.311	0.466	1.688	2.532	2.202	3.303	2.882	4.323	4.231	6.347	6.780	10.170	9.289	13.934				
		0.155		3.376		3.303		11.528		8.462		27.120		9.289		63.233	94.850	18	1707.30
18.5	2	--	--	1.373	2.746	1.791	3.582	2.129	4.258	3.116	6.232	5.625	11.250	8.271	16.542				
		--		2.746		2.687		8.516		6.232		22.500		8.271		50.952	101.903	18.5	1885.21
19	1	--	--	1.149	1.149	1.556	1.556	1.570	1.570	2.032	2.032	4.306	4.306	7.020	7.020				
		--		2.298		2.334		6.280		4.064		17.224		7.020		39.220	39.220	19	745.18
19.5	2	--	--	1.014	2.028	1.440	2.880	1.209	2.418	1.015	2.030	2.779	5.558	5.505	11.010				
		--		2.028		2.160		4.836		2.030		11.116		5.505		27.675	55.350	19.5	1079.33
20	0.5	--	--	0.858	0.429	1.362	0.681	0.977	0.489	0.005	0.003	1.081	0.541	3.594	1.797				
		--		1.716		2.043		3.908		0.010		4.324		3.594		15.595	7.798	20	155.95
F. of WL			218.1		376.8		422.2		467.4		526.6		600.7		657.3		=		71690.2
SM			0.5		2.0		1.5		4.0		2.0		4.0		1.0		7478.8		
F. of Vol.			109.0		753.6		633.4		1869.4		1053.2		2402.9		657.3	=	7478.8		
Lever			0.0		0.5		1.0		2.0		3.0		4.0		5.0				
P. of Mom.			0.0		376.8		633.4		3738.8		3159.7		9611.5		3286.4	=	20806.5		

Displacement=⅓×ST spacing× ⅓× WL spacing× Sum of F. of Volume×2×Density	=	**41946 Tones**
Vertical CB above Keel = Momments about keel/Vol.	=	**7.697 (m)**
Longitudinal CB from aft= Moments about Aft/Vol.	=	**85.31 (m)**

Metacenter Calculation at WL 5

No. of Ord.	SM	Wl 5 Metacenter Calculation							
		Ord. of WL 5	Transverse		Longitudinal				
			Cubes	F. Cubes	F. ord.	Multiplier	F. of CF	Multiplier	F. of MI
0	0.5	9.893	--	--	--	10	--	10	--
0.5	2	10.289	1089.230	2178.460	20.578	9.5	195.491	9.5	1857.16
1	1	10.628	1200.479	1200.479	10.628	9	95.652	9	860.87
1.5	2	10.877	1286.848	2573.697	21.754	8.5	184.909	8.5	1571.73
2	1.5	11.011	1334.997	2002.495	16.5165	8	132.132	8	1057.06
3	4	11.369	1469.491	5877.962	45.476	7	318.332	7	2228.32
4	2	11.591	1557.266	3114.531	23.182	6	139.092	6	834.55
5	4	11.684	1595.051	6380.205	46.736	5	233.680	5	1168.40
6	2	11.750	1622.234	3244.469	23.5	4	94.000	4	376.00
7	4	11.748	1621.406	6485.625	46.992	3	140.976	3	422.93
8	2	11.754	1623.892	3247.783	23.508	2	47.016	2	94.03
9	4	11.778	1633.859	6535.437	47.112	1	47.112	1	47.11
10	2	11.769	1630.117	3260.233	23.538	0	0.000	0	0.00
11	4	11.760	1626.380	6505.519	47.04	-1	-47.040	-1	47.04
12	2	11.751	1622.649	3245.297	23.502	-2	-47.004	-2	94.01
13	4	11.746	1620.578	6482.313	46.984	-3	-140.952	-3	422.86
14	2	11.705	1603.667	3207.334	23.41	-4	-93.640	-4	374.56
15	4	11.571	1549.219	6196.874	46.284	-5	-231.420	-5	1157.10
16	2	11.318	1449.803	2899.606	22.636	-6	-135.816	-6	814.90
17	4	10.663	1212.379	4849.514	42.652	-7	-298.564	-7	2089.95
18	1.5	9.289	801.506	1202.259	13.9335	-8	-111.468	-8	891.74
18.5	2	8.271	565.814	1131.629	16.542	-8.5	-140.607	-8.5	1195.16
19	1	7.020	345.948	345.948	7.02	-9	-63.180	-9	568.62
19.5	2	5.505	166.829	333.658	11.01	-9.5	-104.595	-9.5	993.65
20	0.5	3.594	46.423	23.212	1.797	-10	-17.970	-10	179.70
				82524.542	652.331		196.136		19347.45

Transverse BM=⅓×⅔×ST spacing× Sum of F. cubes/Displacement = 3.89110667 (m)	**Longitudinal Inertia about Amidship=** **⅓×2×Sum of F. of MI×(ST spacing)^3=** 9092900.24 (m^4)
Area of WL 5 = ⅓×2× Sum of F. of Ord.×ST spacing = 3870.49727 (sq. m)	**I(CF)=I(midship)+Ax^2=** 9120615.91 (m^4) **Longitudinal BM=I(CF)/Displacement=** 217.438624
CF abaft midship= (CI×F. of. CF)/F. of ord = 2.67595806 (m)	**MCTC=(Disp.×Long. BM)/(100×total length)=** 525.204006
TPC = (Density×WL area)/1000 = 39.67259698	

SUMMARY

Manual Calculation

WL	Displacement	VCB	LCB(Aft)	BM_T	Area (WL)	CF(Aft)	TPC	Inertia (CF)	BM_L	MCTC	KM_T	KM_L
WL 1	6022.202	1.515	85.094	12.851	2505.273	86.214	25.679	3449261	572.757	198.623	14.366	574.272
WL 2	13317.057	3.057	86.001	7.136	2772.955	86.871	28.423	4061195	304.962	233.861	10.193	308.019
WL 3	21828.800	4.499	86.001	5.106	3117.542	84.783	31.955	5509583	252.400	317.265	9.605	256.899
WL 4	30940.649	6.110	85.829	4.410	3543.117	84.763	36.317	7527753	243.297	433.480	10.520	249.407
WL 5	41945.703	7.697	85.314	3.891	3870.497	86.324	39.673	9120616	217.439	525.204	11.588	225.136

Hydrostatic From MAXSURF

WL	Displacement	VCB	LCB(Aft)	BM_T	Area (WL)	CF(Aft))	TPC	Inertia (CF)	BM_L	MCTC	KM_T	KM_L
WL 3	21517.97	4.453	86.550	5.169	3124.485	83.806	32.026	5509548.6	254.982	321.464	9.622	259.435

12.3 Hydrostatic Curves

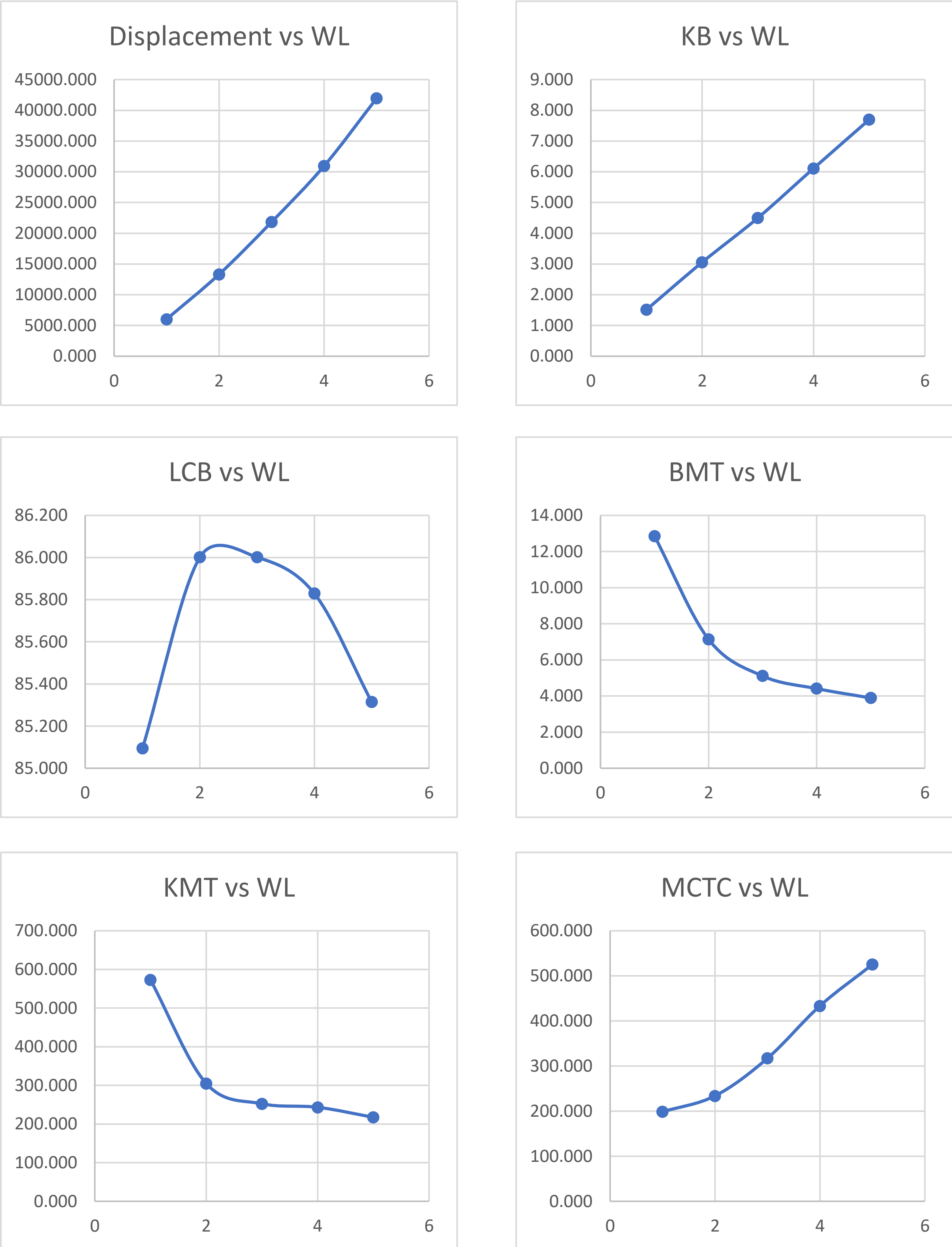


Figure 4: Hydrostatic Curves

12.4 Hydrostatic Curves from Maxsurf

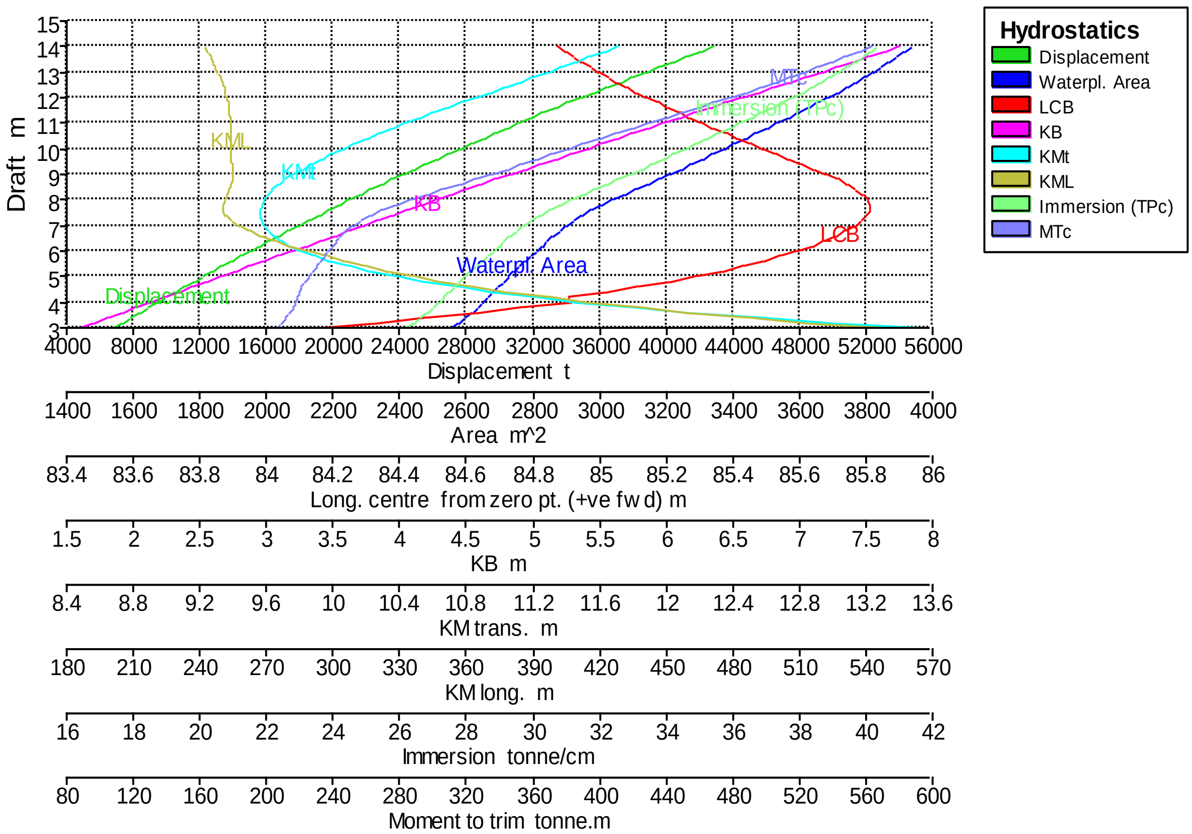


Figure 5: Hydrostatic Curves from Maxsurf

13 Scantlings Calculation

Particulars	:	Value
Frame spacing (a)	:	700 mm
Web frame spacing (c)	:	2800 mm
LOA	:	188.8 m
LBP	:	178 m
LWL	:	183.9 m
L (Scantling)	:	172.66 m
Breadth of the ship, B	:	23.5 m
Draft, T	:	8.3 m
Depth, D	:	14.5 m
Block coefficient, Cb	:	0.6
Cp	:	0.616
CM	:	0.97
Cw	:	0.72
Displacement (∇)	:	21560 m^3
Displacement (Δ)	:	22099 tonnes
Material Factor (k)	:	1
Double Bottom Height	:	1860 mm

13.1 Web Frames & Side Stringers

Length coefficient, $C_L = 1.0$ (for L>90 m).[1]

Distribution factor $C_F = 1$ for amidships.[2]

Service coefficient, $C_{RW} = 1.00$ for unlimited service range.[3]

[1] gl_i-1-1_e, section-4, A.3, page-63
[2] gl_i-1-1_e, section-4, A.3, table-4.1, page-64
[3] gl_i-1-1_e, section-4, A.3, page-63

Wave coefficient, C_O $= [10.75-\{(300-L)/100\}^{1.5}] \times C_{RW}$ (for 90<L<300 m)[4]
$= [10.75-\{(300-172.66)/100\}^{1.5}] \times 1$
$= 9.402465956$

For longitudinal framing, $n_f = 0.83$.[5]

For Transverse framing, $n_f = 1.0$.[6]

For girders & girder system of the outer hull (web frames, stringers, grillage systems),

Probability factor, f= 0.60 [7]

Probability factor, f = 1, for plate panels of the outer hull (shell plating, weather decks)[8]

Basic external dynamic load, P_o $= 2.1(C_B+0.7)\times C_O\times C_L\times f$ [9]
$= 15.4012\ KN/m^2$

Loads on ship's sides, $P_s = P$ $= 10(T-z)+P_O\times C_F\times(1+z/T)$[10]
$= 31.7798\ KN/m^2$

Where,

z = vertical distance of the structure's load center above the baseline
= 0.5× (depth-double bottom depth) + double bottom depth
= 8.18 m

Spacing of web frames, e = 2.8 m

Length of unsupported span, l = 2.8 m

Section modulus, $W = 0.55\times e\times l^2\times P\times n_c\times k$[11]
$= 383.6967\ cm^3$

Where,

n_c (Reduction coefficient) = 1

k (Material factor) = 1

Dimension: T- 254×343×13

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4 gl_i-1-1_e, section-4, A.3, page-63
5 gl_i-1-1_e, section-6, A.2, page-10
6 gl_i-1-1_e, section-6, A.2, page-107
7 gl_i-1-1_e, section-4, A.3, page-63
8 gl_i-1-1_e, section-4, A.3, page-63
9 gl_i-1-1_e, section-4, A.3, page- 62
10 gl_i-1-1_e, section-4, B.2, page-65
11 gl_i-1-1_e, section-9, B.5.3.1, page-163

13.2 Web Frames For Machinery Space

Section modulus, $W = 0.8 \times e \times l^2 \times P \times n_c \times k$

$= 558.104\ cm^3$

Dimension -T = 356×343×17

13.3 Center Girder

The depth of the center girder is not to be less than $h = 350+45\times B$[12]

$= 1407.5$ mm

$= 1410$ mm

So, we take the depth of the center girder, h= 1410 mm

Thickness of the centre girder, $t = h/h_a(h/120+3)\times\sqrt{k}$ for h =1500 mm[13]

$= 13.865$ mm

≈ 14 mm

So, we take the thickness of the center girder, t = 14 mm

Faceplate width, w = approximately 10 times to thickness according to GL

$= 14\times10$ mm

$= 140$ mm

Dimension: T-1410×140×14

13.4 Side Girder

The thickness of the side girder, $t_w = \{h^2/(120.h_a)\}\sqrt{k}$ [14]

$= 11.045$ mm

≈ 12 mm

Dimension: T - 1410×140×12

13.5 Deck Web & Deck Girder

For plate panels of the outer hull (shell plating, weather decks)

Probability factor, f= 1

Basic external dynamic load, $P_O = 2.1(C_B+0.7)\times C_O\times C_L\times f$ [15]

$= 25.6687\ KN/m^2$

$\approx 26\ KN/m^2$

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[12] gl_i-1-1_e, section-8, C.2.2.1, page-146
[13] gl_i-1-1_e, section-8, C.2.2.2, page-147
[14] gl_i-1-1_e, section-8, C.3.2, page-147
[15] gl_i-1-1_e, section-4, A.2, page-62

Load on ship's deck, $P_D = P \quad = P_O \times \frac{20 \times T}{(10+z-T) \times H} \times C_D$ [16]

$= 29.7432 \text{ KN/m}^2$

Where,

C_D (Distribution factor) = 1 [17]

Section modulus, $W = c \times e \times P \times l^2 \times k$[18]

$= 489.6919 \text{ cm}^3$

Where,

e = web frame spacing = 3 m

c = 0.75 for beams, girders, and transverses which are simply supported on one or both ends.

Dimension: T-200×400×18

13.6 Deck Beam

Section modulus, $W = c \times a \times P \times l^2 \times k$[19]

$= 117.4862 \text{ cm}^3$

Where, a (frame spacing) = 0.7 m

Dimension: T-191×229×9

13.7 Bottom Longitudinal

For secondary stiffening members of the outer hull (frames, deck beams)

Probability factor, f= .75

Basic external dynamic load, $P_o \quad = 2.1(C_B+0.7) \times C_O \times C_L \times f$ [20]

$= 19.2515 \text{ KN/m}^2$

$= 20 \text{ KN/m}^2$

Load at the ship's bottom, $P_B \quad = 10T + P_O \times C_F$ [21]

$= 102.2515 \text{ KN/m}^2$

$m_a \quad = 0.204 \times \frac{a}{l} \times \left[4 - \left(\frac{a}{l}\right)^2\right]$ [22]

$= 0.201$

16 gl_i-1-1_e, section-4, B.1, page-64

17 gl_i-1-1_e, section-4, A.3, table-4.1, page-64

18 gl_i-1-1_e, section-10, B.2.2.1, page-175

19 gl_i-1-1_e, section-10, B, section-B.1.1, page-175

20 gl_i-1-1_e, section-4, A.3, page-62

21 gl_i-1-1_e, section-4, B.5, page-63

22 gl_i-1-1_e, section-3, B.3.2, page-32

$m_k \quad = 1 - \sum\left[\left(\frac{l_K}{l}\right) \times \sin 2\alpha K\right]$

$\quad\quad = 1$

$m \quad = m_K^2 - m_a^2$

$\quad\quad = 1^2 - (0.201)^2$

$\quad\quad = 0.96$

$\sigma_{pr} \quad = \frac{150}{k}$

$\quad\quad = 150/1$

$\quad\quad = 150\ N/mm^2$

Section modulus, $W = (83.3/\sigma_{pr}) \times m \times a \times l^2 \times P$[23]

$= 297.985\ cm^3$

$\approx 300\ cm^3$

Dimension: L-250×250×25

13.8 Side Longitudinal

Loads on ship's sides, $P_s = 10(T-z) + P_O \times C_F \times (1+z/T)$[24]

$= 39.425\ KN/m^2$

Section modulus, $W = (83.3/\sigma_{pr}) \times m \times a \times l^2 \times P$[25]

$= 114.893\ cm^3$

$\approx 115\ cm^3$

Dimension: L-200×200×12

13.9 Deck Longitudinal

Load on ship's deck, $P_D = P_O \times \frac{20 \times T}{(10+z-T) \times H} \times C_D$ [26]

$= 22.307\ KN/m^2$

Section modulus, $W = \left(\frac{83.3}{\sigma_{pr}}\right) \times m \times a \times l^2 \times P$

$= 65\ cm^3$

$\approx 65\ cm^3$

Dimension: L-130×130×16

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[23] gl_i-1-1_e, section-9, C.3.2, page-166

[24] gl_i-1-1_e, section-4, B.2, page-65

[25] gl_i-1-1_e, section-9, C.3.2, page-166

[26] gl_i-1-1_e, section-4, B.1, page-64

13.10 Hatch cover stiffener

Probability factor, f = 1

Basic external dynamic load, P_O = 25.669 KN/m²

Load on ship's deck, P_D = $P_O \times \frac{20 \times T}{(10+z-T) \times H} \times C_D$[27]

= 29.743 KN/m²

Where,

C_D (Distribution factor = 1

Section modulus, W = $c \times a \times P \times l^2 \times k$

= 122.423 cm³

Where, a (Frame Spacing) = 0.7 m

C is 0.7 for beams, girders, and transverses which are simply supported on one or both ends.

