7354 Whitby Place
Delta, B.C.
Canada
V4C 4M7

6 June 2005

Mr. Alan Gilbert
ISWSCYDC Representative
133 Reid Ave.
Port Washington, NY 11050
U.S.A.

Dear Mr. Gilbert,

Re: University of British Columbia entry into the 2005 ISWSCYDC

Please accept our entry into the 2005 ISWSCYDC. The enclosed report, titled "Design of a Rescue Diver Deployment Vessel", details the design of a 17.25 m aluminum catamaran intended for use by a search and rescue dive team within the Georgia Strait. This report was completed as part of our four month mechanical engineering course titled MECH 441 – Computer Aided Ship Design.

Thank you very much for your acceptance, and we are confident that this report will meet your expectations. If there is anything more you require, please do not hesitate to contact us either by email at ubc_nav_arch@yahoo.ca, or by telephone at 604-418-9160.

Respectfully submitted,

Bill Rawlings

Joel Atwater

Encl. Faculty Letter, Report

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Mechanical Engineering
6250 Applied Science Lane
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-2781
Fax: (604) 822-2403

June 3, 2005

Mr. Alan Gilbert
ISWSCYDC Representative
133 Reid Avenue
Port Washington, NY 11050
USA

Re: Participation of the University of British Columbia in the 2005 ISWSCYDC

Dear Mr. Gilbert,

This is to confirm that Mr. Bill Rawlings, Mr. Joel Atwater, and Mr. Koyla Harpe, are students enrolled in the Mechanical Engineering Undergraduate Program at the University of British Columbia. These students have been enrolled in our four-month course, MECH441 – Computer Aided Ship Design, which began in January, 2005. Their design project, *Rescue Diver Deployment Vessel,* is to be submitted to the 2005 ISWCCYDC competition.

Since Prof. Sander Calisal is attending conferences in Europe, I am writing this letter on his behalf. Dr. Calisal and I share teaching duties for the UBC Naval Architecture courses and I participate in the ME441 course as an evaluator. If you require further information, please do not hesitate to contact directly at (604) 822-2709 or mikk@mech.ubc.ca.

Sincerely,

Jon Mikkelsen, P.Eng.
Instructor
Naval Architecture

Design of a Rescue Diver Deployment Vessel

Prepared in fulfillment of the requirements for the

International Student Workboat/Small Craft/
Yacht Design Competition

Prepared by:

Joel Atwater Kolya Harpe Bill Rawlings
University of British Columbia
Vancouver, Canada

Submitted to:

Mr. Alan Gilbert
Society of Naval Architects and Marine Engineers

6 June 2005

Abstract

There have been a number of recent tragedies on Canada's Pacific Coast in which people have drowned while trapped in vehicles or boats. In these circumstances, the presence of a rapidly responding search and rescue dive team is invaluable.

Investigation of the dive teams operating in the south-coast region of British Columbia found that the teams were operating using generic, multi-role without specific features like onboard compressors that could have been a great asset. The design of a dedicated, high speed response boat would allow the dive teams to operate more effectively and could potentially save lives.

The design proposed is for a Rescue Diver Deployment Vessel (RDDV), a high speed, 17.25m aluminum catamaran specifically designed with the rescue diver in mind. The vessel will be powered by twin MAN 1300BHP marine diesel engines driving Wärtsilä-Lips water jets, this vessel is capable of 45 knots in calm water.

There are several integral systems included specifically to support the dive team. The most important of these is the high pressure compressor that is capable of filling empty SCUBA tanks or supplying air to submerged divers. In addition, there will be a cascade system for air handling. Finally, there is a victim lift installed in the stern between the hulls. This device facilitates moving equipment and divers in and out of the water as well as recovering victims quickly and easily.

Due to the nature of rescue diving operations, there is a need for onboard medical facilities. The design of the ship fully provides for the electrical communication, storage, space and environmental requirements of a sickbay. There is ample room to move victims onboard and to rapidly disembark. The vessel is also arranged to facilitate evacuation of victims by air ambulance off the aft deck.

The lack of dedicated vessels leaves the dive teams without the equipment to do their job as effectively as possible. If the agencies that protect the public invest in dedicated dive team search and rescue vessels, there could potentially be an increase in the teams effectiveness, perhaps saving lives.

Acknowledgments

Very special thanks to:

Jon Mikkelsen, UBC

Dr. Sander Calisal, UBC

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Hans Muhlert, Robert Allan Ltd.

Chris Mulder, Robert Allan Ltd.

Dan McGreer, Aker Marine

Mike Wadden, Aker Marine

Milen Handjiyski, Aker Marine

Mark Cooke, Aker Marine

Alan Reynolds, Offshore Research

Bob Ayres, John Palliser, and Drew Edey, Canadian Coast Guard

RCMP E Division Recovery Dive Team

Doug Jimmo, Canadian Navy Search and Rescue Dive Team

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Glossary

ABS	American Bureau of Shipping
ITTC	International Towing Tank Conference
PNA	Principles of Naval Architecture
RAO	Response Amplitude Operator
RCMP	Royal Canadian Mounted Police
RDDV	Rescue Diver Deployment Vessel
RIB	Rigid Inflatable Boat
SCUBA	Self Contained Underwater Breathing Apparatus
SWATH	Small-Waterplane Area Twin-Hull

1 Introduction

In August of 2002 the Cap Rouge II, a small, Steveston, BC based fishing vessel capsized in the lower Fraser River, killing five people. The tragedy acutely showed the importance of a rapid response dive team on Canada's west coast.

Presently, there are three dive teams operating on Canada's Pacific coast: the Navy and Coast Guard search and rescue dive teams and the Royal Canadian Mounted Police E-Division Recovery Team. While these teams are extremely well trained, the vessels that are presently being employed are not specifically designed for diving work; the specialized units are using multi-role vessels that were not designed to suit the specific needs of an underwater operation.

It is believed that there is a need for a dive tender that is capable to quickly respond to marine emergencies where people are trapped beneath the water's surface. As such, the Undergraduate Naval Architecture team from the University of British Columbia proposes the design of a high speed Rescue Diver Deployment Vessel (RDDV). This vessel design is to be entered into the International Student Workboat/Small Craft and Yacht Design Competition in June 2005.

2 Owner Specifications

The following specifications were the basis for the design of this vessel. They were developed through discussions with the RCMP, Navy and Coast Guard Dive Teams.

2.1 Vessel Specifications

Range	Typical	120	NM
	Maximum	320	NM
Speed	Calm Water	40	knots
	All Conditions	20	knots
Length	Maximum	70	feet
	Minimum	50	feet

- Classed under ABS Regulations.
- Allow for easy recovery of divers.
- Provide sufficient deck space for providing critical victim stabilization after recovery.
- Allow for the easy transfer of victims to shelter/hospital area.
- Provide means for victim evacuation by Air Ambulance.
- Be able to support multiple divers as they conduct recovery operations.
- Have minimal draft to access shallow areas.

2.2 Diver Support Specifications

- Installed and plumbed high pressure air compressor capable of supplying submerged divers and filling used SCUBA tanks.
- Available facilities and supplies to rinse diving gear with fresh water.
- Ability to deploy a 12 to 16 foot Rigid Inflatable Boat (RIB).

2.3 Medical Equipment Specifications

- Provide sickbay area for a minimum of two victim stretchers and sufficient room to perform Cardiopulmonary Resuscitation.
- Good lighting and ventilation in sickbay.
- Provide Sufficient oxygen supply for victim care while in transit to the hospital (K-Sized Cylinder or equivalent). Should include Humidification for extended transit times.

- Communications equipment in Sickbay for immediate contact with on shore medical services
- Provide sufficient storage space for medical assessment equipment (Blood pressure cuff, stethoscope, tympanic thermometer, etc)
- Provide storage facilities for rewarming equipment such as wool/fleece blankets and rechargeable hot packs

3 Design Focus Areas

All the relevant aspects off the RDDV were addressed in the design process. These include the general hull form, vessel lines, the general arrangement, seakeeping, vessel weight, resistance, powering, machinery, electrical loading, diver support, tank capacities, stability, structure, scantling strength and cost.

3.1 Vessel Particulars

Table 1 below illustrates the final vessel particulars. The following discussion outlines the design process used to arrive at these specifications.

Table 1: Summary of Vessel Particulars

Dimensions	
Water Line Length	16.4m
Length Over All	17.25m
Beam	6.75m
Draft	0.70m
Displacements	
Lightship Weight	24280kg
Fully Loaded Weight	28809kg
Performance	
Maximum Speed	45knots
Cruise Speed	20knots
Operating Range	320NM
Endurance at 40knots	8.4hours
Miscellaneous	
Crew Complement	8

3.2 General Hull Form

Several hull forms were considered for the RDDV including SWATH, catamaran, planing and displacement mono-hull and hovercraft. The considerations regarding hull form choice are discussed below:

1. There is a requirement for very high speeds to quickly reach the scene of marine emergencies. The hull forms that meet this requirement are a planing mono-hull, a catamaran, hovercraft and a SWATH. A displacement hull would require a vessel that was too large to be practical or cost effective.

2. As most marine emergencies occur in high sea-states, the vessel must perform well in rough water. Planing mono-hulls typically perform poorly in heavy sea states.

3. The requirement to able to be operate in shallow water requires a vessel of minimal draft. The nature of SWATH prohibits the use of the hull form for this application.

4. Through discussion with the Coast Guard it was noted hovercraft have some difficulty maintaining position drift during diving operations.

A catamaran provides an excellent balance of high speed and low draft characteristics while providing excellent stability during diving operations. In addition, catamarans provide several other advantages. They typically have up to 40% more usable deck area compared to other ships of the same length. Catamarans also typically operate at higher power to weight ratio than mono-hulls.[1] For these reasons, a catamaran was selected as the optimal hull form for the RDDV.

3.3 Lines Plan

The lines plan for this vessel was generated using the AutoShip modeling package, and exported to AutoCAD for plotting. The vessel form was finalized after many iterations of the powering calculations examining hull spacing, etc with a final frame spacing of 0.8625m. A few points of consideration include the hard chine to aid vessel planing, and the varying freeboard along the length of the vessel. At the aft end of the vessel minimal freeboard was given to facilitate easy water entry and exit. Closer to the bow of the vessel, greater freeboard was allotted to aid in seakeeping and operation in rough seas.

Rhinoceros 3d was used to verify that all hull plates are fully developable for ease of manufacturing. Figure 1 below illustrates a simplified lines plan, while a more detailed lines plan may be found in Appendix A. Figure 2 below displays the green developable surface plot.

[1] Allan, R.G. "Application and Advantages of Catamarans for Coastal Patrol Vessels". Marine Technology, April 1996

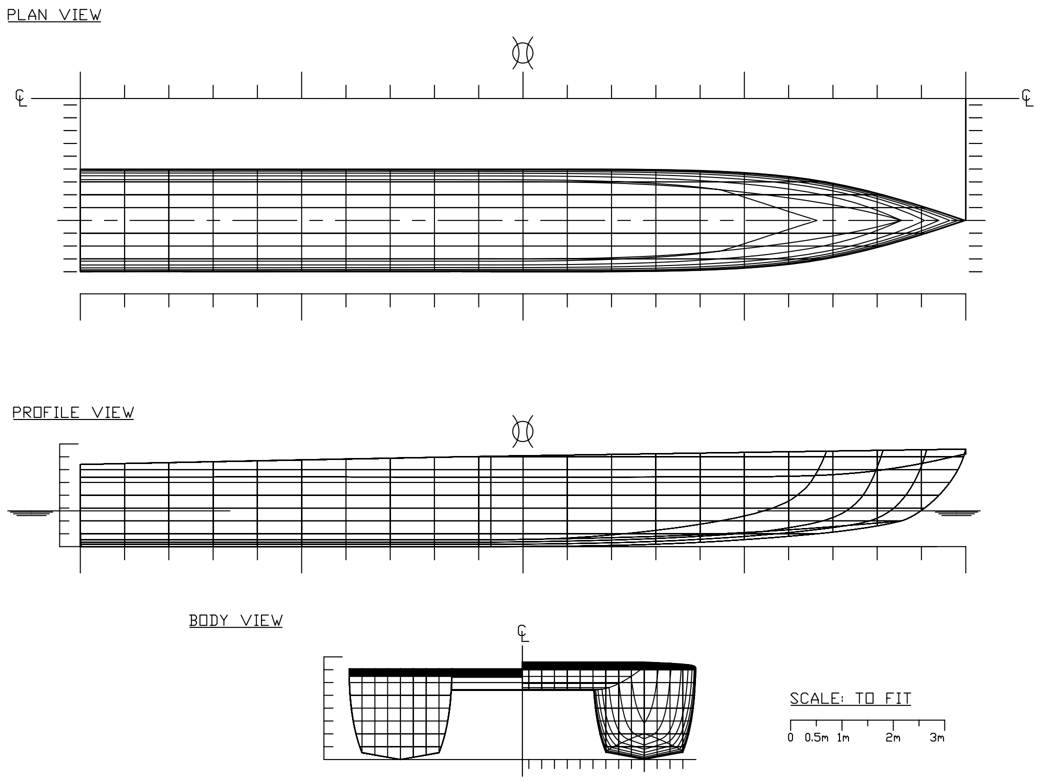


Figure 1: RDDV Lines Plan

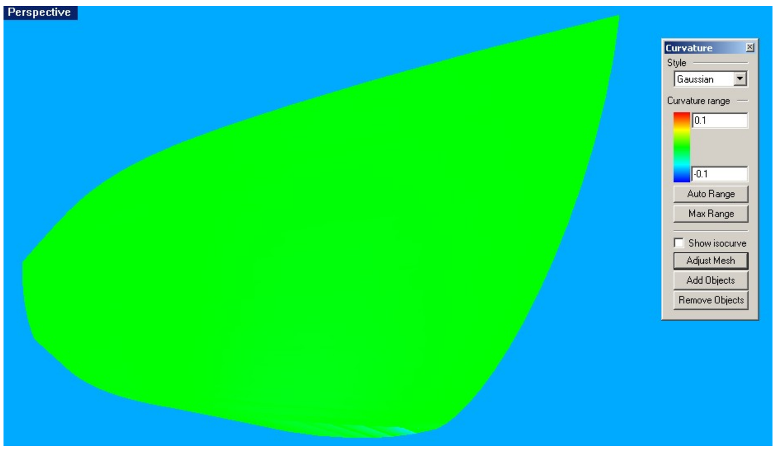


Figure 2: Plot of Developable Surfaces

3.4 General Arrangement

The first consideration when developing the general arrangement was that the deck needed to be sufficiently large to allow diving activities, stretcher maneuvering and to support a recovery lift. Within the main cabin (Figure 3) is a hospital area with sufficient storage for medical equipment, a galley space, and a water closet. Additionally, the helmsman must have good visibility to monitor activities in the water at the stern of the vessel and the ability to maintain adequate lines of sight to the front of the vessel for docking and maneuvering in close quarters. These tasks were accomplished by having an elevated wheelhouse accessed by either stairs from the aft deck, or by a ship ladder from within the main cabin.

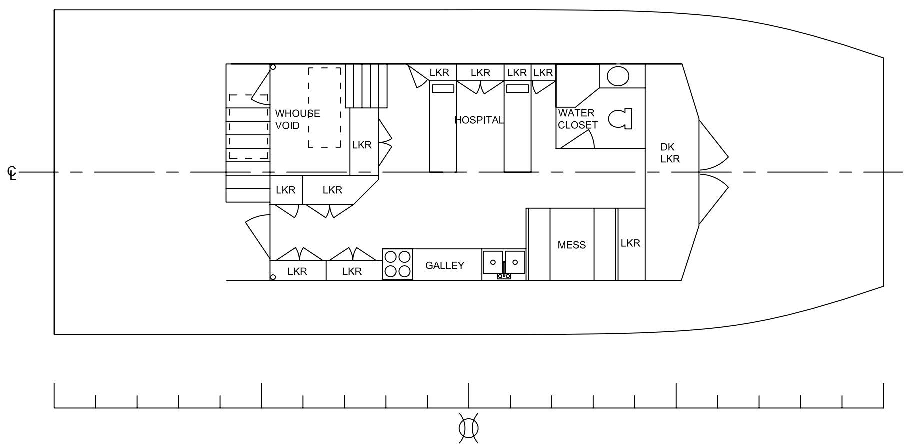


Figure 3: Cabin General Arrangement

The aft windows on the wheelhouse are angled towards the stern of the vessel (Figure 4) to allow for unobstructed viewing of the working deck. The elevated wheelhouse provides excellent lines of sight towards the front of the vessel, while creating space to store the air compressor and cascading storage system beneath the stairwell and wheelhouse respectively.

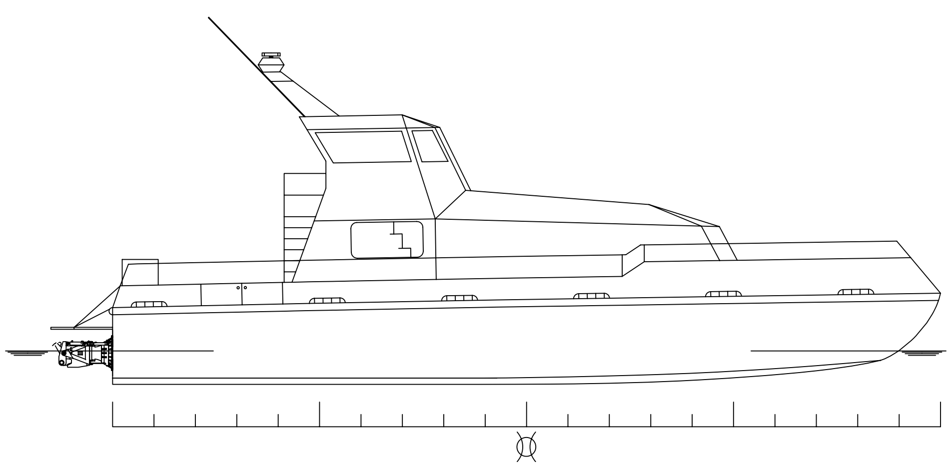


Figure 4: Profile View

The pilots's seat is located along the centerline of the vessel, (Figure 5) further improving visibility. Storage in the wheelhouse is located on the chart table, in drawers beneath the chart table, and in small shelves along the back of the helm, chart table, and wheelhouse. Additionally, having the main cabin entrance pass beneath the chart table in the wheelhouse creates a corridor sufficiently wide to maneuver a stretcher into the main cabin. Lastly, it is recognized that the term chart table is used loosely as the use of paper charts is virtually obsolete; this space may be instead used for liquid crystal display monitors, etc.

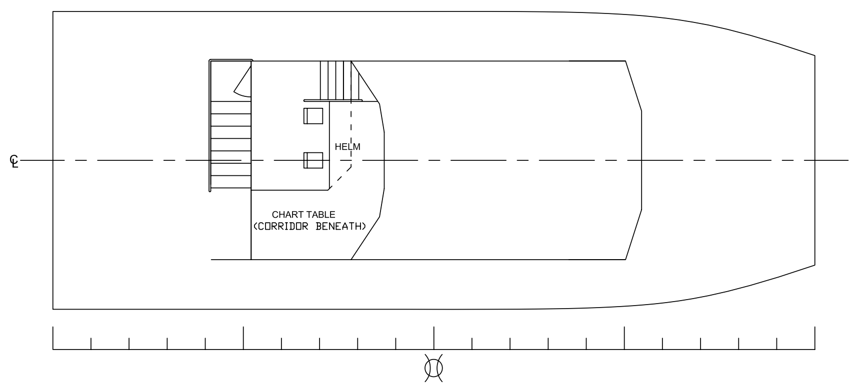


Figure 5: Wheelhouse General Arrangement

On the port side of the main cabin is the hospital area (See Figure 3) with space for two stretchers (capable of being airlifted). Between the stretchers, cabinet space is provided for oxygen canisters and masks and a wall-mounted suction unit. Additional cabinets for other medical equipment such as an automated external defibrillator, airway gear, blankets, and ventilator are located beside each stretcher and in the wheelhouse void next to the air storage system. Beside the hospital area is a water closet containing a head, sink, and shower. On the starboard side of the main cabin are additional storage cabinets, and a mess and galley area. Additional storage space is provided at the forward wall of the cabin, ahead of the mess area.

Outside of the deckhouse, diver tank storage is provided along the port side (Figure 6). Other dive-specific equipment includes a plumbed air status monitoring panel on the aft face of the stairwell leading to the wheelhouse, deck lockers for storage of hose used to breathe surface air, and sufficient freshwater and drainage to rinse equipment. The recovery lift is centered on the stern of the vessel (Figure 7) and is large enough for an emergency stretcher. It employs a four-bar linkage system so as to always remain parallel to the deck for simple loading, and is operated at the air status monitoring panel by two winches. To further facilitate diver entry and exit (in addition to the lift), access to the swim grids is provided by gates in the bulwarks. Additional bulwark gates for boarding and disembarking the vessel are fitted at the sides of the aft deck. There is a small RIB for use in areas the primary vessel cant access stowed on the foredeck. Anchors are stowed on the port side of the fore and aft deck. In addition to holding the vessel in place, the aft anchor may be used as a descent line for divers.

Appendix B contains all general arrangement drawings for this vessel, as well as rendered images of the 3-D model. Lastly, it should be noted that all doorway, stairwell, and accommodation, etc. dimensions were specified according to the *ABS Guide for Crew Habitability on Offshore Installations*.

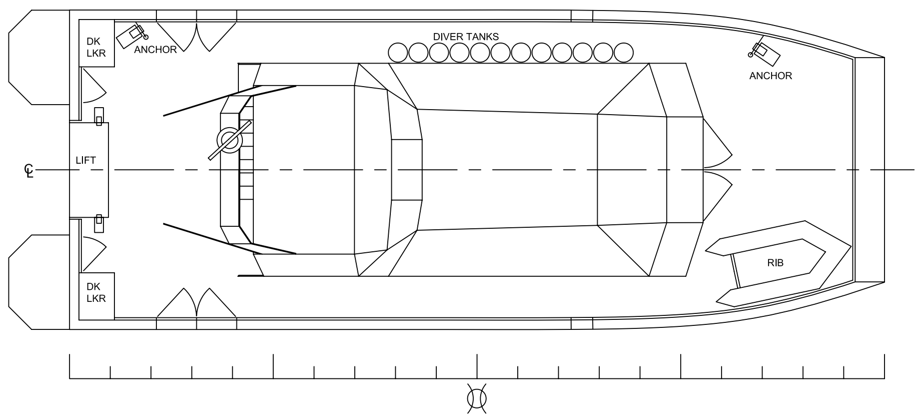


Figure 6: Deck General Arrangement

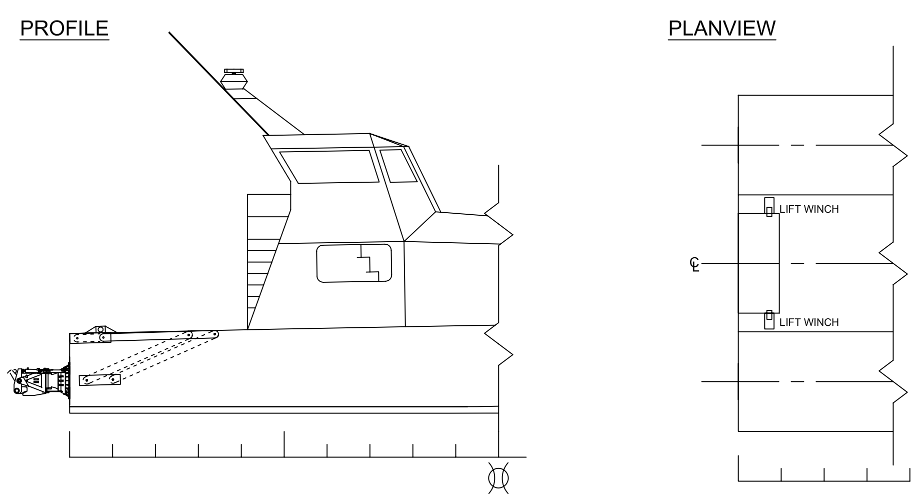


Figure 7: Lift Arrangement

3.5 Structural Analysis

3.5.1 Longitudinal Hull Strength

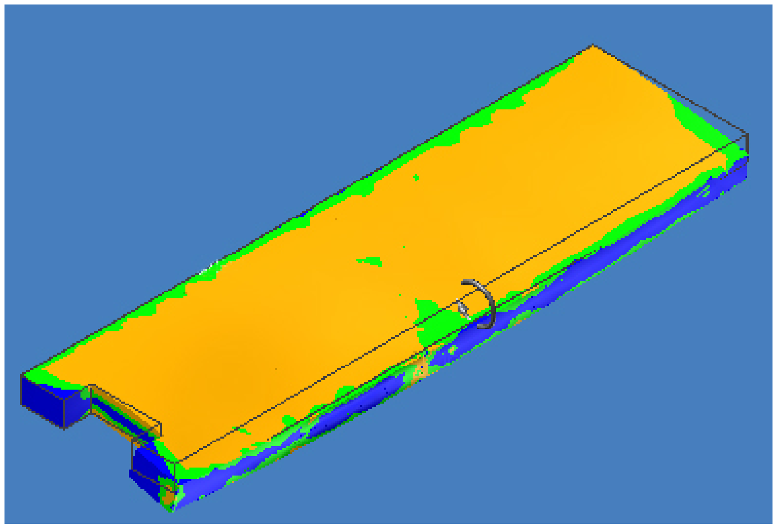
The longitudinal hull structure was analyzed according to the *ABS Guide for Building and Classing High Speed Naval Craft 2003*. The hull scantlings were specified using the ABS rules (See Section 3.6), and then the required section modulus based on the vessel speed and dimensions was obtained. Using this required section modulus, ABS specified a minimum vessel moment of inertia of $31in^2 \cdot ft^2$. Using a scale drawing and the known scantlings, the actual inertia of the vessel was calculated to be $1085in^2 \cdot ft^2$ in AutoCAD. This demonstrates that the RDDV satisfies the ABS requirements for longitudinal hull girder strength. All supporting calculations may be found in Appendix C.