Dimension: T-175×350×14

13.11 Hatch Longitudinal

Load on ship's deck, P_D = $P_O \times \frac{20 \times T}{(10+z-T) \times H} \times C_D$ [28]

= 29.743 KN/m²

Section modulus, W = $(83.3/\sigma_{pr}) \times m \times a \times l^2 \times P$

= 86.679 cm³

≈ 90 cm³

Dimension: L-150×150×16

13.12 Bottom Shell Plating

Permissible design stress, σ_{perm} = 230/ k KN/m² for L≥90 m

= 230 N/mm²

Maximum bottom design hull girder bending stress, σ_{LB} = 120/k, for L≥90m

= 120 N/mm²

Maximum design shear stress due to longitudinal hull girder bending[29]

$$= \sqrt{\left(\sigma_{perm}{}^2 - 3\tau_L^2\right)} - 0.89\sigma_{LB}$$

$= (230^2 - 3 \times 0^2)^{1/2} - 0.89 \times 120$

[27] gl_i-1-1_e, section-4, B.1, page-64

[28] gl_i-1-1_e, section-4, B.1, page-64

[29] gl_i-1-1_e, section-6, B.2, page-109

$= 123.2\ N/mm^2$

Corrosion addition $t_k = 2.5$ mm, for thickness ≥10 mm

$$t_{B1} = 18.3 \times n_f \times a \times \sqrt{\frac{P_B}{\sigma_{pl}}} + t_k = 12.186\ mm$$ [30]

$$t_{B2} = 1.21 \times a \times \sqrt{P_B \cdot K} \cdot t_K = 11.065\ mm$$ [31]

Again, Minimum bottom shell plate thickness, $\mathbf{t_{min}} = \sqrt{L \cdot K}$ =13.341 mm for L ≥ 50m[32]

We accept the bottom plate thickness = 14 mm

13.13 Bilge Plate

Bilge plate thickness = Bottom plate thickness = **14 mm** [33]

13.14 Bilge Strake

The minimum thickness of bilge strake, b = 800+5L [34]

= **1690 mm**

13.15 Side Shell Plating

Side plate thickness = $T + C_O/2$[35]

= 13.001 mm

We take the side plate thickness = 13 mm

13.16 Flat Keel Plate

The thickness of the flat plate keel, $t_{FK} = t_B + 2$[36]

$= 14 + 2$

= 16 mm

The width of the flat keel plate is not to be less than, b = 800+5×L[37]

= **1690 mm**

30 gl_i-1-1_e, section-6, B.1, page-108
31 gl_i-1-1_e, section-6, B.1, page-108]
32 gl_i-1-1_e, section-6, B.2, page-109
33 gl_i-1-1_e, section-6, B.3, page-109
34 gl_i-1-1_e, section-6, B.3.2, page-109
35 gl_i-1-1_e, section-6, C.2, page-111
36 gl_i-1-1_e, section-6, B.4.1, page-110
37 gl_i-1-1_e, section-6, B.4.1, page-110

13.17 Deck Plate Thickness

Minimum deck plate thickness, t_{min} = $(4.5+0.05L)\times\sqrt{k}$[38]

= 13.4 mm

We consider the deck thickness to be 14 mm

13.18 Sheer Strake

The minimum width of the sheer strake, b = 800 + 5L[39]

= 1690 mm

Thickness, t = $0.5\ (t_d+t_s)$

= 0.5 (14+14)

= **14 mm**

13.19 Bulkhead Plating

The thickness of the Bulkhead platin,[40]

$$t = c_p \cdot a \cdot \sqrt{p} + t_K$$

= 55.697 mm

= **56 mm**

13.20 Bracket Thickness

$$W = n\times c\times a\times l^2 \times p \times k$$

$= 58.109\ cm^3$

$= 59\ cm^3$

The thickness of brackets is not to be less than:

$$t = c \times \sqrt[3]{\frac{W}{K_1}} + t_k$$

= 3.97 mm

= 4 mm

We consider the bracket thickness to be 4 mm

Where,

c = 0.5 for flanged brackets

K_1 = material factor k for the section = 1

Arm length = $\frac{2}{3}\times$ Double bottom height

= $\frac{2}{3}\times 1860 =$ **1240 mm**

---

38 gl_i-1-1_e, section-7, B.4.3.1.1, page-136

39 gl_i-1-1_e, section-16, E.2.1, page-258

40 gl_i-1-1_e, section-11, B.1, page-182

13.21 Floor Plating

The thickness of the floor plate, $t_{pf,}$ is not to be less than the following.

$$t_{pf} = t_m - 2.0\sqrt{k}$$ [41]

$$= \mathbf{14\ mm}$$

13.22 Non-effective superstructures

13.22.1 Side plating

The thickness of the side plating above the strength deck is not to be less than the greater of the following values:

$$t = 0\ .8 \times t_{min}$$ [42]

$$= 10.673\ \text{mm}$$

$$\approx \mathbf{11\ mm}$$

13.22.2 Deck plating

$$t = (\ 5.5 + 0.\ 02\ L) \times \sqrt{k}\ \ [\text{mm}]$$ [43]

$$= 9.06\ \text{mm}$$

$$\approx \mathbf{10\ mm}$$

13.22.3 Stiffeners

Section modulus, $W = 0.35 \times a \times l^2 \times P_a \times k\ \text{cm}^3$

$$= 38.416\ \text{cm}^3$$

Dimension: L-130×130×9

13.22.4 Plate thickness

For the lowest tier[44]

$$t_{min} = (5 + L/100) \times \sqrt{k}$$

$$= 6.78$$

$$\approx \mathbf{7\ mm}$$

For the upper tiers[45]

$$t_{min} = \ (4 + L/100) \times \sqrt{k}$$

$$= 5.78$$

$$\approx \mathbf{6\ mm}$$

---

41 gl_i-1-1_e, section-8, C.5.2.1 page-148
42 gl_i-1-1_e, section-16, D.2.1.1, page-257
43 gl_i-1-1_e, section-16, D.2.2.1, page-257
44 gl_i-1-1_e, section-16, E.2.1, page-258
45 gl_i-1-1_e, section-16, E.2.1, page-258

13.22.5 Bulwark thickness

$$t = 0.65 \times \sqrt{L}, \text{ for } L \geq 100 \text{ m}$$ [46]

$$= 8.672$$

$$\approx \mathbf{9\ mm}$$

13.22.6 Dimensions of Hatch Covers

For the hatch cover of a container ship, $t_k = 1$[47]

Material factor, k = 1

Top Plating = 6.0 + t_k[48]

= 6.0 + 1.0 = 7 mm

Main Girder = 5.0 + t_k[49]

= 5 + 1 = 6 mm

Edge Girder = 5.00 + t_k[50]

= 5 + 1 = 6 mm

13.23 Summary of the scantling:

13.23.1 Plate thickness:

Plate	:	Thickness (mm)
Flat Keel plate	:	16
Bottom plate	:	14
Bilge plate	:	14
Bilge strake	:	1690
Side shell plate	:	13
Deck plate	:	10
Shear plate	:	14
Bulkhead plate	:	56
Bracket thickness	:	7
Floor plate	:	15

[46] gl_i-1-1_e, section-6, I.1, page-128
[47] gl_i-1-1_e, section-17, Table – 17.1, page-269
[48] gl_i-1-1_e, section-17, B.5.1.1.1, page-276
[49] gl_i-1-1_e, section-17, B.5.2.1, page-277
[50] gl_i-1-1_e, section-17, B.5.3.1, page-278

13.23.2 Plate thickness for the superstructure

Plate	**:**	**Thickness (mm)**
Side plate	:	11
Deck plate	:	10
Tire plate lowest	:	7
Tire plate upper	:	6
Bulwark thickness	:	9

13.23.3 Member Dimension

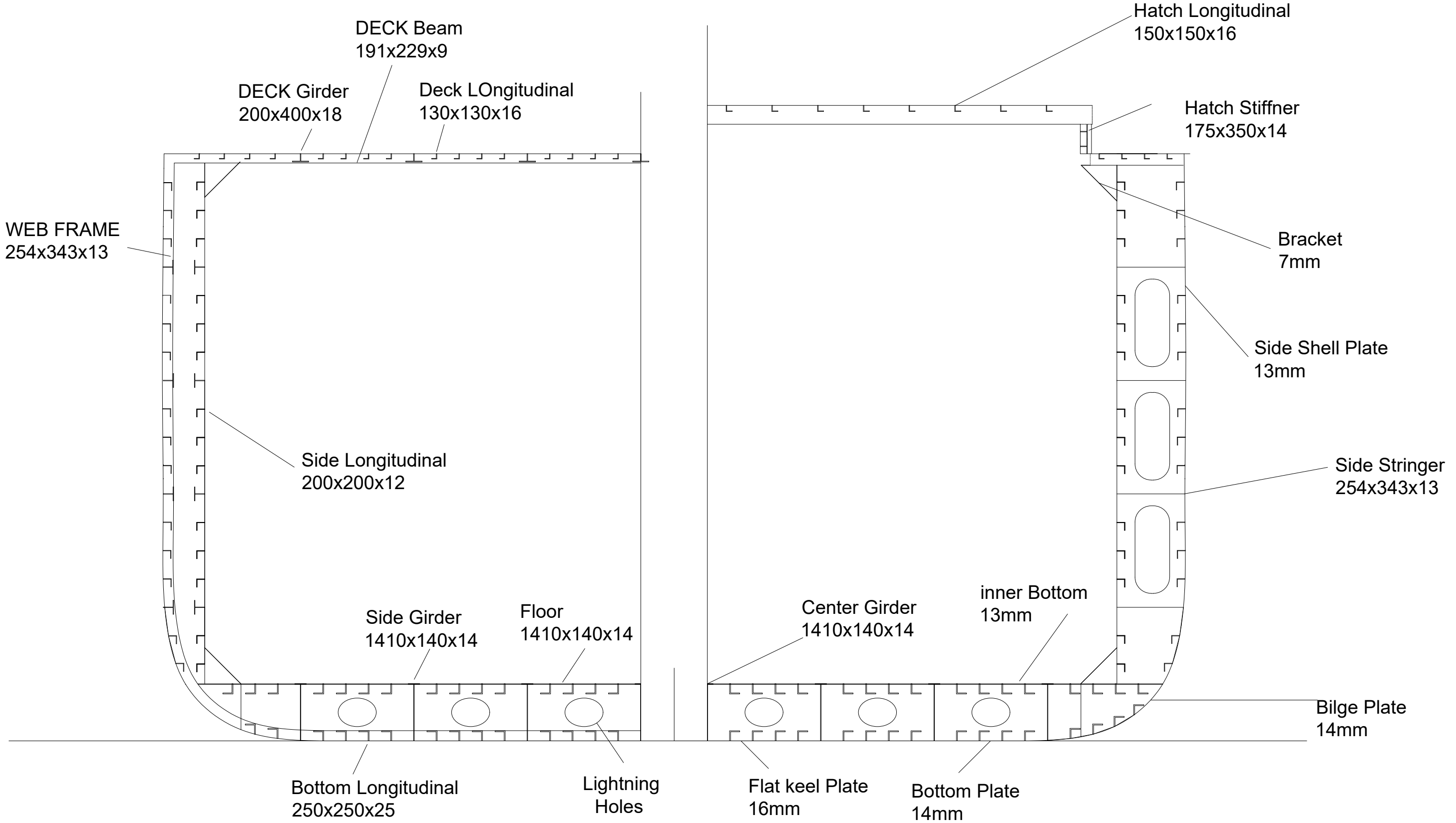
Member	:	Dimension (mm)
Web Frame	:	T-254 × 343× 13
Web frame at machinery space	:	T-356 × 343 × 17
Center girder	:	T-1410 × 140 × 14
Side girder	:	T-1410 × 140 × 12
Side stringers	:	T-254 × 343 × 13
Deck girder	:	T-200 × 400 × 18
Deck beam	:	T-191 × 229 × 9
Bottom longitudinal	:	L-250 × 250 × 25
Side longitudinal	:	L-200 × 200 × 12
Deck longitudinal	:	L-130 × 130 × 16
Superstructure Stiffener	:	L-130 × 130 × 9
Hatch longitudinal	:	L-150 × 150 × 16
Hatch stiffener	:	L-175 × 350 × 14

14 Midship Section Scantling

On the next page, there is a detailed drawing of the midship section. This drawing provides a comprehensive and precise representation of the ship's cross-section at its midship point. It includes essential information about the structural elements, dimensions, and arrangements in this critical area of the vessel.

The midship section drawing is a fundamental aspect of ship design and naval architecture. It allows engineers and designers to visualize and analyze the ship's hull shape, structural components, and buoyancy characteristics. Various critical features, such as the web frames, center girder, side girder, and longitudinal members, are meticulously depicted, ensuring accuracy in the construction and maintenance of the vessel.

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



Frame no : 135

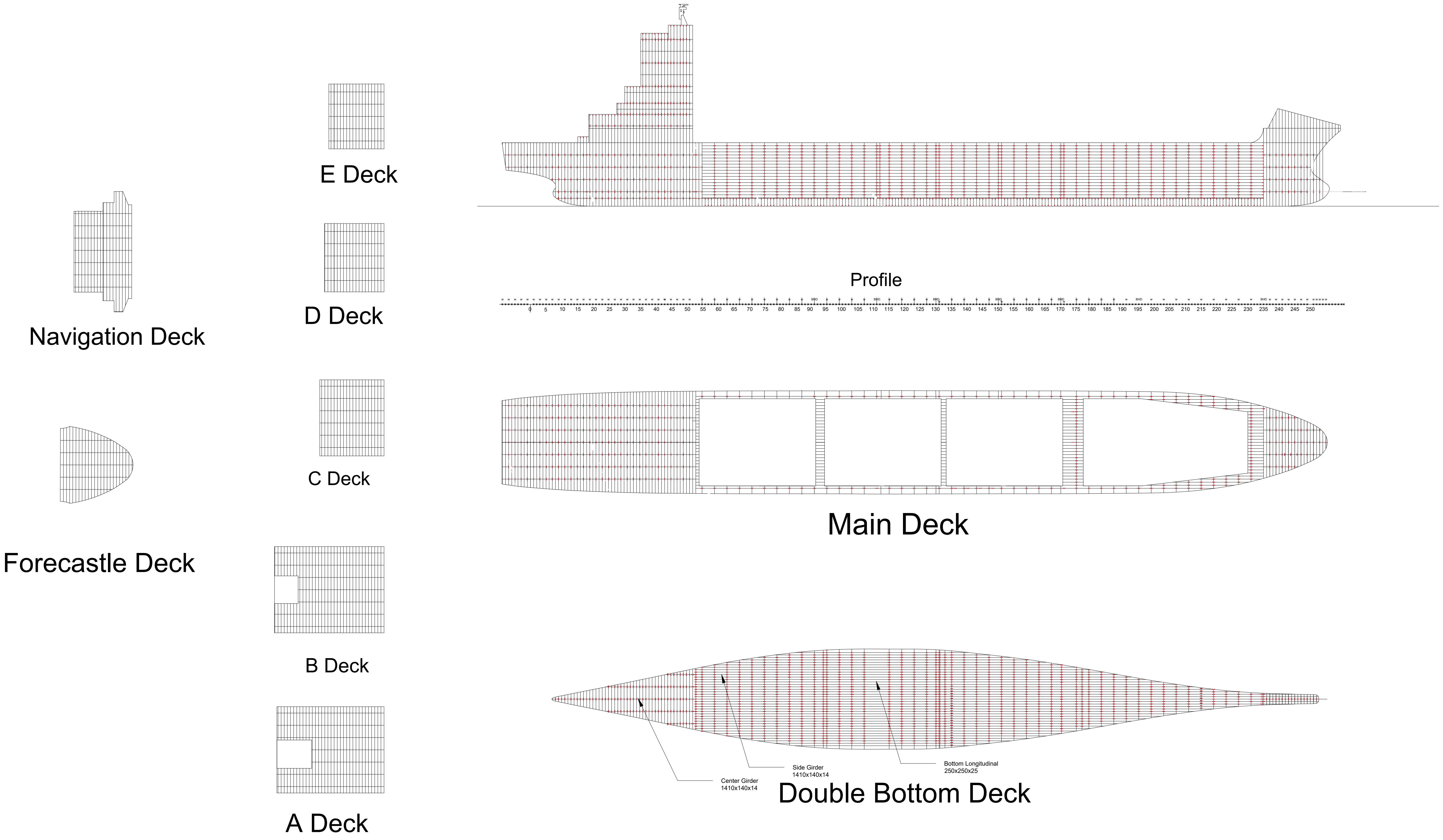
Frame no : 140

15 Longitudinal Construction

On the following page, a detailed drawing of the longitudinal expansion is shown. This drawing provides a comprehensive and intricate representation of the ship's longitudinal structure, showcasing the arrangement and alignment of key components along the length of the vessel.

The longitudinal expansion drawing is an essential part of the ship's design documentation, offering valuable insights into the layout and construction of critical elements such as bulkheads, decks, longitudinal members, and superstructure stiffeners. Each element is meticulously depicted, ensuring accuracy and adherence to the design specifications.

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



16 Shell Expansion

On the subsequent page, a comprehensive and detailed drawing of the Shell expansion is shown. This drawing presents an intricate representation of the ship's outer shell, revealing the arrangement and configuration of various structural elements that compose the hull's external surface.

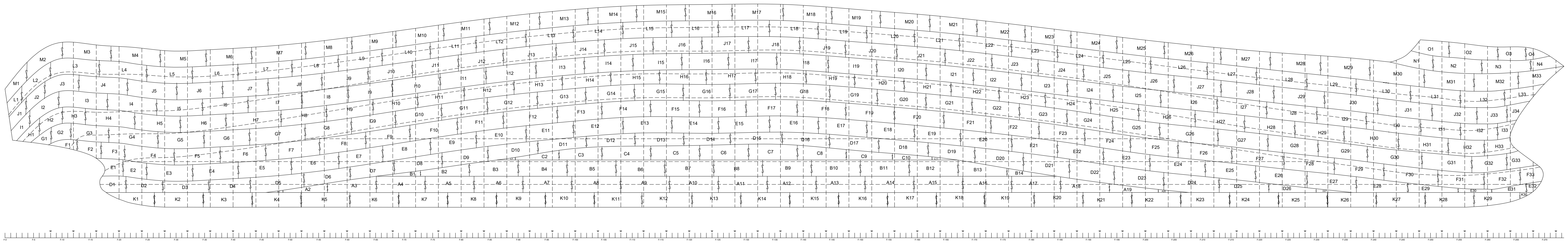
The Shell expansion drawing is a crucial component of ship design and construction, providing vital information about the vessel's outer shell's composition and layout. It includes meticulous depictions of the shell plating, frames, stringers, and other essential components, ensuring precise alignment and adherence to design specifications.

PLATE SIZE TABLE													
K STRAKE		A STRAKE		B STRAKE		C STRAKE		D STRAKE		E STRAKE		F STRAKE	
PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)
K1	5900×1730×16	A1	2100×284×14	B1	5400×1200×14	C1	400×1200×14	D1	2400×1200×14	E1	2000×2000×14	F1	2000×1200×14
K2-K28	6000×1800×16	A2	6000×1100×14	B2	6000×1600×14	C2	6000×1600×14	D2	6000×1600×14	E2	4000×2000×14	F2-F3	2000×2000×14
K29	6000×1700×16	A3	6000×1900×14	B3-B12	6000×2000×14	C3-C8	6000×2000×14	D3-D25	6000×2000×14	E3-E28	6000×2000×14	F4-F31	6000×2000×14
K30	1500×7715×16	A4-A17	6000×2000×14	B13	6000×1800×14	C9	6000×1800×14	D26	5000×1000×14	E29	6000×1000×14	F32	2000×2000×14
		A18	2100×284×14	B14	5000×1000×14	C10	5000×1000×14	D27	2100×300×14	E30	6000×800×14	F33	2000×1200×14
		A19	6000×1100×14			C11	400×1200×14			E31	4000×800×14		
		A20	6000×1900×14							E32	1000×500×14		
H STRAKE		I STRAKE		J STRAKE		L STRAKE		M STRAKE		N STRAKE		O STRAKE	
PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)	PLT. NO.	SIZE(mm)
H1-H3	2000×2000×14	I1	2000×2000×14	J1	3000×2000×14	L1	2000×2000×14	M1	2500×2000×14	N1	4000×1800×14	O1	4500×1800×14
H4-H31	6000×2000×14	I2	4000×2000×14	J2-J3	5000×2000×14	L2-L32	6000×2000×14	M2-M31	6000×2000×14	N2-N3	6000×1800×14	O2	6000×1800×14
H32	3000×2000×14	I3-I31	6000×2000×14	J4-J31	6000×2000×14	L33	2000×2000×14	M32	5500×2000×14	N4	4000×1800×14	O3	4000×1800×14
H33	2000×2000×14	I32	2000×2000×14	J32	5000×2000×14			M33	3000×2000×14			O4	2000×1800×14
		I33	1400×2000×14	J33	2000×2000×14								
				J34	1200×2000×14								

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones

→ Welding

→ Side stringer



17 Weight Calculation

On the ensuing pages, a comprehensive and elaborate account of the weight calculation process for the ship is shown. This detailed analysis delves into the intricate aspects of evaluating and quantifying the various components and factors that contribute to the overall weight of the vessel.

The weight calculation of a ship is an indispensable and complex undertaking, as it plays a pivotal role in ensuring the vessel's stability, safety, and performance. It involves a meticulous examination of every element that constitutes the ship's structure, including the hull, superstructure, machinery, equipment, cargo, and other onboard items.