3.5.2 Wet Deck Hull Strength

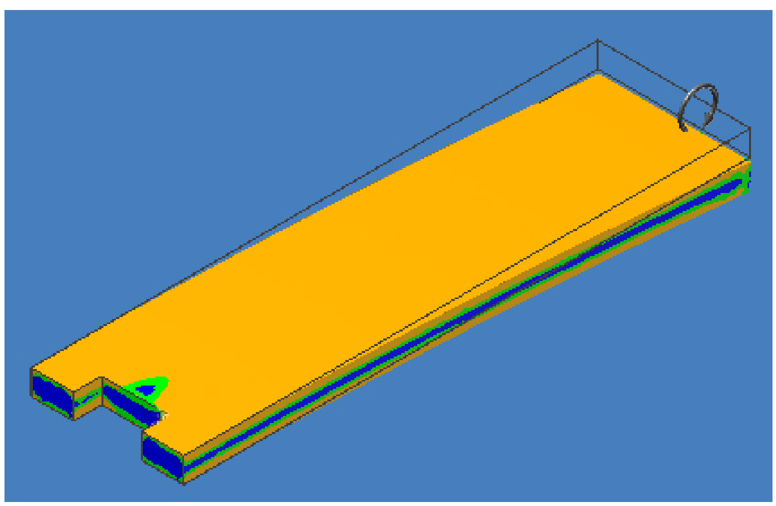
The structure of the wet deck was analysed according to ABS rules. Using tabulated accelerations and vessel parameters the maximum bending moments and shear stresses were found. See Table 2. The wet deck structure was modelled in AutoDesk Inventor with conservative plate thickness of 3.66mm. This solid model was analysed using ANSYS, a commercial Finite Element Analysis (FEA) package. Using FEA, the stress concentrations caused by the lift platform at the stern can be taken into account. Figures 8a and 8b show the effective stress throughout the wet deck in transverse and longitudinal bending. It should be noted that the deflections shown are exaggerated for ease of visualization. Using the bending moments predicted by ABS codes, there were no significant stresses present in the wet deck structure.

Table 2: ABS Bending Moments

Parameters			Calculated Values		
K_1	2.5		M_{tb}	1378	*kN-m*
K_2	1.25		M_{tt}	2429	*kN-m*
Δ	29	*tonnes*	Q_t	290	*kN*
B	4.75	*m*			
L	16.75	*m*			
n_{cg}	3				



(a) Transverse Bending



(b) Longitudinal Bending

Figure 8: Effective Stress in Wet Deck

3.6 Scantling Calculations

The vessel has been designed to satisfy *ABS High Speed Naval Craft Rules 2003*. 5083 H116 aluminum was selected for construction as aluminum is a lightweight material; the 5083 H116 alloy has proven to be a reliable, corrosion resistant solution. In Figure 9, both a typical midship and bulkhead section are shown as specified by the classification society. Though the majority of the design has been conducted in SI units, the dimensions shown below have been selected to coincide with common imperial dimensions for convenient purchase in North America. A larger drawing may be found in Appendix D.

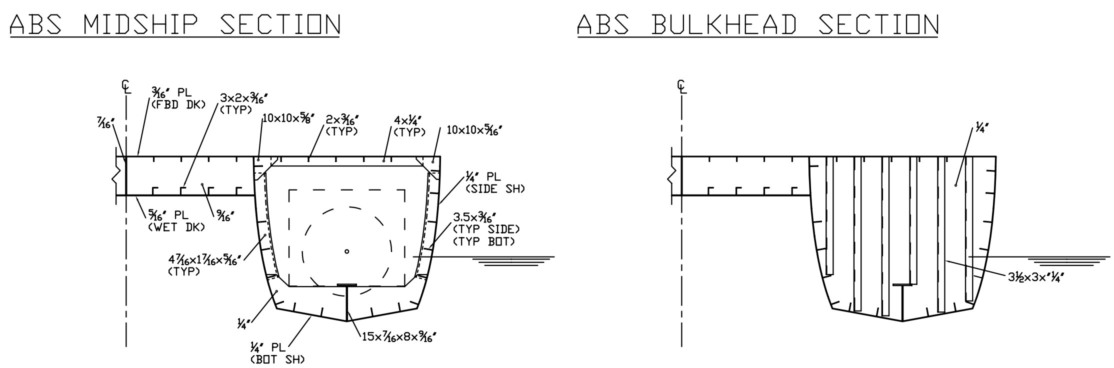


Figure 9: Midship Section

The bottom and side shell plate thicknesses have been increased by 58% above the required rule thickness (from 4 mm to 6.35 mm, or 1/4 inch). The freeboard deck was increased to 36% more than the required value, while the wet deck was increased by 14%. In general, the superstructure plate thicknesses were increased by 30%, while most stiffeners and transverse members were simply increased to the next convenient imperial size. All supporting calculations may be found in Appendix D.

3.7 Weight Estimate

The weight estimate was completed using a commercial spreadsheet package. The structural weight was calculated on a frame-by-frame basis. Frames zero through five contain a 10% margin for extra structure in way of the recovery lift, water jets and engines. Table 3 below summarizes the weights by category and displays the vertical, longitudinal, and transverse centres of gravity for the vessel. Appendix E contains the detailed weight estimate.

As expected, the major contributing factors to the weight of the vessel are the structure and machinery. It should be noted that the machinery weights for this vessel are a much larger proportion of the weight compared to other vessels of this size. This is largely due to the specific requirements of the craft, such as the air compressor and water jets. Lastly, it should be noted that the lightship weight may be obtained simply by subtracting the tank weight from the Total Weight in Table 3.

Table 3: Summary of Ship Weights

Structure	11400	kg
Machinery	7359	kg
Tanks	4530	kg
Electrical	949	kg
Other	3200	kg
Margin	1372	kg
Total Weight:	28809	kg
VCG	1.46	m
LCG	7.26	m
TCG	0.05	m

3.8 Resistance and Powering

The resistance of the RDDV was calculated using Michlet, a potential flow solver. Michlet requires an input file to specify the geometry of the vessel and a file specifying all the constants. The geometry file can be created by projecting points onto the half hull surface and outputting their coordinates. The coordinates are then organized in a comma separated file to provide the half breadths of each station in a single line (the number of lines is the number of stations). The input file specifies the number of stations and waterlines as well as the draft and length of the vessel. From these values, Michlet generates a hull form assuming linear sections between each point. The hull spacing, displacement, number of hulls, speed range, trim angle, and heave can also be specified in the Michlet input file. Michlet was also used to optimize the hull spacing and reduce any wave superposition effects. At cruise speed, there is no cross wave/hull interaction and the wakes from the two hulls do not interact until 25m aft of the vessel. This analysis allows for a reduction of wave superposition effects and, by extension, reduces erosion of shorelines due to the vessel's wake, reducing the overall environmental impact.

The trim angle and heave at each speed as the vessel begins to plane were calculated using formulas developed by Savitsky, available in PNA. These formulas and the geometry of the vessel were put into an Excel spreadsheet and the trim angle and heave were calculated at 10 speeds between 1 and 49 knots. The change in trim and heave can be seen in Figure 10. With all the values specified in the input file, Michlet solved the far field wave pattern to determine the wave resistance on the hull. Figure 11 represents the wave patterns at 20, 30, 40 and 50 knots.

The skin friction is solved using the ITTC57 method. The wave, friction, total resistance, and power curves can be seen in Figures 12 and 13. Correlating the resistance from these curves into horsepower, it was found that the total required horsepower (EHP) was approximately 1330hp at 45 knots.

In addition to the frictional and wave resistances calculated in Michlet, the air resistance for the deck house was also considered. The air resistance at 45 knots corresponds to 125Hp. To calculate the air resistance it was assumed that the deck house was a blunt body with a coefficient of drag

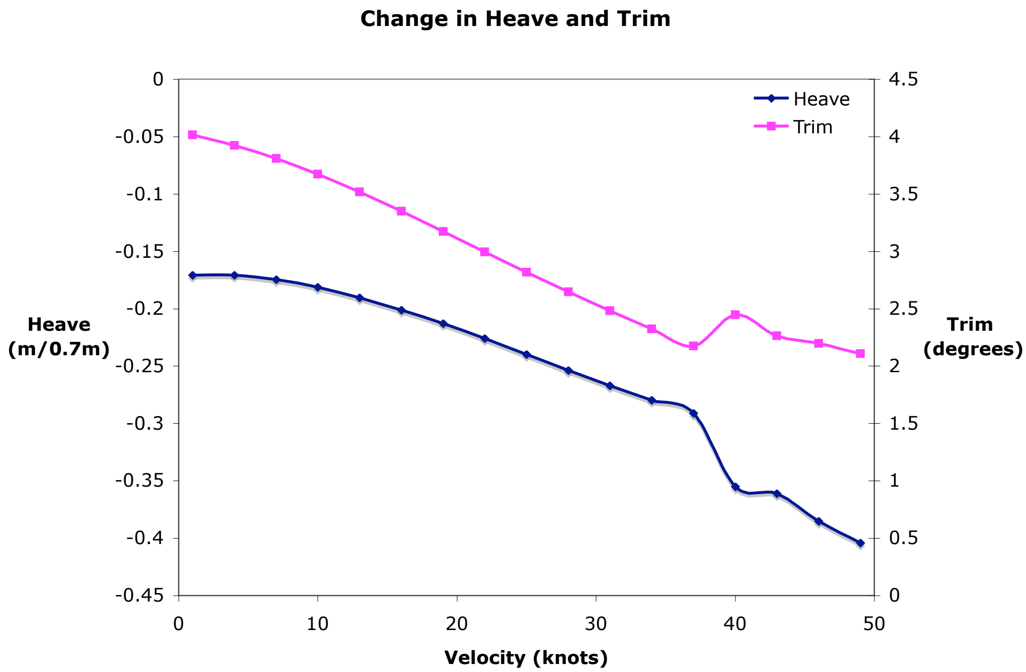


Figure 10: Heave and Trim vs Velocity

of 0.96 based on frontal area. This drag coefficient was derived for a tractor trailer unit; the shape of the deck house was assumed to be geometrically similar to that of a tractor trailer. Note that all resistance calculations may be found in Appendix F.

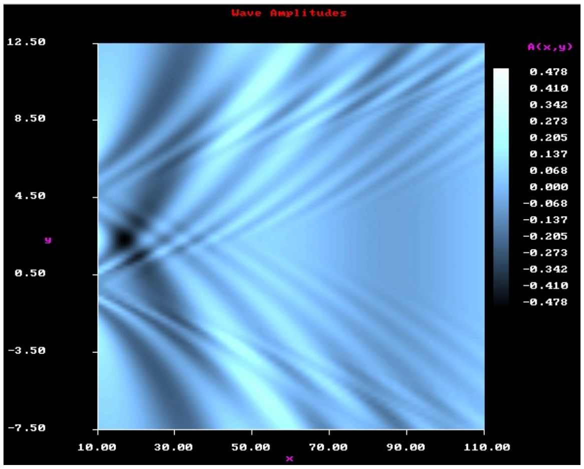
Due to draft requirements and safety concerns with divers in the water, the RDDV is fitted with water jets. The jets to be used were sized based on charts available online from the manufacturer, Wärtsilä-Lips. Figure 14 shows the plots available to determine the water jet size[2]. At an EHP of 1300HP and a ship speed of 45knots, the line above the intersection of the power and design speed allows the selection of the LJ43E.

Through discussions with a representative from Wärtsillä-Lips, the water jets are expected to perform with an efficiency of 69.3% at 45 knots. The water jets are directly driven by the engines, therefore a shaft efficiency of 95% is expected. Combining the EHP, air resistance and total efficiency yields a total engine power of approximately 2200HP.

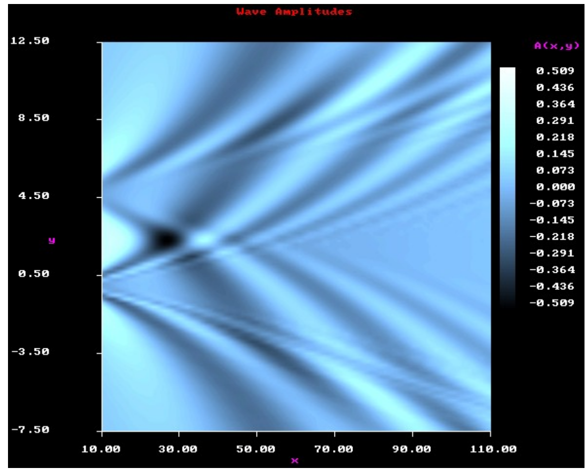
Several engine manufactures were considered including MAN, Caterpillar and Detroit Diesel. Given that this vessel is semi-planing, the weight of the engines was primary concern so the lightest engines that met the power requirements were examined. The specifications of the engines considered are summarized in Table 4.

MAN Marine D2842LE404 Diesel engines were chosen because of the weight savings compared to the Caterpillar and Detroit Diesel engines. In addition, these engines are specifically designed for non-continuous duty in high speed response boats. The manufacturer specifies 1000 hours of running per year, which corresponds well to a midlife refit after 15000 hours, given an approximate

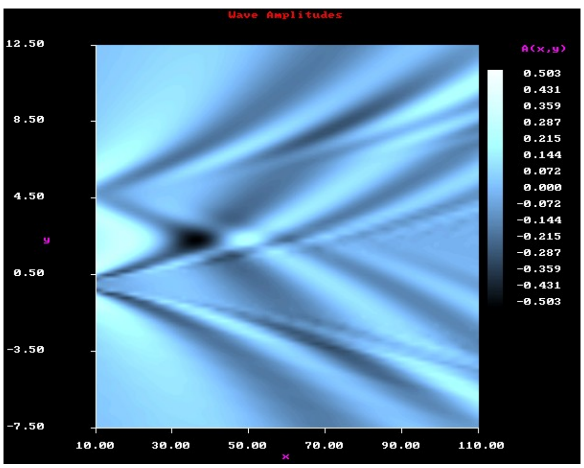
[2]http://www.wartsila.com/wartsila/docs/en/ship_power/media_publications/brochures/product/propulsor/lips_jets.pdf



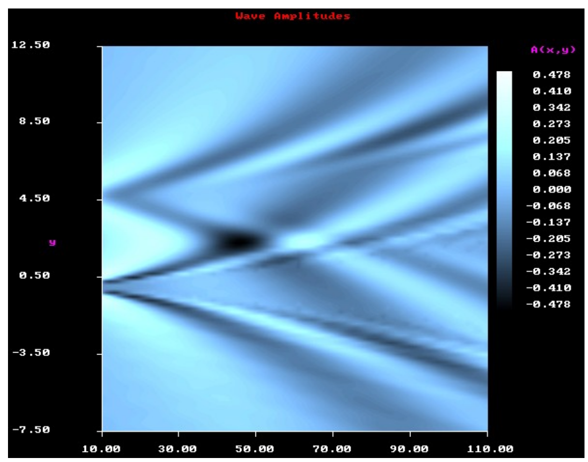
(a) 20 knots



(b) 30 knots



(c) 40 knots



(d) 50 knots

Figure 11: Wave profiles for 20, 30, 40 and 50 knots

vessel llfe of twenty-five to thirty.

The MAN engines produce a 400BHP surplus, which allows for future alterations to the vessel and accounts for weight creep. In addition, one can expect increased reliability from the engines if they are not run at their maximum output capacity.

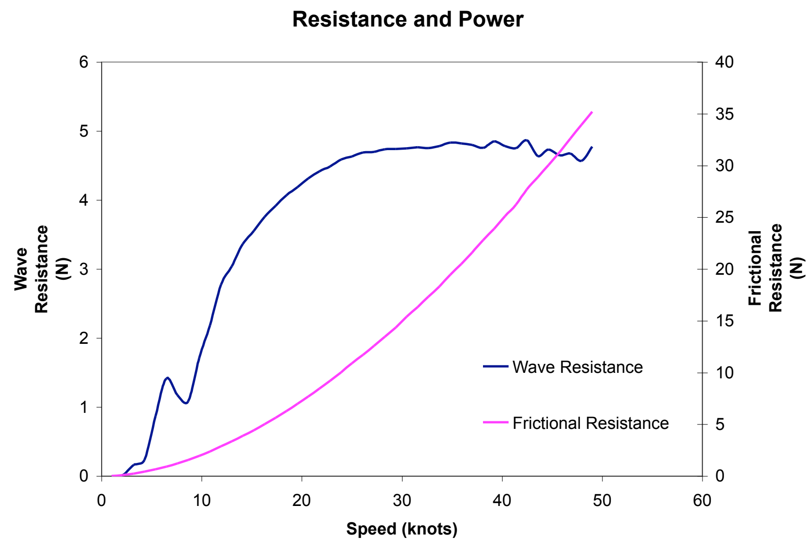


Figure 12: Wave and Frictional Resistance vs Speed

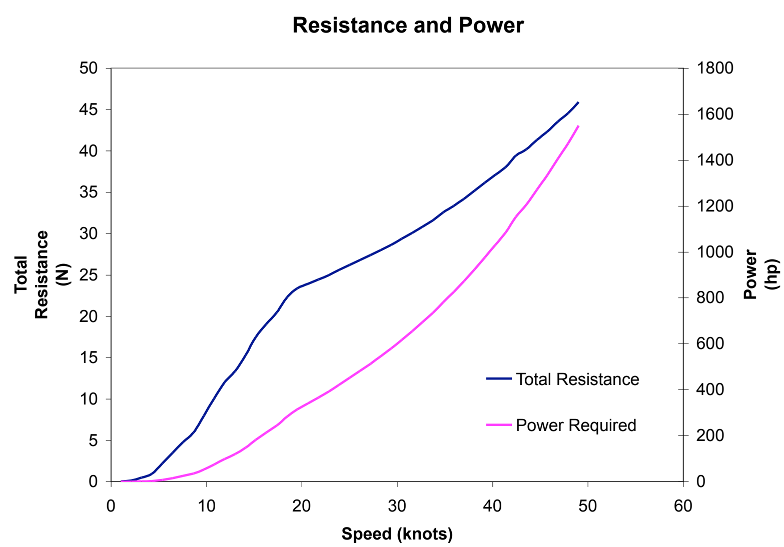


Figure 13: Total Resistance vs Speed

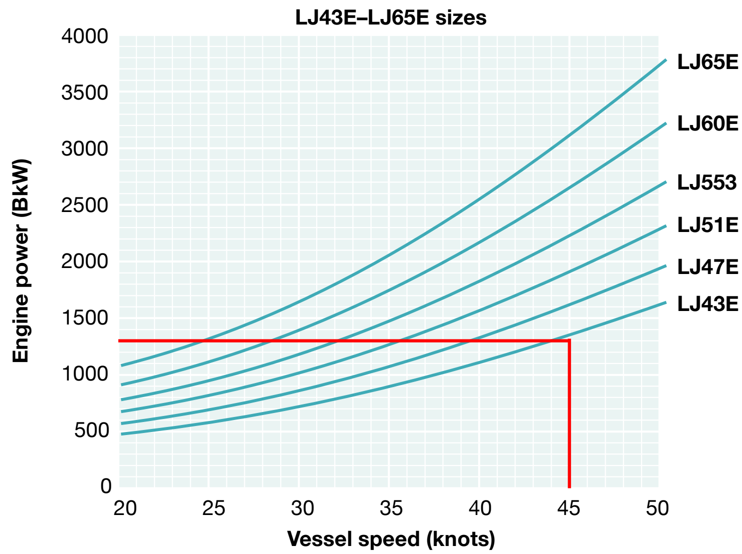


Figure 14: Jet Selection Chart

Table 4: Engine Specifications

Engine	Power Output (HP)	Weight (lb)
MAN D 2842 LE 404EDC	1282	3905
MAN D 2842 LE 407	1187	4092
Detroit Diesel 16V200M7	1225	5190
Caterpillar C32	1401	5617

3.9 Stability

Calculations supporting the following stability discussion may be found in Appendix G.

3.9.1 Intact Stability

The RDDV stability was tested in two conditions:

1. Light ship with no fluids on board
2. Fully loaded departure condition

For obvious practical reasons, the vessel is not expected to operate in a light ship condition (no fuel or water onboard the vessel). The vessel was not tested in a fully loaded arrival condition as there is no significant cargo to be carried, the majority of the fresh water used is to be captured in sewage tanks (environmental), and fuel used is to be offset with salt water ballast. As such, only the fully loaded departure conditions were analyzed.

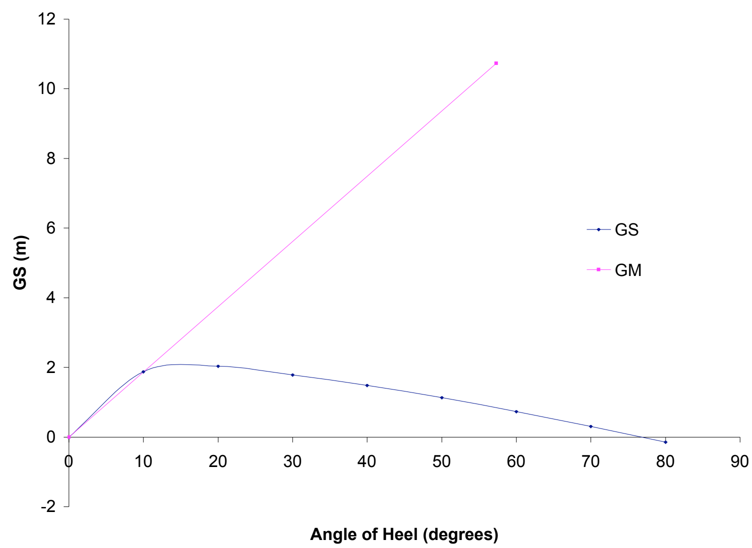
Stability of a vessel is a function of the GM value and the GZ curve. In order to generate both these, the Cross Curves of stability, assuming a VCG of $1.46m$ and $1.54m$ were first generated for displacements ranging from 28.2 to $10.8MT$ and from 0 to 80 degrees. Using the estimated light ship weight of $25.3MT$ and loaded ship of $28.5MT$ the righting arm curve can be generated from the cross curves. Figure 15a shows the real righting arm curve for the light ship condition and Figure 15b shows the righting arm for the loaded condition

One of the requirements of the RDDV is that the vessel must be capable of withstanding up to Hurricane (Beaufort Sea State 11) conditions. A storm not at the level of a hurricane is assumed to have a wind speed less than $63knots$. In order for the vessel to pass the *ABS High Speed Naval Craft* Stability Requirements the intersection between the wind heeling arm and the GZ curve must be less than 60% of the maximum GZ value. The positive area between the wind heeling arm and the GZ curve must be 1.4 times greater than the area from the intersection to from the intersection 25 degrees negative, and the intersection point of the two curves must be at an angle less then 10 degrees. The RDDV passes the stability requirements for wind heeling moments in both light ship and loaded ship conditions. The plot of the wind heeling arm on the GZ curve can be seen in Figure 16.

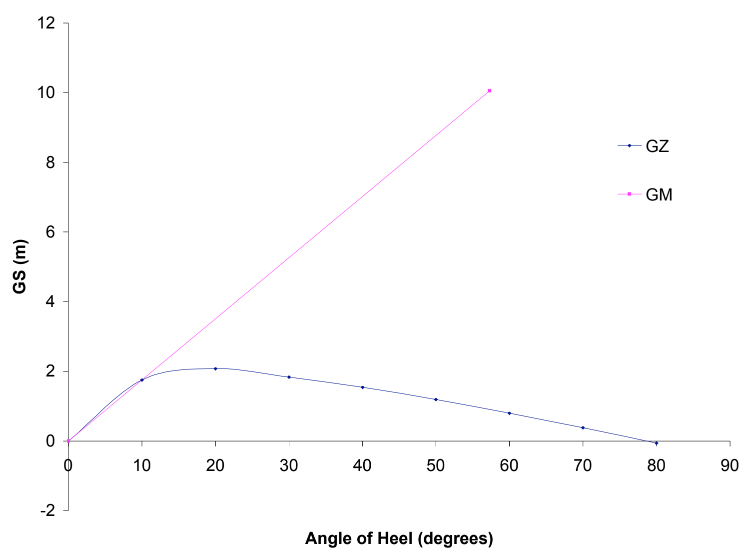
During high speed turns, the effective GZ is reduced. The heeling arm for a high-speed turn is dependant on the velocity of the vessel and the turning radius. In order for a vessel to be able to safely make a turn the same requirements for the heeling arm curve must be met as in the wind heeling arm analysis. In the case of the RDDV the minimum turning radius at a speed of forty five knots is $141m$. This radius will of course decrease as the speed of travel decreases.

3.9.2 Damaged Stability

The floodable length for the vessel was calculated by determining the maximum length of a single compartment before the vessel will heave, heel and trim such that the margin line is submerged.



(a) Lightship Conditions



(b) Loaded Conditions

Figure 15: GZ Curves for Lightship and Loaded Conditions

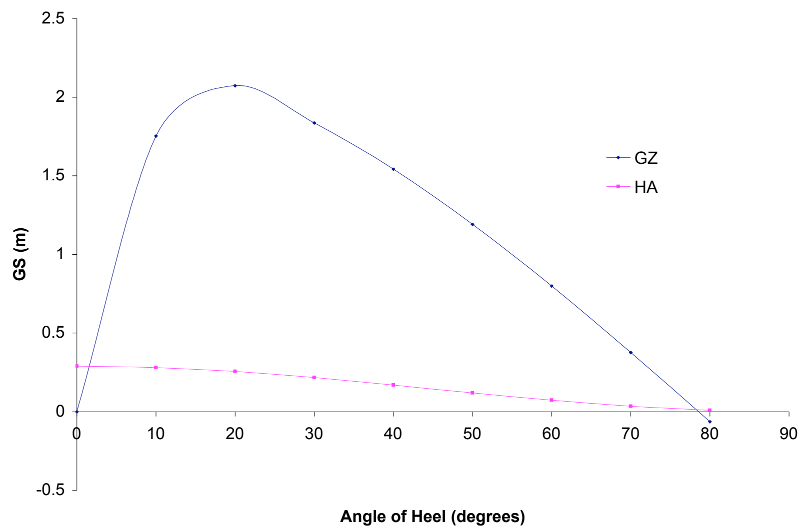


Figure 16: Wind Heeling Arm

From these calculations the floodable length of a single compartment is $15.99m$ in one hull. Note that this in accordance with Transport Canada requirements (TP 7301)[3].

[3]http://www.tc.gc.ca/MarineSafety/TP/Tp7301/menu.htm

3.10 Seakeeping

To perform a seakeeping analysis, RAO values were examined for several different vessels including a catamaran ferry, a SWATH catamaran, and a semi-displacement high-speed catamaran. The RAOs (roll, heave, and pitch) for the semi-displacement catamaran were chosen for analysis due to the geometric similarities between this hull and the RDDV as shown in Table 5.

Table 5: Geometric Properties

Ratio	Semi-Displacement Catamaran	RDDV
Length / Beam	10	8.2
Spacing / Beam	2	2.375

The RAOs for the semi-displacement catamaran were found at a Froude number of 0.8 which corresponds to a speed of 40 knots for the original vessel; using Froude scaling yields a speed of 19.7 knots for the RDDV. Therefore, these RAOs are suitable to investigate the operating characteristics of the vessel at the minimum speed requirement of approximately 20 knots in all seas. These RAOs were developed using a "fully three-dimensional, time-domain seakeeping simulation with extensions to account for lift, viscosity, and nonlinearity"[4].

Two different wave spectra were applied in conjunction with the known RAOs. It is known that the significant wave height in the Georgia Strait exceeds 2.5 m for only about 3 hours per year[5]. The first spectrum applied was that recommended by the I.T.T.C. that best suits ocean conditions at a significant wave height of 2.5m. The closest measured wave spectrum that could be obtained was one observed by wave buoys off of the west coast of Vancouver Island[6]. As this location is open to the Pacific Ocean, it is a higher energy spectrum than that predicted by the I.T.T.C. and will likely over-predict the vessel response occurring in the sheltered Georgia Strait. However, it has been included as this is the nearest measured spectrum. On the West Coast of Vancouver Island, the significant wave height is below 2.5 m 70% of the time.

Upon multiplying the known RAO by the wave spectrum, the significant vessel response amplitude was obtained from the area underneath the plot. Tables 6 and 7 below display the calculated significant vessel response in roll, heave, and pitch using the two wave spectra discussed above at a vessel speed of 19.7 knots (a heading of zero degrees denotes travel in the same direction as the waves). Appendix H contains the spectra plots and detailed seakeeping calculations.

The vessel response predicted in the I.T.T.C. wave spectrum is significantly less than that predicted in the West Coast wave spectrum; predicted values are reasonable and demonstrate the vessel can maintain approximately 20 knots in most headings for over 99.9% of the conditions experienced in the Georgia Strait. However, it is important to note that due to geometry and inertial differences between the modeled vessel and the RDDV, model tests should be performed on the RDDV hull to verify the seakeeping characteristics. As the freeboard has purposely been minimized to aid diving and victim recovery, model tests would also verify that the current freeboard is adequate in rough seas. Additionally, model tests would determine if excessive slamming would occur. If

[4] Kring, et al. "A Time-Domain Seakeeping Simulation for Fast Ships." FAST97 Conference, Sydney, Australia.
[5] http://www.incatdesigns.com.au/publications/The_BC_Ferrie_Catamarans.pdf
[6] Department of Fisheries and Oceans, http://www.meds-sdmm.dfo-mpo.gc.ca/alphapro/wave/TDCAtlas/TDCProducts.htm

Table 6: Vessel Response in I.T.T.C. Wave Spectrum

Heading (deg)	Roll (deg)	Heave (m)	Pitch (deg)
0	19.3	1.677	17.5
45	13.4	1.819	11.5
90	9.7	1.675	5.7
135	14.4	1.675	5.9
180	17.1	1.675	5.8

Table 7: Vessel Response in West Coast Wave Spectrum

Heading (deg)	Roll (deg)	Heave (m)	Pitch (deg)
0	24.1	4.193	26.1
45	20.9	3.778	18.2
90	17.2	3.466	12
135	19.8	3.466	12.1
180	21.2	3.466	12.1

excessive slamming does occur, the freeboard should be increased, or the hulls should be widened, particularly near the front of the vessel.

3.11 Machinery and Major Systems

Close consideration was given to several aspects of the vessel in relation to machinery and ship's systems. Discussed below is the general machinery arrangement and an electrical loan analysis.

3.11.1 Machinery Arrangement

The RDDV has specific requirements due to its mission as a rescue vessel supporting divers. High speed and reliability are of primary concern along with the need for open deck and sickbay space. The machinery has been arranged in a way to keep the working areas of the vessel open while not compromising the RDDVs performance. The machinery arrangement is shown in Figure 17 and Appendix B. In general, diving operations will be conducted off the stern and off the starboard side of the vessel with support equipment on the port.

Propulsion

The prime movers of the RDDV are a pair of MAN D2842LE 404 Marine Diesel engines, producing approximately 1300HP each, located just aft of the deckhouse. The vessel is driven by two Wärtsillä-Lips LJ43E water jets mounted on the transom. Careful selection of the engines, matching engine and jet RPM, allows for direct drive from the engine, through only a universal joint; this precludes the need for a gearbox and increases overall efficiency. Selection of the engines and jets was discussed in Section 3.8.

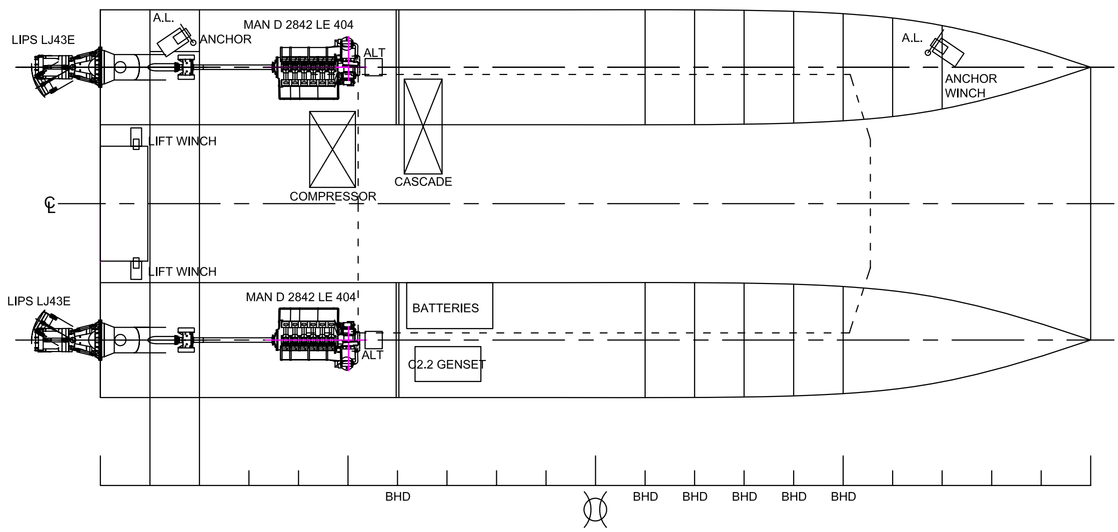


Figure 17: Machinery Arrangement

Air Handling Equipment
Rescue diving operations are typically conducted using surface supplied air; this allows for much longer dive durations when compared to SCUBA equipment; however SCUBA is still used when surface supplied air is not feasible.The RDDV is fitted with a high-pressure Bauer compressor and a Breathing Air Systems PK6 6000psi cascade system used to fill SCUBA tanks and for low pressure surface supplied air. In order to increase vessel loiter time, the compressor is driven by an independent diesel engine. This factory option has minimal weight and size costs over an electrically powered device. A significant air reserve is maintained for safety reasons which requires a large number of tanks stowed on the deck. These tanks are kept on the port side of the vessel to allow unfettered access to the starboard working side. The compressor and cascade system are installed in the void space beneath the stairs and boat ladder accessing the wheelhouse.

Electrical Machinery
An electrical load analysis was performed for the RDDV systems (See Section 3.11.2) which provided baseline requirements. Using this data, alternators, batteries and a generator set were specified. Each main engine is fitted with a 24V, 70A alternator to provide electrical power for general ship operations such as radios, controls, GPS and navigation lighting. A Catapillar C2.2 genset is installed producing up to 21.5kW at 120/240VAC to provide power for additional lighting, cooking and heating. The genset and batteries are installed in the starboard hull to balance the weight of the compressor and cascade system on the port side.

Other Systems
Several other pieces of machinery are installed on the RDDV. Anchor windlasses are fitted on the port side of the vessel. This ensures that if the vessel is anchored, the lines will not interfere with operations being conducted off the starboard side. To assist in the recovery of victims, a recovery lift is installed in the stern. This platform can be lowered into the water, loaded and then lifted to deck level. The lift is raised and lowered by means of two winches fitted into the void space in the wet deck.

3.11.2 Electrical Systems

A predicted electrical load analysis was completed on the RDDV accounting for 12VDC, 24VDC and 120/240VAC systems. The values were derived from a different vessel of similar size and mission. The electrical loads are summarized in Table 8. The complete analysis is available in Appendix I

Table 8: Electrical System Loads

	Power (W)	Current (A)
12VDC	760	63
24VDC	4410	184
120VAC	21100	88

Consideration was given to gensets driven by the main engines, however due to the mission of this vessel, prolonged loiter times can be expected. As such, using an independent genset with a smaller engine reduces fuel consumption, allowing for longer mission duration.

Power is distributed using electronically controlled AC-DC (rectifying) and DC-AC (inverting) converters. This allows some AC systems such as the computer and lighting to be driven by the batteries and alternators without the need for the genset to be running. Conversely, DC systems can be powered and batteries charged using the genset when the vessel is at loiter without the main engines running.

3.12 Endurance and Tank Capacities

Tank capacities were calculated knowing the requirements for range, speed and diving operations. In some circumstances, the tank capacities were increased to fully utilize the space between frames. Figure 18 illustrates the tank arrangement. A larger view may be found in Appendix B.

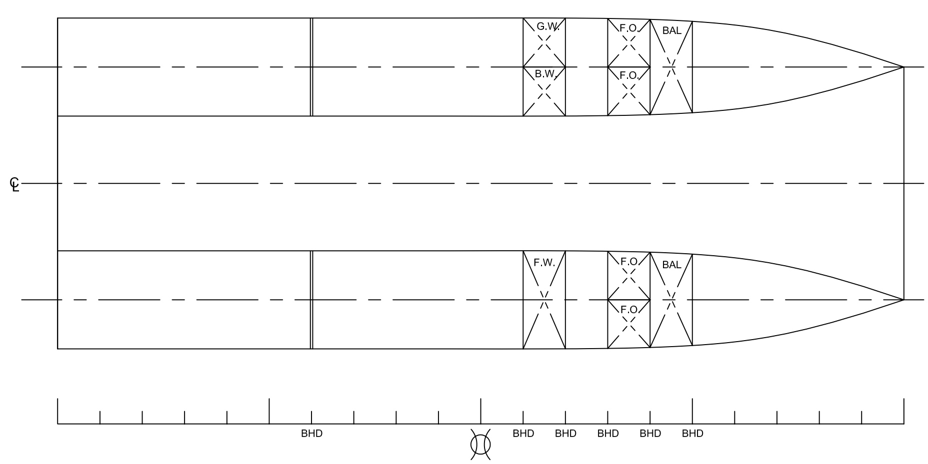


Figure 18: Tank Arrangement

3.12.1 Fuel Oil

Knowing the fuel consumption rate of the chosen engine, the required fuel for the 320 nautical-mile round trip can be calculated. The fuel consumption rate for a range of 1200 RPM to 2300RPM was known for the MAN D engine. This RPM range corresponded to a speed range of 30 to 45 knots. At the maximum required speed of 40 knots, $0.42m^3$ of diesel would be consumed in 160 nautical miles per engine. Therefore, assuming that one third of the fuel would be used on the trip out, one third used on the trip back and one third of the fuel used loitering at the site and for reserve, the required fuel would be $2.52m^3$. At the design speed of 45knots, the fuel required for a 160 nautical mile round trip, based on the same fuel consumption pattern, is $7.15m^3$. Figure 19 shows the fuel consumption rate at each speed between 30 and 45 knots and the fuel consumed per engine in the same speed range for a 160 nautical mile trip.

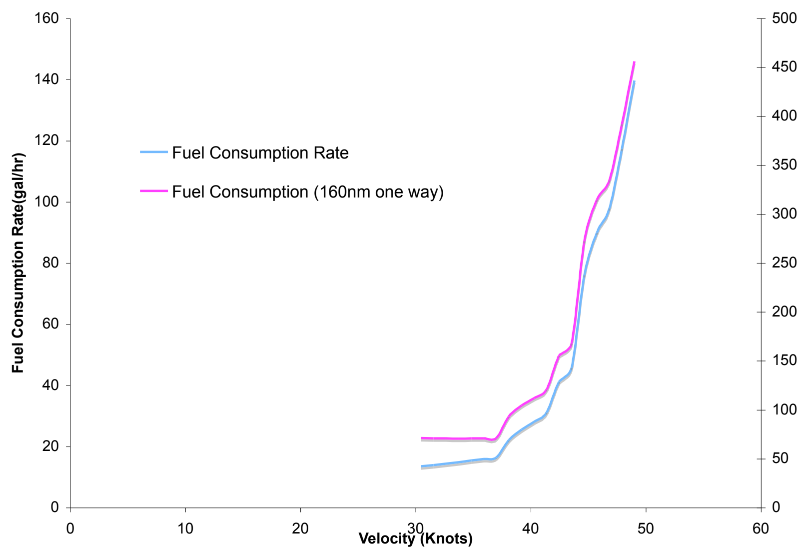


Figure 19: Fuel Consumption vs Speed

Table 9: Fuel Oil Tank Capacity Parameters

Number of Tanks	4	
Midship Station Area (1 hull)	2.25	m^2
Half Midship Area	1.125	m^2
Permeability	0.95	
Single Tank Volume	0.882	m^3
Diesel Specific Density	0.85	
Single Tank Weight	749.461	kg
Four Tank Weight	2997.844	kg

3.12.2 Ballast

The key role of the ballast tanks is to maintain the trim of the vessel. As fuel is consumed, salt water is pumped into the forward ballast tanks to counteract the loss of the mass of the fuel. As such, the capacity of the ballast tank should be approximately the fuel oil capacity plus some mass for lost fresh water. The parameters for the tank capacity can be found in Table 10.

Table 10: Ballast Tank Capacity Parameters

Number of Tanks	2	
Average Station Area (1 hull)	1.93	m^2
Number of Stations	1	
Permeability	0.95	
Single Tank Volume	1.512638	m^3
SW Specific Density	1.025	
SW Specific Density	1025	kg/m^3
Single Tank Weight	1550.453	kg

3.12.3 Fresh Water

Fresh water is generally estimated based on the number of crew of the vessel and the type of activities they are involved in. For the RDDV, there is an additional requirement for fresh water in order to wash all of the dive equipment. The parameters can be found in Table 11.

Table 11: Fresh Water Tank Capacity Parameters

Number of Tanks	1	
Station Area (1 hull)	2.443	m^2
Number of Stations	1	
Permeability	0.95	
Single Tank Volume	1.915	m^3
FW Specific Density	1	
Single Tank Weight	957.351	kg

3.12.4 Grey and Black Water

The grey and black water tanks were sized to be able to store all of the available fresh water. As it is against most environmental regulations to dump grey or black water into the ocean, all waste water must be stored onboard. Parameters can be found in Table 12.

3.13 Cost Analysis

Through discussion with industry members and quotation on machinery, an approximate cost for the construction of the RDDV was generated. The total cost of the vessel is CAD$2,045,600. plus

Table 12: Grey and Black Water Tank Capacity Parameters

Grey Water		
Number of Tanks	1	
Half Station Area (1 hull)=	1.22	m^2
Number of Stations =	1.00	
Permeability =	0.95	
Single Tank Volume =	0.96	m^3
GW Specific Density =	1.00	
Single Tank Weight =	287.21	kg
Black Water		
Number of Tanks	1	
Half Station Area (1 hull)=	1.22	m^2
Number of Stations =	1.00	
Permeability =	0.95	
Single Tank Volume =	0.96	m^3
GW Specific Density =	1.00	
Single Tank Weight =	287.21	kg

any applicable taxes. Table 13 summarizes the costs for the construction of the RDDV. A detailed breakdown of costs can be found in appendix J

Table 13: Summary of Estimated Costs

Structural	\$329086
Deck Equipment	\$77152
Machinery	\$738200
Electrical	\$15600
Miscellaneous	\$583600
Engineering	\$116003.8
10% Contingency	\$182604.2
Total	CAD\$2045606

4 Technical Risk and Mitigation

The RDDV is a single mission vessel, designed for rapid response to underwater emergencies. As such, there are a limited number of circumstances that might cause the design to perform inadequately, namely:

1. Failure to meet design speed.
2. Inability to operate in storms/poor weather.
3. Insufficient equipment or space to support diving operations.
4. Insufficient equipment or space to provide medical assistance.

To reduce the risk of any of these failures occurring, there has been substantial research, modelling and design changes.

The maximum speed of the vessel was of great concern during the design. As such, care was made to computationally model the hull for wave and frictional resistance using Michlet (See section 3.8). In addition, the engines have a 16% power surplus. If unforeseen events do occur, there is power in reserve to compensate.

One of the major reasons for designing this vessel as a catamaran is the excellent roll stability characteristic of this hull form. RAOs for a catamaran of similar geometry were found and analysed for the wave climate of southern British Columbia. The analytical result shows the vessel should be able to operate in virtually all conditions; however there is neither specific data for the RDDV nor wave data for the east coast of Vancouver Island. Before this vessel is constructed, it is recommended that model tests be performed to verify the vessels sea keeping performance.

When preliminary specifications for the RDDV were being established, the three major rescue and recovery dive teams in British Columbia were consulted, these being the Royal Canadian Mounted Police Recovery Dive Team, the Canadian Coast Guard Rescue Dive Team and the Canadian Navy Rescue Dive Team. Input was taken from divers, crew and officers as to the key features a dive vessel would require; these characteristics have been incorporated into the design. Some specific features included in the design of the RDDV include a compressor system (specifically requested) and a stern recovery lift. The lift will allow easy rescue of victims, even in rough weather.

The requirements for the medical facilities were found through discussions with the Canadian Coast Guard and the variety of equipment that was recommended has been accounted for in the design. Due to developments in technology, there may be equipment to be installed at some later date. To account for this, there is abundant storage and power available in the sickbay area.

5 Conclusions

The RDDV described above presents a solution satisfying all of the requirements for an emergency response dive team vessel as specified by the RCMP, Navy, and Coast Guard dive teams. The 17.25m aluminum catamaran is intended for use in the Southern region of the Georgia Strait, British Columbia.

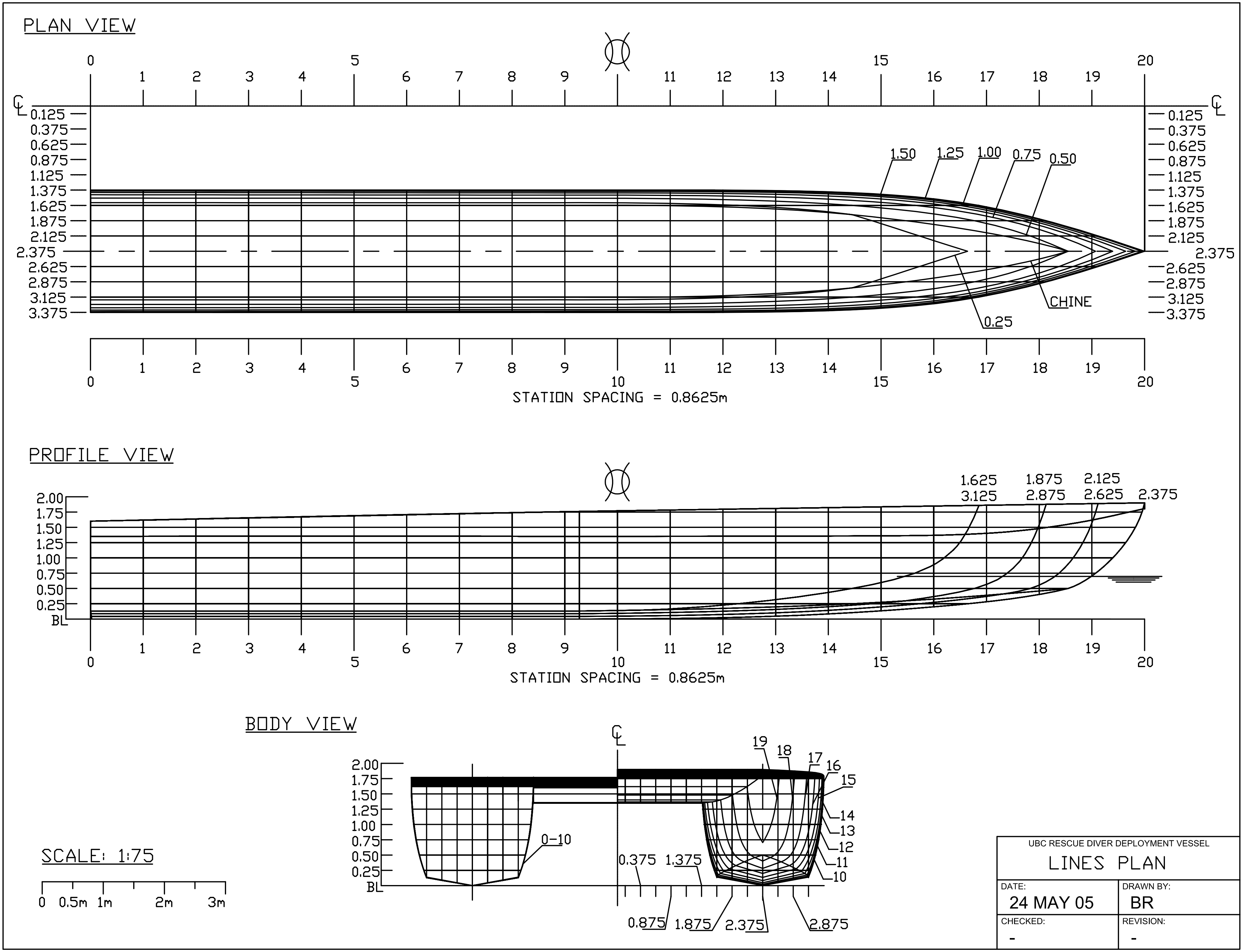
In calm water, the vessel speed is predicted to be at least 45 knots, while a seakeeping analysis was performed to predict sustained speeds of 20 knots in over 99.9% of the conditions encountered in the operating region. Two MAN 1300BHP diesel engines coupled with two Wärtsilä-Lips water jets propel the vessel.

Diving-specific equipment includes a high-pressure compressor in conjunction with a cascade storage system capable of filling empty SCUBA cylinders or supplying air to submerged divers. Monitoring panels and air lines are specifically plumbed into the vessel to increase the efficiency and convenience of diving operations. Other diving-specific equipment includes a recovery lift both to be used by divers for entering and exiting the water, and for recovery of victims.

Significant medical facilities are also provided on the vessel. A hospital area with space for two stretchers has been provided, along with an over-sized doorway and corridor for ease of stretcher maneuvering. Storage space for all required medical equipment such as oxygen canisters and masks and an automated external defibrillator is conveniently provided near the stretchers. The final vessel cost is predicted to be approximately CAD$2,045,600.