Steel Weight

	Items	Quantities	Height (mm)	Breadth (mm)	Thickness (mm)	Sectional Area (m^2)	Length (m)	Volume (m^3)	Specific weight (tonne/m^3)	Weight (tonne)	L.C.G from Aft (m)	Moment about Aft (tonne-m)	V.C.G from keel (m)	Moment about keel (tone-m)
Bottom	center girder, T	1	1410	140	14	0.021504	175	3.763	7.86	29.58	90.9125	2689.08	0.76	22.48
	side girder-1, T	2	1410	140	12	0.0184	134.21	4.939	7.86	38.82	84.3767	3275.52	0.76	29.50
	longitudinal, L	32	250	250	25	0.012	109.06	41.879	7.86	329.17	82.7088	27225.19	0.18	59.25
	Web Frame, T	45	254	343	13	0.0076	22	7.524	7.86	59.14	83.304	4926.49	0.195	11.53
	Web Frame for Machinery Space, T	26	356	343	17	0.0116	20.4	6.153	7.86	48.36	32.51	1572.18	0.26	12.57
	Side girder-2	2	1410	140	12	0.0184	103.21	3.798	7.86	29.85	82.478	2462.30	0.76	22.69
	Side girder-3	2	1410	140	12	0.0184	72.93	2.684	7.86	21.09	81.337	1715.79	0.76	16.03
Double Bottom Deck	longitudinal, L	32	250	250	25	0.012	109.06	41.879	7.86	329.17	82.7088	27225.19	1.23	404.88
Inner Hull	side longitudinal, L	14	200	200	12	0.0047	128.16	8.433	7.86	66.28	103.24	6843.04	7.25	480.55
	side stringers, T	4	254	343	13	0.0076	175.82	5.345	7.86	42.01	92.46	3884.35	7.5	315.08
Outer Hull	side longutudinal, L	14	200	200	14	0.0047	129.3	8.508	7.86	66.87	104.5	6988.17	7.57	506.22
	side stringers, T	4	254	343	13	0.0076	177.56	5.398	7.86	42.43	93	3945.70	7.5	318.20
Main Deck	Deck girder T	7	200	400	18	0.0105	71.01	5.219	7.86	41.02	34.7	1423.50	14.4	590.73
	Deck longitudinal, L	6	130	130	16	0.004	118.5	2.844	7.86	22.35	32	715.32	14.35	320.78
	Deck beam, T	42	191	229	9	0.0037	23.5	3.652	7.86	28.70	87.7	2517.34	14.48	415.63
	Deck beam for machinery space, T	26	356	343	17	0.0116	28.4	8.565	7.86	67.32	33	2221.70	14.7	989.67
Deck A	web frame, T	17	254	343	13	0.0076	2.66	0.344	7.86	2.70	31	83.74	20	54.03
	side stringers, T	1	254	343	13	0.0076	26.1	0.198	7.86	1.56	34.9	54.41	20.2	31.49
	deck girder, T	7	200	400	18	0.0105	25.29	1.859	7.86	14.61	33.24	485.65	20.225	295.49
	deck beam, T	11	191	229	9	0.0037	23.5	0.956	7.86	7.52	33.12	248.99	20.2	151.86
	girder,T	7	200	400	18	0.0076	6	0.319	7.86	2.51	32.97	82.72	20.4	51.18
Deck B	web frame, T	17	254	343	13	0.0076	2.66	0.344	7.86	2.70	31.98	86.39	23.25	62.80
	side stringers, T	1	254	343	13	0.0076	16.18	0.123	7.86	0.97	35.98	34.78	20.22	19.54
	deck girder, T	7	200	400	18	0.0105	16.12	1.185	7.86	9.31	33.35	310.58	25.4	236.54
	deck beam, T	11	191	229	9	0.0037	24.47	0.996	7.86	7.83	34.11	267.01	23.4	183.18
	girder,T	7	200	400	18	0.0105	6	0.441	7.86	3.47	34.11	118.23	25.4	88.04
Deck C	web frame, T	10	254	343	13	0.0076	2.66	0.202	7.86	1.59	33.1	52.60	29.7	47.19
	side stringers, T	1	254	343	13	0.0076	16.18	0.123	7.86	0.97	33.17	32.06	25.7	24.84
	deck girder, T	7	200	400	18	0.0105	16.12	1.185	7.86	9.31	33.1	308.25	27.35	254.70
	deck beam, T	15	191	229	9	0.0037	24.52	1.361	7.86	10.70	33.1	354.05	27.5	294.15
	girder,T	7	200	400	18	0.0105	6	0.441	7.86	3.47	35.1	121.67	27.93	96.81
Deck D	web frame, T	9	254	343	13	0.0076	2.66	0.182	7.86	1.43	33.56	47.99	30.24	43.25
	side stringers, T	1	254	343	13	0.0076	16.18	0.123	7.86	0.97	35.96	34.76	30.1	29.09
	deck girder, T	7	200	400	18	0.0105	16.12	1.185	7.86	9.31	33.56	312.53	30.15	280.78
	deck beam, T	15	191	229	9	0.0037	24.52	1.361	7.86	10.70	33.65	359.93	30.42	325.38
	girder, T	7	200	400	18	0.0105	6	0.441	7.86	3.47	34.91	121.01	30.21	104.72
Navigation Deck	web frame, T	9	254	343	13	0.0076	2.83	0.194	7.86	1.52	33.56	51.06	27.59	41.98
	side stringers, T	4	254	343	13	0.0076	6.68	0.203	7.86	1.60	35.96	57.40	22.39	35.74
	deck girder, T	7	200	400	18	0.0105	14.27	1.049	7.86	8.24	33.56	276.67	21.57	177.82
	deck beam, T	7	191	229	9	0.0037	8.68	0.225	7.86	1.77	33.65	59.46	31.91	56.39
	girder, T	7	200	400	18	0.0105	6	0.441	7.86	3.47	34.91	121.01	31.17	108.04
Forecastle Deck	web frame, T	11	254	343	13	0.0076	2.25	0.188	7.86	1.48	33.56	49.62	31.41	46.44
	side stringers, T	1	254	343	13	0.0076	15.66	0.119	7.86	0.94	35.96	33.64	32.42	30.33
	deck girder, T	5	200	400	18	0.0105	17.98	0.944	7.86	7.42	33.56	249.00	33.47	248.33
	deck beam, T	10	191	229	9	0.0037	26.6	0.984	7.86	7.74	33.65	260.31	33.58	259.77

	Items	Quantities	Height (mm)	Breadth (mm)	Thickness (mm)	Sectional Area (m^2)	Length (m)	Volume (m^3)	Specific weight (tonne/m^3)	Weight (tonne)	L.C.G from Aft (m)	Moment about Aft (tonne-m)	V.C.G from keel (m)	Moment about keel (tone-m)
Platings	Flat keel plate	--	--	--	--	--	--	--	7.86	47.98	80.43	3859.03	0.008	0.38
	bilge plate	--	--	--	--	--	--	--	7.86	43.45	90	3910.50	0.12	5.21
	bottom shell plate	--	--	--	--	--	--	--	7.86	435.65	91	39644.15	0.12	52.28
	side shell plate	--	--	--	--	--	--	--	7.86	467.56	88	41145.28	7.5	3506.70
	Solid plate Floor	--	--	--	--	--	--	--	7.86	243.87	55	13412.85	7.5	1829.03
	deck plate	--	--	--	--	--	--	--	7.86	12.70	56.25	714.38	12.8	162.56
	Spr str side shell	--	--	--	--	--	--	--	7.86	54.00	32.54	1757.16	18.5	999.00
	Fcastle side shell	--	--	--	--	--	--	--	7.86	76.80	34.9	2680.32	15.2	1167.36
	Spr str deck plate	--	--	--	--	--	--	--	7.86	170.00	32.78	5572.60	7.25	1232.50
	Aft Coll. BHD	1	--	--	--	--	--	--	7.86	60.00	12.4952	749.71	7.25	435.00
	For coll. BHD	1	--	--	--	--	--	--	7.86	60.00	167	10020.00	7.25	435.00
	Trans. BHD	8	--	--	--	--	--	--	7.86	360.00	94.67	34081.20	7.25	2610.00
	Floor Plate	--	--	--	--	--	--	--	7.86	302.45	55	16634.75	0.75	226.84
	Bracket	--	--	--	--	--	--	--	7.86	140.34	55	7718.70	7.5	1052.55
	Bulwark	--	--	--	--	--	--	--	7.86	0.67	173.2	116.04	16.25	10.89
Hatch Cover	Hatch Cover 1	--	--	--	--	--	--	--	--	68.45	47.1252	3225.72	16.54	1132.16
	Hatch Cover 2	--	--	--	--	--	--	--	--	68.45	59.99	4106.32	16.54	1132.16
	Hatch Cover 3	--	--	--	--	--	--	--	--	68.45	75.06	5137.86	16.54	1132.16
	Hatch Cover 4	--	--	--	--	--	--	--	--	68.45	87.83	6011.96	16.54	1132.16
	Hatch Cover 5	--	--	--	--	--	--	--	--	68.45	101.8	6968.21	16.54	1132.16
	Hatch Cover 6	--	--	--	--	--	--	--	--	68.45	115.801	7926.58	16.54	1132.16
	Hatch Cover 7	--	--	--	--	--	--	--	--	68.45	133.156	9114.53	16.54	1132.16
	Hatch Cover 8	--	--	--	--	--	--	--	--	100.50	146.59	14732.30	16.54	1662.27
	TOTAL									**4456.54**		**343546.49**		**31508.42**

LCG from aft	**77.0881**	**m**
VCG from keel	**7.0701**	**m**

Wood and Outfits Weight

Deck	Room	Item	No. of Items	Weight (kg)	total weight (ton)	LCG(m)	LCG moment	VCG(m)	VCG Moment
NAVIGATION DECK		Control Panel	1	500.00	0.500	36.75	18.375	39.000	19.500
		Wing Control Panel (Starboard)	1	15.00	0.015	35.46	0.532	39.000	0.585
		Wing Control Panel (Port side)	1	15.00	0.015	35.46	0.532	39.000	0.585
		Cabinet	3	36.00	0.036	32.08	1.155	39.000	1.404
		Chart Table	1	10.00	0.010	34.27	0.343	39.000	0.390
		Chart Table-Chair	1	3.00	0.003	34.47	0.103	39.000	0.117
		Map Table	1	13.00	0.013	34.27	0.446	39.000	0.507
		Map Table- Chair	1	3.00	0.003	34.47	0.103	39.000	0.117
		Control Panel- Chair	2	6.00	0.006	35.59	0.214	39.000	0.234
		Radio Instrument Table	1	20.00	0.020	32.06	0.641	39.000	0.780
		Radio Operator's Chair	1	3.00	0.003	33.66	0.101	39.000	0.117
		Sofa	3	39.00	0.039	32.91	1.283	39.000	1.521
		Wash cabin item	2	25.00	0.025	32.09	0.802	39.000	0.975
E DECK	Owner's cabin	Bed	1	30.00	0.030	35.989	1.080	35.400	1.062
		Sofa	2	26.00	0.026	36.089	0.938	35.400	0.920
		Television	1	6.00	0.006	37.589	0.226	35.400	0.212
		Wash cabin items	3	35.00	0.035	35.989	1.260	35.400	1.239
		Cabinet	1	12.00	0.012	37.519	0.450	35.400	0.425
		Locker	1	10.00	0.010	32.959	0.330	35.400	0.354
	Chief engineer's cabin	Double bed	1	30.00	0.030	26.829	0.805	35.400	1.062
		sofa	4	52.00	0.052	31.319	1.629	35.400	1.841
		Table	1	7.50	0.008	29.989	0.225	35.400	0.266
		Television	1	6.00	0.006	25.319	0.152	35.400	0.212
		wash cabin items	3	35.00	0.035	29.489	1.032	35.400	1.239
		Cabinet	2	24.00	0.024	25.219	0.605	35.400	0.850
	Captain's bed room	Double Bed	1	30.00	0.030	35.589	1.068	35.400	1.062
		Wardrobe	1	20.00	0.020	36.719	0.734	35.400	0.708
		Locker	1	10.00	0.010	34.119	0.341	35.400	0.354
		Cabinet	2	24.00	0.024	35.589	0.854	35.400	0.850
		Wash cabin items	3	35.00	0.035	29.619	1.037	35.400	1.239
		Television	1	6.00	0.006	32.189	0.193	35.400	0.212
	Captain's dayroom	Table	1	7.50	0.008	29.619	0.222	35.400	0.266
		chair	4	12.00	0.012	29.619	0.355	35.400	0.425
		Sofa	4	52.00	0.052	26.349	1.370	35.400	1.841
D DECK	Chief Officer's Cabin	Single bed	1	23.00	0.023	27.117	0.624	32.249	0.742
		Cabinet	1	12.00	0.012	25.567	0.307	32.249	0.387
		Wardrobe	1	20.00	0.020	30.307	0.606	32.249	0.645
		Wash room items	3	35.00	0.035	26.587	0.931	32.249	1.129
	1st Engineer's Cabin	Single bed	1	23.00	0.023	36.517	0.840	32.249	0.742
		Cabinet	2	24.00	0.024	37.517	0.900	32.249	0.774
		wardrobe	1	20.00	0.020	30.677	0.614	32.249	0.645
		Sofa	2	26.00	0.026	31.247	0.812	32.249	0.838
		Table	1	10.00	0.010	31.247	0.312	32.249	0.322
		Wash room items	3	35.00	0.035	26.617	0.932	32.249	1.129
	2nd Engineer's Cabin	Single bed	1	23.00	0.023	36.147	0.831	32.249	0.742
		Sofa	2	26.00	0.026	33.117	0.861	32.249	0.838
		Wardrobe	1	20.00	0.020	32.747	0.655	32.249	0.645
		Cabinet	2	24.00	0.024	37.717	0.905	32.249	0.774
		Table	1	10.00	0.010	35.917	0.359	32.249	0.322
		Wash room items	3	35.00	0.035	35.617	1.247	32.249	1.129
	Smoke room								
		Table	1	15.00	0.015	34.617	0.519	32.249	0.484
		Chair	4	12.00	0.012	34.617	0.415	32.249	0.387

Deck	Room	Item	No. of Items	Weight (kg)	total weight (ton)	LCG(m)	LCG moment	VCG(m)	VCG Moment
C DECK	Bath house	Shower	3	3.00	0.003	24.280	0.073	26.700	0.080
						-3.970		4.800	
	Sea man room-1	Single bed	1	23.00	0.023	26.130	0.601	26.700	0.614
		Locker	1	12.00	0.012	27.730	0.333	26.700	0.320
		Sofa	1	13.00	0.013	25.330	0.329	26.700	0.347
	Sea man room-2	Single bed	1	23.00	0.023	31.130	0.716	26.700	0.614
		Locker	1	12.00	0.012	32.730	0.393	26.700	0.320
		Sofa	1	13.00	0.013	30.230	0.393	26.700	0.347
	Sea man room-3	Single bed	1	23.00	0.023	33.630	0.773	26.700	0.614
		Locker	1	12.00	0.012	35.230	0.423	26.700	0.320
		Sofa	1	13.00	0.013	32.730	0.425	26.700	0.347
	Steward room-1	Single bed	1	23.00	0.023	28.630	0.658	26.700	0.614
		Locker	1	12.00	0.012	30.230	0.363	26.700	0.320
		Sofa	1	13.00	0.013	27.730	0.360	26.700	0.347
	Steward room-2	Single bed	1	23.00	0.023	36.130	0.831	26.700	0.614
		Locker	1	12.00	0.012	37.730	0.453	26.700	0.320
		Sofa	1	13.00	0.013	35.230	0.458	26.700	0.347
	Driver Room-1	Single bed	1	23.00	0.023	36.830	0.847	26.700	0.614
		Cabinet	1	12.00	0.012	37.630	0.452	26.700	0.320
		Table	1	7.00	0.007	35.530	0.249	26.700	0.187
		Chair	1	3.00	0.003	35.530	0.107	26.700	0.080
		Sofa	2	26.00	0.026	33.630	0.874	26.700	0.694
		Wardrobe	1	20.00	0.020	32.930	0.659	26.700	0.534
		Wash room items	3	35.00	0.035	36.730	1.286	26.700	0.935
	Driver Room-2	Single bed	1	23.00	0.023	36.830	0.847	26.700	0.614
		Cabinet	1	12.00	0.012	37.630	0.452	26.700	0.320
		Table	1	7.00	0.007	35.530	0.249	26.700	0.187
		Chair	1	3.00	0.003	35.530	0.107	26.700	0.080
		Sofa	2	26.00	0.026	33.630	0.874	26.700	0.694
		Wardrobe	1	20.00	0.020	32.930	0.659	26.700	0.534
		Wash room items	3	35.00	0.035	36.730	1.286	26.700	0.935
	Radio Operator's Room	Single bed	1	23.00	0.023	29.630	0.681	26.700	0.614
		Cabinet	1	12.00	0.012	29.530	0.354	26.700	0.320
		Sofa	2	26.00	0.026	27.430	0.713	26.700	0.694
		Wardrobe	1	20.00	0.020	27.430	0.549	26.700	0.534
		Wash room items	3	35.00	0.035	29.430	1.030	26.700	0.935
	Electrician's Room	Single bed	1	23.00	0.023	33.230	0.764	26.700	0.614
		Cabinet	1	12.00	0.012	33.130	0.398	26.700	0.320
		Sofa	2	26.00	0.026	31.030	0.807	26.700	0.694
		Wardrobe	1	20.00	0.020	31.030	0.621	26.700	0.534
		Wash room items	3	35.00	0.035	33.030	1.156	26.700	0.935
	Chief Cook's Room	Single bed	1	23.00	0.023	36.830	0.847	26.700	0.614
		Cabinet	1	12.00	0.012	36.730	0.441	26.700	0.320
		Sofa	2	26.00	0.026	34.630	0.900	26.700	0.694
		Wardrobe	1	20.00	0.020	34.630	0.693	26.700	0.534
		Wash room items	3	35.00	0.035	36.630	1.282	26.700	0.935
	Lounge	Sofa(Double)	4	80.00	0.080	27.300	2.184	26.700	2.136
		Table	1	40.00	0.040	27.300	1.092	26.700	1.068
		Wall Cabinet	2	40.00	0.040	24.130	0.965	26.700	1.068
	Hospital	Single Bed	2	46.00	0.046	36.850	1.695	26.700	1.228
		Cabinet	1	12.00	0.012	37.550	0.451	26.700	0.320
		Chair	1	3.00	0.003	33.170	0.100	26.700	0.080
		Wall Cabinet	1	30.00	0.030	33.170	0.995	26.700	0.801
	Swimming Pool	Total	1	600.00	0.600	26.030	15.618	26.700	16.020
	Changing room	Changing room items	2	20.00	0.020	24.430	0.489	26.700	0.534

		Item	No. of Items	Weight (kg)	total weight (ton)	LCG(m)	LCG moment	VCG(m)	VCG Moment
B DECK	Crew Cabin-1	Single bed	1	23.00	0.023	24.81	0.57063	23.461	0.539603
		Locker	1	12.00	0.012	25.17	0.30204	23.461	0.281532
		Sofa	1	13.00	0.013	24.09	0.31317	23.461	0.304993
	Crew Cabin-2	Single bed	1	23.00	0.023	27.31	0.62813	23.461	0.539603
		Locker	1	12.00	0.012	27.37	0.32844	23.461	0.281532
		Sofa	1	13.00	0.013	26.59	0.34567	23.461	0.304993
	Crew Cabin-3	Single bed	1	23.00	0.023	29.81	0.68563	23.461	0.539603
		Locker	1	12.00	0.012	30.17	0.36204	23.461	0.281532
		Sofa	1	13.00	0.013	29.09	0.37817	23.461	0.304993
	Crew Cabin-4	Single bed	1	23.00	0.023	32.31	0.74313	23.461	0.539603
		Locker	1	12.00	0.012	32.67	0.39204	23.461	0.281532
		Sofa	1	13.00	0.013	31.59	0.41067	23.461	0.304993
	Crew Cabin-5	Single bed	1	23.00	0.023	34.81	0.80063	23.461	0.539603
		Locker	1	12.00	0.012	35.17	0.42204	23.461	0.281532
		Sofa	1	13.00	0.013	34.09	0.44317	23.461	0.304993
	Crew Cabin-6	Single bed	1	23.00	0.023	37.31	0.85813	23.461	0.539603
		Locker	1	12.00	0.012	37.67	0.45204	23.461	0.281532
		Sofa	1	13.00	0.013	36.59	0.47567	23.461	0.304993
	Pump man Room-1	Single bed	1	23.00	0.023	27.05	0.62215	23.461	0.539603
		Cabinet	1	12.00	0.012	27.93	0.33516	23.461	0.281532
		Wardrobe	1	20.00	0.020	25.13	0.5026	23.461	0.46922
		Wash room items	3	35.00	0.035	27.92	0.9772	23.461	0.821135
	Pump man Room-2	Single bed	1	23.00	0.023	30.65	0.70495	23.461	0.539603
		Cabinet	1	12.00	0.012	31.53	0.37836	23.461	0.281532
		Wardrobe	1	20.00	0.020	28.72	0.5744	23.461	0.46922
		Wash room items	3	35.00	0.035	31.52	1.1032	23.461	0.821135
	Cook Room-1	Single bed	1	23.00	0.023	34.25	0.78775	23.461	0.539603
		Cabinet	1	12.00	0.012	35.13	0.42156	23.461	0.281532
		Wardrobe	1	20.00	0.020	32.32	0.6464	23.461	0.46922
		Wash room items	3	35.00	0.035	35.12	1.2292	23.461	0.821135
	Cook Room-2	Single bed	1	23.00	0.023	37.85	0.87055	23.461	0.539603
		Cabinet	1	12.00	0.012	38.73	0.46476	23.461	0.281532
		Wardrobe	1	20.00	0.020	35.92	0.7184	23.461	0.46922
		Wash room items	3	35.00	0.035	38.72	1.3552	23.461	0.821135
	Recreation Room	Television	1	6.00	0.006	28.22	0.16932	23.461	0.140766
		Sofa	8	72.00	0.072	26.32	1.89504	23.461	1.689192
		Table	2	30.00	0.030	23.32	0.6996	23.461	0.70383
		Chair	8	24.00	0.024	23.62	0.56688	23.461	0.563064
	Crew Mess	Cabinet	1	12.00	0.012	23.12	0.27744	23.461	0.281532
		Table	1	20.00	0.020	27.3	0.546	23.461	0.46922
		Chair	8	24.00	0.024	27.3	0.6552	23.461	0.563064
	Officers' Mess	Cabinet	1	12.00	0.012	35.62	0.42744	23.461	0.281532
		Table	1	15.00	0.015	33.32	0.4998	23.461	0.351915
		Chair	6	18.00	0.018	33.32	0.59976	23.461	0.422298
	Common Room	Table Tennis Table	1	20.00	0.020	34.22	0.6844	23.461	0.46922
		Pool Table	1	50.00	0.050	34.22	1.711	23.461	1.17305
		Table	1	15.00	0.015	37.32	0.5598	23.461	0.351915
		Chair	4	12.00	0.012	37.32	0.44784	23.461	0.281532
		Sports' Cabinet	1	8.00	0.008	32.22	0.25776	23.461	0.187688
	Galle y	Galley Items		40.00	0.040	25.42	1.0168	23.461	0.93844
		Cabinet	2	24.00	0.024	23.02	0.55248	23.461	0.563064