As this vessel is specifically designed to meet the needs of an emergency response dive team, it will improve the teams effectiveness as compared to that when operating from the more generic vessels currently in use. It is likely that such a vessel, capable of both improving diving operations and enabling comprehensive care for victims, will result in lives being saved during future marine emergencies.

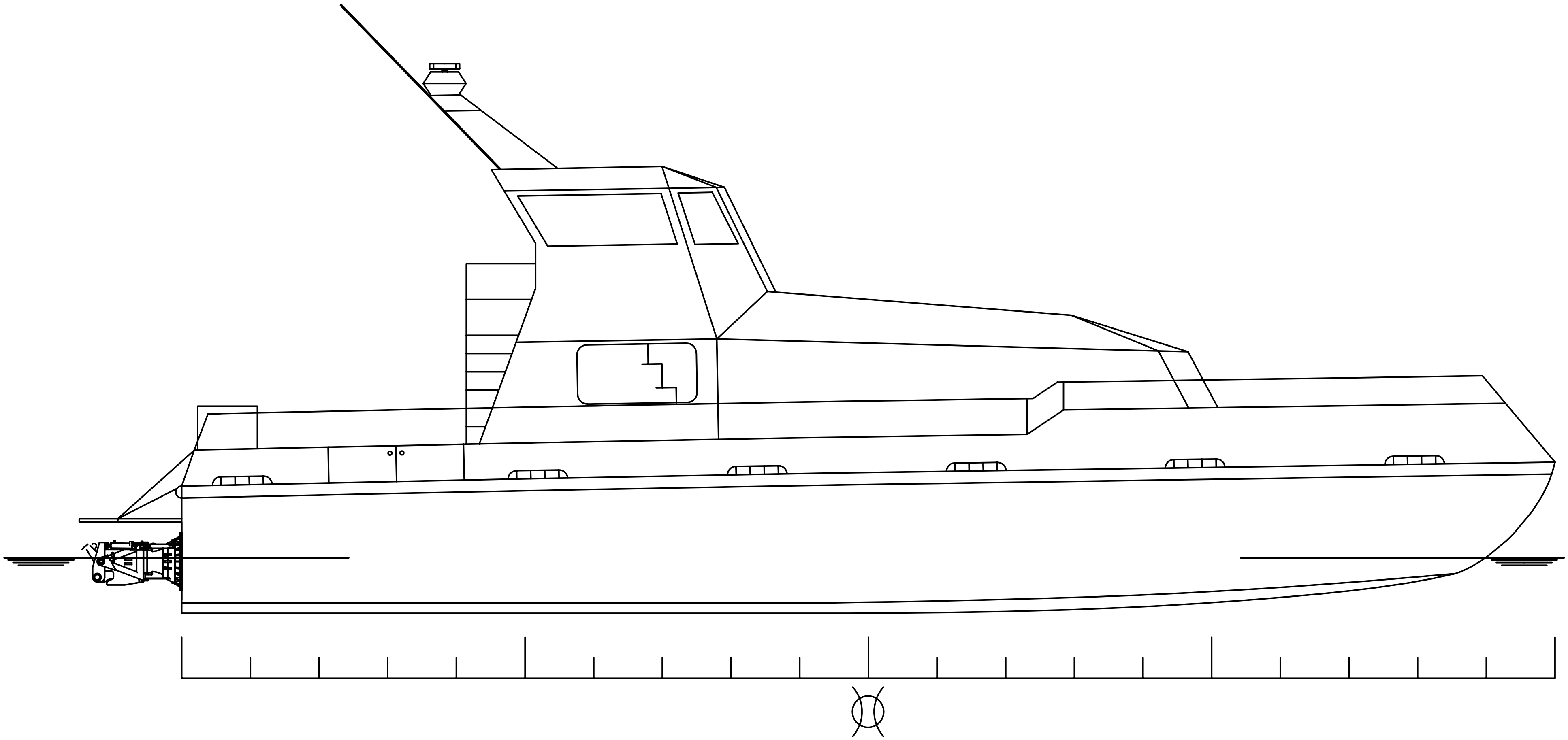
A Lines Plan



UBC RESCUE DIVER DEPLOYMENT VESSEL	
LINES PLAN	
DATE: 24 MAY 05	DRAWN BY: BR
CHECKED: -	REVISION: -

B Vessel Drawings

PROFILE - EXTERIOR GA



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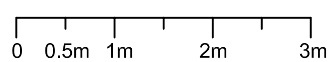

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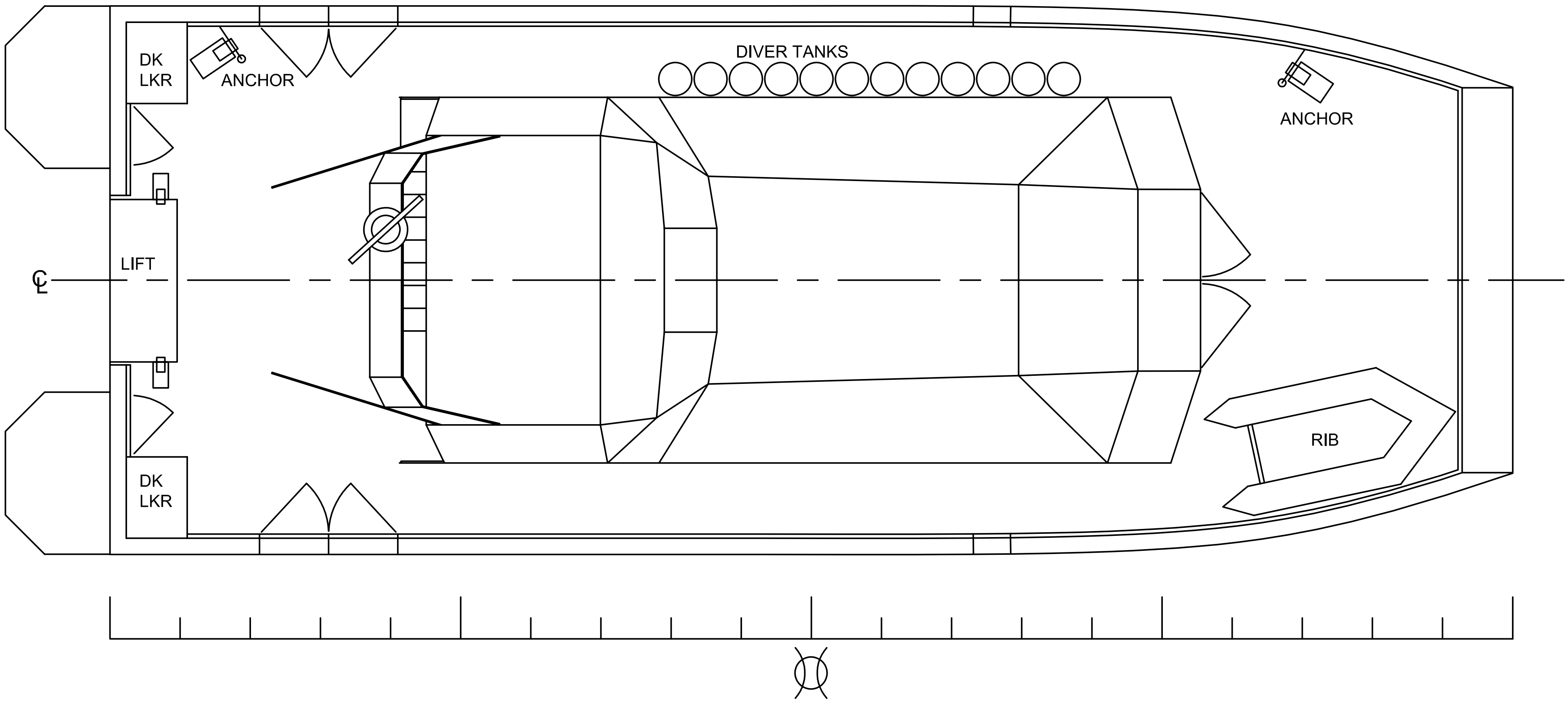
PROFILE GA	
DATE: 4 JUN 05	DRAWN BY: BR
CHECKED: -	REVISION: -

PLANFORM - EXTERIOR GA



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0 0.5m 1m 2m 3m

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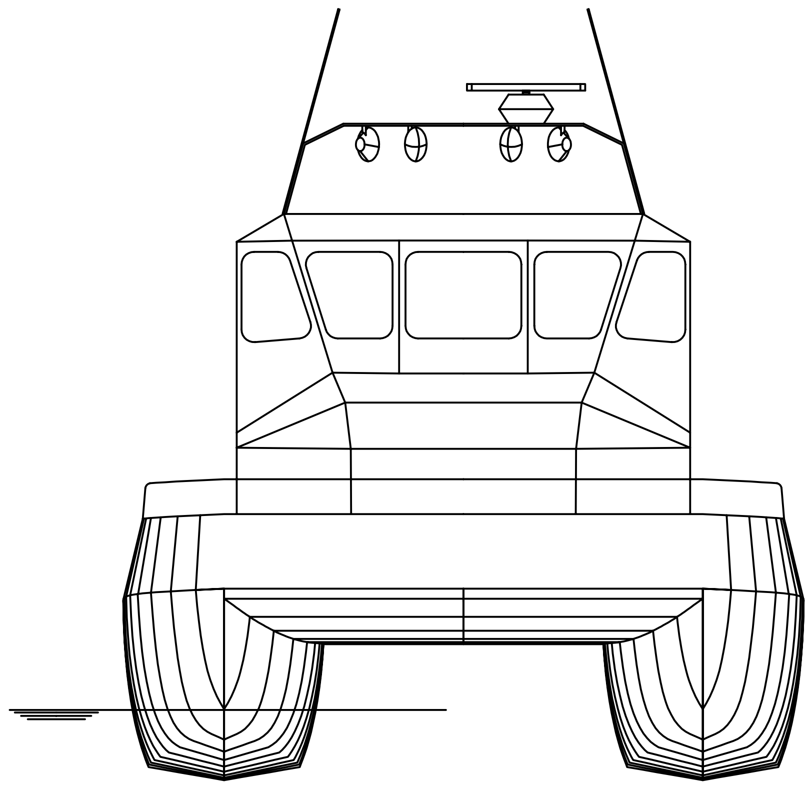
PLANFORM GA	
DATE: 4 JUN 05	DRAWN BY: BR
CHECKED: -	REVISION: -

FWD BODY - EXTERIOR GA



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FWD BODY GA	
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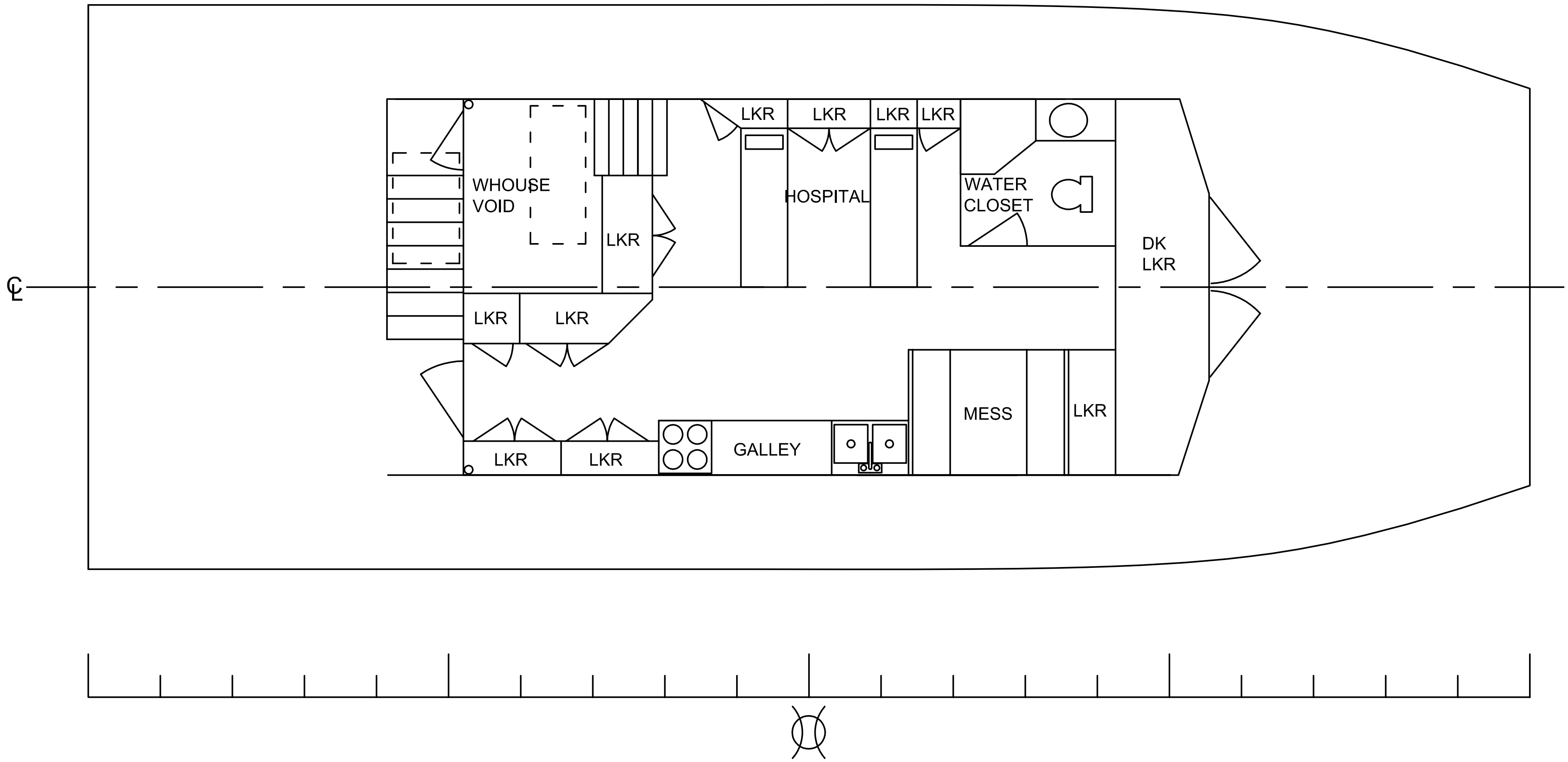
PLANFORM - CABIN GA



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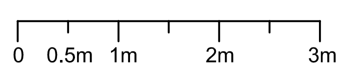

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CABIN GA	
DATE: 4 JUN 05	DRAWN BY: BR
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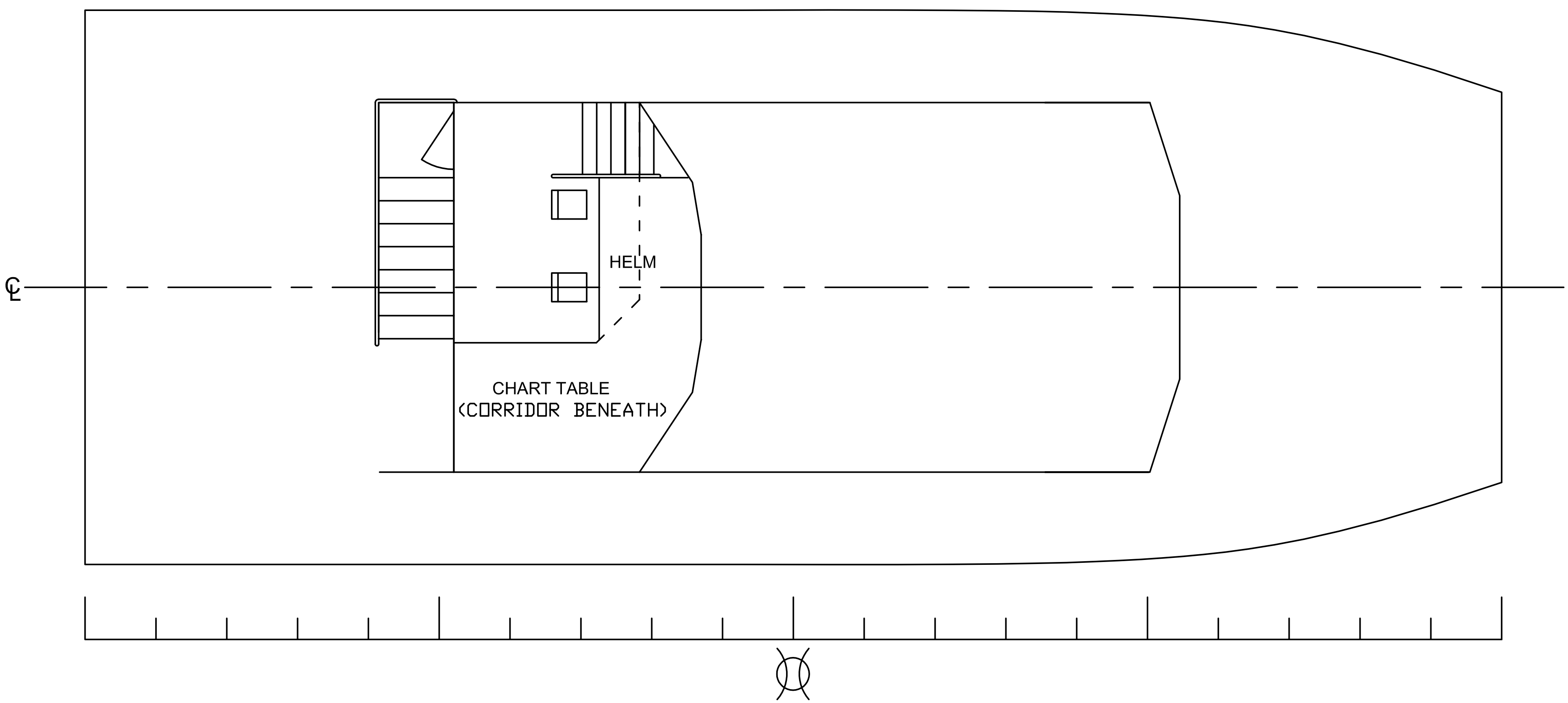
PLANFORM - WHEELHOUSE GA



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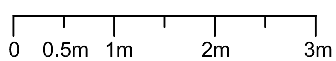
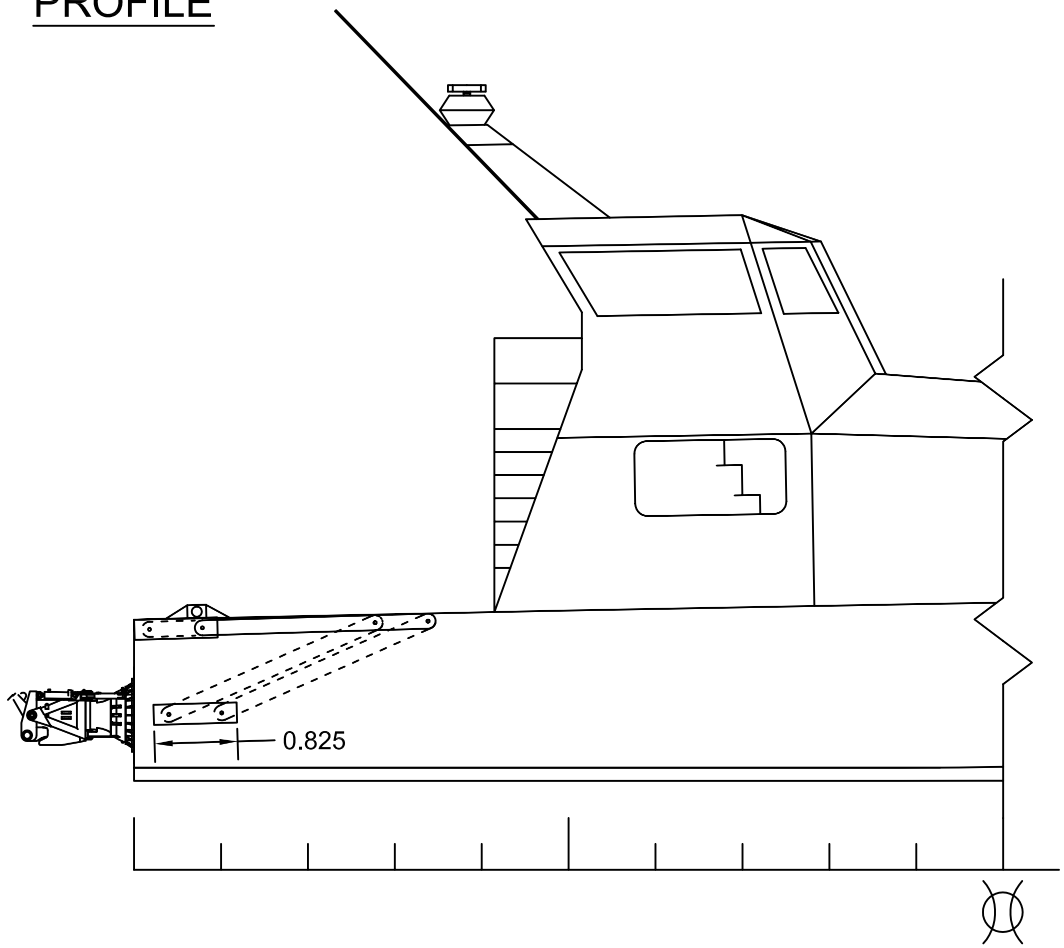


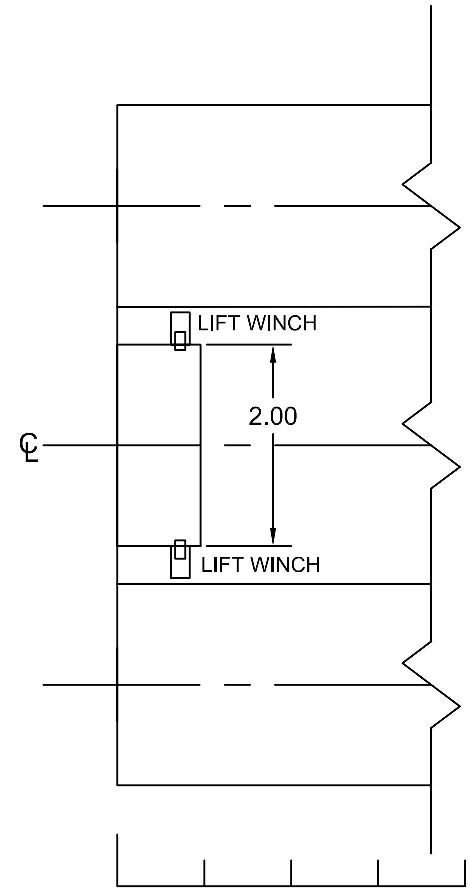
UBC RESCUE DIVER DEPLOYMENT VESSEL	
WHEELHOUSE GA	
DATE: 4 JUN 05	DRAWN BY: BR
CHECKED: -	REVISION: -

RECOVERY LIFT - GA

PROFILE



PLANVIEW



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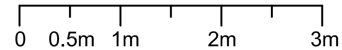

UBC RESCUE DIVER DEPLOYMENT VESSEL	
RECOVERY LIFT GA	
DATE: 4 JUN 05	DRAWN BY: BR
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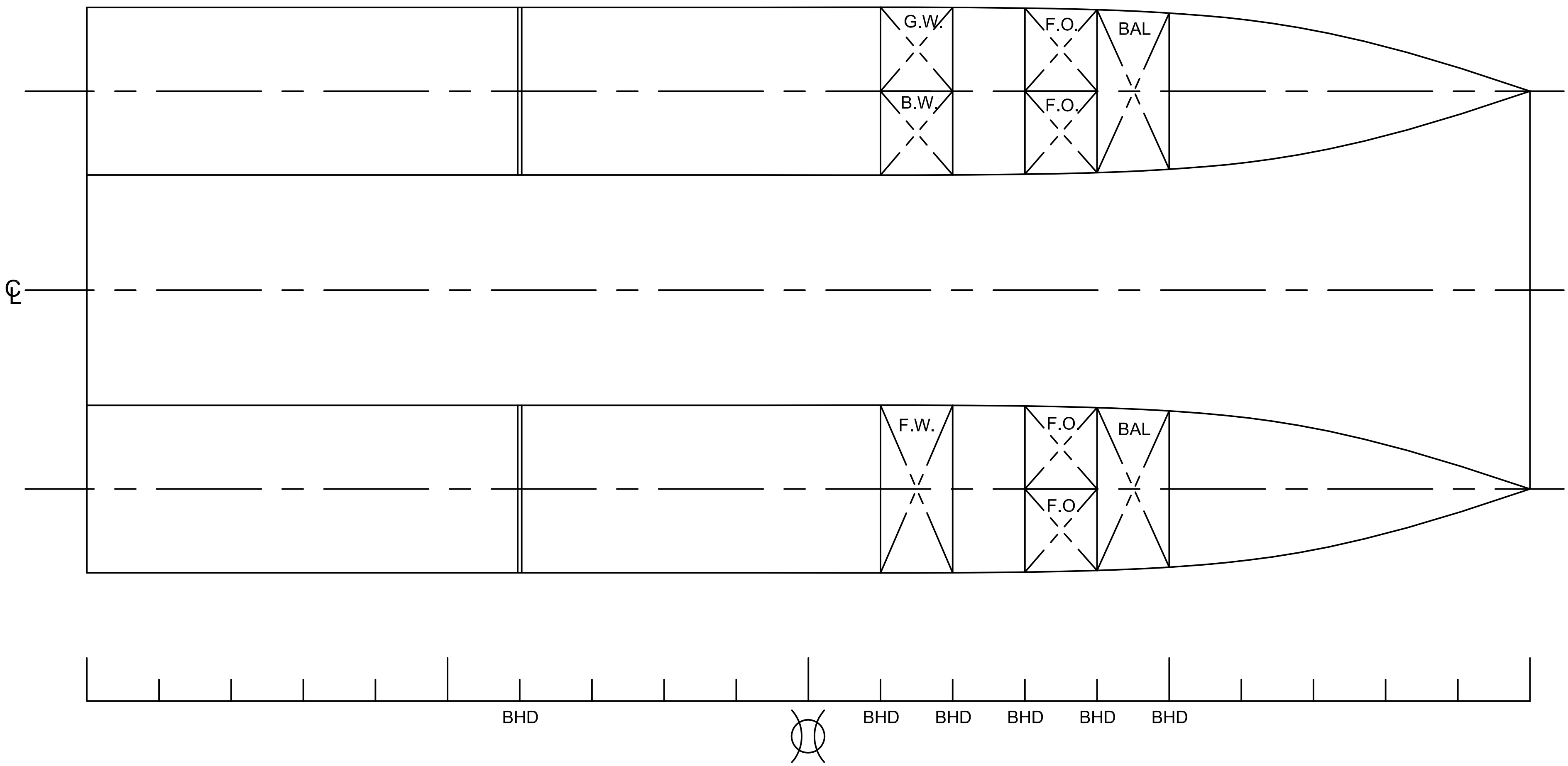
TANK ARRANGEMENT