		Item	No. of Items	Weight (kg)	total weight (ton)	LCG(m)	LCG moment	VCG(m)	VCG Moment
A DECK		Dispensary Cabinet	2	20	0.020	32.22	0.6444	19.45	0.389
		Gym Items		150	0.150	32.82	4.923	19.45	2.9175
	Pantry	Beverage Storage		150	0.150	35.22	5.283	19.45	2.9175
		Vegetable Storage		50	0.050	32.12	1.606	19.45	0.9725
		Frozen Food Storage		300	0.300	29.12	8.736	19.45	5.835
		Cabinet		20	0.020	28.82	0.5764	19.45	0.389
		Store-1 Cabinet	1	10	0.010	22.12	0.2212	19.45	0.1945
		Store-2 Cabinet	1	15	0.015	20.12	0.3018	19.45	0.29175
	Laundry	Washing Machine	2	120	0.120	19.62	2.3544	19.45	2.334
		Cabinet	2	20	0.020	23.22	0.4644	19.45	0.389
Main Deck		Deck Store Cabinet	2	24	0.024	15.32	0.36768	15.21	0.36504
	Engine C	Table	3	36	0.036	19.32	0.69552	15.21	0.54756
		Chair	13	39	0.039	19.32	0.75348	15.21	0.59319
		Fan Controller	2	16	0.016	37.22	0.59552	15.21	0.24336
		Engine Controll Room Electronics	1	150	0.150	33.42	5.013	15.21	2.2815
		Common Wash Room item	5	55	0.055	27.12	1.4916	15.21	0.83655
		Co2 Room Equipments	1	80	0.080	25.12	2.0096	15.21	1.2168
		Deck Store-2 Cabinet	1	8	0.008	19.12	0.15296	15.21	0.12168
ForeCastle Deck		Lash Storage	--	30	0.030	168.325	5.04975	15.46	0.4638
			--						
		Deck Workshop		50	0.050	168.325	8.41625	15.46	0.773
		Store	--	20	0.020	180.975	3.6195	15.46	0.3092
Below ForeCastle		Electric Room	--	15	0.015	167.565	2.513475	12.87	0.19305
		Boatswine Store	--	25	0.025	173.015	4.325375	12.87	0.32175
		Paint Store	--	15	0.015	167.665	2.514975	12.87	0.19305
		TOTAL			**5.733**		**198.3571689**		**151.630987**

LCG from aft	**34.60 m**
VCG from keel	**26.45 m**

Machinery Weight

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	215	215	24.11	5183.65	4	860
Gear box	1	38	38	22.83	867.54	1.4	53.2
Generator	1	112	112	23.8	2665.6	4.5	504
Pump	20	0.5	10	22.9	229	3.98	39.8
Auxiliary machinery	11	15	165	23.8	3927	1.56	257.4
HFO preheater	1	43	43	23.8	1023.4	1.75	75.25
Turbocharger	1	20	20	23.78	475.6	17.5	350
Exhaust+chimney	1	23	23	23.78	546.94	22	506
Engine Control Room equipment	1	30	30	25.98	779.4	18	540
Cargo loadind System	1	35	35	23	805	5.65	197.75
Cargo control room equipment	1	20	20	23.15	463	4	80
Air cooling system	3	25	75	21.7	1627.5	5.4	405
Navigation system NAUT OC	1	35	35	20.22	707.7	17.79	622.65
TOTAL			**821**		**19301.33**		**4491.05**

LCG from aft	**23.5095 m**
VCG from keel	**5.4702 m**

Summary of Light Weight

Items	Weight (tonne)	L.C.G from Aft (m)	Moment abt Aft (tonne-m)	V.C.G from keel (m)	Moment abt keel (tone-m)
Steel weight	4456.542	77.088	343546.487	7.070	31508.418
Wood & outfits	5.733	34.599	198.357	26.449	151.631
Machinery weight	821.000	23.510	19301.330	5.470	4491.050
Outfittings	771.100	112.113	86450.084	13.461	10380.144
TOTAL	**6054.375**		**449496.258**		**46531.243**

Light Weight	6054.375	tonnes
Allowance	3	%

Light Weight 6054 tonnes at 2.86 m Draft

Net Light Weight	6236.006	tonnes
LCG from Aft	74.2432	m
VCG from Keel	7.686	m

Dead Weight

Items	Tier	Bay	Quantities	Per container weight	Weight (tonne)	L.C.G from aft (m)	Moment about Aft (tonne-(m)	V.C.G from keel (m)	Moment about keel (tone-(m)
Container		3	0	11	0	159.84	0	2.726	0
		5	2	11	22	153.62	3379.64	2.726	59.972
		7	3	11	33	147.37	4863.21	2.726	89.958
		9	5	11	55	139.93	7696.15	2.726	149.93
		11	7	11	77	133	10241	2.726	209.902
		13	9	11	99	123	12177	2.726	269.874
		15	9	11	99	116.75	11558.25	2.726	269.874
		17	9	11	99	108.45	10736.55	2.726	269.874
		19	9	11	99	102.207	10118.493	2.726	269.874
		21	9	11	99	94.16	9321.84	2.726	269.874
		23	9	11	99	89.94	8904.06	2.726	269.874
		25	9	11	99	80.71	7990.29	2.726	269.874
		27	9	11	99	74.46	7371.54	2.726	269.874
		29	9	11	99	65.54	6488.46	2.726	269.874
		31	9	11	99	59.5	5890.5	2.726	269.874
		33	9	11	99	52.127	5160.573	2.726	269.874
		35	7	11	77	45.885	3533.145	2.726	209.902
		37	0	11	0	12.457	0	2.726	0
		39	0	11	0	6.246	0	2.726	0
	4	1	0	11	0	0	0	2.726	0
		3	0	11	0	159.84	0	5.331	0
		5	2	11	22	153.62	3379.64	5.331	117.282
		7	3	11	33	147.37	4863.21	5.331	175.923
		9	5	11	55	139.93	7696.15	5.331	293.205
		11	7	11	77	133	10241	5.331	410.487
		13	9	11	99	123	12177	5.331	527.769
		15	9	11	99	116.75	11558.25	5.331	527.769
		17	9	11	99	108.45	10736.55	5.331	527.769
		19	9	11	99	102.207	10118.493	5.331	527.769
		21	9	11	99	94.16	9321.84	5.331	527.769
		23	9	11	99	89.94	8904.06	5.331	527.769
		25	9	11	99	80.71	7990.29	5.331	527.769
		27	9	11	99	74.46	7371.54	5.331	527.769
		29	9	11	99	65.54	6488.46	5.331	527.769
		31	9	11	99	59.5	5890.5	5.331	527.769
		33	9	11	99	52.127	5160.573	5.331	527.769
		35	7	11	77	45.885	3533.145	5.331	410.487
		37	0	11	0	12.457	0	5.331	0
		39	0	11	0	6.246	0	5.331	0
	6	1	0	11	0	0	0	5.331	0
		3	6	11	66	159.84	10549.44	7.93	523.38
		5	6	11	66	153.62	10138.92	7.93	523.38
		7	7	11	77	147.37	11347.49	7.93	610.61
		9	7	11	77	139.93	10774.61	7.93	610.61
		11	9	11	99	133	13167	7.93	785.07
		13	9	11	99	123	12177	7.93	785.07
		15	9	11	99	116.75	11558.25	7.93	785.07
		17	9	11	99	108.45	10736.55	7.93	785.07
		19	9	11	99	102.207	10118.493	7.93	785.07
		21	9	11	99	94.16	9321.84	7.93	785.07
		23	9	11	99	89.94	8904.06	7.93	785.07
		25	9	11	99	80.71	7990.29	7.93	785.07
		27	9	11	99	74.46	7371.54	7.93	785.07
		29	9	11	99	65.54	6488.46	7.93	785.07
		31	9	11	99	59.5	5890.5	7.93	785.07
		33	9	11	99	52.127	5160.573	7.93	785.07
		35	9	11	99	45.885	4542.615	7.93	785.07
		37	0	11	0	12.457	0	7.93	0
		39	0	11	0	6.246	0	7.93	0
	8	1	0	12	0	0	0	7.93	0
		3	6	12	72	159.84	11508.48	10.54	758.88

Items	Tier	Bay	Quantities	Per container weight	Weight (tonne)	L.C.G from aft (m)	Moment about Aft (tonne-m)	V.C.G from keel (m)	Moment about keel (tone-m)
Container		5	6	12	72	153.62	11060.64	10.54	758.88
		7	7	12	84	147.37	12379.08	10.54	885.36
		9	7	12	84	139.93	11754.12	10.54	885.36
		11	9	12	108	133	14364	10.54	1138.32
		13	9	12	108	123	13284	10.54	1138.32
		15	9	12	108	116.75	12609	10.54	1138.32
		17	9	12	108	108.45	11712.6	10.54	1138.32
		19	9	12	108	102.207	11038.356	10.54	1138.32
		21	9	12	108	94.16	10169.28	10.54	1138.32
		23	9	12	108	89.94	9713.52	10.54	1138.32
		25	9	12	108	80.71	8716.68	10.54	1138.32
		27	9	12	108	74.46	8041.68	10.54	1138.32
		29	9	12	108	65.54	7078.32	10.54	1138.32
		31	9	12	108	59.5	6426	10.54	1138.32
		33	9	12	108	52.127	5629.716	10.54	1138.32
		35	9	12	108	45.885	4955.58	10.54	1138.32
		37	0	12	0	12.457	0	10.54	0
		39	0	12	0	6.246	0	10.54	0
	10	1	0	12	0	0	0	10.54	0
		3	8	12	96	159.84	15344.64	13.18	1265.28
		5	8	12	96	153.62	14747.52	13.18	1265.28
		7	9	12	108	147.37	15915.96	13.18	1423.44
		9	9	12	108	139.93	15112.44	13.18	1423.44
		11	9	12	108	133	14364	13.18	1423.44
		13	9	12	108	123	13284	13.18	1423.44
		15	9	12	108	116.75	12609	13.18	1423.44
		17	9	12	108	108.45	11712.6	13.18	1423.44
		19	9	12	108	102.207	11038.356	13.18	1423.44
		21	9	12	108	94.16	10169.28	13.18	1423.44
		23	9	12	108	89.94	9713.52	13.18	1423.44
		25	9	12	108	80.71	8716.68	13.18	1423.44
		27	9	12	108	74.46	8041.68	13.18	1423.44
		29	9	12	108	65.54	7078.32	13.18	1423.44
		31	9	12	108	59.5	6426	13.18	1423.44
		33	9	12	108	52.127	5629.716	13.18	1423.44
		35	9	12	108	45.885	4955.58	13.18	1423.44
		37	0	12	0	12.457	0	13.18	0
		39	0	12	0	6.246	0	13.18	0
	12	1	0	12	0	0	0	13.18	0
		3	8	12	96	159.84	15344.64	15.75	1512
		5	8	12	96	153.62	14747.52	15.75	1512
		7	9	12	108	147.37	15915.96	15.75	1701
		9	9	12	108	139.93	15112.44	15.75	1701
		11	9	12	108	133	14364	15.75	1701
		13	9	12	108	123	13284	15.75	1701
		15	9	12	108	116.75	12609	15.75	1701
		17	9	12	108	108.45	11712.6	15.75	1701
		19	9	12	108	102.207	11038.356	15.75	1701
		21	9	12	108	94.16	10169.28	15.75	1701
		23	9	12	108	89.94	9713.52	15.75	1701
		25	9	12	108	80.71	8716.68	15.75	1701
		27	9	12	108	74.46	8041.68	15.75	1701
		29	9	12	108	65.54	7078.32	15.75	1701
		31	9	12	108	59.5	6426	15.75	1701
		33	9	12	108	52.127	5629.716	15.75	1701
		35	9	12	108	45.885	4955.58	15.75	1701
		37	0	12	0	12.457	0	15.75	0
		39	0	12	0	6.246	0	15.75	0
	14	1	0	12	0	0	0	15.75	0
		3	8	12	96	159.84	15344.64	19.6	1881.6
		5	8	12	96	153.62	14747.52	19.6	1881.6
		7	9	12	108	147.37	15915.96	19.6	2116.8
		9	11	12	132	139.93	18470.76	19.6	2587.2
		11	11	12	132	133	17556	19.6	2587.2

Items	Tier	Bay	Quantities	Per container weight	Weight (tonne)	L.C.G from aft (m)	Moment about Aft (tonne-m)	V.C.G from keel (m)	Moment about keel (tone-m)
Container		13	11	12	132	123	16236	19.6	2587.2
		15	11	12	132	116.75	15411	19.6	2587.2
		17	11	12	132	108.45	14315.4	19.6	2587.2
		19	11	12	132	102.207	13491.324	19.6	2587.2
		21	11	12	132	94.16	12429.12	19.6	2587.2
		23	11	12	132	89.94	11872.08	19.6	2587.2
		25	11	12	132	80.71	10653.72	19.6	2587.2
		27	11	12	132	74.46	9828.72	19.6	2587.2
		29	11	12	132	65.54	8651.28	19.6	2587.2
		31	11	12	132	59.5	7854	19.6	2587.2
		33	11	12	132	52.127	6880.764	19.6	2587.2
		35	11	12	132	45.885	6056.82	19.6	2587.2
		37	9	12	108	12.457	1345.356	19.6	2116.8
		39	9	12	108	6.246	674.568	19.6	2116.8
	16	1	9	11	108	0	0	19.6	2116.8
		3	8	11	88	159.84	14065.92	22.21	1954.48
		5	8	11	88	153.62	13518.56	22.21	1954.48
		7	9	11	99	147.37	14589.63	22.21	2198.79
		9	9	11	99	139.93	13853.07	22.21	2198.79
		11	9	11	99	133	13167	22.21	2198.79
		13	11	11	121	123	14883	22.21	2687.41
		15	11	11	121	116.75	14126.75	22.21	2687.41
		17	11	11	121	108.45	13122.45	22.21	2687.41
		19	11	11	121	102.207	12367.047	22.21	2687.41
		21	11	11	121	94.16	11393.36	22.21	2687.41
		23	11	11	121	89.94	10882.74	22.21	2687.41
		25	11	11	121	80.71	9765.91	22.21	2687.41
		27	11	11	121	74.46	9009.66	22.21	2687.41
		29	11	11	121	65.54	7930.34	22.21	2687.41
		31	11	11	121	59.5	7199.5	22.21	2687.41
		33	11	11	121	52.127	6307.367	22.21	2687.41
		35	9	11	99	45.885	4542.615	22.21	2198.79
		37	5	11	55	12.457	685.135	22.21	1221.55
		39	5	11	55	6.246	343.53	22.21	1221.55
	18	1	5	11	55	0	0	22.21	1221.55
		3	0	11	0	159.84	0	24.73	0
		5	0	11	0	153.62	0	24.73	0
		7	3	11	33	147.37	4863.21	24.73	816.09
		9	3	11	33	139.93	4617.69	24.73	816.09
		11	5	11	55	133	7315	24.73	1360.15
		13	5	11	55	123	6765	24.73	1360.15
		15	5	11	55	116.75	6421.25	24.73	1360.15
		17	5	11	55	108.45	5964.75	24.73	1360.15
		19	5	11	55	102.207	5621.385	24.73	1360.15
		21	5	11	55	94.16	5178.8	24.73	1360.15
		23	5	11	55	89.94	4946.7	24.73	1360.15
		25	5	11	55	80.71	4439.05	24.73	1360.15
		27	5	11	55	74.46	4095.3	24.73	1360.15
		29	3	11	33	65.54	2162.82	24.73	816.09
		31	3	11	33	59.5	1963.5	24.73	816.09
		33	3	11	33	52.127	1720.191	24.73	816.09
		35	3	11	33	45.885	1514.205	24.73	816.09
		37	3	11	33	12.457	411.081	24.73	816.09
		39	3	11	33	6.246	206.118	24.73	816.09
Total			**1297**				**1424953.335**		**209782.18**
Crew wight					1.8	15	27	12	21.6
Fuel Oil weight					367.06	45.8	16811.3022	4	1468.236
Disel Oil Weight					63.62	42.8	2722.936	3.79	241.1198
Lube oil Wight					2.3	10.28	23.644	1.25	2.875
Fresh Water for main Engine					14.01	13.25	185.6325	4.98	69.7698
Fresh Water for auxiliary Engine					2.8	8.5	23.8	10.12	28.336
Fresh Water for crews					216	7.31	1578.96	10.8	2332.8
Stores and provisions					1.44	25.9	37.296	18.9	27.216
Total					**15587**		**1446363.906**		**213974.133**

Summary

Items	Weight (tonne)	L.C.G from Aft (m)	Moment abt Aft (tonne-m)	V.C.G from keel (m)	Moment abt keel (tone-m)
Light Weight	6236.006	74.243	462981.146	7.686	47927.180
Dead Weight	15587.029	90.670	1413275.919	9.373	146095.508
TOTAL	**21823.035**		**1876257.065**		**194022.689**

LCG from aft	**85.9760 m**
VCG from keel	**8.89 m**

18 Trim Calculation

18.1 Parameters at the loaded condition

Particular	:	Value
LCB (aft)	:	86.10 m
LCG (aft)	:	85.98 m
Displacement at LWL	:	21823.04 tonnes
MCTC	:	313.27 tonnes-m
LCF	:	4.22 m-aft
Draft	:	8.3 m

$$\text{Change of trim} = \frac{(\text{LCB} - \text{LCG}) \times \Delta}{\text{MCTC}}$$

$$= \frac{(86.10 - 85.98) \times 21823.04}{313.27}$$

$$= 0.086 \text{ m}$$

$$= 8.6 \text{ cm}$$

$$\text{Change of draft (aft)} = \frac{l}{L} \times \text{Change of Trim}$$

$$= \frac{40.5 - 4.22}{173} \times 8.6$$

$$= 1.81 \text{ cm}$$

$$\text{Change of draft (forward)} = \text{Change of Trim} - \text{Change of the draft aft}$$

$$= 8.6 - 1.81$$

$$= 6.79 \text{ cm}$$

18.2 Final draft

	Forward	Aft
Original Draft	8.3 m	8.3 m
Change due to Trim	0.0679 m	0.018 m
Final Draft	8.23 m	8.32 m

19 Stability Calculation

On the upcoming pages, a comprehensive and detailed exposition of the stability calculation for the ship is presented. This meticulous analysis delves into the intricate aspects of assessing and quantifying the vessel's stability under various operating conditions and loading scenarios.

Stability is a paramount consideration in ship design and naval architecture, as it directly impacts the vessel's safety and seaworthiness. The stability calculation involves a profound examination of the ship's center of gravity, metacentric height, and righting arm, among other essential parameters.

Data

	Angel	**0**		**10**		**20**		**30**		**40**		**50**		**60**		**70**		**80**		**90**	
ST	**Draft**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**	**Imm**	**Em**
0	**8.3**	2.37	2.37	4.16	1.64	7.1	1.35	11.66	1.17	9.65	1.06	8.09	0.99	7.16	0.94	6.6	0.91	6.3	0.9	6.2	0.9
1	**8.3**	4.42	4.43	6.43	3.25	9.44	2.66	12.4	2.44	9.85	2.36	8.09	2.35	7.15	2.52	6.6	2.93	6.3	5.92	6.16	7.82
2	**8.3**	6.48	6.48	8.19	5.45	10.48	4.94	12.4	4.78	9.65	4.81	8.09	5.17	7.16	6.13	6.6	7.41	6.3	8.24	6.18	8.3
3	**8.3**	8.28	8.28	9.65	7.41	11.36	6.95	12.4	6.79	9.65	7.06	8.09	7.62	7.16	8.22	6.6	8.56	6.3	8.41	6.2	8.3
4	**8.3**	9.77	9.77	10.76	9.17	12.04	8.87	12.42	8.85	9.65	9.04	8.09	9.21	7.16	9.12	6.6	8.83	6.3	8.42	6.2	8.3
5	**8.3**	10.86	10.86	11.41	10.56	12.26	10.48	12.42	10.48	9.65	10.42	8.09	10.11	7.16	9.48	6.6	8.84	6.3	8.41	6.2	8.28
6	**8.3**	11.49	11.49	11.82	11.41	12.48	11.57	12.4	11.65	9.65	11.42	8.09	11.61	7.16	9.55	6.69	8.83	6.33	8.42	6.16	8.3
7	**8.3**	11.78	11.78	11.94	11.87	12.43	12.19	12.42	12.63	9.66	12.03	8.12	10.87	7.19	9.53	6.62	8.86	6.3	8.42	6.2	8.31
8	**8.3**	11.82	11.82	11.94	11.96	12.51	12.49	12.48	13.04	9.65	12.55	8.08	10.81	7.15	9.55	6.52	8.87	6.29	8.5	6.2	8.33
9	**8.3**	11.75	11.64	11.94	11.86	12.42	12.52	12.4	13.2	9.64	12.59	8.09	10.75	7.13	9.58	6.6	8.84	6.29	8.47	6.14	8.32
10	**8.3**	11.75	11.64	11.94	11.86	12.42	12.52	12.4	13.2	9.64	12.59	8.09	10.75	7.13	9.58	6.6	8.84	6.29	8.47	6.14	8.32
11	**8.3**	11.75	11.64	11.94	11.86	12.42	12.52	12.4	13.2	9.64	12.59	8.09	10.75	7.13	9.58	6.6	8.84	6.29	8.47	6.14	8.32
12	**8.3**	11.62	11.62	11.9	11.63	12.5	11.86	12.4	11.97	9.65	11.61	8.09	10.77	7.16	9.58	6.6	8.83	6.3	8.43	6.2	8.3
13	**8.3**	11.27	11.27	11.72	11.09	12.46	11.09	12.4	11.06	9.65	11.86	8.09	10.34	7.16	9.58	6.6	8.83	6.3	8.43	6.2	8.3
14	**8.3**	10.62	10.32	11.15	10.2	12.32	9.94	10.4	9.93	9.65	9.88	8.09	9.71	7.16	9.28	6.6	8.85	6.3	8.43	6.2	8.3
15	**8.3**	9.53	9.53	10.5	8.97	11.96	8.69	12.4	8.6	9.65	8.64	8.09	8.76	7.16	8.82	6.6	8.75	6.3	8.43	6.2	8.3
16	**8.3**	8.08	8.08	9.25	7.48	11.18	7.2	12.4	7.12	9.65	7.25	8.09	7.56	7.16	7.93	6.6	8.24	6.3	8.43	6.2	8.3
17	**8.3**	6.34	6.34	7.48	5.75	9.61	5.5	12.4	5.47	9.65	5.61	8.05	6	7.16	6.68	6.6	7.46	6.3	8.21	6.2	8.3
18	**8.3**	4.22	4.22	5.08	3.78	6.73	3.63	10.35	3.66	9.65	3.87	8.09	4.28	7.16	4.99	6.6	6.2	6.3	7.63	6.2	8.3
19	**8.3**	2.3	2.3	2.35	1.88	2.92	1.84	4.26	1.9	9.65	2.07	8.09	2.41	7.16	3.14	6.6	4.8	6.3	6.88	6.2	8.3
20	**8.3**	0	0	0	0	0	0	0	0	0	0	0	0	2.16	0	3.86	0	4.87	6.43	6.2	8.35

WATER SECTION INCLINED AT 0° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	2.37	1	2.37	5.6169	5.6169	13.312053	13.312053
1	6.48	4	25.92	41.9904	167.9616	272.097792	1088.39117
2	9.77	2	19.54	95.4529	190.9058	932.574833	1865.14967
3	11.49	4	45.96	132.0201	528.0804	1516.91095	6067.6438
4	11.82	2	23.64	139.7124	279.4248	1651.40057	3302.80114
5	11.75	4	47	138.0625	552.25	1622.23438	6488.9375
6	11.62	2	23.24	135.0244	270.0488	1568.98353	3137.96706
7	10.62	4	42.48	112.7844	451.1376	1197.77033	4791.08131
8	8.08	2	16.16	65.2864	130.5728	527.514112	1055.02822
9	4.22	4	16.88	17.8084	71.2336	75.151448	300.605792
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	263.19	**S_3=**	2647.2323	**S_6=**	28110.9177

WATER SECTION INCLINED AT 0° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	2.37	1	2.37	5.6169	5.6169	13.312053	13.312053
1	6.48	4	25.92	41.9904	167.9616	272.097792	1088.39117
2	9.77	2	19.54	95.4529	190.9058	932.574833	1865.14967
3	11.49	4	45.96	132.0201	528.0804	1516.91095	6067.6438
4	11.82	2	23.64	139.7124	279.4248	1651.40057	3302.80114
5	11.64	4	46.56	135.4896	541.9584	1577.09894	6308.39578
6	11.62	2	23.24	135.0244	270.0488	1568.98353	3137.96706
7	10.32	4	41.28	106.5024	426.0096	1099.10477	4396.41907
8	8.08	2	16.16	65.2864	130.5728	527.514112	1055.02822
9	4.22	4	16.88	17.8084	71.2336	75.151448	300.605792
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	261.55	**S_4=**	2611.8127	**S_5=**	27535.7137

WATER SECTION INCLINED AT 10° (wl-3)

Immersed Wedge

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	4.16	1	4.16	17.3056	17.3056	71.991296	71.991296
1	8.19	4	32.76	67.0761	268.3044	549.35326	2197.413
2	10.76	2	21.52	115.7776	231.5552	1245.767	2491.534
3	11.82	4	47.28	139.7124	558.8496	1651.4006	6605.6023
4	11.94	2	23.88	142.5636	285.1272	1702.2094	3404.4188
5	11.94	4	47.76	142.5636	570.2544	1702.2094	6808.8375
6	11.9	2	23.8	141.61	283.22	1685.159	3370.318
7	11.15	4	44.6	124.3225	497.29	1386.1959	5544.7835
8	9.25	2	18.5	85.5625	171.125	791.45313	1582.9063
9	5.08	4	20.32	25.8064	103.2256	131.09651	524.38605
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	284.58	**S_3=**	2986.257	**S_6=**	32602.191

WATER SECTION INCLINED AT 10° (wl-3)

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	1.64	1	1.64	2.6896	2.6896	4.410944	4.410944
1	5.45	4	21.8	29.7025	118.81	161.87863	647.5145
2	9.17	2	18.34	84.0889	168.1778	771.09521	1542.1904
3	11.41	4	45.64	130.1881	520.7524	1485.4462	5941.7849
4	11.96	2	23.92	143.0416	286.0832	1710.7775	3421.5551
5	11.86	4	47.44	140.6596	562.6384	1668.2229	6672.8914
6	11.63	2	23.26	135.2569	270.5138	1573.0377	3146.0755
7	10.2	4	40.8	104.04	416.16	1061.208	4244.832
8	7.48	2	14.96	55.9504	111.9008	418.50899	837.01798
9	3.78	4	15.12	14.2884	57.1536	54.010152	216.04061
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	252.92	**S_4=**	2514.8796	**S_5=**	26674.313

WATER SECTION INCLINED AT 20° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	7.1	1	7.1	50.41	50.41	357.911	357.911
1	10.48	4	41.92	109.8304	439.3216	1151.0226	4604.0904
2	12.04	2	24.08	144.9616	289.9232	1745.3377	3490.6753
3	12.48	4	49.92	155.7504	623.0016	1943.765	7775.06
4	12.51	2	25.02	156.5001	313.0002	1957.8163	3915.6325
5	12.42	4	49.68	154.2564	617.0256	1915.8645	7663.458
6	12.5	2	25	156.25	312.5	1953.125	3906.25
7	12.32	4	49.28	151.7824	607.1296	1869.9592	7479.8367
8	11.18	2	22.36	124.9924	249.9848	1397.415	2794.8301
9	6.73	4	26.92	45.2929	181.1716	304.82122	1219.2849
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	321.28	**S_3=**	3683.4682	**S_6=**	43207.029

WATER SECTION INCLINED AT 20° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	1.35	1	1.35	1.8225	1.8225	2.460375	2.460375
1	4.94	4	19.76	24.4036	97.6144	120.55378	482.21514
2	8.87	2	17.74	78.6769	157.3538	697.8641	1395.7282
3	11.57	4	46.28	133.8649	535.4596	1548.8169	6195.2676
4	12.49	2	24.98	156.0001	312.0002	1948.4412	3896.8825
5	12.52	4	50.08	156.7504	627.0016	1962.515	7850.06
6	11.86	2	23.72	140.6596	281.3192	1668.2229	3336.4457
7	9.94	4	39.76	98.8036	395.2144	982.10778	3928.4311
8	7.2	2	14.4	51.84	103.68	373.248	746.496
9	3.63	4	14.52	13.1769	52.7076	47.832147	191.32859
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	252.59	**S_4=**	2564.1733	**S_5=**	28025.315

WATER SECTION INCLINED AT 30° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	11.66	1	11.66	135.9556	135.9556	1585.2423	1585.2423
1	12.4	4	49.6	153.76	615.04	1906.624	7626.496
2	12.42	2	24.84	154.2564	308.5128	1915.8645	3831.729
3	12.4	4	49.6	153.76	615.04	1906.624	7626.496
4	12.48	2	24.96	155.7504	311.5008	1943.765	3887.53
5	12.4	4	49.6	153.76	615.04	1906.624	7626.496
6	12.4	2	24.8	153.76	307.52	1906.624	3813.248
7	10.4	4	41.6	108.16	432.64	1124.864	4499.456
8	12.4	2	24.8	153.76	307.52	1906.624	3813.248
9	10.35	4	41.4	107.1225	428.49	1108.7179	4434.8715
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	342.86	**S_3=**	4077.2592	**S_6=**	48744.813

WATER SECTION INCLINED AT 30° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	1.17	1	1.17	1.3689	1.3689	1.601613	1.601613
1	4.78	4	19.12	22.8484	91.3936	109.21535	436.86141
2	8.85	2	17.7	78.3225	156.645	693.15413	1386.3083
3	11.65	4	46.6	135.7225	542.89	1581.1671	6324.6685
4	13.04	2	26.08	170.0416	340.0832	2217.3425	4434.6849
5	13.2	4	52.8	174.24	696.96	2299.968	9199.872
6	11.97	2	23.94	143.2809	286.5618	1715.0724	3430.1447
7	9.93	4	39.72	98.6049	394.4196	979.14666	3916.5866
8	7.12	2	14.24	50.6944	101.3888	360.94413	721.88826
9	3.66	4	14.64	13.3956	53.5824	49.027896	196.11158
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	256.01	**S_4=**	2665.2933	**S_5=**	30048.728

WATER SECTION INCLINED AT 40° (wl-3)

Immersed Wedge

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	9.65	1	9.65	93.1225	93.1225	898.63213	898.63213
1	9.65	4	38.6	93.1225	372.49	898.63213	3594.5285
2	9.65	2	19.3	93.1225	186.245	898.63213	1797.2643
3	9.65	4	38.6	93.1225	372.49	898.63213	3594.5285
4	9.65	2	19.3	93.1225	186.245	898.63213	1797.2643
5	9.64	4	38.56	92.9296	371.7184	895.84134	3583.3654
6	9.65	2	19.3	93.1225	186.245	898.63213	1797.2643
7	9.65	4	38.6	93.1225	372.49	898.63213	3594.5285
8	9.65	2	19.3	93.1225	186.245	898.63213	1797.2643
9	9.65	4	38.6	93.1225	372.49	898.63213	3594.5285
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	279.81	**S_3=**	2699.7809	**S_6=**	26049.169

WATER SECTION INCLINED AT 40° (wl-3)

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	1.06	1	1.06	1.1236	1.1236	1.191016	1.191016
1	4.81	4	19.24	23.1361	92.5444	111.28464	445.13856
2	9.04	2	18.08	81.7216	163.4432	738.76326	1477.5265
3	11.42	4	45.68	130.4164	521.6656	1489.3553	5957.4212
4	12.55	2	25.1	157.5025	315.005	1976.6564	3953.3128
5	12.59	4	50.36	158.5081	634.0324	1995.617	7982.4679
6	11.61	2	23.22	134.7921	269.5842	1564.9363	3129.8726
7	9.88	4	39.52	97.6144	390.4576	964.43027	3857.7211
8	7.25	2	14.5	52.5625	105.125	381.07813	762.15625
9	3.87	4	15.48	14.9769	59.9076	57.960603	231.84241
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	252.24	**S_4=**	2552.8886	**S_5=**	27798.65

WATER SECTION INCLINED AT 50° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	8.09	1	8.09	65.4481	65.4481	529.47513	529.47513
1	8.09	4	32.36	65.4481	261.7924	529.47513	2117.9005
2	8.09	2	16.18	65.4481	130.8962	529.47513	1058.9503
3	8.09	4	32.36	65.4481	261.7924	529.47513	2117.9005
4	8.08	2	16.16	65.2864	130.5728	527.51411	1055.0282
5	8.09	4	32.36	65.4481	261.7924	529.47513	2117.9005
6	8.09	2	16.18	65.4481	130.8962	529.47513	1058.9503
7	8.09	4	32.36	65.4481	261.7924	529.47513	2117.9005
8	8.09	2	16.18	65.4481	130.8962	529.47513	1058.9503
9	8.09	4	32.36	65.4481	261.7924	529.47513	2117.9005
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	234.59	**S_3=**	1897.6715	**S_6=**	15350.857

WATER SECTION INCLINED AT 50° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	0.99	1	0.99	0.9801	0.9801	0.970299	0.970299
1	5.17	4	20.68	26.7289	106.9156	138.18841	552.75365
2	9.21	2	18.42	84.8241	169.6482	781.22996	1562.4599
3	11.61	4	46.44	134.7921	539.1684	1564.9363	6259.7451
4	10.81	2	21.62	116.8561	233.7122	1263.2144	2526.4289
5	10.75	4	43	115.5625	462.25	1242.2969	4969.1875
6	10.77	2	21.54	115.9929	231.9858	1249.2435	2498.4871
7	9.71	4	38.84	94.2841	377.1364	915.49861	3661.9944
8	7.56	2	15.12	57.1536	114.3072	432.08122	864.16243
9	4.28	4	17.12	18.3184	73.2736	78.402752	313.61101
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	243.77	**S_4=**	2309.3775	**S_5=**	23209.8

WATER SECTION INCLINED AT 60° (wl-3)

Immersed Wedge

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	7.16	1	7.16	51.2656	51.2656	367.0617	367.0617
1	7.16	4	28.64	51.2656	205.0624	367.0617	1468.2468
2	7.16	2	14.32	51.2656	102.5312	367.0617	734.12339
3	7.16	4	28.64	51.2656	205.0624	367.0617	1468.2468
4	7.15	2	14.3	51.1225	102.245	365.52588	731.05175
5	7.13	4	28.52	50.8369	203.3476	362.4671	1449.8684
6	7.16	2	14.32	51.2656	102.5312	367.0617	734.12339
7	7.16	4	28.64	51.2656	205.0624	367.0617	1468.2468
8	7.16	2	14.32	51.2656	102.5312	367.0617	734.12339
9	7.16	4	28.64	51.2656	205.0624	367.0617	1468.2468
10	2.16	2	4.32	4.6656	9.3312	10.077696	20.155392
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	211.82	**S_3=**	1494.0326	**S_6=**	10643.495

WATER SECTION INCLINED AT 60° (wl-3)

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	0.94	1	0.94	0.8836	0.8836	0.830584	0.830584
1	6.13	4	24.52	37.5769	150.3076	230.3464	921.38559
2	9.12	2	18.24	83.1744	166.3488	758.55053	1517.1011
3	9.55	4	38.2	91.2025	364.81	870.98388	3483.9355
4	9.55	2	19.1	91.2025	182.405	870.98388	1741.9678
5	9.58	4	38.32	91.7764	367.1056	879.21791	3516.8716
6	9.58	2	19.16	91.7764	183.5528	879.21791	1758.4358
7	9.28	4	37.12	86.1184	344.4736	799.17875	3196.715
8	7.93	2	15.86	62.8849	125.7698	498.67726	997.35451
9	4.99	4	19.96	24.9001	99.6004	124.2515	497.006
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	231.42	**S_4=**	1985.2572	**S_5=**	17631.603

WATER SECTION INCLINED AT 70° (wl-3)

Immersed Wedge

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	6.6	1	6.6	43.56	43.56	287.496	287.496
1	6.6	4	26.4	43.56	174.24	287.496	1149.984
2	6.6	2	13.2	43.56	87.12	287.496	574.992
3	6.69	4	26.76	44.7561	179.0244	299.41831	1197.6732
4	6.52	2	13.04	42.5104	85.0208	277.16781	554.33562
5	6.6	4	26.4	43.56	174.24	287.496	1149.984
6	6.6	2	13.2	43.56	87.12	287.496	574.992
7	6.6	4	26.4	43.56	174.24	287.496	1149.984
8	6.6	2	13.2	43.56	87.12	287.496	574.992
9	6.6	4	26.4	43.56	174.24	287.496	1149.984
10	3.86	2	7.72	14.8996	29.7992	57.512456	115.02491
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	199.32	**S_3=**	1295.7244	**S_6=**	8479.4418

WATER SECTION INCLINED AT 70° (wl-3)

No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	0.91	1	0.91	0.8281	0.8281	0.753571	0.753571
1	7.41	4	29.64	54.9081	219.6324	406.86902	1627.4761
2	8.83	2	17.66	77.9689	155.9378	688.46539	1376.9308
3	8.83	4	35.32	77.9689	311.8756	688.46539	2753.8615
4	8.87	2	17.74	78.6769	157.3538	697.8641	1395.7282
5	8.84	4	35.36	78.1456	312.5824	690.8071	2763.2284
6	8.83	2	17.66	77.9689	155.9378	688.46539	1376.9308
7	8.85	4	35.4	78.3225	313.29	693.15413	2772.6165
8	8.24	2	16.48	67.8976	135.7952	559.47622	1118.9524
9	6.2	4	24.8	38.44	153.76	238.328	953.312
10	0	2	0	0	0	0	0
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	230.97	**S_4=**	1916.9931	**S_5=**	16139.79

WATER SECTION INCLINED AT 80° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	6.3	1	6.3	39.69	39.69	250.047	250.047
1	6.3	4	25.2	39.69	158.76	250.047	1000.188
2	6.3	2	12.6	39.69	79.38	250.047	500.094
3	6.33	4	25.32	40.0689	160.2756	253.63614	1014.5445
4	6.29	2	12.58	39.5641	79.1282	248.85819	497.71638
5	6.29	4	25.16	39.5641	158.2564	248.85819	995.43276
6	6.3	2	12.6	39.69	79.38	250.047	500.094
7	6.3	4	25.2	39.69	158.76	250.047	1000.188
8	6.3	2	12.6	39.69	79.38	250.047	500.094
9	6.3	4	25.2	39.69	158.76	250.047	1000.188
10	4.87	2	9.74	23.7169	47.4338	115.5013	231.00261
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	192.5	**S_3=**	1199.204	**S_6=**	7489.5893

WATER SECTION INCLINED AT 80° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	0.9	1	0.9	0.81	0.81	0.729	0.729
1	8.24	4	32.96	67.8976	271.5904	559.47622	2237.9049
2	8.42	2	16.84	70.8964	141.7928	596.94769	1193.8954
3	8.42	4	33.68	70.8964	283.5856	596.94769	2387.7908
4	8.5	2	17	72.25	144.5	614.125	1228.25
5	8.47	4	33.88	71.7409	286.9636	607.64542	2430.5817
6	8.43	2	16.86	71.0649	142.1298	599.07711	1198.1542
7	8.43	4	33.72	71.0649	284.2596	599.07711	2396.3084
8	8.43	2	16.86	71.0649	142.1298	599.07711	1198.1542
9	7.63	4	30.52	58.2169	232.8676	444.19495	1776.7798
10	6.43	2	12.86	41.3449	82.6898	265.84771	531.69541
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	246.08	**S_4=**	2013.319	**S_5=**	16580.244

WATER SECTION INCLINED AT 90° (wl-3)							
Immersed Wedge							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	6.2	1	6.2	38.44	38.44	238.328	238.328
1	6.18	4	24.72	38.1924	152.7696	236.02903	944.11613
2	6.2	2	12.4	38.44	76.88	238.328	476.656
3	6.16	4	24.64	37.9456	151.7824	233.7449	934.97958
4	6.2	2	12.4	38.44	76.88	238.328	476.656
5	6.14	4	24.56	37.6996	150.7984	231.47554	925.90218
6	6.2	2	12.4	38.44	76.88	238.328	476.656
7	6.2	4	24.8	38.44	153.76	238.328	953.312
8	6.2	2	12.4	38.44	76.88	238.328	476.656
9	6.2	4	24.8	38.44	153.76	238.328	953.312
10	6.2	2	12.4	38.44	76.88	238.328	476.656
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_1=	191.72	**S_3=**	1185.7104	**S_6=**	7333.2299

WATER SECTION INCLINED AT 90° (wl-3)							
No of sec	Ordinates	SM	F of ord.	Sq of ord.	F of sq.	Cube of ord	F of cubes
0	0.9	1	0.9	0.81	0.81	0.729	0.729
1	8.3	4	33.2	68.89	275.56	571.787	2287.148
2	8.3	2	16.6	68.89	137.78	571.787	1143.574
3	8.3	4	33.2	68.89	275.56	571.787	2287.148
4	8.33	2	16.66	69.3889	138.7778	578.00954	1156.0191
5	8.32	4	33.28	69.2224	276.8896	575.93037	2303.7215
6	8.3	2	16.6	68.89	137.78	571.787	1143.574
7	8.3	4	33.2	68.89	275.56	571.787	2287.148
8	8.3	2	16.6	68.89	137.78	571.787	1143.574
9	8.3	4	33.2	68.89	275.56	571.787	2287.148
10	8.35	2	16.7	69.7225	139.445	582.18288	1164.3658
11	0	4	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	4	0	0	0	0	0
14	0	2	0	0	0	0	0
15	0	4	0	0	0	0	0
16	0	2	0	0	0	0	0
17	0	4	0	0	0	0	0
18	0	2	0	0	0	0	0
19	0	4	0	0	0	0	0
20	0	1	0	0	0	0	0
		S_2=	250.14	**S_4=**	2071.5024	**S_5=**	17204.149

Some Necessary Perticulars

Vol of Displacement	
Lt. Wt.	Dead. Wt.
6236.00	15587.00

ST SP.	8.9
WL SP.	2.767

KB	
Lt. Wt.	Dead. Wt.
1.58	4.50

KG	
Lt. Wt.	Dead. Wt.
1.58	8.89

Waterline 3 Combination Table

Angle of heel : 10

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	5	26494.4475	5260.9505	5	26304.7525
10	5993.0054	8	47944.0432	5034.1072	8	40272.8576
20	7372.284	-1	-7372.284	5147.9553	-1	-5147.9553
S_7=			**67066.2067**	∑8=		**61429.6548**

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	5	559312.7869	10	0.98	550815.5689
10	119036.8833	8	952295.0662	0	1.00	952295.0662
20	143116.1683	-1	-143116.1683	-10	0.98	-140941.9121
∑9=						**1362168.723**