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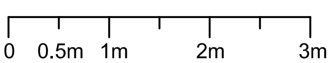

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TANK ARRANGEMENT	
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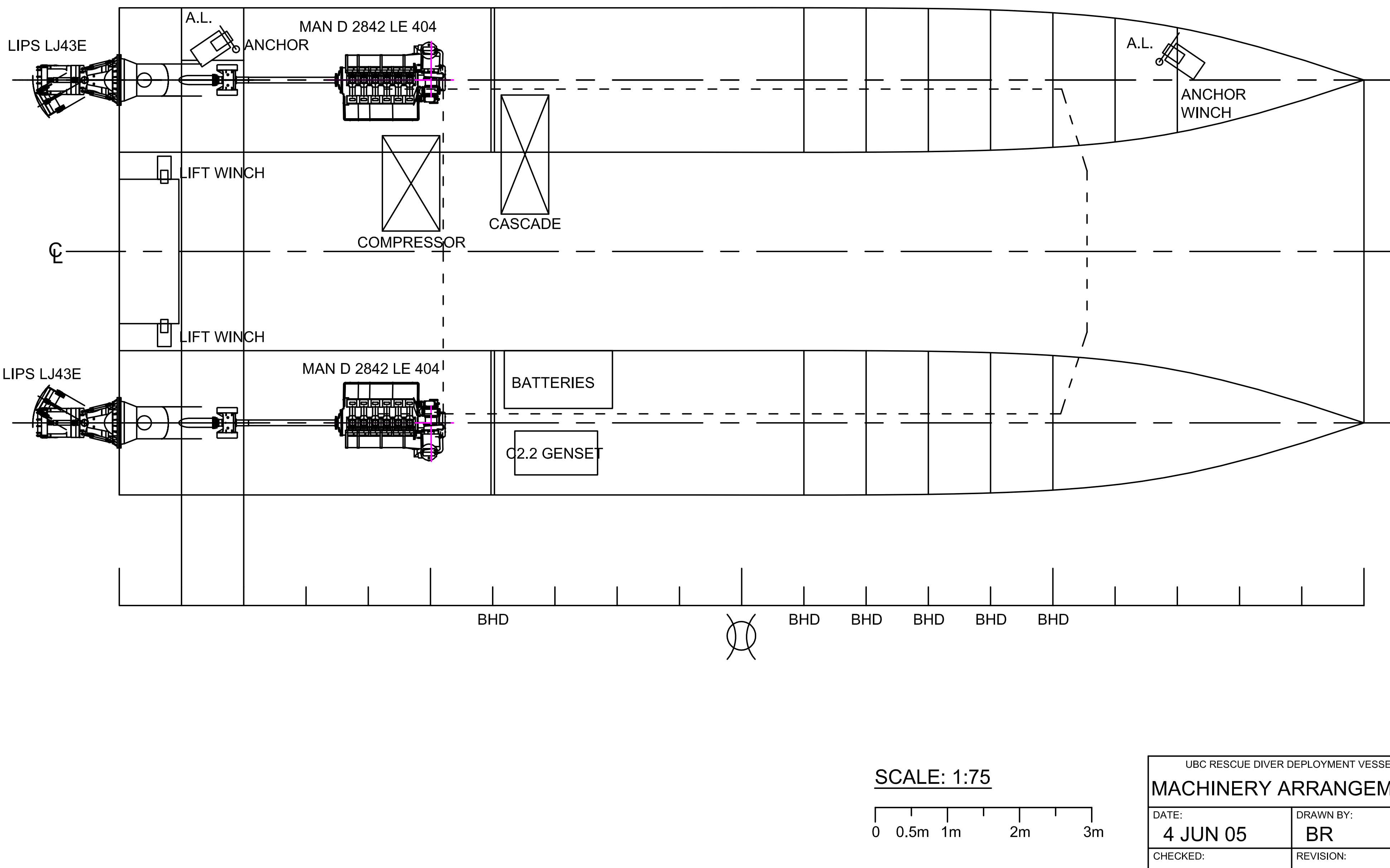
MACHINERY ARRANGEMENT



UBC RESCUE DIVER DEPLOYMENT VESSEL	
MACHINERY ARRANGEMENT	
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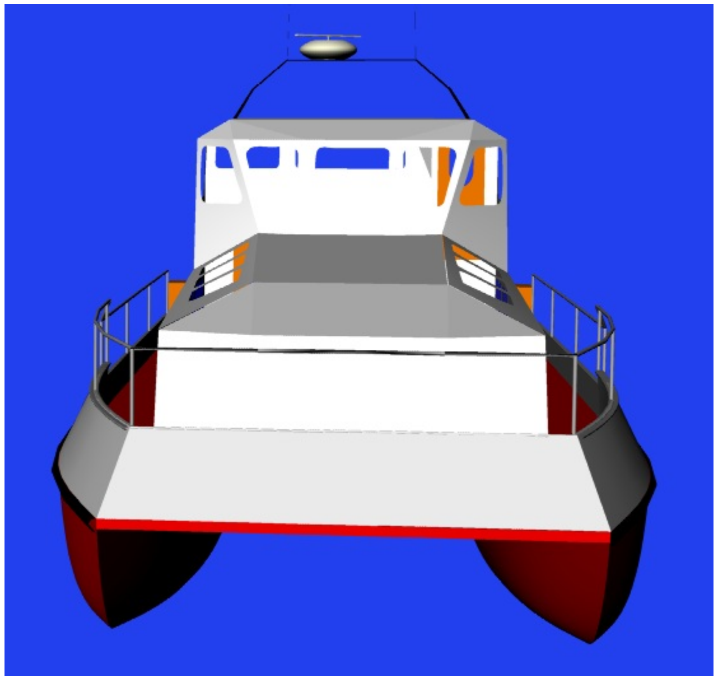
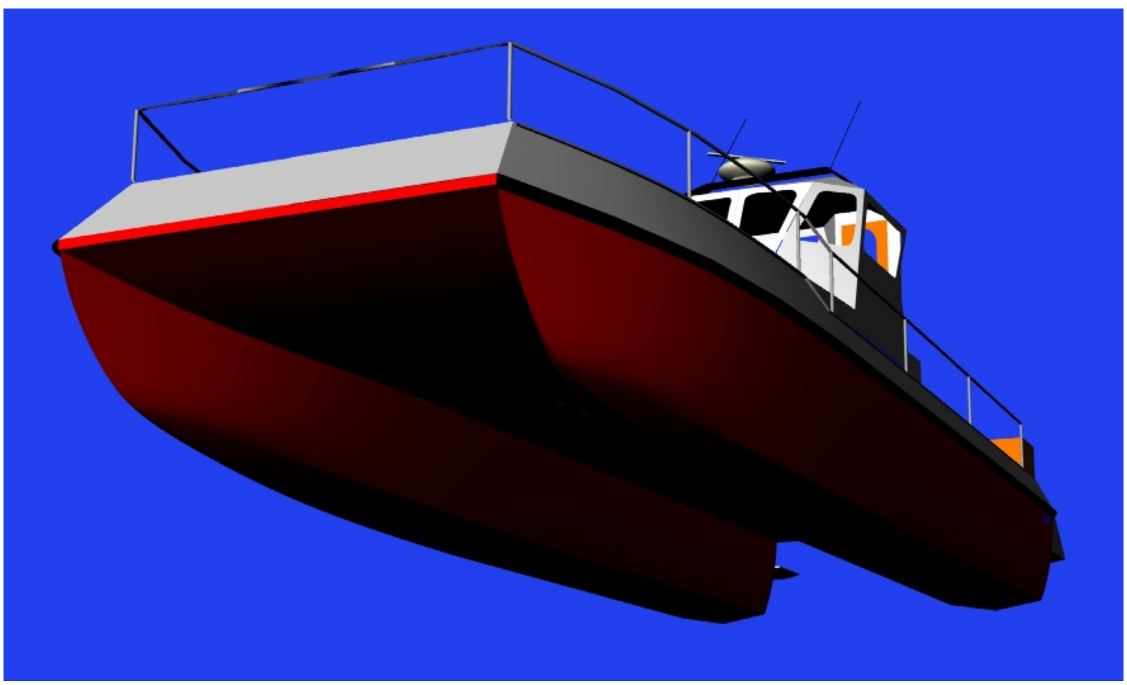
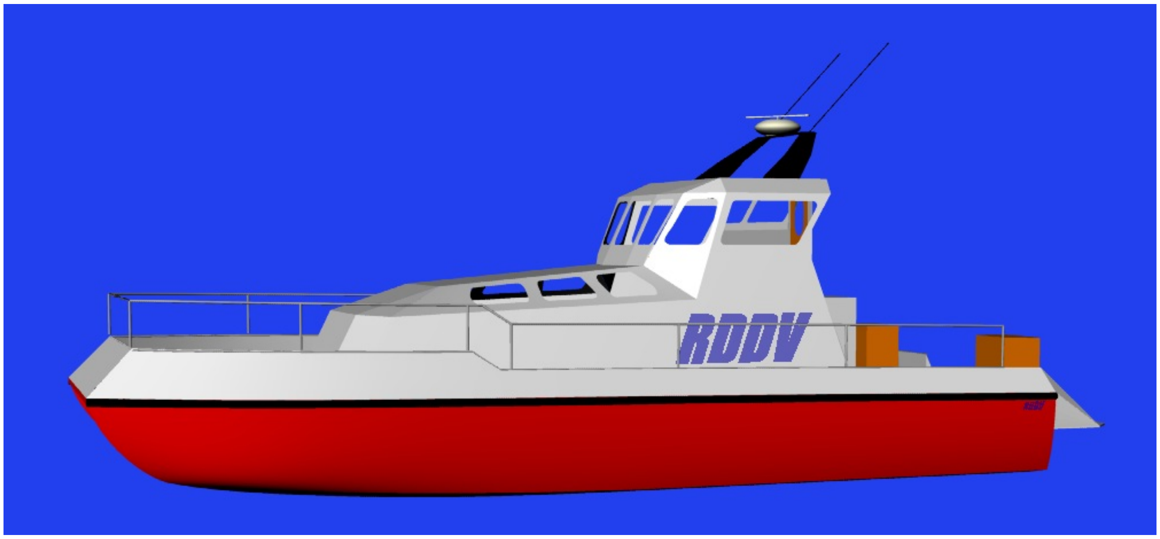
CHECKED: -	REVISION: -

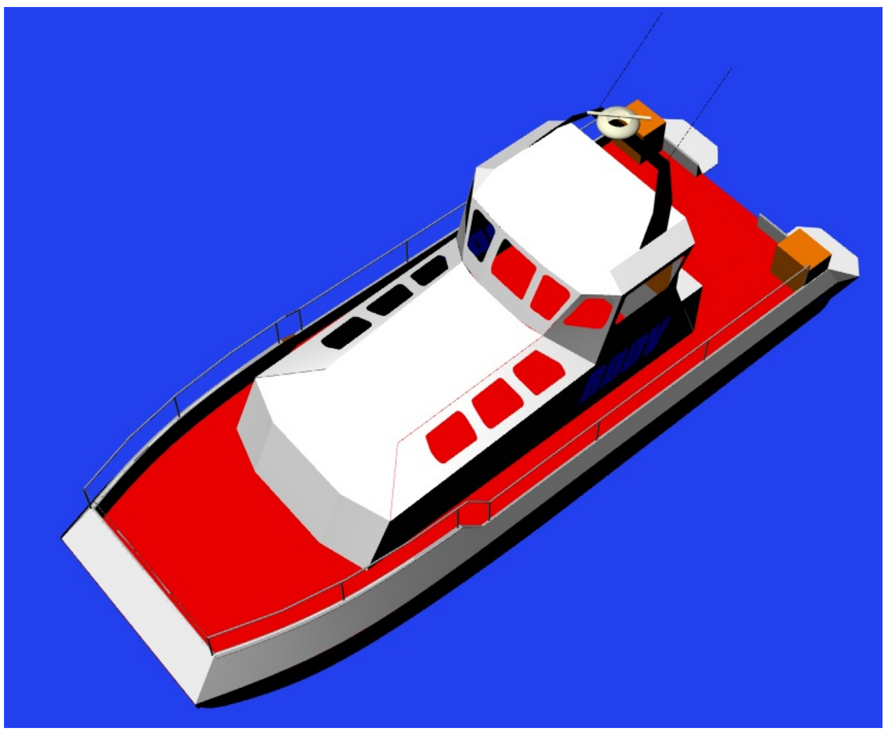

RDDV


RDDV






RDDV



C Ship Structure

The hull structural analysis has been performed to meet ABS High Speed Naval Craft Rules requirements (2003)

Part 3 - Hull Construction and Equipment
Chapter 2 - Hull Construction
Section 1 - Primary Hull Strength

3. Primary Hull Strength - Twin-Hulled Craft

3.1 Longitudinal Hull Girder Strength

3-2-1/1.1 Section Modulus

SM = $C_1 * C_2 * L^2 * B * (C_b + 0.7) * K_3 * C * Q$ (in^2-ft)

SM = 2.96 (in^2-ft)

where:

C_1 = 0.0134*L + 3.75 for L<295 ft
C_1 = 4.44 ft

C_2 = 1.44E-04

L = 51.168 ft

B = sum of WL breadths of side hulls
B = 11.864096 ft

V = maximum speed
V = 45 knots

Cb = 0.45 (not to be less than 0.45)

K_3 = (0.7 + 0.3*(V/sqrt(L))/1.3)
K_3 = 1.3

C = 0.9 for aluminum craft

Q = 0.9 + q_5 (not less than Qo)
Q = 1.314285714

q_5 = 115/σy
q_5 = 0.004791667

Qo = 92000/(σy + σu)
Qo = 1.314285714

σy = 24000 psi
σu = 46000 psi

Neutral Axis Calculation:

Drawing the item in AutoCAD:

NA =	1.04	m above baseline
Ixx =	0.065	m^4
Ixx =	650	cm^2-m^2
Ixx =	1085	in^2-ft^2

3-2-1/1.5 Moment of Inertia

		(in^2-ft^2) Moment of inertia must be greater than this value
I =	L*SM/(Q*C*K)	
I =	30.90	(in^2-ft^2)
L =	51.168	ft
Q =	1.31	
C =	0.9	
K =	4.14	Table 2 p. 48

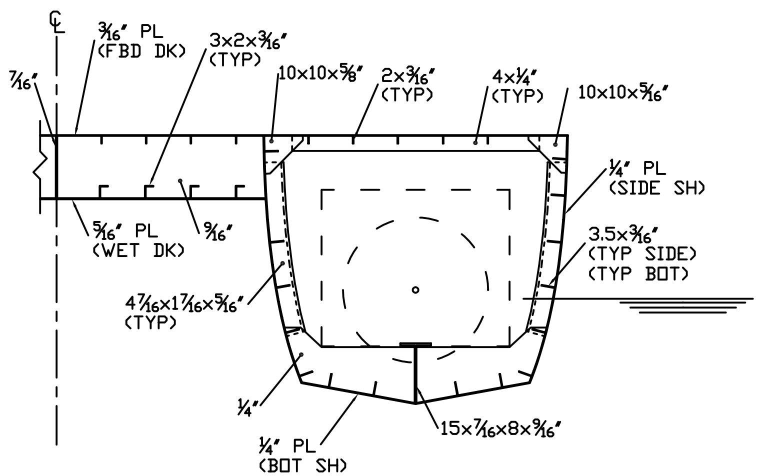
Inertia ok? **OK**

D Scantling Calculations

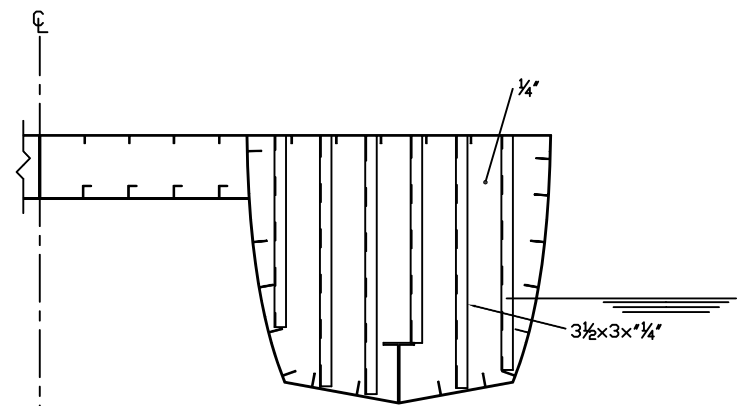
The following tables are for ABS High Speed Naval Craft.

They were generously provided, courtesy of Mr. Dan McGreer of Aker Marine.

ABS MIDSHIP SECTION



ABS BULKHEAD SECTION



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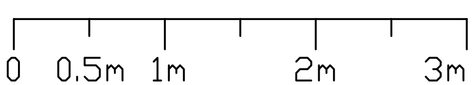


UBC RESCUE DIVER DEPLOYMENT VESSEL

MIDSHIP STRUCTURE

DATE:	DRAWN BY:
24 MAY 05	BR
CHECKED:	REVISION:
-	-

WET DECK PLATE

Part 3 Chapter 2 **ABS High Speed Naval Craft, 2003**

Section 2 Design Pressure

3.5 Wet deck or cross-deck - taken as the lower deck b/w the side and center hulls

design pressure, Pwd = **18.13** psi

$Pwd = 30N_1F_DF_1V{*}V_1(1-0.85h_a/h_{1/3})$ psi — p. 64

where

N_1 =	0.00442		
h_a =	**2.3**	ft	
	not greater than $(1.176{*}h_{1/3})$		
$h_{1/3}$ =	**8.50**	**ft**	
F_D =	**0.83**	design area factor, not less than 0.83(based on s)(see page 60)	
F_I =	**0.4**	**Varies with Length**	
V =	45	knots	
V_I =	11.88	ft/s	
A_D =	360	in^2	area of plate panel (page 59)
A_R =	1.61Δ/d	in^2	
A_R =	9.97	in^2	
d=	**3.020**	**ft (not less than 0.04L)**	2.04672
long'l span, l=	**36.000**	in.	
long'l spacing, s =	**12.000**	in.	
A_D/A_R =	36.12		

$V_1 = 7.24h_{1/3}/\sqrt{L}+3.28$ ft/s

= 11.88

Part 3 Chapter 2

Section 3 Plating

1.3 Thickness — **Wet deck plate** **6.24** mm

1.3.1 Lateral Loading

plate thickness, t = 0.246 in. 6.24 mm

wet deck

$t = s\sqrt{pk/\sigma_a}$ in. — p. 75

where

s =	12	in.	
p =	18.13	psi (design pressure)	
k =	0.5	plate panel ratio factor,3-2-3 Table 1	
σ_a =	21600	psi	
l/s=	**3.00**		
l=	36	in.	
s_a=	21600	(0.9sy)	
(alum.5083-H321/H116) sy=	24000	psi	Yield strength of welded aluminum (2-5-A1)

1.3.2 Secondary stiffening

plate thickness, t = 0.144 in 3.66 mm
wet deck

t = 0.012*s in

where
s= 12 in.

1.3.3 Minimum Thickness - Bottom Shell

plate thickness, t =
wet deck

t = 0.015*sqrt(L*qa) + 0.04 in

0.12 in
3.14 mm

qa= $17000/\sigma_{ya}$
qa= 0.607
$s_{ya=}$ 28000 N/mm^2

L= 51.168 ft

Part 3 Chapter 2
Section 4 Internals

1.3 Strength and stiffness
Wet Deck longitudinals

1.3.1 Section Modulus

SM = 1.566 in^3 25664.445 mm^3

SM = $144*p*s*l^2/\sigma a$ in^3 p. 95

where,

p =	18.13	psi
s =	1	ft.
l=	3	ft.
s_a=	15000	(.75sy)
(alum.6061-T6) sy=	20000	psi

Stiffener Dimensions from "Select_A_Stiffener"

web depth	web thk	flange width	flange thk
3	0.1875	3	3/16
76.2	4.7625	76.2	4.76

Actual SM: 2.09

Therefore, web must be at least 2.5x the depth of the stiffener,
127 mm

Location	F_l	Design P	Wet Deck Pl.	Req.Long. SM	Stiffener Dimensions from "Select_A_Stiffener"				Actual SM	Stiff Area (mm2)	
					web depth	web thk	flange width	flange thk			
Fr. 0 - 4	**0.5**	22.66	6.98	1.96	3	0.1875	3	3/16	2.09	725.81	**Long. Spacing at 12 inches**
Fr. 5 - 14	**0.4**	18.13	6.24	1.566	3	0.1875	2	3/16	1.67	604.84	**Long. Spacing at 12 inches**
Fr. 14 - end	**1**	45.32	6.58	2.58	3	0.25	2	1/4	2.85	806.45	**Long. Spacing at 8 inches**

WET DECK TRANS

Part 3 Chapter 2 **ABS High Speed Naval Craft, 2003**

Section 2 Design Pressure

3.5 Wet deck or cross-deck **For wet deck transverse**

design pressure, Pwd = **45.32** psi

$Pwd = 30N_1F_DF_1V^*V_1(1\text{-}0.85h_a/h_{1/3})$ psi

where

N_1 =	0.00442			
h_a =	**2.3**	ft	p.64	
	not greater than $(1.176*h_{1/3})$		=	9.996
$h_{1/3}$ =	**8.50**	**ft**		
F_D =	0.83	design area factor, not less than 0.83(based on s)(see page 60)		
F_1 =	**1**	**Varies with L**		
V =	45	knots		
V_1 =	11.88	ft/s		
A_D =	3240	in^2	area of plate panel (page 59)	
A_R =	1.61Δ/d	in^2		
A_R =	9.97	in^2		
d=	**3.020**	**ft (not less than 0.04L)**		
Transv.span, l=	**108.000**	in.		
Transv. spacing, s =	**36.000**	in.		
A_D/A_R =	325.09			

$V_1 = 7.24h_{1/3}/\sqrt{L}+3.28$ ft/s

= 11.88

Part 3 Chapter 2

Section 4 Internals

1.3 Strength and stiffness

Wet Deck transverse

1.3.1 Section Modulus

SM = 38.468 in^3

$SM = 144*p*s*l^2/\sigma a$ in^3

where,

p =	45.32	psi	
s =	**1.31**	ft.	(0.8m)
l=	**9**	ft.	
s_a=	**18000**	**(0.75sy)**	
(alum.5083-H116,H321) sy=	**24000**	psi	

Internals

1.3.2 Moment of Inertia

Moment of Inertia = **111.283** in^4

Inertia = $54*p*s*l^3/K_4E$ in^4

where,

K_4= **0.0021** **for shell and deep tank stringers and transverse**

E= 10000000 psi alum.

Use the following to obtain section modulus and inertia, and web thickness check for section, then enter blue data to table below

	Wet Deck Transverse		**Section used:**				
	deck plate mm	web depth mm	web thk mm	flange width mm	flange thk mm	actual SM, in^3	actual I, in^4
Enter blue data	**6.6**	**250**	**14.3**	**125**	**12.7**	**under**	**189**
		web check 1	**okay**				
		web check 2	**okay**				

CALCULATION OF SECTION PROPERTIES Project No.