Volume of Immersed=	**1446.900**	**cu. m**
Volume of Emerged=	**1325.296**	**cu. m**
New Volume=	**21417.994**	**cu. m**
Moment=	**19591.808**	**m^4**
BR=	**0.915**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinΘ =	**0.763**	**m**
GZ=BR-BGsinΘ=	**0.152**	**m**

Waterline 3 Combination Table

Angle of heel : 20

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	4	23972.0216	5034.1072	4	20136.4288
20	7372.284	1	7372.284	5147.9553	1	5147.9553
S_7=		**36643.1951**		∑8=	**30545.3346**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	20	0.94	105116.4197
10	119036.8833	4	476147.5331	10	0.98	468913.7822
20	143116.1683	1	143116.1683	0	1.00	143116.1683
∑9=					**717146.3702**	

Volume of Immersed=	**3162.192**	**cu. m**
Volume of Emerged=	**2635.966**	**cu. m**
New Volume=	**21822.616**	**cu. m**
Moment=	**41258.308**	**m^4**
BR=	**1.891**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinΘ =	**1.502**	**m**
GZ=BR-BGsinΘ=	**0.388**	**m**

Waterline 3 Combination Table

Angle of heel : 30

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	3	17979.0162	5034.1072	3	15102.3216
20	7372.284	3	22116.852	5147.9553	3	15443.8659
30	8336.0558	1	8336.0558	5374.4685	1	5374.4685
S_7=		**53730.8135**		$\sum 8$=	**41181.6065**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	30	0.87	96875.81642
10	119036.8833	3	357110.6498	20	0.94	335574.2424
20	143116.1683	3	429348.5049	10	0.98	422825.7364
30	162882.0539	1	162882.0539	0	1.00	162882.0539
$\sum 9$=					**1018157.849**	

Volume of Immersed=	**5216.399**	**cu. m**
Volume of Emerged=	**3998.073**	**cu. m**
New Volume=	**22514.717**	**cu. m**
Moment=	**65897.850**	**m^4**
BR=	**2.927**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinϴ =	**2.196**	**m**
GZ=BR-BGsinϴ=	**0.731**	**m**

Waterline 3 Combination Table

Angle of heel : 40

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	4	23972.0216	5034.1072	4	20136.4288
20	7372.284	2	14744.568	5147.9553	2	10295.9106
30	8336.0558	4	33344.2232	5374.4685	4	21497.874
40	5508.6709	1	5508.6709	5210.7564	1	5210.7564
S_7=		**82868.3732**		∑8=	**62401.9203**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	40	0.77	85691.69047
10	119036.8833	4	476147.5331	30	0.87	412355.8596
20	143116.1683	2	286232.3366	20	0.94	268970.4146
30	162882.0539	4	651528.2155	10	0.98	641630.0379
40	110701.1112	1	110701.1112	0	1.00	110701.1112
∑9=					**1519349.114**	

Volume of Immersed=	**7151.278**	**cu. m**
Volume of Emerged=	**5385.088**	**cu. m**
New Volume=	**23062.580**	**cu. m**
Moment=	**87410.013**	**m^4**
BR=	**3.790**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinϴ =	**2.823**	**m**
GZ=BR-BGsinϴ=	**0.967**	**m**

Waterline 3 Combination Table

Angle of heel : 50

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	0.4	2119.5558	5260.9505	0.4	2104.3802
10	5993.0054	1	5993.0054	5034.1072	1	5034.1072
20	7372.284	1	7372.284	5147.9553	1	5147.9553
30	8336.0558	1	8336.0558	5374.4685	1	5374.4685
40	5508.6709	1	5508.6709	5210.7564	1	5210.7564
50	3860.4773	0.4	1544.19092	4492.1743	0.4	1796.86972
S_7=		**30873.76282**		∑8=	**24668.53732**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	0.4	44745.02295	50	0.64	28761.54635
10	119036.8833	1	119036.8833	40	0.77	91187.54296
20	143116.1683	1	143116.1683	30	0.87	123942.2374
30	162882.0539	1	162882.0539	20	0.94	153059.0641
40	110701.1112	1	110701.1112	10	0.98	109019.3126
50	75620.56737	0.4	30248.22695	0	1.00	30248.22695
		∑9=			**536217.9304**	

Volume of Immersed=	**8325.963**	**cu. m**
Volume of Emerged=	**6652.552**	**cu. m**
New Volume=	**22969.801**	**cu. m**
Moment=	**96403.980**	**m^4**
BR=	**4.197**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinΘ =	**3.365**	**m**
GZ=BR-BGsinΘ=	**0.832**	**m**

Waterline 3 Combination Table

Angle of heel : 60

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	4	23972.0216	5034.1072	4	20136.4288
20	7372.284	2	14744.568	5147.9553	2	10295.9106
30	8336.0558	4	33344.2232	5374.4685	4	21497.874
40	5508.6709	2	11017.3418	5210.7564	2	10421.5128
50	3860.4773	4	15441.9092	4492.1743	4	17968.6972
60	3025.9124	1	3025.9124	3970.9634	1	3970.9634
S_7=		**106844.8657**		∑8=	**89552.3373**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	60	0.50	55931.27869
10	119036.8833	4	476147.5331	50	0.64	306061.7347
20	143116.1683	2	286232.3366	40	0.77	219266.6909
30	162882.0539	4	651528.2155	30	0.87	564239.9859
40	110701.1112	2	221402.2224	20	0.94	208050.0346
50	75620.56737	4	302482.2695	10	0.98	297886.8841
60	57220.65371	1	57220.65371	0	1.00	57220.65371
∑9=					**1708657.263**	

Volume of Immersed=	**9220.374**	**cu. m**
Volume of Emerged=	**7728.083**	**cu. m**
New Volume=	**22788.681**	**cu. m**
Moment=	**98301.143**	**m^4**
BR=	**4.314**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinϴ =	**3.804**	**m**
GZ=BR-BGsinϴ=	**0.510**	**m**

Waterline 3 Combination Table

Angle of heel : 70

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	4	23972.0216	5034.1072	4	20136.4288
20	7372.284	2	14744.568	5147.9553	2	10295.9106
30	8336.0558	4	33344.2232	5374.4685	4	21497.874
40	5508.6709	1	5508.6709	5210.7564	1	5210.7564
$S_{7,1}$=		**82868.3732**		∑8,1=	**62401.9203**	

40	5508.6709	1	5508.6709	5210.7564	1	5210.7564
50	3860.4773	3	11581.4319	4492.1743	3	13476.5229
60	3025.9124	3	9077.7372	3970.9634	3	11912.8902
70	2586.2902	1	2586.2902	3773.4945	1	3773.4945
$S_{7,2}$=		**28754.1302**		∑8,2=	**34373.664**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	70	0.34	38259.24791
10	119036.8833	4	476147.5331	60	0.50	238073.7665
20	143116.1683	2	286232.3366	50	0.64	183986.5995
30	162882.0539	4	651528.2155	40	0.77	499099.569
40	110701.1112	1	110701.1112	30	0.87	95869.97452
∑9=					**1055289.157**	

40	110701.1112	1	110701.1112	30	0.87	95869.97452
50	75620.56737	3	226861.7021	20	0.94	213180.2674
60	57220.65371	3	171661.9611	10	0.98	169054.0302
70	48955.7688	1	48955.7688	0	1.00	48955.7688
∑9=					**527060.041**	

Volume of Immersed=	**9942.843**	**cu. m**
Volume of Emerged=	**8722.219**	**cu. m**
New Volume=	**22517.014**	**cu. m**
Moment=	**94824.787**	**m^4**
BR=	**4.211**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinΘ =	**4.128**	**m**
GZ=BR-BGsinΘ=	**0.084**	**m**

Waterline 3 Combination Table

Angle of heel : 80

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	4	23972.0216	5034.1072	4	20136.4288
20	7372.284	2	14744.568	5147.9553	2	10295.9106
30	8336.0558	4	33344.2232	5374.4685	4	21497.874
40	5508.6709	2	11017.3418	5210.7564	2	10421.5128
50	3860.4773	4	15441.9092	4492.1743	4	17968.6972
60	3025.9124	2	6051.8248	3970.9634	2	7941.9268
70	2586.2902	4	10345.1608	3773.4945	4	15093.978
80	2364.6739	1	2364.6739	3883.3371	1	3883.3371
S_7=		**122580.6128**		∑8=	**112500.6158**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	80	0.17	19424.72924
10	119036.8833	4	476147.5331	70	0.34	162852.0475
20	143116.1683	2	286232.3366	60	0.50	143116.1683
30	162882.0539	4	651528.2155	50	0.64	418794.2643
40	110701.1112	2	221402.2224	40	0.77	169603.9422
50	75620.56737	4	302482.2695	30	0.87	261957.3296
60	57220.65371	2	114441.3074	20	0.94	107539.6521
70	48955.7688	4	195823.0752	10	0.98	192848.0827
80	46707.14978	1	46707.14978	0	1.00	46707.14978
∑9=					**1522843.366**	

Volume of Immersed=	**10578.319**	**cu. m**
Volume of Emerged=	**9708.447**	**cu. m**
New Volume=	**22166.262**	**cu. m**
Moment=	**87611.042**	**m^4**
BR=	**3.952**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinΘ =	**4.326**	**m**
GZ=BR-BGsinΘ=	**-0.373**	**m**

Waterline 3 Combination Table

Angle of heel : 90

HEEL ANGLE (a)	S_3	SM	PRD.	S_4	SM	PRD.
0	5298.8895	1	5298.8895	5260.9505	1	5260.9505
10	5993.0054	3	17979.0162	5034.1072	3	15102.3216
20	7372.284	3	22116.852	5147.9553	3	15443.8659
30	8336.0558	2	16672.1116	5374.4685	2	10748.937
40	5508.6709	3	16526.0127	5210.7564	3	15632.2692
50	3860.4773	3	11581.4319	4492.1743	3	13476.5229
60	3025.9124	2	6051.8248	3970.9634	2	7941.9268
70	2586.2902	3	7758.8706	3773.4945	3	11320.4835
80	2364.6739	3	7094.0217	3883.3371	3	11650.0113
90	2295.5344	1	2295.5344	4038.8619	1	4038.8619
S_7=		**113374.5654**		∑8=	**110616.1506**	

HEEL ANGLE (a)	S_5+S_6	SM	PRD.	(j-a)	Cos(j-a)	PRD.
0	111862.5574	1	111862.5574	90	0.00	0
10	119036.8833	3	357110.6498	80	0.17	62011.61357
20	143116.1683	3	429348.5049	70	0.34	146845.8372
30	162882.0539	2	325764.1077	60	0.50	162882.0539
40	110701.1112	3	332103.3336	50	0.64	213471.908
50	75620.56737	3	226861.7021	40	0.77	173786.1463
60	57220.65371	2	114441.3074	30	0.87	99109.07947
70	48955.7688	3	146867.3064	20	0.94	138010.1241
80	46707.14978	3	140121.4493	10	0.98	137992.6897
90	47616.97755	1	47616.97755	0	1.00	47616.97755
∑9=					**1181726.43**	

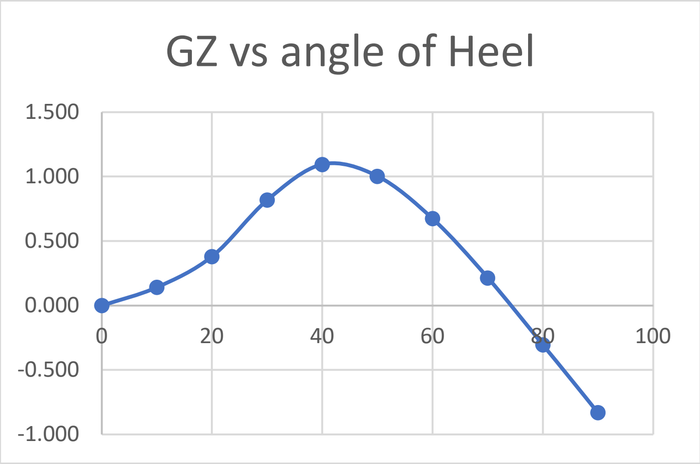
Volume of Immersed=	**11006.849**	**cu. m**
Volume of Emerged=	**10739.052**	**cu. m**
New Volume=	**21564.188**	**cu. m**
Moment=	**76484.438**	**m^4**
BR=	**3.547**	**m**
BG=KG-KB=	**4.393**	**m**
BGsinϴ =	**4.393**	**m**
GZ=BR-BGsinϴ=	**-0.846**	**m**

Values of GZ

	Angle of heel in degree									
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Loaded Wt.	0.000	0.142	0.381	0.819	1.096	1.004	0.675	0.215	-0.305	-0.831
Loaded Wt. Arrival	0.000	0.142	0.380	0.820	1.133	1.054	0.730	0.267	-0.258	-0.794
Balast Condition	0.000	0.844	1.697	2.468	3.152	3.778	3.951	3.678	3.124	2.383
Balast Condition Arrival	0.000	0.885	1.759	2.513	3.136	3.776	4.015	3.764	3.202	2.458

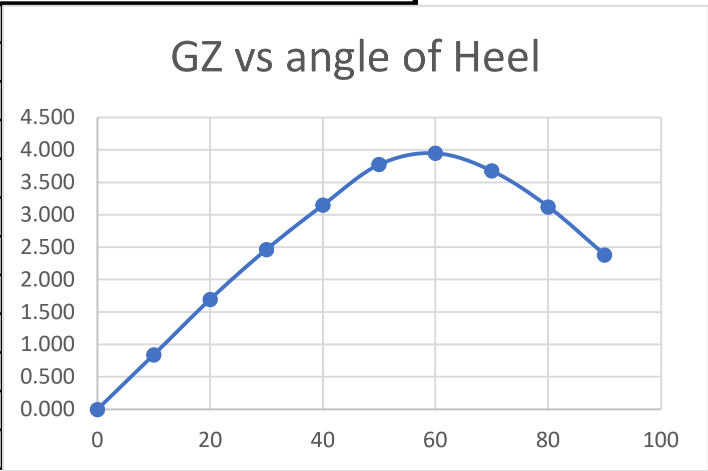
Load Weight

Load Weight	
Angel	**GZ**
0	0.000
10	0.142
20	0.381
30	0.819
40	1.096
50	1.004
60	0.675
70	0.215
80	-0.305
90	-0.831



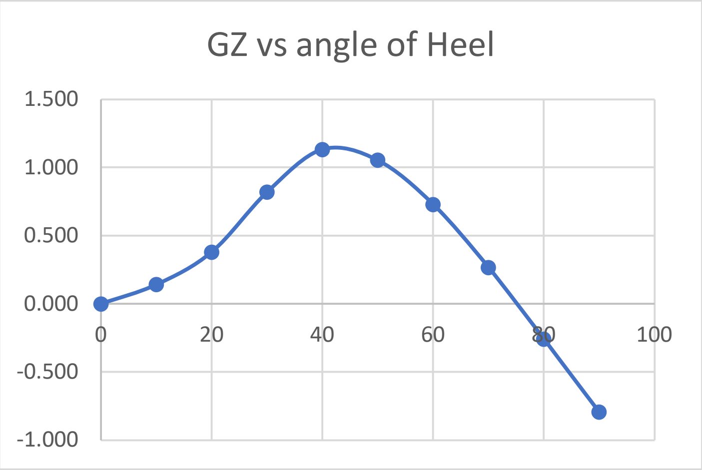
Balast Condition

Balast Condition	
Angel	**GZ**
0	0.000
10	0.844
20	1.697
30	2.468
40	3.152
50	3.778
60	3.951
70	3.678
80	3.124
90	2.383



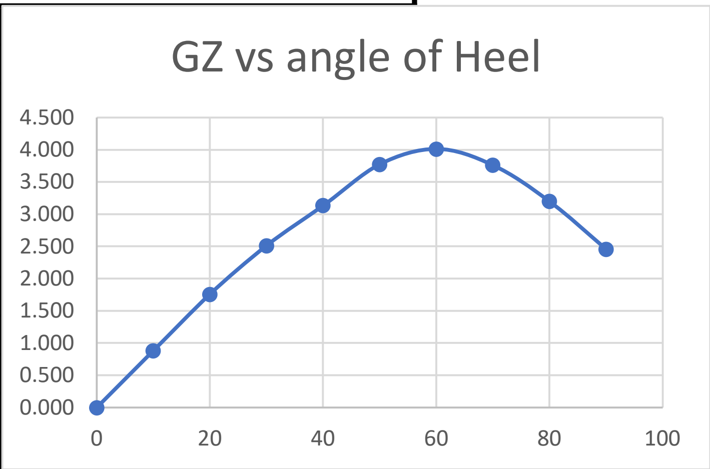
Load Weight Arrival

Load Weight Arrival	
Angel	**GZ**
0	0.000
10	0.142
20	0.380
30	0.820
40	1.133
50	1.054
60	0.730
70	0.267
80	-0.258
90	-0.794



Balast Condition

Balast Condition Arrival	
Angel	**GZ**
0	0.000
10	0.885
20	1.759
30	2.513
40	3.136
50	3.776
60	4.015
70	3.764
80	3.202
90	2.458



IMO CRITERIA

Loaded Weight

	Criterias	Required Value	Actual Value	Remarks
Area under GZ curve	**Up to 30 degree**	>0.055	0.16	PASS
	From 30 to 40 degree	>0.03	0.17	PASS
	Up to 40 degree	>0.09	0.33	PASS
	Max GZ at an angel	>25 degree	40	PASS
	Initial GM	at least 0.15	0.6	PASS

Loaded Weight Arrival

	Criterias	Required Value	Actual Value	Remarks
Area under GZ curve	**Up to 30 degree**	>0.055	0.16	PASS
	From 30 to 40 degree	>0.03	0.18	PASS
	Up to 40 degree	>0.09	0.33	PASS
	Max GZ at an angel	>25 degree	40	PASS
	Initial GM	at least 0.15	0.6	PASS

Balast Condition

	Criterias	Required Value	Actual Value	Remarks
Area under GZ curve	**Up to 30 degree**	>0.055	0.66	PASS
	From 30 to 40 degree	>0.03	0.49	PASS
	Up to 40 degree	>0.09	1.15	PASS
	Max GZ at an angel	>25 degree	60	PASS
	Initial GM	at least 0.15	0.65	PASS

Balast Condition Arrival

	Criterias	Required Value	Actual Value	Remarks
Area under GZ curve	**Up to 30 degree**	>0.055	0.68	PASS
	From 30 to 40 degree	>0.03	0.49	PASS
	Up to 40 degree	>0.09	1.18	PASS
	Max GZ at an angel	>25 degree	60	PASS
	Initial GM	at least 0.15	0.65	PASS

20 Resistance and Power Calculation

On the forthcoming pages, you will be presented with an extensive and comprehensive exposition of the resistance and power calculation for the ship. This meticulous analysis delves into the intricate aspects of evaluating and quantifying the forces that oppose the ship's movement through the water and the power required to overcome these resistances.

The resistance and power calculation are pivotal components in ship design and naval architecture, as they directly influence the vessel's performance, fuel efficiency, and overall operational costs. Understanding the resistance forces acting on the ship is essential for optimizing its hull form, propulsion system, and energy consumption.

Ship Resistance and Power Calculation (Holtrop's & Mennen's Method)

Geometry	
C_B	0.6
C_P	0.614
C_M	0.97
C_W	0.723

Principal Particulars	
L_{WL}	183.900
L_{PP}	178.000
H	14.500
B	23.500
T	8.300
LCB	-2.450
V (Speed)	10.2888
∇ (Volume)	21300.000
Density	1025
F_n	0.2422

The total resistance of a ship can be subdivided into:

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

Frictional Resistance, $R_F(1+k_1)$

$$(1+k_1) = c_{13}\left(0.93 + c_{12} \times \left(\frac{B}{L_R}\right)^{0.92497} \times (0.95 - C_P)^{-0.521448} \times (1 - C_P + 0.0225\,LCB)^{0.6906}\right)$$

$$c_{12} = 48.20\left(\frac{T}{L} - 0.02\right)^{2.078} + 0.479948$$

c_{12}	**0.50279**

$$c_{13} = 1 + 0.003 \times C_{stern}$$

c_{13}	**1**

T/L	0.04513322
C_{stern}	0

$$\frac{L_R}{L} = 1 - C_P + 0.06 \times C_P \times LCB(4C_P - 1)$$

L_R	**46.81806233**

$1+k_1$	1.148661148

$$R_F = 0.5\rho S V^2 C_F$$

$$R_e = \frac{\rho V L}{\mu}$$

R_e	**1.08E+09**

μ	0.001793
A_{BT}	17

$$C_F = \frac{0.075}{(\log R_N - 2)^2}$$

C_F	**1.52E-03**

C_{WP}	**0.723**

$$S = L(2T+B)\sqrt{C_M}\left(0.4530 + 0.4425C_B - 0.2862C_M - 0.003467 \times \frac{B}{T} + 0.3696C_{WP}\right) + 2.38 \times \frac{A_{BT}}{C_B}$$

S	**2904.266207**

R_F	238838.9537

Frictional Resistance = 274345 N

Appendage Resistance

$$R_{APP} = 0.5\rho V^2 S_{APP}(1+k_2)_{eq} C_F$$

$$(1+k_2)_e = \frac{\Sigma(1+k_2)S_{APP}}{\Sigma S_{APP}}$$

$(1+k_2)_{eq}$	2.851429

List of Appendage		
Appendage	Area	$1+k_2$
Rudder	13.000	2.8
Shaft Brack	2	3.0
Shaft	2.5	3.0
ΣS_{APP}	17.50000	

Appendage Resistance = 4104 N

Wave making and Wave breaking Resistance

$$R_W = c_1 c_2 c_5 \nabla \rho g \times e^{\{m_1 F_n^d + m_2 \cos(\lambda F_n^{-2})\}}$$

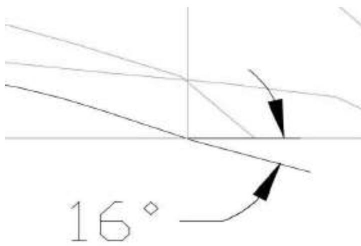
B/L	0.13
i_E	16
L/B	7.82553
L^3/∇	291.988

$$c_7 = \frac{B}{L}, when\ 0.11 < \frac{B}{L} < 0.25$$

c_7	0.13

$$c_1 = 2223105 \times c_7^{3.78613} \times \left(\frac{T}{B}\right)^{1.07961} (90 - i_E)^{-1.37565}$$

c_1	0.616



$$c_3 = \frac{0.56 A_{BT}^{1.5}}{BT(0.31\sqrt{A_{BT}} + T_F - h_B)}$$

c_3	0.02430981

$$c_2 = e^{-1.89\sqrt{c_3}}$$

c_2	1.024607698

$$c_5 = 1 - \frac{0.48 A_T}{BTC_M}$$

c_5	1

$$\lambda = 1.446 C_P - 0.03\frac{L}{B} \quad for \frac{L}{B} < 12$$

λ	0.407

$$c_{16} = 8.07981 C_P - 13.8673 C_P^2 + 6.984388 C_P^3 \quad for\ C_P < 0.8$$

c_{16}	1.3498

$$m_1 = 0.0140407 \times \frac{L}{T} - 1.75254 \times \frac{\Delta^{\frac{1}{3}}}{L} - 4.79323 \times \frac{B}{L} - c_{16}$$

m_1	-1.6512

$$c_{15} = -1.69385\ for \frac{L^3}{\Delta} < 512$$

c_{15}	-1.69385

$$m_2 = c_{15} C_P^2 e^{-0.1 F_n^{-2}}$$

m_2	-0.116167809
d	-0.9

Wave making Resistance = 332297 N

Resistance due to bulbous bow and Transom

$$P_B = \frac{0.56\sqrt{A_{BT}}}{T_F - 1.5h_B}$$

P_B	-0.92357566

$$F_{ni} = \frac{V}{g\left(T_F - h_B - 0.25\sqrt{A_{BT}}\right) + 1.15V^2}$$

F_{ni}	2.606891135

$$R_B = \frac{0.11e^{-3P_B^{-2}} F_{ni}^3 A_{BT}^{1.5} \rho g}{1 + F_{ni}^2}$$

R_B	5225.068183

$$F_{nT} = \frac{V}{\sqrt{\frac{2gA_T}{B + BC_{WP}}}}$$

A_T	0.8

F_{nT}	24.88800352

$$c_6 = 0 \quad \text{if } F_{nT} \geq 5$$

c_6	0

$$R_{TR} = 0.5\rho V^2 A_T c_6$$

R_{TR}	0

Correlation Resistance

$$R_A = \frac{1}{2}\rho V^2 S C_A$$

T_F/L	0.045133
c_2	1.00

$$c_4 = \frac{T_F}{L} \quad for \frac{T_F}{L} < 0.04$$

c_4	**0.0451**

$$C_A = 0.006(L+100)^{-0.16} - 0.00205 + 0.003\sqrt{\frac{L}{7.5}}C_B^4 c_2 (0.04 - c_4)$$

C_A	**0.00024**

Correlation Resistance = 37283 N

Total Rsistance 653.25 kN

Power Calculation

Effective power, $P_E = R \times V$

P_E	6721.20 kW

Hull Efficiency, $\eta_H = \frac{1-t}{1-W_t}$

Taylor wake fraction, $W_t = (0.71 - 2.39C_B + 2.33C_B^2) + 0.12C_B^4\left(6.5 - \frac{L}{B}\right)$

w_t	0.11579

η_H	98.6 %

Propeller Dia	60% of draft
D	4.98

$$t = 0.325C_B - 0.1885\frac{D}{\sqrt{BT}}$$

t	0.1278

Pitch Ratio	Assume
P/D	0.8

Relative rotative efficiency, $\eta_R = 0.9737 + 0.111(C_P - 0.0225lcb) - 0.06325\frac{P}{D}$

η_R	99.7 %

Open Water Efficiency Calculation

Determination	Formula	Value
w	Tylor wake fraction	0.116
t	Thrust deduction fraction	0.128
T_h	$T_h = \frac{R_T}{1-t}$	748.960 kN
h	h = 0.5D + 0.2	2.690 m
Z	Number of Blade	4
H	H = T-h	5.610 m
P_{atm}	Atmospheric Pressure	101.325 kPa
P_0	$P_0 = P_{atm} + H\rho g$	157.735 kPa
P_v	Vapour Pressure	1.646 kPa
K	0.1 for twin screw	0.100
A_E/A_0	$\frac{A_E}{A_0} = \frac{(1.3+0.3Z)T_h}{(P_0-P_v)D^2} + K$	0.584
D_0	$D_0 = \frac{D}{0.95}$	17.199 ft
V_s	Ship Speed	20 knot
V_a	$V_a = V_s(1-w)$	17.68 knot
P_E	Effective power	6721.20 kW

Using $B\ 4.70\ B_P - \delta\ Chart$

$$\boxed{B_P = \frac{N\sqrt{P_D}}{V_a^{2.5}}} \qquad \boxed{\delta = \frac{ND_0}{V_a}}$$

First Iteration

η_D	Assume QPC	0.68
P_D	Delevered Power	13249.492 HP

Speed (RPM)	B_P	δ	η_0
80	7.002	77.802	0.615
90	7.877	87.528	0.63
100	8.752	97.253	0.652
110	9.628	106.978	0.651
120	10.503	116.704	0.681
130	11.378	126.429	0.67
140	12.253	136.154	0.67
150	13.129	145.880	0.65
160	14.004	155.605	0.61
170	14.879	165.330	0.61
180	15.754	175.055	0.6

η_0	Open water Efficiency	0.681
η_D	Resulted QPC	0.6700
ε	Defference	0.0100

Second Iteration

η_D	Assume QPC	0.685
P_D	Delevered Power	13152.780 HP

Speed (RPM)	B_P	δ	η_0
80	6.976	77.802	0.62
90	7.848	87.528	0.63
100	8.720	97.253	0.66
110	9.593	106.978	0.67
120	10.465	116.704	0.7
130	11.337	126.429	0.69
140	12.209	136.154	0.68
150	13.081	145.880	0.66
160	13.953	155.605	0.64
170	14.825	165.330	0.62
180	15.697	175.055	0.62

η_0	Open water Efficiency	0.7
η_D	Resulted QPC	0.6887
ε	Defference	**0.0037 <0.005**

η_D	**70.0 %**

R_T	Sum of All Resistance	653.25 kN
P_E	Effective Power	6721.20 kW
η_D	Quasi propulsive coefficient	0.68
P_D	Delevered Power	9884.12 kW
η_S	Shaft Efficiency	0.95
P_S	Shaft Power	10404.34 kW
Engine Power	5% transmition loss via Gear box	10951.93 kW
Brake Power	85% MCR (15% Safety)	12884.63 kW

Total Installed Power	**100% MCR**	**14983 kW**

Power for Each Engine	**7491.5 kW**

21 Propeller Design

21.1 Some parameters for propeller

Parameters	Symbol	Value	Unit
Engine RPM at 85% MCR	Ne	500	rpm
Gear ratio		4.2	
Shaft rpm		120	Rpm
No of blades	Z	4	
Shaft immersion (Distance of propeller axis and LWL)	h	5.407	m
Taylor's Wake Fraction	w_t	0.116	
Advanced Speed	V_a	17.68	knots
Blade Area ratio (BAR)	A_e/A_o	0.59	
Delivered power	P_d	13244.7208	Hp
		9884.12	Kw

21.2 $\boldsymbol{B_p - \delta}$ Diagram

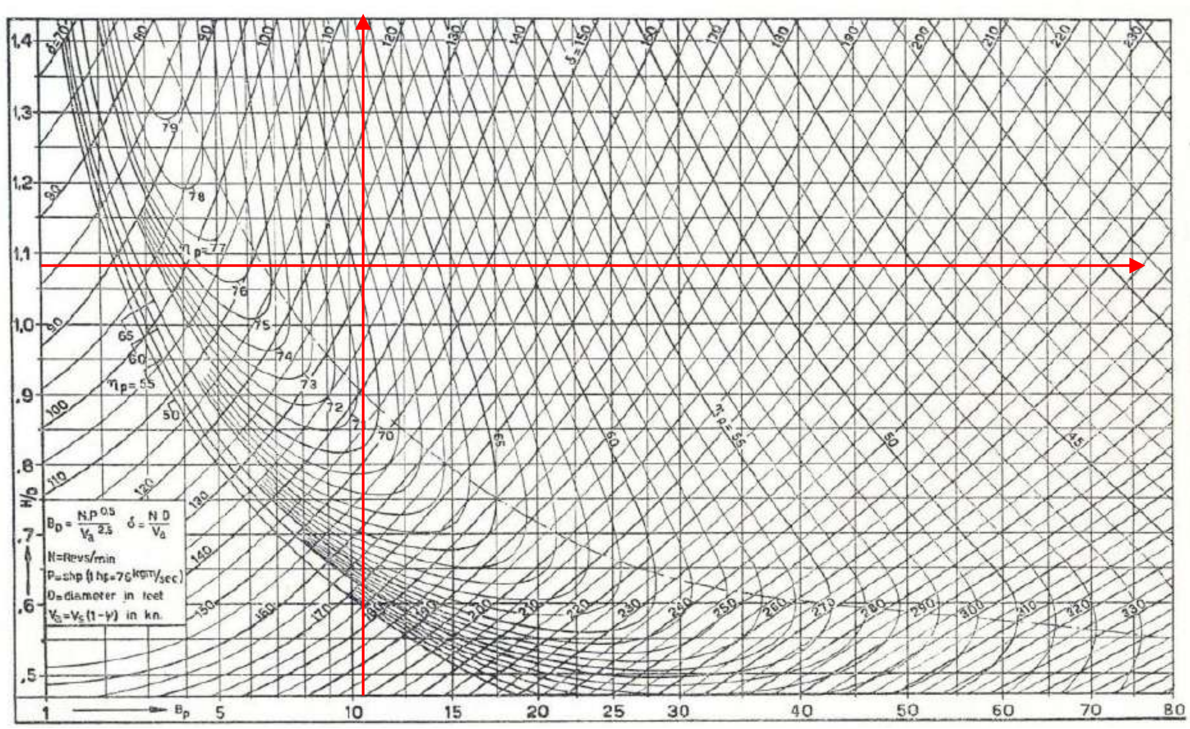
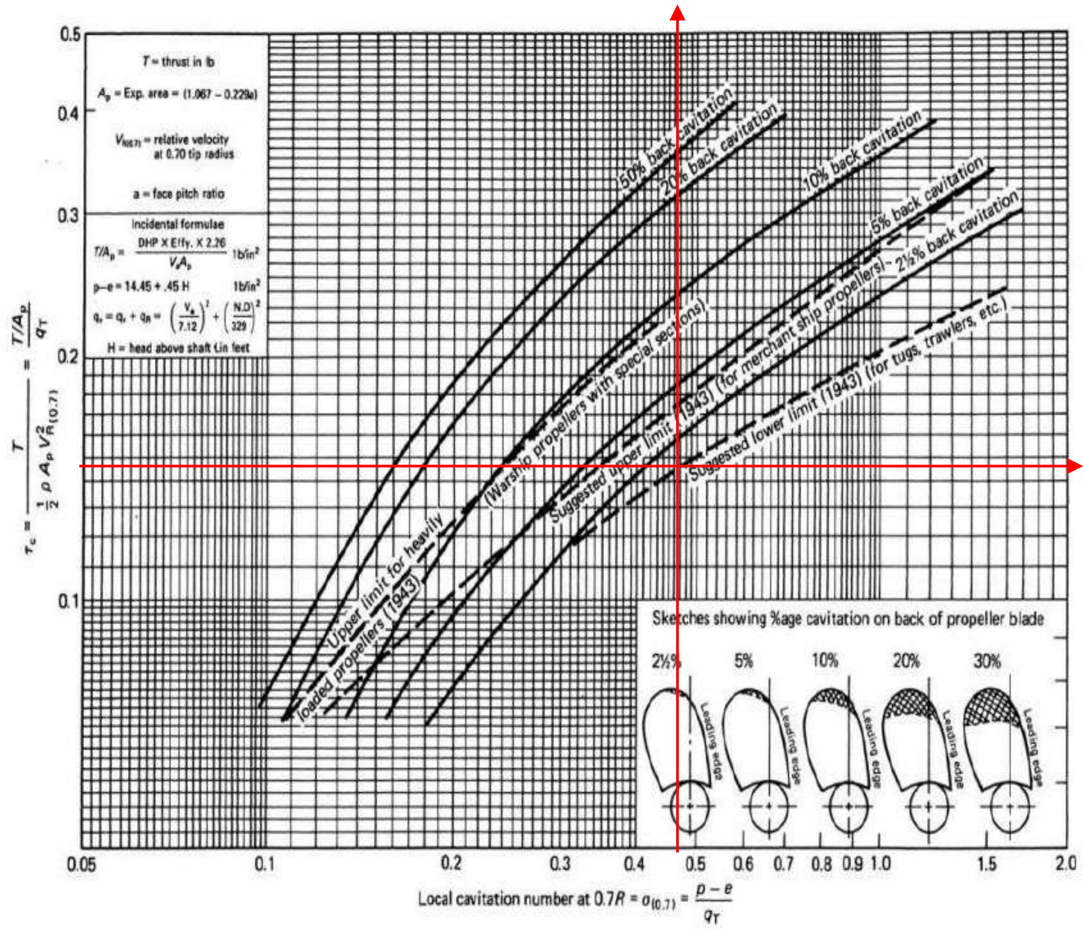


Figure 6: $B_p - \delta$ Chart

$$B_p = \frac{N\sqrt{1.34P_d}}{V_a^{2.5}} = 10.5, \qquad \frac{H}{D} = 1.086$$

From the $\boldsymbol{B_p - \delta}$ diagram, $\boldsymbol{\delta = 128}$, $\boldsymbol{\eta_0 = 69.5\%}$

21.3 Cavitation Check



Burril Cavitation Number at 0.7R = **0.446**

Thrust Loading Coefficient = **0.145**

Projected Blade Area, $\boldsymbol{A_p} = \mathbf{14.336\ m^2}$

Bar needed $= \mathbf{0.074}$, BAR $= \mathbf{0.59}$

Minimum Tip Clearance: $\boldsymbol{x} = \mathbf{0.29\ m}, \boldsymbol{y} = \mathbf{0.86\ m}, \boldsymbol{z} = \mathbf{0.17\ m}$

Pitch, $\boldsymbol{P} = \mathbf{4.5\ m}$

Propeller Radius, $\boldsymbol{R} = \mathbf{2.49\ m}$

Propeller Diameter, $\boldsymbol{D} = \mathbf{4.98\ m}$

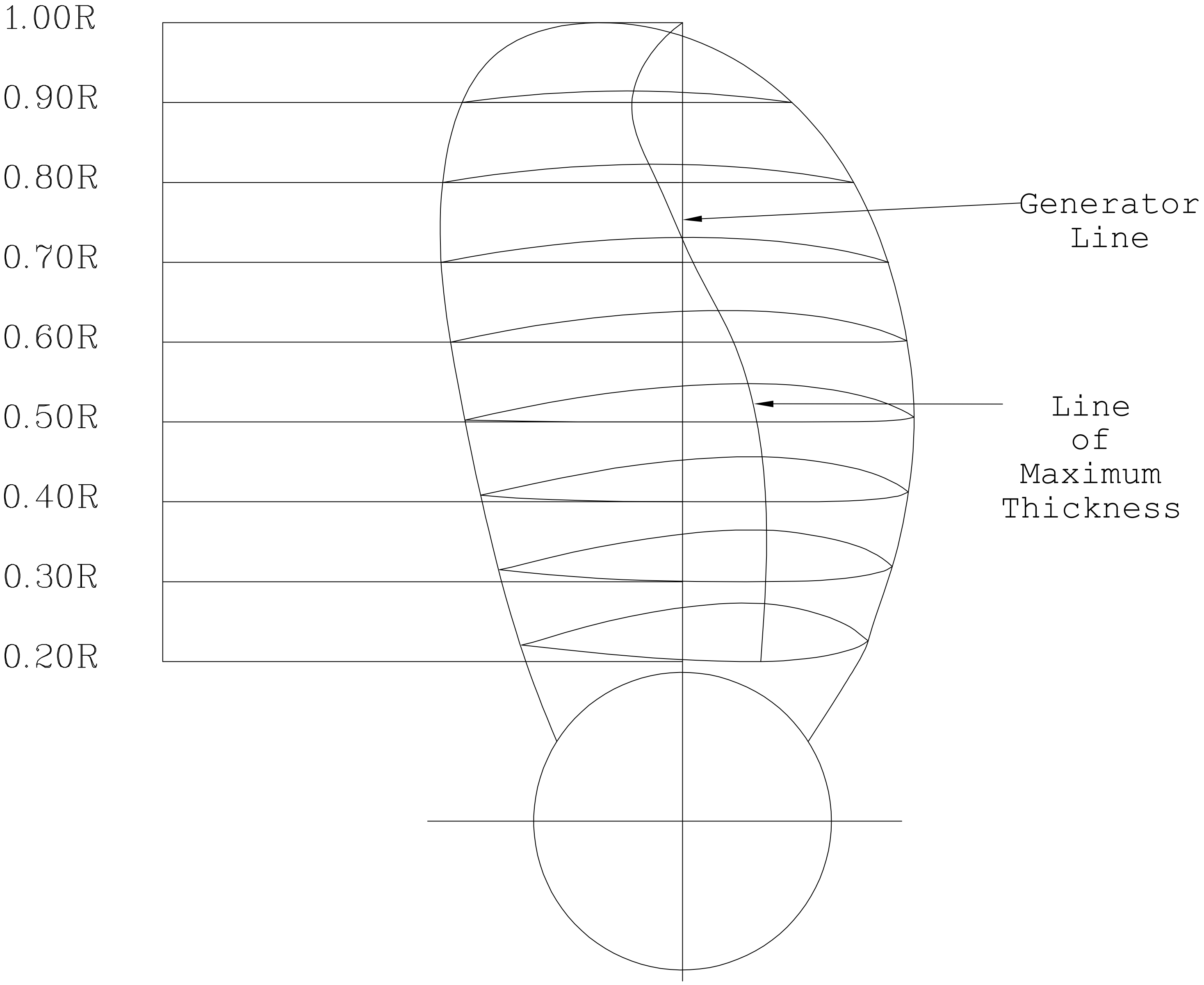
Blade no. $\boldsymbol{Z} = \mathbf{4}$

$$\frac{\boldsymbol{A_E}}{\boldsymbol{A_0}} = \mathbf{0.59}$$

21.4 The geometry of the Wageningen B-screw series Propeller

r/R	(c/D)(Z/BAR)	a/c	b/c	Ar	Br	c	a	b	T (max)
0.2	1.662	0.617	0.35	0.0526	0.004	1223.28	754.77	428.15	182.27
0.3	1.882	0.613	0.35	0.0464	0.0035	1385.21	849.13	484.82	161.352
0.4	2.05	0.601	0.351	0.0402	0.003	1508.86	906.83	529.61	140.436
0.5	2.152	0.586	0.355	0.034	0.0025	1583.94	928.19	562.30	119.52
0.6	2.187	0.561	0.389	0.0278	0.002	1609.70	903.04	626.17	98.604
0.7	2.144	0.524	0.443	0.0216	0.0015	1578.05	826.90	699.08	77.688
0.8	1.97	0.463	0.479	0.0154	0.001	1449.98	671.34	694.54	56.772
0.9	1.582	0.341	0.5	0.0092	0.0005	1164.40	397.06	582.20	35.856
1	0	0	0	0.003	0	0	0	0	14.94