Type of member Deck or location

Deck plate **12 in W** x .26 in thk Req'd rule SM = 38.468 in^3

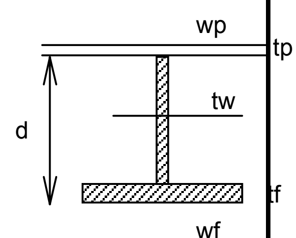
Actual SM = **under** in^3

web 9.84 in x .56 in

Face Flat 4.92 in x .5 in span = ft

US **TEE**

Plate thickness, tp	0.260	in
Plate width, wp	12.00	in
Depth of Section, d	10.34	in
Web thickness, tw	0.5630	in
Flange width, wf	4.92	in
Flange thickness, tf	0.5000	in



Section Piece	y (in)	Area (in^2)	Area*y (in^3)	Area*y^2 (in^4)	Io (in^4)
Plate	0.13	3.12	0.41	0.05	0.02
Web	5.18	5.54	28.71	149	45
Flange	10.35	2.46	25.47	264	0.05
Totals		11.12	54.59	413	45

wp=5000/3

Centroid	4.91	in
Ixx at centroid	189	in^4
SM pl	38.57	in^3
SM flg	33.26	in^3
Shear Area	5.97	in^2
Iyy		

rx = 4.13

ry =

Effective Weight	
Plate	11.00
Web	19.54
Flange	8.68
W+FLG	28.22

web thickness check

Part 3	**Chapter 2**			**Enter All Blue data**				
section 4		**1.9**						
minimum web thickness								
	$t = 144psl/2d_w\tau_a$			**check 1**				
	t=	**0.554**	in.	**14.08**	mm			
	t = dw/1.15*sqrt(E/ty)=		0.438796	**11.15**	mm for slamming			
where				actual web, t		actual flg thk.		
p=		**45.000**		**14.3**	mm	**12.7**		mm
l=		**9.00**	ft.					
s=		**1.31**	ft.			actual web depth		
dw=		9.84	in.(web depth)			**250**		mm
$\tau a=$		$0.5\tau_{yw}$						
$\tau a=$		7000	psi					
$\tau_{yw=}$		**14000**	psi (minimum shear yield welded condition)					
also web thickness not less than					**check 2**			
	dw/tw=	30.0		min tw=	**8.32**	mm		
dw/tw=	$1.54(E/\tau_y)^{0.5}$				**okay**			
alum, E=		10000000	psi					
	$\tau_{y=}$	**26285**	psi (minimum shear yield unwelded condition)					
			(alum.5083-H116,H321)					

Location	F_l	Design P	Wet Deck Pl.	Req.Long. SM	Transverse Dimensions web depth	web thk	flange width	flange thk	Actual SM	Area (mm^2)	Stiff VCG (m)	
Fr. 0-4	0.5	22.66	6.98	38.5	250	19	125	14.30	38.7	6537.5	0.127	
Fr. 4 - 14	0.4	18.13	6.24	1.566	250	14.3	125	12.70	32.94	5162.5	0.127	
Fr. 14 - end	1	45.32	6.58	38.5	250	19	125	14.30	38.7	6537.5	0.127	every 1/2 frame

SIDE SHELL

Part 3 Chapter 2 **ABS High Speed Naval Craft, 2003**

Section 2 Design Pressure

3.1 Side Design Pressure, Shel **4.55** psi

Greater of the following

3.3.1 Slamming Pressure

At any section **Psxx =** **0.0037** psi

$Psxx = N_1\Delta/L_wN_h*B_w*(1+nxx)((70-\beta\sigma x)/(70-\beta cg))F_D$

3.1.1 Side Hydrostatic Pressure

Ps = **4.5540** psi

Ps= $N_3(Hs-y)$ psi

where

y=	0.4	ft.(distance above baseline from location)
Hs=	10.75	ft.
Hs=	0.64H+d	ft. (not less than D+1.22)
H=	13	ft.
H=	(0.0172L+11.98)	ft.(not less than survival wave height, 20 ft.)
N_3=	0.44	
n_{xx}=	8.61	g's
$n_{xx}= n_{cg}K_v$		
Kv=	2	vert. Acc. Dist. Factor at midship (page 72) (Varies with length along ship)
$\beta\sigma x$=	20	deadrise of side at any section, max.55
βcg=	20	deadrise at any LCG, min. 10, max.30
N_1 =	0.069	
Δ =	18.69	L tons
Lw=	53.30	ft.
N_h=	2	no. of hulls
B_w =	**26.24**	**ft**
F_D =	0.83	design area factor, not less than 0.4 (see page 71)
$h_{1/3}$ =	8.5	ft.(3.2.2 Table 1)
n_{cg} =	4.30	g's (see definition sheet)
V_1 =	11.88	ft/s
A_D =	360	in^2 area of plate panel (page 59)
A_R =	$1.61\Delta/d$	in^2
A_R =	12.39	in^2
shell location to DWL=	**2.430**	**ft (not less than 0.04L)**
side shell panel, l=	**36.000**	in.
spacing, s =	**12.000**	in.
A_D/A_R =	29.06	

$V_1 = 7.24h_{1/3}/\sqrt{L}+3.28$ ft/s

= 11.88

vert acc. $n_{cg} = N_2((12h_{1/3}/(NhB_w))+1)*\tau*(50-\beta_{cg})(V^2(NhB_w)^2)/\Delta$ g's **page 58**

126455.12 g's

N_2 =	0.0016	
$h_{1/3}$ =	8.5	ft (Naval craft)
B_w=	26.24	ft
τ =	3	degree, running trim
βcg =	20	deadrise at LCG
V =	45	knot craft speed see 3.2.2/ Table 1
N_h=	2	no. of hulls

Maximum and minimum value see 3.2.2/1.1

not greater than, n_{cg} = 1.39+k_n(V/L^0.5)

= 4.30 g's k_n = 0.463

for speed greater than 18√L(9.94-√L) = 358.823164 knots

max. n_{cg} = 6 g

vert.acc **Use n_{cg} =** **4.30** g's

Part 3 **Chapter 2**
Section 3 **Plating**
1.3 **Thickness** 0.00 ft. above baseline

1.3.1 Lateral loading **Side shell plate** **4.00** mm

plate thickness, t = 0.158 in. 4.00 mm
wet deck

t = s√pk/σ_a in.

where		
s =	12	in.
p =	4.55	psi (design pressure)
k =	0.5	plate panel ratio factor,3-2-3 Table 1
σ_a =	13200	psi (design stress)
l/s=	**2.67**	
l=	32	in.
s_a=	13200	(0.55sy)
(alum.5083-H321/H116) sy=	24000	psi

not to less than (based on stiffener spacing)

Minimum Thickness

1.3.2 **t_{al}=** 0.012s in.   s= 12 in

t_{al}= 0.144 in. 3.66 mm

1.3.3(a) **Side shell**

t_{al}= 0.013√Lqa +0.04 in.   qa= 17000/σ_{ya}

t_{al}= 0.112 in. 2.86 mm   qa= 0.607

unwelded yield s_{ya}= 28000 psi

but not less than,t_{al} = 0.140 in. 3.56 mm

L= 51.168 ft

Part 3 Chapter 2
Section Internals

1.3 Strength and stiffness
Side shell longitudinals

1.3.1 Section Modulus

SM = 0.590 in^3

SM = $144*p*s*l^2/\sigma a$ in^3

where,

p = 4.55 psi
s = 1 ft.
l= 3 ft.
s_a= 10000 (0.5sy)
(alum.6061-T6) sy= 20000 psi

Use: ok **sm = 0.7** in^3

web depth	web thk	flange width	flange thk
3.5	0.1875	0	0
88.9	4.7625	0	0.00

Part 3 Chapter 2
Section 4 Internals

1.3 Strength and stiffness
Side shell transverse

1.3.1 Section Modulus

SM = 4.099 in^3

SM = $144*p*s*l^2/\sigma a$ in^3

where,

p = **4.55** psi
s = 3 ft.
l= 5 ft.
s_a= **12000** **(0.6sy)**
(alum.5083-H321/H116) sy= 24000 psi

Internals
1.3.2 Moment of Inertia

Moment of Inertia = **4.391** in^4

Inertia = $54*p*s*l^3/K_4E$ in^4

where,

K_4= **0.0021** **for shell and deep tank stringers and transverse**
E= 10000000 psi alum.

Use the following to obtain section modulus and inertia, and web thickness check for section, then enteblue data to table below

	Side Shell Transverse		Section used:				
	deck plate mm	web depth mm	web thk mm	flange width mm	flange thk mm	actual SM, in^3	actual I, in^4
Enter blue data	**6.35**	**112.5**	**8**	**37**	**8**	**under**	**17**
		web check 1	**okay**				
		web check 2	**okay**				

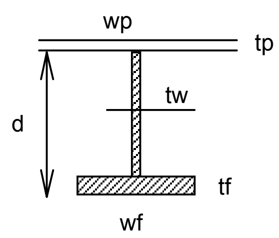
CALCULATION OF SECTION PROPERTIES Project No.

Type of member Deck or location

Deck plate	**36 in W**	x .25 in thk	Req'd rule SM =	4.099	in^3	
			Actual SM =	**under**	in^3	
web	4.43 in	x .31 in				wp
Face Flat	1.46 in	x .31 in	span =		ft	

US TEE

Plate thickness, tp	0.250 in
Plate width, wp	36.00 in
Depth of Section, d	4.74 in
Web thickness, tw	0.3150 in
Flange width, wf	1.46 in
Flange thickness, tf	0.3150 in



Section Piece	y (in)	Area (in^2)	Area*y (in^3)	Area*y^2 (in^4)	Io (in^4)
Plate	0.13	9.00	1.13	0.14	0.05
Web	2.46	1.40	3.44	8	2
Flange	4.84	0.46	2.22	11	0.00
Totals		10.85	6.78	19	2

wp=5000/3

		Centroid	0.62 in
		Ixx at centroid	17 in^4
		SM pl	27.91 in^3
rx =	1.27	SM flg	**3.99** in^3
ry =		Shear Area	1.57 in^2
		Iyy	

Effective Weight	
Plate	31.74
Web	4.92
Flange	1.62
W+FLG	6.54

Shell Plate

	thickness
Full length:	4

Longitudinals:

	Kv value	Req. SM	web depth	web thk	flange width	flange thk	Actual SM	Stiff. Area:
Full Length	**2**	0.59	3.5	0.1875	0	0	0.7	
			88.9	4.7625	0	0.00		423
								(mm^2)

Transverses:

	Kv value	Req. SM	web depth	web thk	flange width	flange thk	actual	Stiff. Area:
Full Length	**2**	3.42	112.5	8	37	8	3.85	1196
			4.429133858	0.31496063	1.4566929	0.314961		(mm^2)
			4 7/16	5/16	1 7/16	5/16		

BOTTOM SHELL PLATE

Part 3 Chapter 2 **ABS High Speed Naval Craft, 2003**

Section 2 Design Pressure

1.1 Bottom Design Pressure, Shell **4.73** psi

Greater of the following

1.1.1 Bottom Slamming Pressure

At LCG **Pbcg =** **0.0020** psi

$Pbcg = N_1\Delta/L_wN_h{}^*B_w{}^*(1+n_{cg})F_D$

Bottom Slamming Pressure

At any section **Pbxx =** **0.0037** psi

(Midship)

$Pbxx = [N_1\Delta_/L_w{}^*B_{w]}{}^*(1+nxx)((70-\beta bx)/(70-\beta cg))F_D$

1.1.2 For Ships less than 61m:

Pbxx = 0.007353056

$Pbxx = [N_1\Delta/L_wN_h]^*B_w{}^*(1+ncg)F_D{}^*F_v$

1.1.3 Bottom Hydrostatic Pressure

(Midship) **Pd =** **4.7300** psi

Pd = $N_3(0.64H+d)$ psi

where

H=	13	ft.	
H=	(0.0172L+11.9	ft.(not less than survival wave height, 13 ft.)	
N_3=	0.44		
n_{xx}=	8.61	g's	
n_{xx}=	$n_{cg}K_v$		
Kv=	2	vert. Acc. Dist. Factor at midship (page 72) **(Varies with L)**	
βbx=	20	deadrise at any section, min. 10, max.30	
βcg=	20	deadrise at any LCG, min. 10, max.30	
N_1 =	0.069		
Δ =	18.69	L tons	
Lw=	53.30	ft.	
N_h=	2	no. of hulls	
B_w =	**26.24**	**ft**	
F_D =	0.83	design area factor, not less than 0.4 (see page 71)	
$h_{1/3}$ =	8.5	ft.(3.2.2 Table 1)	
n_{cg} =	4.30	g's	(see definition sheet)
V_1 =	11.88	ft/s	
A_D =	360	in^2	area of plate panel (page 59)
A_R =	$1.61\Delta/d$	in^2	
A_R =	12.39	in^2	
d=	**2.430**	**ft (not less than 0.04L)**	2.04672 taken as draft
bottom shell panel, l=	**36.000**	in.	
spacing, s =	**12.000**	in.	
A_D/A_R =	29.06		
Fv =	1	p72	
V_1 =	$7.24h_{1/3}/\sqrt{L}+3.28$ ft/s		
=	11.88		

vert acc. $n_{cg} = N_2((12h_{1/3}/N_hB_w)+1)*\tau*(50-\beta_{cg})(V^2(N_hB_w)^2/\Delta$ g's **page 62**

170658.75 g's

$N_{2\,=}$	0.0016	
$h_{1/3\,=}$	13	ft (Naval craft)
B_w=	26.24	ft
τ =	3	degree, running trim
βcg =	20	deadrise at LCG
V =	45	knot craft speed see 3.2.2/ Table 1
N_h=	2	no. of hulls

Maximum and minimum value see 3.2.2/1.1

not greater than, n_{cg} = 1.39+k_n(V/L^0.5)

= 4.30 g's k_n = 0.463

for speed greater than 18√L(9.94-√L) 358.823164 knots

max. n_{cg} = 6 g

vert.acc Use n_{cg} = **4.30** g's

Part 3 Chapter 2
Section 3 Plating
1.3 Thickness

1.3.1 Lateral loading **Bottom shell plate** **4.08** mm

plate thickness, t = 0.161 in. 4.08 mm
wet deck

t = $s\sqrt{pk}/\sigma_a$ in.

where

s =	12	in.
p =	4.73	psi (design pressure)
k =	0.5	plate panel ratio factor,3-2-3 Table 1
$\sigma_{a\,=}$	13200	psi (design stress)
l/s=	**3.00**	
l=	36	in.

	s_a=	13200	(0.55sy)
(alum.5083-H321/H116)	sy=	24000	psi

not to less than (based on stiffener spacing)

Minimum Thickness

1.3.2 t_{al}= 0.012s in. s= 12 in

t_{al}= 0.144 in. 3.66 mm

1.3.3(a) Bottom shell

t_{al}= 0.015√Lqa +0.04 in. qa= $17000/\sigma_{ya}$

t_{al}= 0.124 in. 3.14 mm qa= 0.607

unwelded yield $s_{ya=}$ 28000 N/mm^2

but not less than,t_{al} = 0.160 in. 4.06 mm

L= 51.17 ft

Part 3 Chapter 2
Section 4 Internals

1.3 Strength and stiffness

Bottom shell longitudinals

1.3.1 Section Modulus

SM = **0.613** in^3

SM = $144 \cdot p \cdot s \cdot l^2/\sigma a$ in^3

where,

p =	4.73	psi
s =	1	ft.
l=	3	ft.
s_a=	10000	(0.5sy)
(alum.6061-T6) sy=	20000	psi

Use: **ok** **sm = 1.04** in^3

includes 4" of plate

web depth	web thk	flange width	flange thk
3	0.1875	1	0.1875
76.2	4.7625	25.4	4.76

Part 3 Chapter 2
Section 4 Internals

1.3 Strength and stiffness

Bottom Shell Transv.

1.3.1 Section Modulus

SM = 0.859 in^3 **Floors to be selected accordingly.**

SM = $144 \cdot p \cdot s \cdot l^2/\sigma a$ in^3

where,

p =	**4.73**	psi
s =	3	ft.
l=	2.46	ft.
s_a=	**14400**	**(0.6sy)**
(alum.5083-H321/H116) sy=	24000	psi

Internals

1.3.2 Moment of Inertia

Moment of Inertia = **0.543** in^4

Inertia = $54 \cdot p \cdot s \cdot l^3/K_4 E$ in^4

where,

K_4= **0.0021** **for shell and deep tank stringers and transverse**

E= 10000000 psi alum.

Use the following to obtain section modulus and inertia, and web thickness check for section, then enter blue data to table below

	Bottom Transverse		**Section used:**				
Enter blue data	deck plate mm	web depth mm	web thk mm	flange width mm	flange thk mm	actual SM, in^3	actual I, in^4
	4.08	**150**	**6.35**	**0**	**0**	**2.47**	**11**
		web check 1	**okay**				
		web check 2	**okay**				

CALCULATION OF SECTION PROPERTIES Project No.

Type of member Deck or location

Deck plate **9 in W** x .16 in thk Req'd rule SM = 0.859 in^3

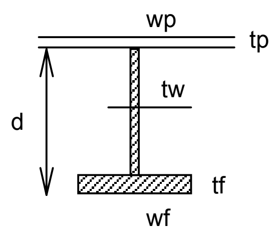
Actual SM = **2.47** in^3

web 5.91 in x .25 in wp

Face Flat . in x . in span = ft

US **TEE**

Plate thickness, tp	0.161	in
Plate width, wp	9.00	in
Depth of Section, d	5.91	in
Web thickness, tw	0.2500	in
Flange width, wf	0.00	in
Flange thickness, tf	0.0000	in



Section Piece	y (in)	Area (in^2)	Area*y (in^3)	Area*y^2 (in^4)	Io (in^4)
Plate	0.08	1.45	0.12	0.01	0.00
Web	3.11	1.48	4.60	14	4
Flange	6.07	0.00	0.00	0	0.00
Totals		2.92	4.71	14	4

wp=5000/3

Centroid	1.61	in	
Ixx at centroid	11	in^4	
SM pl	6.83	in^3	
SM flg	2.47	in^3	
Shear Area	1.52	in^2	
Iyy			

rx = 1.94

ry =

Effective Weight	
Plate	5.10
Web	5.21
Flange	0.00
W+FLG	5.21

web thickness check

Part 3 **Chapter 2** **Enter All Blue data**

section 4 **1.9**

minimum web thickness

$t = 144psl/2d_w\tau_a$

t= **0.106** in.

check 1

2.70 mm

where

p=	**4.730**		actual web, t: **6.4** mm		actual flg thk.: **0.0** mm
l=	**8.60**	ft.			
s=	**1.5**	ft.			actual web depth: **150** mm
dw=	5.91	in.(web depth)			
τa=	$0.5\tau_{yw}$				
τa=	7000	psi			
$\tau_{yw=}$	**14000**	psi (minimum shear yield welded condition)			

also web thickness not less than

dw/tw= 30.0

$dw/tw = 1.54(E/\tau_y)^{0.5}$

check 2

min tw= **4.99** mm

okay

alum, E= 10000000 psi

$\tau_{y=}$ **26285** psi (minimum shear yield unwelded condition)

(alum.5083-H116,H321)

FREEBOARD DECK
FBD Deck
(Applies along the full length of the vessel)

3.2.2 Design Pressures
3.5 Deck Design Pressure

From Table 4, for an exposed Freeboard deck and decks included in the hull girder bending moment,
(does not depend on length along ship)
Pd = 0.0088*L + 0.88 psi
1.11 psi

3.2.3 Plating
1.3 Thickness Plate thickness = **3.50 mm**
1.3.1 Lateral Loading

plate thickness, t = 0.112 in.
strength deck

t = $s\sqrt{pk}/\sigma_a$ in.

where

s =	18	in.
p =	1.11	psi (design pressure)
k =	0.5	plate panel ratio factor,3-2-3 Table 1
σ_{a} =	14400	psi (design stress)
l/s=	**2.00**	
l=	36	in.
s_a=	14400	(0.6sy for strength deck)
(alum.5083-H321/H116) sy=	24000	psi

1.3.2 Strength deck based on secondary stiffening

t_{al} = 0.072 in

t_{al} = 0.013*sqrt(l*qa)

where
qa= 0.61
qa= $17000/\sigma_{ya}$
$s_{ya=}$ 28000 psi

Also not to be less than:

1.3.3[c] Strength deck

t = 0.013*sqrt(L*qa) + 0.04 in
= 0.11245828 in

where: qa= $17000/\sigma_{ya}$
qa= 0.607
$s_{ya=}$ 28000 psi

Not to be less than **3.5** mm

3.2.4 - Internals:

Longitudinals:
1.3.1

SM = $144*p*s*l^2/\sigma a$

=	0.271 in^3

Where:

s = 1.5 ft
l = 3 ft
p = 1.11 psi
s_a= 0.33*σy
s_a= 7920 (0.33 σy)

σy = 24000 psi Welded yield strength

1.3.2 **Internals**
Moment of Inertia

Inertia = **0.134** in^3

I = $54*p*s*l^3/K_4E$ in^4

where,
K_4= 0.0018
E= 10000000 psi alum.

Based on this, select Longitudinals of geometry: SM = 0.33

	web depth	web thk	flange widt	flange thk	Stiff Area:	
	2	0.1875	0	0		
Transverses:	50.8	4.7625	0	0.00	241.935	mm^2

Part 3 Chapter 2
Section 4 Internals

1.3 Strength and stiffness
Free Board Deck Transverse **To be used in way of side hulls, else use wet deck calculations.**

1.3.1 Section Modulus

SM = 1.142 in^3

SM = $144*p*s*l^2/\sigma a$ in^3

where,
p = **1.11** psi
s = 3 ft.
l= 6.562 ft.
s_a= **18000** **(0.75sy)**
(alum.5083-H321/H116) sy= 24000 psi

Internals
1.3.2 Moment of Inertia

Moment of Inertia = **2.409** in^4

Inertia = $54*p*s*l^3/K_4E$ in^4

where,
K_4= **0.0021** **for shell and deep tank stringers and transverse**
E= 10000000 psi alum.

Use the following to obtain section modulus and inertia, and web thickness check for section, then enter blue data to table below

	Side Shell Transverse		Section used:				
Enter blue data	deck plate mm	web depth mm	web thk mm	flange widt mm	flange thk mm	actual SM, in^3	actual I, in^4
	4.76	**100**	**6**	**0**	**0**	**1.24**	**5**
		web check 1	**okay**				
		web check 2	**okay**				

CALCULATION OF SECTION PROPERTIES Project No.

Type of member Deck or location

Deck plate **36 in W** x .19 in thk Req'd rule SM = 1.142 in^3

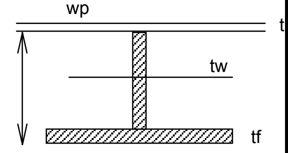
Actual SM = **1.24** in^3

web 3.94 in x .24 in wp

Face Flat . in x . in span = ft

US **TEE**

Plate thickness, tp	0.187	in
Plate width, wp	36.00	in
Depth of Section, d	3.94	in
Web thickness, tw	0.2362	in
Flange width, wf	0.00	in
Flange thickness, tf	0.0000	in



wp=5000/3

Section Piece	y (in)	Area (in^2)	Area*y (in^3)	Area*y^2 (in^4)	Io (in^4)
Plate	0.09	6.75	0.63	0.06	0.02
Web	2.16	0.93	2.00	4	1
Flange	4.12	0.00	0.00	0	0.00
Totals		7.68	2.64	4	1

	Centroid	0.34 in		
	Ixx at centroid	5 in^4		
	SM pl	13.67 in^3		
rx = 0.78	SM flg	1.24 in^3		
ry =	Shear Area	0.97 in^2		
	Iyy			

Effective Weight

Plate	23.79
Web	3.28
Flange	0.00
W+FLG	3.28

web thickness check

Part 3 **Chapter 2** **Enter All Blue data**

section 4 **1.9**

minimum web thickness

t= $144psl/2d_w\tau_a$

t= **0.057** in.

check 1

1.44 mm

where			
p=	**1.100**		
l=	**6.56**	ft.	
s=	**3**	ft.	
dw=	3.94	in.(web depth)	
τa=	$0.5\tau_{yw}$		
τa=	7000	psi	
$\tau_{yw=}$	**14000**	psi (minimum shear yield welded condition)	

actual web, t **6.0** mm

actual flg thk. **0.0** mm

actual web depth **100** mm

also web thickness not less than

dw/tw= 30.0

dw/tw= $1.54(E/\tau_y)^{0.5}$

check 2

min tw= **3.33** mm

okay

alum, E= 10000000 psi

$\tau_{y=}$ **26285** psi (minimum shear yield unwelded condition)

(alum.5083-H116,H321)

DEEP TANK
ABS Guide for Building and Classing High-Speed Naval Craft 2003
Part 3 Chapter 2

Section 2 **Design pressure** — **3.2.2 9.1** **pt1=** N_3*h psi

9.1 **Tank Boundaries** — **Design pressure** **pt1=** **3.836008** psi

N_3=	0.44	3.2.2/1.1
h=	8.7182	ft (from btm of pl)

Design pressure **14.49** psi

Tank bulkheads (full depth of hull)
overflow at 760 mm above crew deck

pt2= $pg*(1+0.5n_{xx})h_2$ psi
= **14.49** psi

Distance to top of tank	h_2=	6.562	ft
.from side center	pg=	0.44	lbf/in^2-ft.
	nxx=	8.04	g's
	ncg=	4.02	g's
	Kv=	2	Vary with L along ship

Part 3 **Chapter 2**
Section 3 **Plating**
1.3 **Thickness**

USE MACHINERY SPACE

1.3.1 Lateral loading — **Tank Bhd.** **3.56** mm;
This applies to the full length of the vessel.

plate thickness, t = 0.135 in. 3.42 mm
wet deck

$t = s\sqrt{pk/\sigma_a}$ in.

where

s =	6	in.
p =	14.49	psi (design pressure)
k =	0.5	plate panel ratio factor,3-2-3 Table 1
σ_a =	14400	psi (design stress)
l/s=	11.33	
l=	68	in.
s_a=	14400	(0.6sy)
(alum.5083-H321/H116) sy=	24000	psi

1.3.3 **Minimum Thickness**

1.3.3(d) **Deep tanks**

t_{al}= $0.011\sqrt{Lqa} + 0.04$ in. — qa= $17000/\sigma_{ya}$

t_{al}= 0.101 in. 2.57 mm — qa= 0.607

unwelded yield — s_{ya}= 28000 psi

but not less than, t_{al} = 0.140 in. 3.56 mm

L= 51.168 ft

ABS Guide for Building and Classing High-Speed Naval Craft 2003

Part 3 Chapter 2

Section 2 Design pressure

9.1 **Tank Boundaries**

Design pressure 0.66 psi

Location **Tank TOP plate**

overflow at 760 mm above officer deck

3.2.2 9.1	**pt1=**	**N_3*h**	psi
Design pressure	**pt1=**	**0.66**	psi
	N_3=	0.44	3.2.2/1.1
	h=	1.5	ft (from btm of pl)
	pt2=	**pg*(1+0.5n_{xx})h_2**	psi
	=	**0.00**	psi
	h_2=	0	ft
	pg=	0.44	lbf/in^2-ft.
	nxx=	4.58	g's
	ncg=	2.29	g's
	Kv=	**2**	

Part 3 Chapter 2

Section 3 Plating

1.3 Thickness

1.3.1 Lateral loading

Tank Top **3.56** mm;

This applies to the full length of the vessel.

plate thickness, t = 0.086 in. 2.19 mm

h1=	0
h2=	0
h3=	0
h4=	1.5

t = $s\sqrt{pk/\sigma_a}$ in.

where

s =	**18**	in.
p =	0.66	psi (design pressure)
k =	**0.5**	plate panel ratio factor,3-2-3 Table 1
σ_a =	14400	psi (design stress)
l/s=	**4.44**	
l=	**80**	in.
s_a=	**14400**	**(0.6sy)**
(alum.5083-H321/H116) sy=	24000	psi

1.3.3 Minimum Thickness

1.3.3(d) Deep tanks

t_{al}= $0.011\sqrt{Lqa} + 0.04$ in.

t_{al}= 0.101 in. 2.57 mm

unweled yield /0.7welded UTS

but not less than, t_{al} = 0.140 in. 3.56 mm

qa=	17000/σ_{ya}	
qa=	0.607	
s_{ya}=	28000	psi
L=	51.168	ft

Part 3 Chapter 2

Section 2 **Design pressure**

9.1 **Tank Boundaries**

Design pressure **14.49** psi

Tank bhd stiffener

overflow at 760 mm above crew deck

with stringer at mid tank height

3.2.2 9.1	**pt1=**	N_3*h	psi
Design pressure	**pt1=**	**3.836008**	psi
	N_3=	0.44	3.2.2/1.1
	h=	8.7182	ft
	pt2=	**pg*(1+0.5n_{xx})h_2**	psi
	=	**14.49**	psi
	h_2=	6.562	ft
	pg=	0.44	lbf/in^2-ft.
	nxx=	8.04	g's
	ncg=	4.02	g's
	Kv=	**2**	

Part 3 **Chapter 2**

Section **Internals**

h1=	0
h2=	0
h3=	0
h4=	0

1.3 Strength and stiffness

Tank bhd stiffeners

1.3.1 Section Modulus

SM = **2.106** in^3

SM = 144*p*s*l^2/σa in^3

where,

p =	14.49	psi
s =	**0.5**	ft.
l=	4.9215	ft.
s_a=	**12000**	**(0.6sy)**
(alum.6061-T6) sy=	20000	psi

USE

SM **2.55** in^3

web depth	web thk	flange	flange thk
3.5	0.25	3	0.25
88.9	6.35	76.2	6.35

d wpwfp tw tf tp

WTB MIDSHIP (same anywhere on the vessel)
ABS Guide for Building and Classing High-Speed Naval Craft 2003
Part 3 Chapter 2
Section 2 **Design pressure**
9.3 **Water-tight bhd**

Design Pressure for water-tight bhd stiffeners

location	to	stiffener spacing , in	h, ft.	N_3=	design pressure, Pw,psi	plate thickness, t	h , m
tank bottom	Tank Top	12.0	6.56	0.44	2.89	3.56	
Along Tank Top		18.0	1.50	0.44	0.66	3.56	

Design Pressure for water-tight bhd plate and web

location			h, ft.	N_3=	design pressure, Pw,psi		h , m
tank bhd			6.56	0.44	2.89	3.56	
Tank Top			1.50	0.44	0.66	3.56	

Part 3 **Chapter 2**
Section 3 **Plating**
1.3 **Thickness**

1.3.1 Lateral loading W.T. BHD **3.56** mm

plate thickness, t = 0.110 in. 2.80 mm
wet deck

t = $s\sqrt{pk}/\sigma_a$ in.

where
s = **12** in.
p = **3.84** psi (design pressure)
k = **0.5** plate panel ratio factor,3-2-3 Table 1
σ_a = 22800 psi (design stress)
l/s= **5.71**
l= **68.56** in. 1.215 m = 47.83 in
s_a= **22800** **(0.95sy)**
(alum.5083-H321/H116) sy= 24000 psi

1.3.3 **Minimum Thickness**
not to less than (based on stiffener spacing)
Minimum Thickness
1.3.2 t_{al}= 0.012s in. s= 12 in
t_{al}= 0.144 in. 3.66 mm

1.3.3(d) **Water -tight bulkhead and Deep tanks**

t_{al}= $0.011\sqrt{Lqa}+0.04$ in. qa= $17000/\sigma_{ya}$
t_{al}= 0.101 in. 2.57 mm qa= 0.607
unwelded yield s_{ya}= 28000 psi
but not less than, t_{al} = 0.140 in. 3.56 mm
L= 51.168 ft

Part 3 **Chapter 2**
Section 4 Internals

1.3 Strength and stiffness
Water -tight bhd stiffener in midship
Note that the top of the overflow is assumed to extend 0.75 m above the top of the tank.
1.3.1 Section Modulus

location	to	l, span, ft.	s in ft.	Design stress, s_a psi	design pressure, Pw,psi	section modulus, in^3	structural profile	actual SM, in^3	
tank bottom(outbd)	Tank Top	6.5620	1	20400	2.89	0.88	2 x 3/16 in	0.88	
Tank Top	Tank Top	3.0000	1.5	20400	0.66	0.06	2 x 3/16 in	0.88	

		web depth	web thk	flange width	flange thk
tank bottom(outbd)	Tank Top	2.0000	0.1875		
		50.8	4.7625	0	0.00
Tank Top	Tank Top	2.0000	0.1875		
		50.8	4.7625	0	0.00

d wp wfpw tf tp

Deckhouse aft Stiffeners

1.3.1 Section Modulus

SM = **0.936** in^3

SM = $144*p*s*l^2/$ in^3

where,

p =	1.50	psi
s =	1	ft.
l=	**7.21**	ft.
s_a=	**12000**	**(0.6sy)**
(alum.6061-T6) sy=	20000	psi

web depth	web thk	flange widt	flange thk
2	0.1875	2	0.1875
50.8	4.7625	50.8	4.76

SM **0.96** in^3

E Weight Estimate

Frame: 0
Spacing: 0 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	0.00	(kg)
Floor Thick.		(mm)
Floor Area	0	(m^2)
Floor VCG:		(m)
Floor Weight:		(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	0.00	(kg)
Total Bot. Shell Weight:	0.00	(kg)
Bot. Shell VCG:	#DIV/0!	(m)

Side Shell

1/4 length:	1.5176	(m)
Total Length:	6.0704	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.874	(m)
Shell Weight:	0.00	(kg)
Trans. Length:	0	(m)
Trans. Area:		(m)
Trans. Wt.:		(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	19.91601	
True # stiff.	20	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.874	(m)
Stiff. Weight:	0.00	(kg)
Total Side Shell Weight:	0.00	(kg)
Side Shell VCG:	#DIV/0!	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	0.00	(kg)
Trans Length:	0	(m)
Trans Dim:		(m)
Trans. VCG:		(m)
Trans Wt.:		(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	0.00	(kg)
Total Wet Deck Weight:	0.00	(kg)
Wet Deck VCG:	#DIV/0!	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.6	(m)
Plate Weight:	0.00	(kg)
Transverse as for Wet Deck		
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.5746	(m)
Stiff. Weight:	0.00	(kg)
Total Fbd. Deck Weight:	0.00	(kg)
Freeboard Deck VCG:	#DIV/0!	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	6.41	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0.9473	(m)
Bhd. Weight:	108.3	(kg)
Total Stiff. Length:	19.95	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	22.45	(kg)
Total Bulkhead Weight:	130.72	(kg)
Bulkhead VCG:	0.947	(m)

Frame Summary:

Frame Weight:	130.72	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	6.54	(kg)
Margin VCG:	0.947	(m)
Net Weight:	137.25	(kg)
Longitudinal CG:	0.00	(m)
Vertical Centre of Gravity:	0.95	(m)

	From:	To:
Frame 0.25	**0**	**0.5**

Frame: 0.25
Spacing: 0.43125 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	22.18	(kg)
Rule Floor T.:	0	(mm)
Actual Floor T.:	0	(mm)
Floor Area	0	(m^2)
Floor VCG:		(m)
Floor Weight:		(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	4.85	(kg)
Total Bot. Shell Weight:	27.03	(kg)
Bot. Shell VCG:	0.073	(m)

Side Shell

1/4 length:	1.5176	(m)
Total Length:	6.0704	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.874	(m)
Shell Weight:	44.22	(kg)
Trans. Length:	0	(m)
Trans. Area:		(m)
Trans. Wt.:		(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	19.91601	
True # stiff.	20	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.874	(m)
Stiff. Weight:	9.70	(kg)
Total Side Shell Weight:	53.92	(kg)
Side Shell VCG:	0.874	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	25.05	(kg)
Trans Length:	0	(m)
Trans Dim:		(m)
Trans. VCG:		(m)
Trans Wt.:		(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	7.49	(kg)
Total Wet Deck Weight:	32.54	(kg)
Wet Deck VCG:	1.363	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.6	(m)
Plate Weight:	36.86	(kg)
Trans Length:	0	(m)
Trans Dim:		(m)
Trans. VCG:		(m)
Trans Wt.:		(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.5746	(m)
Stiff. Weight:	6.11	(kg)
Total Fbd. Deck Weight:	42.96	(kg)
Freeboard Deck VCG:	1.596	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	156.46	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	7.82	(kg)
Margin VCG:	0.874	(m)
Net Weight:	164.28	(kg)
Longitudinal CG:	0.216	(m)
Vertical Centre of Gravity:	1.03	(m)

	From:	To:
Frame 1	**0.5**	**1.5**

Frame : 1
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.5176	(m)
Total Length:	6.0704	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.874	(m)
Shell Weight:	88.44	(kg)
Trans. Length:	5.44	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.95	(m)
Trans. Wt.:	17.31	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	19.91601	
True # stiff.	20	
Stiff. Area.	423	(mm^2)
Stiff. VCG:	0.874	(m)
Stiff. Weight:	19.41	(kg)
Total Side Shell Weight:	125.15	(kg)
Side Shell VCG:	0.885	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	47.83	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area.	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	14.99	(kg)
Total Wet Deck Weight:	112.91	(kg)
Wet Deck VCG:	1.411	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.62	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.57	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area.	241.93	(mm^2)
Stiff VCG:	1.5946	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.613	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	395.60	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	19.78	(kg)
Margin VCG:	0.885	(m)
Net Weight:	415.38	(kg)
Longitudinal CG:	0.8625	(m)
Vertical Centre of Gravity:	1.06	(m)

	From:	To:
Frame 2	**1.5**	**2.5**

Frame : 2
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.53	(m)
Total Length:	6.12	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.883	(m)
Shell Weight:	89.16	(kg)
Trans. Length:	5.48	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.958	(m)
Trans. Wt.:	17.43	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.07874	
True # stiff.	20	
Stiff. Area.	423	(mm^2)
Stiff. VCG:	0.883	(m)
Stiff. Weight:	19.41	(kg)
Total Side Shell Weight:	126.00	(kg)
Side Shell VCG:	0.893	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	47.83	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area.	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	14.99	(kg)
Total Wet Deck Weight:	112.91	(kg)
Wet Deck VCG:	1.411	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.635	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.585	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area.	241.93	(mm^2)
Stiff VCG:	1.6096	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.628	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	396.45	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	19.82	(kg)
Margin VCG:	0.893	(m)
Net Weight:	416.28	(kg)
Longitudinal CG:	1.7250	(m)
Vertical Centre of Gravity:	1.07	(m)

	From:	To:	
Frame 3	**2.5**	**3.5**	**(Contains Bulkhead)**

Frame : 3

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	54.06	(kg)
Bot. Shell VCG:	0.073	(m)

Side Shell

1/4 length:	1.555	(m)
Total Length:	6.22	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.893	(m)
Shell Weight:	90.62	(kg)
Trans. Length:	0	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.893	(m)
Trans. Wt.:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.40682	
True # stiff.	20	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.893	(m)
Stiff. Weight:	19.41	(kg)
Total Side Shell Weight:	110.03	(kg)
Side Shell VCG:	0.893	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	47.83	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	14.99	(kg)
Total Wet Deck Weight:	112.91	(kg)
Wet Deck VCG:	1.411	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.656	(m)
Plate Weight:	73.71	(kg)
Trans Length:	0	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.606	(m)
Trans Wt.:	0	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.6306	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	85.93	(kg)
Freeboard Deck VCG:	1.652	(m)

Bulkhead

Single Bhd Area:	2.91	(m^2)
Both Side Area:	5.82	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.894	(m)
Bhd. Weight:	73.7	(kg)
Total Stiff. Length:	17.47	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	11.25	(kg)
Total Bulkhead Weight:	84.94	(kg)
Bulkhead VCG:	0.894	(m)

Frame Summary:

Frame Weight:	447.86	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	22.39	(kg)
Margin VCG:	0.893	(m)
Net Weight:	470.25	(kg)
Longitudinal CG:	2.5875	(m)
Vertical Centre of Gravity:	1.06	(m)

	From:	To:
Frame 4	**3.5**	**4.5**

Frame : 4

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.572	(m)
Total Length:	6.288	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.902	(m)
Shell Weight:	91.61	(kg)
Trans. Length:	5.64	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.977	(m)
Trans. Wt.:	17.94	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.62992	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.902	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	129.93	(kg)
Side Shell VCG:	0.912	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.98	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	47.83	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	725.81	(mm^2)
Stiff VCG:	1.408	(m)
Stiff. Weight:	14.99	(kg)
Total Wet Deck Weight:	112.91	(kg)
Wet Deck VCG:	1.411	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.67	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.62	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.6446	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.663	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	400.38	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	20.02	(kg)
Margin VCG:	0.912	(m)
Net Weight:	420.40	(kg)
Longitudinal CG:	3.4500	(m)
Vertical Centre of Gravity:	1.08	(m)

	From:	To:
Frame 5	**4.5**	**5.5**

Frame : 5
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.59	(m)
Total Length:	6.36	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.911	(m)
Shell Weight:	92.66	(kg)
Trans. Length:	5.68	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.986	(m)
Trans. Wt.:	18.07	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.86614	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.911	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	131.11	(kg)
Side Shell VCG:	0.921	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.69	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.64	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.6646	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.683	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	389.00	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	19.45	(kg)
Margin VCG:	0.921	(m)
Net Weight:	408.45	(kg)
Longitudinal CG:	4.3125	(m)
Vertical Centre of Gravity:	1.08	(m)

	From:	To:	
Frame 6	**5.5**	**6.5**	**(Contains Bulkhead)**

Frame : 6
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	54.06	(kg)
Bot. Shell VCG:	0.073	(m)

Side Shell

1/4 length:	1.6	(m)
Total Length:	6.4	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.919	(m)
Shell Weight:	93.24	(kg)
Trans. Length:	0	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	0.919	(m)
Trans. Wt.:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.99738	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.919	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	113.62	(kg)
Side Shell VCG:	0.919	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.708	(m)
Plate Weight:	73.71	(kg)
Trans Length:	0	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.658	(m)
Trans Wt.:	0	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.6826	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	85.93	(kg)
Freeboard Deck VCG:	1.704	(m)

Bulkhead

Single Bhd Area:	3.01	(m^2)
Both Side Area:	6.02	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.925	(m)
Bhd. Weight:	76.2	(kg)
Total Stiff. Length:	18	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	11.59	(kg)
Total Bulkhead Weight:	87.81	(kg)
Bulkhead VCG:	0.925	(m)

Frame Summary:

Frame Weight:	441.77	(kg)
Margin IWO Propulsion?	Yes	
Margin Weight:	22.09	(kg)
Margin VCG:	0.919	(m)
Net Weight:	463.86	(kg)
Longitudinal CG:	5.1750	(m)
Vertical Centre of Gravity:	1.07	(m)

	From:	To:
Frame 7	**6.5**	**7.5**

Frame : 7

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.62	(m)
Total Length:	6.48	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.926	(m)
Shell Weight:	94.40	(kg)
Trans. Length:	5.84	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1	(m)
Trans. Wt.:	18.58	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	21.25984	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.926	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	133.36	(kg)
Side Shell VCG:	0.936	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.72	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.67	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.6946	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.713	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	391.26	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.936	(m)
Net Weight:	391.26	(kg)
Longitudinal CG:	6.0375	(m)
Vertical Centre of Gravity:	1.10	(m)

	From:	To:
Frame 8	**7.5**	**8.5**

Frame : 8

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.6375	(m)
Total Length:	6.55	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.935	(m)
Shell Weight:	95.42	(kg)
Trans. Length:	5.88	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.01	(m)
Trans. Wt.:	18.71	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	21.4895	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.935	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	134.51	(kg)
Side Shell VCG:	0.945	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.74	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.69	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.7146	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.733	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	392.40	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.945	(m)
Net Weight:	392.40	(kg)
Longitudinal CG:	6.9000	(m)
Vertical Centre of Gravity:	1.11	(m)

Frame 9	From:	To:
	8.5	9.5

Frame : 9

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	54.06	(kg)
Bot. Shell VCG:	0.073	(m)

Side Shell

1/4 length:	1.65	(m)
Total Length:	6.6	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.943	(m)
Shell Weight:	96.15	(kg)
Trans. Length:	5.88	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.02	(m)
Trans. Wt.:	18.71	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	21.65354	
True # stiff.	22	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.943	(m)
Stiff. Weight:	21.35	(kg)
Total Side Shell Weight:	136.21	(kg)
Side Shell VCG:	0.954	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.76	(m)
Plate Weight:	73.71	(kg)
Trans Length:	0	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.71	(m)
Trans Wt.:	0	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.7346	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	85.93	(kg)
Freeboard Deck VCG:	1.756	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.953	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.953	(m)

Frame Summary:

Frame Weight:	376.55	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.954	(m)
Net Weight:	376.55	(kg)
Longitudinal CG:	7.7625	(m)
Vertical Centre of Gravity:	1.13	(m)

Frame 10	From:	To:
	9.5	10.5

Frame : 10

Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.7612	(m)
Total Length:	3.0448	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.065	(m)
Shell Weight:	44.36	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.6614	(m^2)
Floor VCG:	0.17	(m)
Floor Weight:	11.17	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.9895013	
True # stiff.	10	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	9.70	(kg)
Total Bot. Shell Weight:	65.23	(kg)
Bot. Shell VCG:	0.090	(m)

Side Shell

1/4 length:	1.66	(m)
Total Length:	6.64	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.955	(m)
Shell Weight:	96.73	(kg)
Trans. Length:	6	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.0255	(m)
Trans. Wt.:	19.09	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	21.78478	
True # stiff.	22	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	0.955	(m)
Stiff. Weight:	21.35	(kg)
Total Side Shell Weight:	137.17	(kg)
Side Shell VCG:	0.965	(m)

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.77	(m)
Plate Weight:	73.71	(kg)
Trans Length:	4	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.72	(m)
Trans Wt.:	6.384	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	22.14567	
True # stiff.	22	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.7446	(m)
Stiff. Weight:	12.21	(kg)
Total Fbd. Deck Weight:	92.31	(kg)
Freeboard Deck VCG:	1.763	(m)

Bulkhead

Single Bhd Area:		(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	6.35	(mm)
Bhd. VCG:	0	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	423	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.000	(m)

Frame Summary:

Frame Weight:	395.07	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.965	(m)
Net Weight:	395.07	(kg)
Longitudinal CG:	8.6250	(m)
Vertical Centre of Gravity:	1.12	(m)

	From:	To:	
Frame 11	**10.5**	**11.5**	(Contains Bulkhead)

Frame : 11
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.76	(m)	
Total Length:	3.04	(m)	
Rule Shell T.:	4.08	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.0818	(m)	
Shell Weight:	44.29	(kg)	
Rule Floor T.:	4.08	(mm)	
Actual Floor T.:	6.35	(mm)	
Floor Area	0	(m^2)	0.6296
Floor VCG:	0.182	(m)	
Floor Weight:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	9.9737533		
True # stiff.	10		
Stiff. Area.	423	(mm^2)	
Stiff VCG:	0.1095	(m)	
Stiff. Weight:	9.70	(kg)	
Total Bot. Shell Weight:	53.99	(kg)	
Bot. Shell VCG:	0.087	(m)	

Side Shell

1/4 length:	1.657	(m)	
Total Length:	6.628	(m)	
Rule Shell T.:	4	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.969	(m)	
Shell Weight:	96.56	(kg)	
Trans. Length:	0	(m)	6.04
Trans. Area:	1196	(mm^2)	
Trans. VCG:	1.035	(m)	
Trans. Wt.:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	21.74541		
True # stiff.	22		
Stiff. Area:	423	(mm^2)	
Stiff. VCG:	0.969	(m)	
Stiff. Weight:	21.35	(kg)	
Total Side Shell Weight:	117.91	(kg)	
Side Shell VCG:	0.969	(m)	

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)	
Rule Plate T.:	3.5	(mm)	
Actual Plate T.:	4.76	(mm)	
Plate VCG:	1.7825	(m)	
Plate Weight:	73.71	(kg)	
Trans Length:	0	(m)	4
Trans Area:	600	(mm^2)	
Trans. VCG:	1.7325	(m)	
Trans Wt.:	0	(kg)	
Stiffener Sp.	12	in.	
Exact # stiff.	22.14567		
True # stiff.	22		
Stiff. Area:	241.93	(mm^2)	
Stiff VCG:	1.7571	(m)	
Stiff. Weight:	12.21	(kg)	
Total Fbd. Deck Weight:	85.93	(kg)	
Freeboard Deck VCG:	1.779	(m)	

Bulkhead

Single Bhd Area:	3.11	(m^2)
Both Side Area:	6.22	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.973	(m)
Bhd. Weight:	78.8	(kg)
Total Stiff. Length:	18.66	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	12.01	(kg)
Total Bulkhead Weight:	90.77	(kg)
Bulkhead VCG:	0.973	(m)

Frame Summary:

Frame Weight:	448.95	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.969	(m)
Net Weight:	448.95	(kg)
Longitudinal CG:	9.4875	(m)
Vertical Centre of Gravity:	1.12	(m)

	From:	To:	
Frame 12	**11.5**	**12.5**	(Contains Bulkhead)

Frame : 12
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.742	(m)	
Total Length:	2.968	(m)	
Rule Shell T.:	4.08	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.0989	(m)	
Shell Weight:	43.24	(kg)	
Rule Floor T.:	4.08	(mm)	
Actual Floor T.:	6.35	(mm)	
Floor Area	0	(m^2)	0.606
Floor VCG:	0.176	(m)	
Floor Weight:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	9.7375328		
True # stiff.	10		
Stiff. Area.	423	(mm^2)	
Stiff VCG:	0.1095	(m)	
Stiff. Weight:	9.70	(kg)	
Total Bot. Shell Weight:	52.94	(kg)	
Bot. Shell VCG:	0.101	(m)	

Side Shell

1/4 length:	1.655	(m)	
Total Length:	6.62	(m)	
Rule Shell T.:	4	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.985	(m)	
Shell Weight:	96.44	(kg)	
Trans. Length:	0	(m)	6.04
Trans. Area:	1196	(mm^2)	
Trans. VCG:	1.05	(m)	
Trans. Wt.:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	21.71916		
True # stiff.	22		
Stiff. Area:	423	(mm^2)	
Stiff. VCG:	0.985	(m)	
Stiff. Weight:	21.35	(kg)	
Total Side Shell Weight:	117.79	(kg)	
Side Shell VCG:	0.985	(m)	

Wet Deck (varies along length by rule)