Expanded View of Propeller section



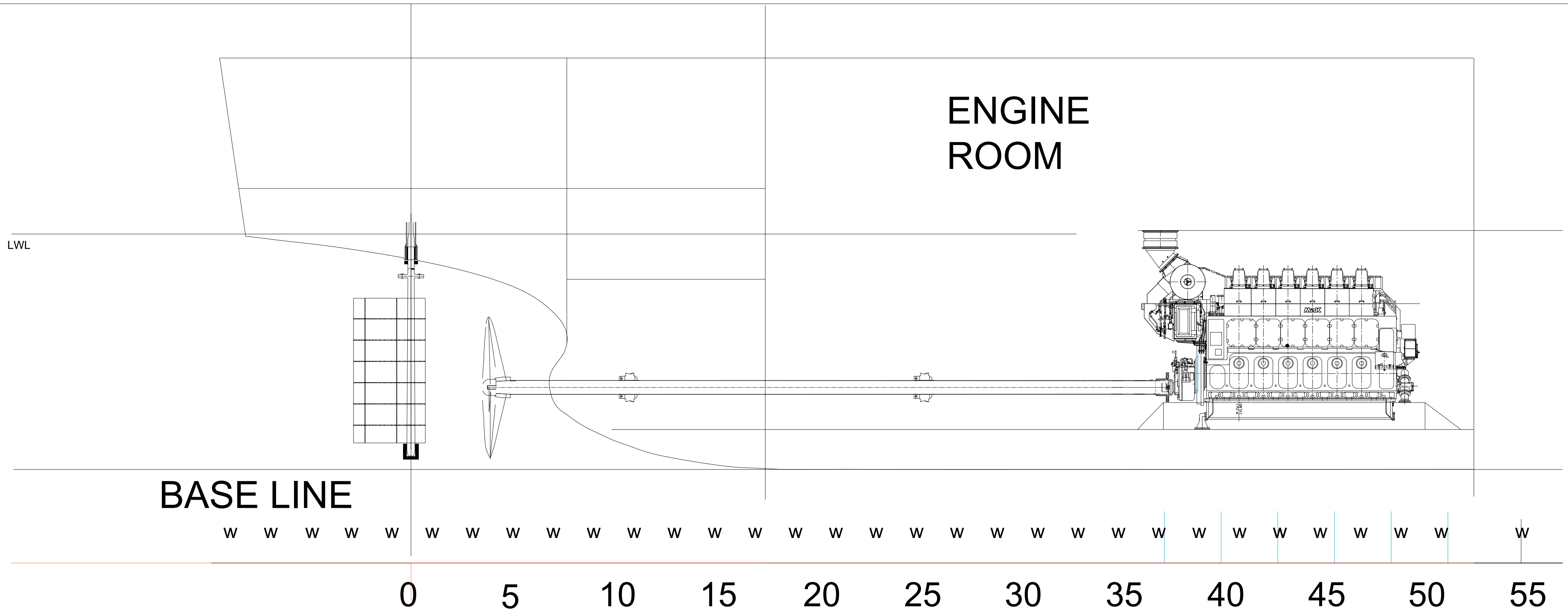
Expanded View

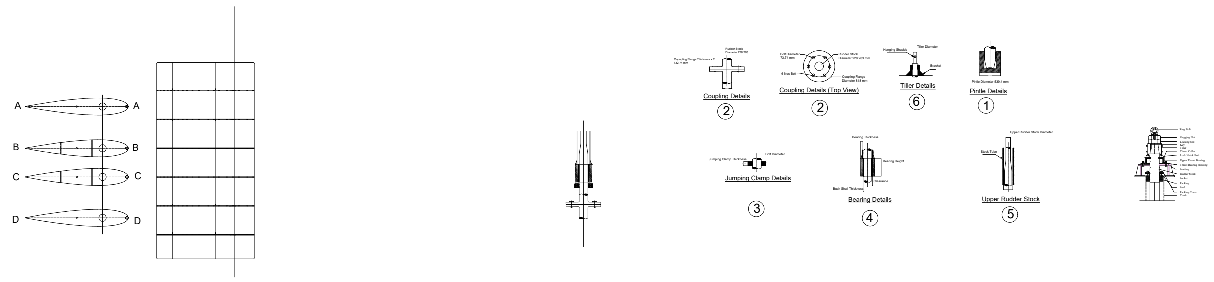
22 Rudder and Steering Arrangement

22.1 Rudder Scantling

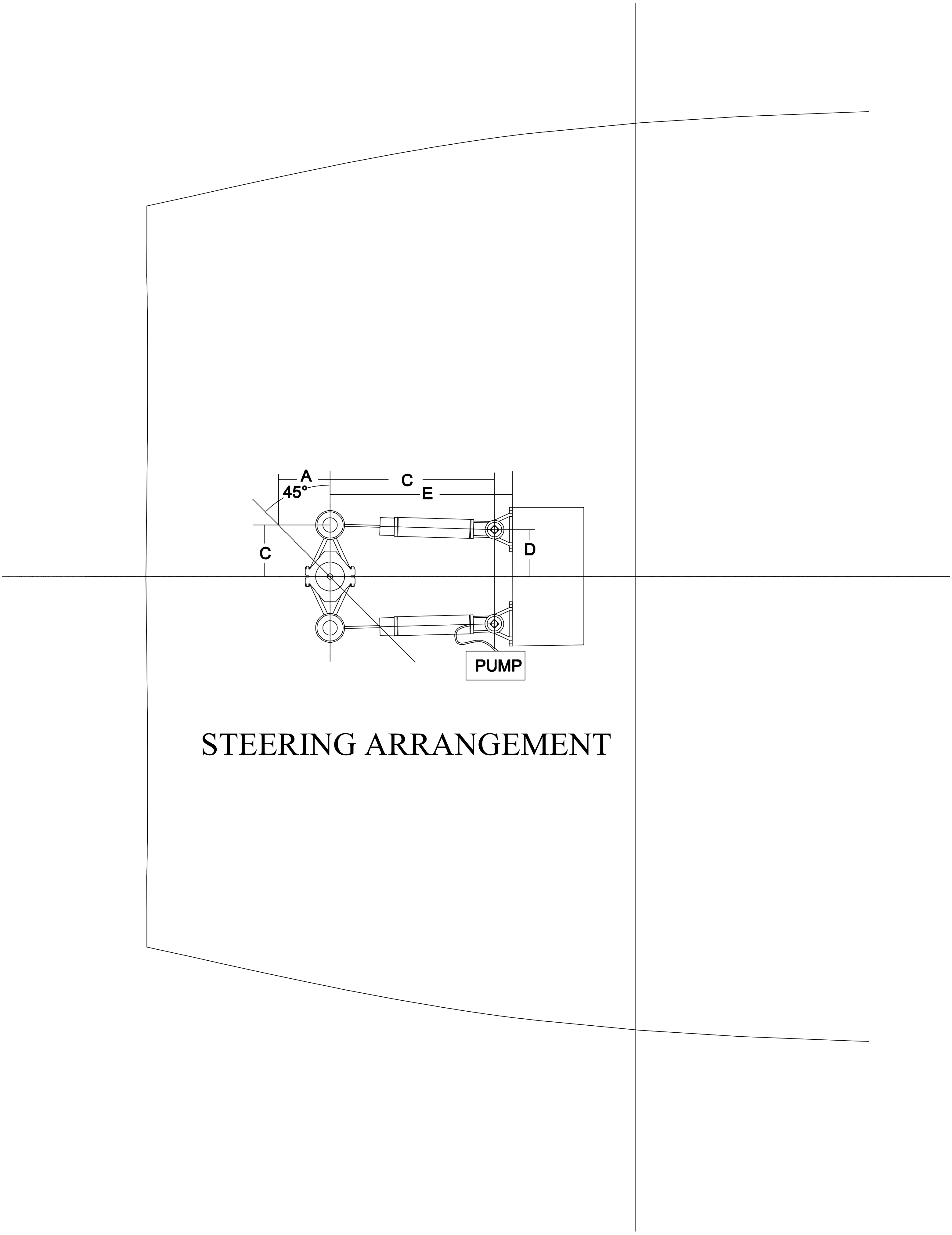
Particular	:	Value
Rudder Area, A	:	2×12.9 m^2
Aspect ratio, ⌢	:	2
Rudder Height, h	:	5.1 m
Rudder Breadth, b	:	2.53 m
Rudder Torque, O_r	:	2×264694 Nm
No of Bolt	:	6
Horizontal Web Thickness	:	0.756 m
Vertical Web Thickness	:	1.134 m

Rudder Parts	Material	Dimension (mm)
Rudder Stock Diameter	HTS LR EH-36	228.2
Coupling Flange Thickness	HTS LR EH-36	66.37
Coupling Bolt	HTS LR EH-36	73.7
Steering Type	HTS LR EH-36	Hydraulic
Web Plate	HTS LR EH-36	10
Rudder Plate	HTS LR EH-36	16.08
Pintle Diameter	HTS LR EH-36	539.4
Bush (Thickness)	HTS LR EH-36	13
Horizontal Web Thickness	HTS LR EH-36	756
Vertical Web Thickness	HTS LR EH-36	1134
Neck Bearing Height	HTS LR EH-36	973.04





Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



STEERING ARRANGEMENT

23 Engine and Gear Box

23.1 Engine Selection

Model: Mak 8M 43 C

Brand: Mak

Figure 7: Illustration of the Engine from the website

23.2 Engine Specification

Parameters	**:**	**Value**
Length	:	9,798 mm
Height	:	4,749 mm
Width	:	2,878 mm
Rated Power	:	8,000 KW
Rated Rpm	:	500
Emissions	:	IMO compliant
Rotation	:	Counterclockwise or clockwise
Dry weight (approx.)	:	114 tons
Fuel Consumption	:	175 gm/KW-hr

23.3 Gear Box Selection

Model: MG-514c

Brand: Twin Disc

Gear ratio: 1:4.17

Figure 8: External Illustration of gear box from the website

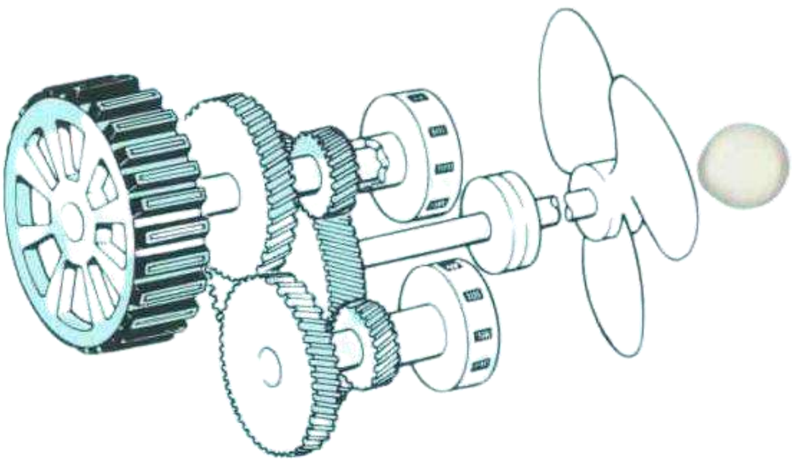


Figure 9: Internal Illustration of gear box from the website

23.4 Summary of Engine Scantling

ITEMS	**:**	**Dimensions**
Floor plate	:	13 mm
Inner bottom plating	:	18 mm
Longitudinal girders	:	26 mm
Foundation bolts	:	18 mm
Top plate dimension	:	100 cm
Web frame	:	$254 \times 343 \times 13$ mm

Scantling of Engine Foundation

Length	L	183.90	m
Breadth	B	23.50	m
Depth	H	14.5	
Total Power	P	8000.00	kW

The depth h of centre girder	h = Double bottom height	1410.00 mm	
Thickness of centre girder	t_m	14 mm	
	$c=1+(3.6+P/500)*10^{-3}$	1.02	
	$t_{pf}=t_m-2\sqrt{k}$	12	
Plate floor thickness	$t=c.t_{pf}$	12.24	
		13 mm	
Thickness of side girder	t=(P/1875)+20	24.27 mm	
		25.00 mm	
Thickness of inner bottom in way of engine seating		15 mm	
sectional area AT of the top plate	A =(P/75)+ 70 [cm]	176.67 cm^2	
Top plate thickness should be equal to diameter of bolt		18 mm	
Width of top plate		98.15 cm	
		100.00 cm	
Foundation bolt diameter(m35)	d	18 mm	D.4.1.4
spacing betweed bolts	3*d	54 mm	D.4.1.4
The depth of web frame for tarnsverse support h	50·H	725 mm	D.4.2.4
		250 mm	
The thickness of web frame for tarnsverse support t	t=h/32+0.03*h	13.49 mm	
		7 mm	D.4.2.4

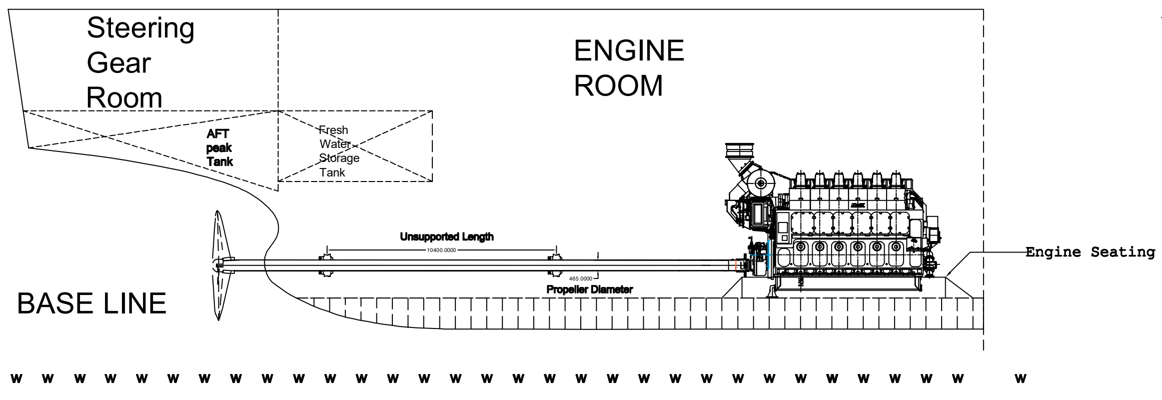
Brackets

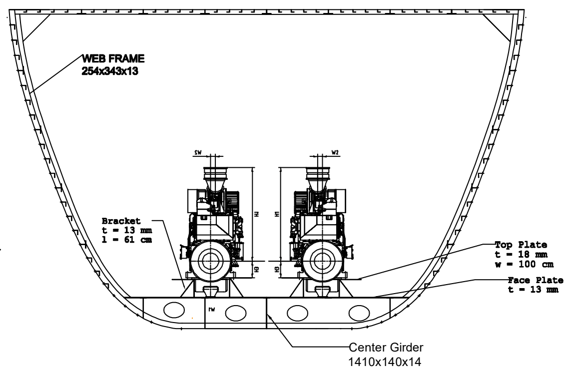
Thickness	$t = c*\sqrt[3]{(W/k_1)}+t_k$	12.58 mm
		13 mm
Arm length	$46.2*\sqrt[3]{(W/k1)}*\sqrt{k2}*c_t$	601.48 mm
		602 mm

c	0.95
W	2319.45
k_1	1
k_2	1
t_k	0

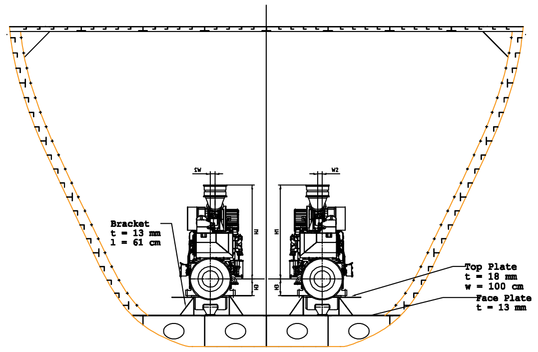
Engine Foundation Drawing

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones

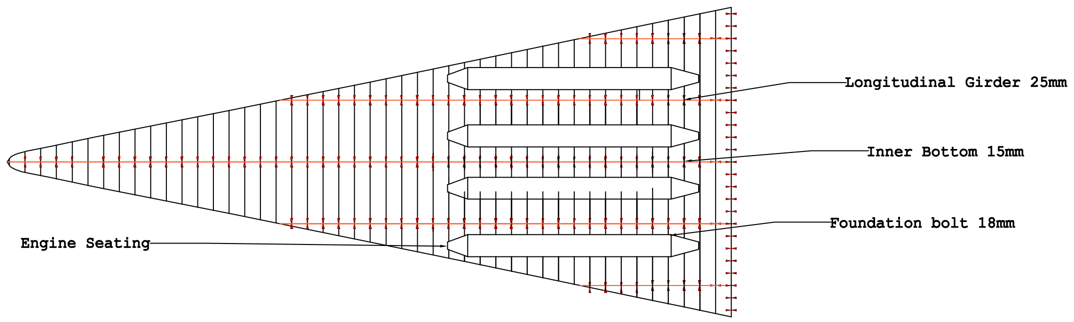




FRAME 47



FRAME 38(Gearbox)



24 Propeller Shaft Design

On the forthcoming pages, you will find an elaborate and comprehensive exposition of the propeller shaft calculation for the ship. This meticulous analysis delves into the intricate aspects of designing and evaluating the propeller shaft system, which is an essential component in the ship's propulsion system.

The propeller shaft plays a crucial role in transmitting power from the ship's main engine to the propeller, converting rotational energy into forward thrust, and propelling the vessel through the water. The efficiency and reliability of the propeller shaft system directly impact the ship's overall performance, maneuverability, and fuel consumption.

Shafting Calculation

L		180.9726	m
B		23.5	m
T		8.3	m
Δ		21708.70396	tonnes
ρ		1.025	tons/m3
ϑ		0.00000114	m2/s
∇		21179.22338	m3
CB		0.6	0.00
CM		0.97	0.00
CP		0.613	0.00
LBP			178
Depth	H		14.5 m

Engine power **P** 8000*2 kw

Engine power **P =** 8000 KW single engine

CALCULATION OF SHAFT DIAMETER (Using theoretical formula) :

Engine Speed 500 RPM

Gear Ratio 4.17

Propeller speed= Shaft Speed= **f** 119.9040767 RPM $\textbf{Shaft speed, f} = \frac{\text{Engine speed}}{\text{Gear ratio}}$

120 RPM

Torque, T $P \times \frac{60}{2\pi f}$ 636618.2837 N-m

Tensile strength 400 N/mm2

Allowable yield stress 200 N/mm2 200000000 N/m2

Working Stress **τ=Allowable stress/3** 66666666.67 N/m2

Now

$$\textbf{Stress, } \tau = \frac{TC}{J}$$

$C = d/2$

$J = \pi d^4/32$

Shaft Diameter, d = **(16*T/Π*τ)^(1/3)** **0.365017052 m**

365.0170523 mm

0.37 m

CALCULATION OF SHAFT DIAMETER (Using G L rule book)
Shaft Diameter:

F	100	
k	1.26	
Pw=power delevered by shaft	6000	kw
Cw	1	
n	120	rpm
di	1	
d	464.1879688	mm
	464.2	mm
Selected Propeller Shaft Dia	**464.2**	**mm**
	0.465	m

Twisting Angle :

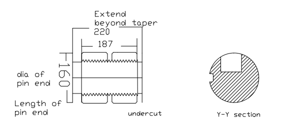
$$\theta = \frac{TL}{GJ}$$

Θ	1 degree		0.017452007 radian	max twisting angle
G		83000000000 Pa		
J		0.00459 m^4		
So, Unsupported length,L		**10.44376484 m**		
		10.4 m		
	(10.4 m por por sternpost dite hobe)			

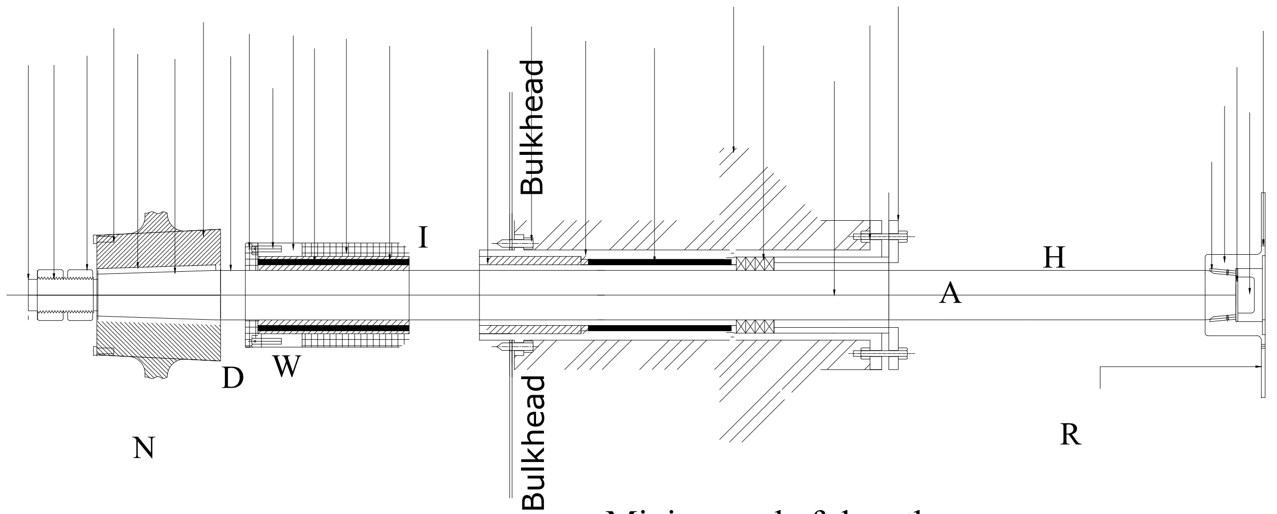
Minimum wall thickness of shaft liner :	21.426	mm
	21.5	mm

Thickness of coupling flange	92.84 mm				
lmax = Maximum permissible distance between bearings		7540.855389 mm			
		7.54 m			
Length of aft Stern Tube Bearing	1856.8 mm	1.8568 m			
Length of Forward stern tube bearing	696.3 mm	0.6963 m			
Shaft of Sir		shaft length	=	19150	mm
Total	16.73 cm	shaft dia	=	154	mm
Upto 4	2.83 cm				
ratio	0.169157203				
	3239.36043				
Shaft dia	0.74	0.081291094			
First portion	0.94	1556.724447			
ratio	1.27027027				
	195.6216216				
	0.038254632				
	732.5762104				

Principal Particulars	
LBP	178 m
BREADTH	23.5 m
DRAFT	8.3 m
DEPTH	14.5 m
Cb	0.6000
Displacement	21560 tones



Propeller Shaft End Detail
(Approved SAE dimension)



Minimum shaft length

SHAFTING ARRANGEMENT

LIST OF ITEMS

Sl. No.	Description	15	Stern Tube-fwd
1	PIN END	16	Jack Bolt
2	THREAD	17	Neck bearing Holder
3	PROPELLER LOCK NUT	18	Neck bearing
4	SECURING SCREW	19	Gland housing
5	PROPELLER KEY	20	Packing Gland
6	Taper	21	Gland nut
7	Propeller hub	22	Lock nut
8	SHAFT	23	Gland Locking Flange
9	Check ring	24	Propeller Shaft Coupling key
10	BOLT	25	Propeller Shaft Coupling
11	LOCKING RING	26	Backing washer
12	Shaft bearing	27	Coupling Nut
13	Bearing holder	28	Coupling bolt
14	Stern Tube-aft	29	Coupling Flange

25 CONCLUSION

Our main task in this course was to design a 1500 TEUs container ship capable of navigating the waterways from Chittagong to the Singapore port. We have successfully designed a vessel that meets all the requirements of the course task. Throughout the course, we encountered various difficulties, but with the guidance of our honorable teachers, we managed to overcome them. Their support has been invaluable and helped us numerous times.

During the course, we also acquired essential skills in using various software such as AutoCAD, Rhinoceros, MaxSurf, Microsoft Office, and Microsoft Excel, as they were necessary for our assignments. Additionally, we learned how to generate a ship from scratch and elaborate on various ship drawings, which were covered in design courses. However, one of the challenges we faced was the lack of integration among the design courses. The data from one course did not align with the others, which made it difficult for us to perceive the complete integration of all the drawings. Nevertheless, we persevered and completed the project, giving us a valuable glimpse into the vessel design process.

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