Total length:	2.75	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.09	(kg)
Trans Length:	2.75	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.77	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.02231	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.35	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.75	(m)	
Rule Plate T.:	3.5	(mm)	
Actual Plate T.:	4.76	(mm)	
Plate VCG:	1.8	(m)	
Plate Weight:	73.71	(kg)	
Trans Length:	0	(m)	4
Trans Area:	600	(mm^2)	
Trans. VCG:	1.75	(m)	
Trans Wt.:	0	(kg)	
Stiffener Sp.	12	in.	
Exact # stiff.	22.14567		
True # stiff.	22		
Stiff. Area:	241.93	(mm^2)	
Stiff VCG:	1.7746	(m)	
Stiff. Weight:	12.21	(kg)	
Total Fbd. Deck Weight:	85.93	(kg)	
Freeboard Deck VCG:	1.796	(m)	

Bulkhead

Single Bhd Area:	3.11	(m^2)
Both Side Area:	6.22	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.973	(m)
Bhd. Weight:	78.8	(kg)
Total Stiff. Length:	18.66	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	12.01	(kg)
Total Bulkhead Weight:	90.77	(kg)
Bulkhead VCG:	0.973	(m)

Frame Summary:

Frame Weight:	447.78	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	0.985	(m)
Net Weight:	447.78	(kg)
Longitudinal CG:	10.3500	(m)
Vertical Centre of Gravity:	1.13	(m)

From: To:

Frame 13	12.5	13.5	(Contains Bulkhead)

Frame : 13
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.707	(m)	
Total Length:	2.828	(m)	
Rule Shell T.:	4.08	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.0818	(m)	
Shell Weight:	41.20	(kg)	
Rule Floor T.:	4.08	(mm)	
Actual Floor T.:	6.35	(mm)	
Floor Area	0	(m^2)	0.579
Floor VCG:	0.22	(m)	
Floor Weight:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	9.2782152		
True # stiff.	9		
Stiff. Area.	423	(mm^2)	
Stiff VCG:	0.1095	(m)	
Stiff. Weight:	8.73	(kg)	
Total Bot. Shell Weight:	49.93	(kg)	
Bot. Shell VCG:	0.087	(m)	

Side Shell

1/4 length:	1.65	(m)	
Total Length:	6.6	(m)	
Rule Shell T.:	4	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	1	(m)	
Shell Weight:	96.15	(kg)	
Trans. Length:	0	(m)	1.5
Trans. Area:	1196	(mm^2)	
Trans. VCG:	1.07	(m)	
Trans. Wt.:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	21.65354		
True # stiff.	22		
Stiff. Area:	423	(mm^2)	
Stiff. VCG:	1	(m)	
Stiff. Weight:	21.35	(kg)	
Total Side Shell Weight:	117.50	(kg)	
Side Shell VCG:	1.000	(m)	

Wet Deck (varies along length by rule)

Total length:	2.765	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.35	(m)
Plate Weight:	50.37	(kg)
Trans Length:	2.765	(m)
Trans Area:	5163	(mm^2)
Trans. VCG:	1.477	(m)
Trans Wt.:	37.97	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	9.071522	
True # stiff.	9	
Stiff. Area:	604.84	(mm^2)
Stiff VCG:	1.404	(m)
Stiff. Weight:	12.49	(kg)
Total Wet Deck Weight:	100.83	(kg)
Wet Deck VCG:	1.405	(m)

Freeboard Deck

Total length:	6.73	(m)	
Rule Plate T.:	3.5	(mm)	
Actual Plate T.:	4.76	(mm)	
Plate VCG:	1.81	(m)	
Plate Weight:	73.50	(kg)	
Trans Length:	0	(m)	3.96
Trans Area:	600	(mm^2)	
Trans. VCG:	1.76	(m)	
Trans Wt.:	0	(kg)	
Stiffener Sp.	12	in.	
Exact # stiff.	22.08005		
True # stiff.	22		
Stiff. Area:	241.93	(mm^2)	
Stiff VCG:	1.7846	(m)	
Stiff. Weight:	12.21	(kg)	
Total Fbd. Deck Weight:	85.71	(kg)	
Freeboard Deck VCG:	1.806	(m)	

Bulkhead

Single Bhd Area:	3.01	(m^2)
Both Side Area:	6.02	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	1.01	(m)
Bhd. Weight:	76.2	(kg)
Total Stiff. Length:	18.2	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	11.72	(kg)
Total Bulkhead Weight:	87.94	(kg)
Bulkhead VCG:	1.010	(m)

Frame Summary:

Frame Weight:	441.91	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.000	(m)
Net Weight:	441.91	(kg)
Longitudinal CG:	11.2125	(m)
Vertical Centre of Gravity:	1.15	(m)

	From:	To:	
Frame 14	13.5	14.5	(Contains Bulkhead)

Frame : 14
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.633	(m)	
Total Length:	2.532	(m)	
Rule Shell T.:	4.08	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.158	(m)	
Shell Weight:	36.89	(kg)	
Rule Floor T.:	4.08	(mm)	
Actual Floor T.:	6.35	(mm)	
Floor Area	0	(m^2)	0.5438
Floor VCG:	0.254	(m)	
Floor Weight:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	8.3070866		
True # stiff.	8		
Stiff. Area.	423	(mm^2)	
Stiff VCG:	0.1095	(m)	
Stiff. Weight:	7.76	(kg)	
Total Bot. Shell Weight:	44.65	(kg)	
Bot. Shell VCG:	0.150	(m)	

Side Shell

1/4 length:	1.65	(m)	
Total Length:	6.6	(m)	
Rule Shell T.:	4	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	1.03	(m)	
Shell Weight:	96.15	(kg)	
Trans. Length:	0	(m)	1.47
Trans. Area:	1196	(mm^2)	
Trans. VCG:	1.09	(m)	
Trans. Wt.:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	21.65354		
True # stiff.	22		
Stiff. Area:	423	(mm^2)	
Stiff. VCG:	1.03	(m)	
Stiff. Weight:	21.35	(kg)	
Total Side Shell Weight:	117.50	(kg)	
Side Shell VCG:	1.030	(m)	

Wet Deck (varies along length by rule)

Total length:	2.81	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	51.19	(kg)
Trans Length:	5.62	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	97.74	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	13.82874	
True # stiff.	14	
Stiff. Area:	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	25.90	(kg)
Total Wet Deck Weight:	174.83	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	6.695	(m)	
Rule Plate T.:	3.5	(mm)	
Actual Plate T.:	4.76	(mm)	
Plate VCG:	1.835	(m)	
Plate Weight:	73.11	(kg)	
Trans Length:	0	(m)	3.88
Trans Area:	600	(mm^2)	
Trans. VCG:	1.785	(m)	
Trans Wt.:	0	(kg)	
Stiffener Sp.	12	in.	
Exact # stiff.	21.96522		
True # stiff.	22		
Stiff. Area:	241.93	(mm^2)	
Stiff VCG:	1.8096	(m)	
Stiff. Weight:	12.21	(kg)	
Total Fbd. Deck Weight:	85.32	(kg)	
Freeboard Deck VCG:	1.831	(m)	

Bulkhead

Single Bhd Area:	2.88	(m^2)
Both Side Area:	5.76	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	1.04	(m)
Bhd. Weight:	72.9	(kg)
Total Stiff. Length:	17.81443	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	11.47	(kg)
Total Bulkhead Weight:	84.40	(kg)
Bulkhead VCG:	1.040	(m)

Frame Summary:

Frame Weight:	506.71	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.030	(m)
Net Weight:	506.71	(kg)
Longitudinal CG:	12.0750	(m)
Vertical Centre of Gravity:	1.23	(m)

	From:	To:	
Frame 15	14.5	15.5	(Contains Bulkhead)

Frame : 15
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.565	(m)	
Total Length:	2.26	(m)	
Rule Shell T.:	4.08	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	0.205	(m)	
Shell Weight:	32.92	(kg)	
Rule Floor T.:	4.08	(mm)	
Actual Floor T.:	6.35	(mm)	
Floor Area	0	(m^2)	0.498
Floor VCG:	0.313	(m)	
Floor Weight:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	7.4146982		
True # stiff.	7		
Stiff. Area.	423	(mm^2)	
Stiff VCG:	0.1095	(m)	
Stiff. Weight:	6.79	(kg)	
Total Bot. Shell Weight:	39.72	(kg)	
Bot. Shell VCG:	0.189	(m)	

Side Shell

1/4 length:	1.64	(m)	
Total Length:	6.56	(m)	
Rule Shell T.:	4	(mm)	
Actual Shell T.:	6.35	(mm)	
Shell VCG:	1.05	(m)	
Shell Weight:	95.57	(kg)	
Trans. Length:	0	(m)	1.45
Trans. Area:	1196	(mm^2)	
Trans. VCG:	1.125	(m)	
Trans. Wt.:	0.00	(kg)	
Stiffener Sp.	12	(in.)	
Exact # stiff.	21.52231		
True # stiff.	22		
Stiff. Area:	423	(mm^2)	
Stiff. VCG:	1.05	(m)	
Stiff. Weight:	21.35	(kg)	
Total Side Shell Weight:	116.92	(kg)	
Side Shell VCG:	1.050	(m)	

Wet Deck (varies along length by rule)

Total length:	2.89	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	52.65	(kg)
Trans Length:	5.78	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	100.52	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	14.22244	
True # stiff.	14	
Stiff. Area:	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	25.90	(kg)
Total Wet Deck Weight:	179.07	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	6.614	(m)	
Rule Plate T.:	3.5	(mm)	
Actual Plate T.:	4.76	(mm)	
Plate VCG:	1.835	(m)	
Plate Weight:	72.23	(kg)	
Trans Length:	0	(m)	3.728
Trans Area:	600	(mm^2)	
Trans. VCG:	1.785	(m)	
Trans Wt.:	0	(kg)	
Stiffener Sp.	12	in.	
Exact # stiff.	21.69948		
True # stiff.	22		
Stiff. Area:	241.93	(mm^2)	
Stiff VCG:	1.8096	(m)	
Stiff. Weight:	12.21	(kg)	
Total Fbd. Deck Weight:	84.44	(kg)	
Freeboard Deck VCG:	1.831	(m)	

Bulkhead

Single Bhd Area:	2.67	(m^2)
Both Side Area:	5.34	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	1.08	(m)
Bhd. Weight:	67.6	(kg)
Total Stiff. Length:	17.22581	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	11.09	(kg)
Total Bulkhead Weight:	78.70	(kg)
Bulkhead VCG:	1.080	(m)

Frame Summary:

Frame Weight:	498.85	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.050	(m)
Net Weight:	498.85	(kg)
Longitudinal CG:	12.9375	(m)
Vertical Centre of Gravity:	1.26	(m)

	From:	To:
Frame 16	**15.5**	**16.5**

Frame : 16
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.457	(m)
Total Length:	1.828	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.263	(m)
Shell Weight:	26.63	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.4372	(m^2)
Floor VCG:	0.374	(m)
Floor Weight:	7.38	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	5.9973753	
True # stiff.	6	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	5.82	(kg)
Total Bot. Shell Weight:	39.84	(kg)
Bot. Shell VCG:	0.261	(m)

Side Shell

1/4 length:	1.63	(m)
Total Length:	6.52	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	1.09	(m)
Shell Weight:	94.99	(kg)
Trans. Length:	1.4	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.16	(m)
Trans. Wt.:	4.45	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	21.39108	
True # stiff.	21	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	1.09	(m)
Stiff. Weight:	20.38	(kg)
Total Side Shell Weight:	119.82	(kg)
Side Shell VCG:	1.093	(m)

Wet Deck (varies along length by rule)

Total length:	3.03	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	55.20	(kg)
Trans Length:	6.06	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	105.39	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	14.91142	
True # stiff.	15	
Stiff. Area:	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	27.75	(kg)
Total Wet Deck Weight:	188.34	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	6.47	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.85	(m)
Plate Weight:	70.66	(kg)
Trans Length:	3.432	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.8	(m)
Trans Wt.:	5.477472	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	21.22703	
True # stiff.	21	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.8246	(m)
Stiff. Weight:	11.66	(kg)
Total Fbd. Deck Weight:	87.79	(kg)
Freeboard Deck VCG:	1.844	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.969	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.969	(m)

Frame Summary:

Frame Weight:	435.79	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.093	(m)
Net Weight:	435.79	(kg)
Longitudinal CG:	13.8000	(m)
Vertical Centre of Gravity:	1.32	(m)

	From:	To:
Frame 17	**16.5**	**17.5**

Frame : 17
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.3712	(m)
Total Length:	1.4848	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.346	(m)
Shell Weight:	21.63	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.3552	(m^2)
Floor VCG:	0.455	(m)
Floor Weight:	6.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	4.8713911	
True # stiff.	5	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	4.85	(kg)
Total Bot. Shell Weight:	32.48	(kg)
Bot. Shell VCG:	0.331	(m)

Side Shell

1/4 length:	1.54	(m)
Total Length:	6.16	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	1.135	(m)
Shell Weight:	89.74	(kg)
Trans. Length:	1.32	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.21	(m)
Trans. Wt.:	4.20	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	20.20997	
True # stiff.	20	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	1.135	(m)
Stiff. Weight:	19.41	(kg)
Total Side Shell Weight:	113.35	(kg)
Side Shell VCG:	1.138	(m)

Wet Deck (varies along length by rule)

Total length:	3.3	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	60.11	(kg)
Trans Length:	6.6	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	114.78	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	16.24016	
True # stiff.	16	
Stiff. Area:	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	29.61	(kg)
Total Wet Deck Weight:	204.50	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	6.2	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.85	(m)
Plate Weight:	67.71	(kg)
Trans Length:	2.9	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.8	(m)
Trans Wt.:	4.6284	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	20.34121	
True # stiff.	20	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.8246	(m)
Stiff. Weight:	11.10	(kg)
Total Fbd. Deck Weight:	83.44	(kg)
Freeboard Deck VCG:	1.844	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.969	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.969	(m)

Frame Summary:

Frame Weight:	433.77	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.138	(m)
Net Weight:	433.77	(kg)
Longitudinal CG:	14.6625	(m)
Vertical Centre of Gravity:	1.36	(m)

	From:	To:
Frame 18	**17.5**	**18.5**

Frame : 18
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0.259	(m)
Total Length:	1.036	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.465	(m)
Shell Weight:	15.09	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.116	(m^2)
Floor VCG:	0.575	(m)
Floor Weight:	1.96	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	3.3989501	
True # stiff.	3	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	2.91	(kg)
Total Bot. Shell Weight:	19.96	(kg)
Bot. Shell VCG:	0.424	(m)

Side Shell

1/4 length:	1.43	(m)
Total Length:	5.72	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	1.192	(m)
Shell Weight:	83.33	(kg)
Trans. Length:	1.21	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.28	(m)
Trans. Wt.:	3.85	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	18.7664	
True # stiff.	19	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	1.192	(m)
Stiff. Weight:	18.44	(kg)
Total Side Shell Weight:	105.62	(kg)
Side Shell VCG:	1.195	(m)

Wet Deck (varies along length by rule)

Total length:	3.69	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	67.22	(kg)
Trans Length:	7.38	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	128.35	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	18.15945	
True # stiff.	18	
Stiff. Area:	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	33.31	(kg)
Total Wet Deck Weight:	228.87	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	5.81	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.87	(m)
Plate Weight:	63.45	(kg)
Trans Length:	2.12	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.82	(m)
Trans Wt.:	3.38352	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	19.06168	
True # stiff.	19	
Stiff. Area:	241.93	(mm^2)
Stiff VCG:	1.8446	(m)
Stiff. Weight:	10.55	(kg)
Total Fbd. Deck Weight:	77.38	(kg)
Freeboard Deck VCG:	1.864	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.969	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.969	(m)

Frame Summary:

Frame Weight:	431.83	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.195	(m)
Net Weight:	431.83	(kg)
Longitudinal CG:	15.5250	(m)
Vertical Centre of Gravity:	1.41	(m)

	From:	To:
Frame 19	**18.5**	**19.5**

Frame : 19
Spacing: 0.8625 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0	(m)
Total Length:	0	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.465	(m)
Shell Weight:	0.00	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0.0828	(m^2)
Floor VCG:	0.886	(m)
Floor Weight:	1.40	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	0	
True # stiff.	0	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	0.00	(kg)
Total Bot. Shell Weight:	1.40	(kg)
Bot. Shell VCG:	0.886	(m)

Side Shell

1/4 length:	1.23	(m)
Total Length:	4.92	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	1.296	(m)
Shell Weight:	71.68	(kg)
Trans. Length:	0.92	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.44	(m)
Trans. Wt.:	2.93	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	16.14173	
True # stiff.	16	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	1.296	(m)
Stiff. Weight:	15.53	(kg)
Total Side Shell Weight:	90.13	(kg)
Side Shell VCG:	1.301	(m)

Wet Deck (varies along length by rule)

Total length:	4.19	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	76.33	(kg)
Trans Length:	8.38	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	145.74	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	20.62008	
True # stiff.	21	
Stiff. Area.	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	38.86	(kg)
Total Wet Deck Weight:	260.92	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	5.31	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.89	(m)
Plate Weight:	57.99	(kg)
Trans Length:	1.16	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.84	(m)
Trans Wt.:	1.85136	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	17.42126	
True # stiff.	17	
Stiff. Area.	241.93	(mm^2)
Stiff VCG:	1.8646	(m)
Stiff. Weight:	9.44	(kg)
Total Fbd. Deck Weight:	69.28	(kg)
Freeboard Deck VCG:	1.885	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.969	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.969	(m)

Frame Summary:

Frame Weight:	421.73	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.301	(m)
Net Weight:	421.73	(kg)
Longitudinal CG:	16.3875	(m)
Vertical Centre of Gravity:	1.48	(m)

	From:	To:
Frame 19.75	**19.5**	**20**

Frame : 19.75
Spacing: 0.43125 m (corresponds to plate width and stiffener length)

Bottom Shell

1/4 length:	0	(m)
Total Length:	0	(m)
Rule Shell T.:	4.08	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	0.465	(m)
Shell Weight:	0.00	(kg)
Rule Floor T.:	4.08	(mm)
Actual Floor T.:	6.35	(mm)
Floor Area	0	(m^2)
Floor VCG:	1.45	(m)
Floor Weight:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	0	
True # stiff.	0	
Stiff. Area.	423	(mm^2)
Stiff VCG:	0.1095	(m)
Stiff. Weight:	0.00	(kg)
Total Bot. Shell Weight:	0.00	(kg)
Bot. Shell VCG:	0.000	(m)

Side Shell

1/4 length:	0.7	(m)
Total Length:	2.8	(m)
Rule Shell T.:	4	(mm)
Actual Shell T.:	6.35	(mm)
Shell VCG:	1.57	(m)
Shell Weight:	20.40	(kg)
Trans. Length:	0	(m)
Trans. Area:	1196	(mm^2)
Trans. VCG:	1.71	(m)
Trans. Wt.:	0.00	(kg)
Stiffener Sp.	12	(in.)
Exact # stiff.	9.186352	
True # stiff.	9	
Stiff. Area:	423	(mm^2)
Stiff. VCG:	1.57	(m)
Stiff. Weight:	4.37	(kg)
Total Side Shell Weight:	24.76	(kg)
Side Shell VCG:	1.570	(m)

Wet Deck (varies along length by rule)

Total length:	4.58	(m)
Rule Shell T.:	6.24	(mm)
Actual Shell T.:	7.94	(mm)
Plate VCG:	1.36	(m)
Plate Weight:	41.72	(kg)
Trans Length:	4.58	(m) (spaced every 1/2 frame)
Trans Area:	6538	(mm^2)
Trans. VCG:	1.487	(m)
Trans Wt.:	79.65	(kg)
Stiffener Sp.	8	in.
Exact # stiff.	22.53937	
True # stiff.	23	
Stiff. Area.	806.5	(mm^2)
Stiff VCG:	1.414	(m)
Stiff. Weight:	21.28	(kg)
Total Wet Deck Weight:	142.65	(kg)
Wet Deck VCG:	1.439	(m)

Freeboard Deck

Total length:	4.9	(m)
Rule Plate T.:	3.5	(mm)
Actual Plate T.:	4.76	(mm)
Plate VCG:	1.87	(m)
Plate Weight:	26.76	(kg)
Trans Length:	0	(m)
Trans Area:	600	(mm^2)
Trans. VCG:	1.82	(m)
Trans Wt.:	0	(kg)
Stiffener Sp.	12	in.
Exact # stiff.	16.07612	
True # stiff.	16	
Stiff. Area.	241.93	(mm^2)
Stiff VCG:	1.8446	(m)
Stiff. Weight:	4.44	(kg)
Total Fbd. Deck Weight:	31.20	(kg)
Freeboard Deck VCG:	1.866	(m)

Bulkhead

Single Bhd Area:	0	(m^2)
Both Side Area:	0	(m^2)
Rule Bhd. T.:	3.56	(mm)
Actual Bhd. T:	4.76	(mm)
Bhd. VCG:	0.969	(m)
Bhd. Weight:	0.0	(kg)
Total Stiff. Length:	0	(m)
Stiff Area:	242	(mm^2)
Stiff. Weight:	0.00	(kg)
Total Bulkhead Weight:	0.00	(kg)
Bulkhead VCG:	0.969	(m)

Frame Summary:

Frame Weight:	198.60	(kg)
Margin IWO Propulsion?	No	
Margin Weight:	0.00	(kg)
Margin VCG:	1.570	(m)
Net Weight:	198.60	(kg)
Longitudinal CG:	17.0344	(m)
Vertical Centre of Gravity:	1.52	(m)

CL Hull Girders

Girder Area:	7137	(mm^2)
Total Length:	34	m
Girder VCG:	0.371	m
Girder Weight:	645.47028	(kg)

Net Weight:	645.47	(kg)
Longitudinal CG:	8.5	(m)
Vertical Centre of Gravity:	0.37	(m)

Hull Structure Summary:

Frame	Mass	LCG	VCG	M*LCG	M*VCG
Transom	137.25	0.00	0.95	0	130.0213
0.25	164.28	0.2156	1.03	35.42303	168.8887
1	415.38	0.8625	1.06	358.2684	442.3189
2	416.28	1.7250	1.07	718.076	445.7859
3	470.25	2.5875	1.06	1216.771	499.4783
4	420.40	3.4500	1.08	1450.378	455.5465
5	408.45	4.3125	1.08	1761.443	440.8759
6	463.86	5.1750	1.07	2400.453	497.2795
7	391.26	6.0375	1.10	2362.219	429.8015
8	392.40	6.9000	1.11	2707.593	433.9486
9	376.55	7.7625	1.13	2922.954	425.6945
10	395.07	8.6250	1.12	3407.463	441.8943
11	448.95	9.4875	1.12	4259.38	501.0534
12	447.78	10.3500	1.13	4634.534	504.9824
13	441.91	11.2125	1.15	4954.939	507.0842
14	506.71	12.0750	1.23	6118.483	623.3212
15	498.85	12.9375	1.26	6453.863	627.5943
16	435.79	13.8000	1.32	6013.89	574.1867
17	433.77	14.6625	1.36	6360.171	587.8551
18	431.83	15.5250	1.41	6704.195	608.3237
19	421.73	16.3875	1.48	6911.033	624.5281
19.75	198.60	17.0344	1.52	3383.096	302.3637
CL Grdr	645.47	8.5	0.37	5486.497	239.4695

	Mass	LCG	VCG
Totals:	**9362.82**	**8.610776**	**1.122771**

	Plate (mm)	Actual Plate	Webs and Angles					Weight		Length	Number	Wt per Station	Wt	VCG	M*VCG	LCG	M*LCG
			deck plate mm	web depth mm	web thk mm	flange width mm	flange thk mm	(kg/m)		(m)		half beam(kg)	(kg)	(m)	(kg*m)	(m)	
Superstructure Side																	
Plate:	3.66	4.76					area =	42.16	m^2				534	3.3	1762	7.57	4041
Stiffeners:				50.80	4.76	50.80	4.76	1.287		140.486			181	3.3	597	7.57	1369
													715				
Superstructure Front																	
1st Tier:																	
Plate:	3.12	4.76					area =	10.935	m^2				138	2.78	385	12.6	1745
Stiffeners:				76.20	6.35	76.20	6.35	2.574		48.67			125	2.78	348	12.6	1579
													264				
2nd Tier:																	
Plate:	2.44	4.76					area =	9.9	m^2				125	4.82	604	7.2	903
Stiffeners:				63.50	6.35	50.80	6.35	1.931		42.4			82	4.82	395	7.2	589
													207				
Superstructure Top																	
Plate:	3.66	4.76					area =	31.095	m^2				394	4.62	1819	7.5	2953
Stiffeners:				50.80	4.76	38.10	4.76	1.126		89.25			101	4.62	464	7.5	754
Girder:				165.10	12.50	82.60	12.50	8.236		4.05			33	4.62	154	9	300
													528				
Superstructure Aft End																	
Plate:	3.6576	4.76					area =	19.08	m^2				242	4.85	1172	4.49	1085
Stiffeners:				50.80	4.76	50.80	4.76	1.287		63.7			82	4.85	398	4.49	368
													324				
												Total:	2036.73	**3.98**	8097.0	**7.70**	15684.5
Once an accurate weight estimate is complete, must complete hull girder calculations																	

Weight Estimate:

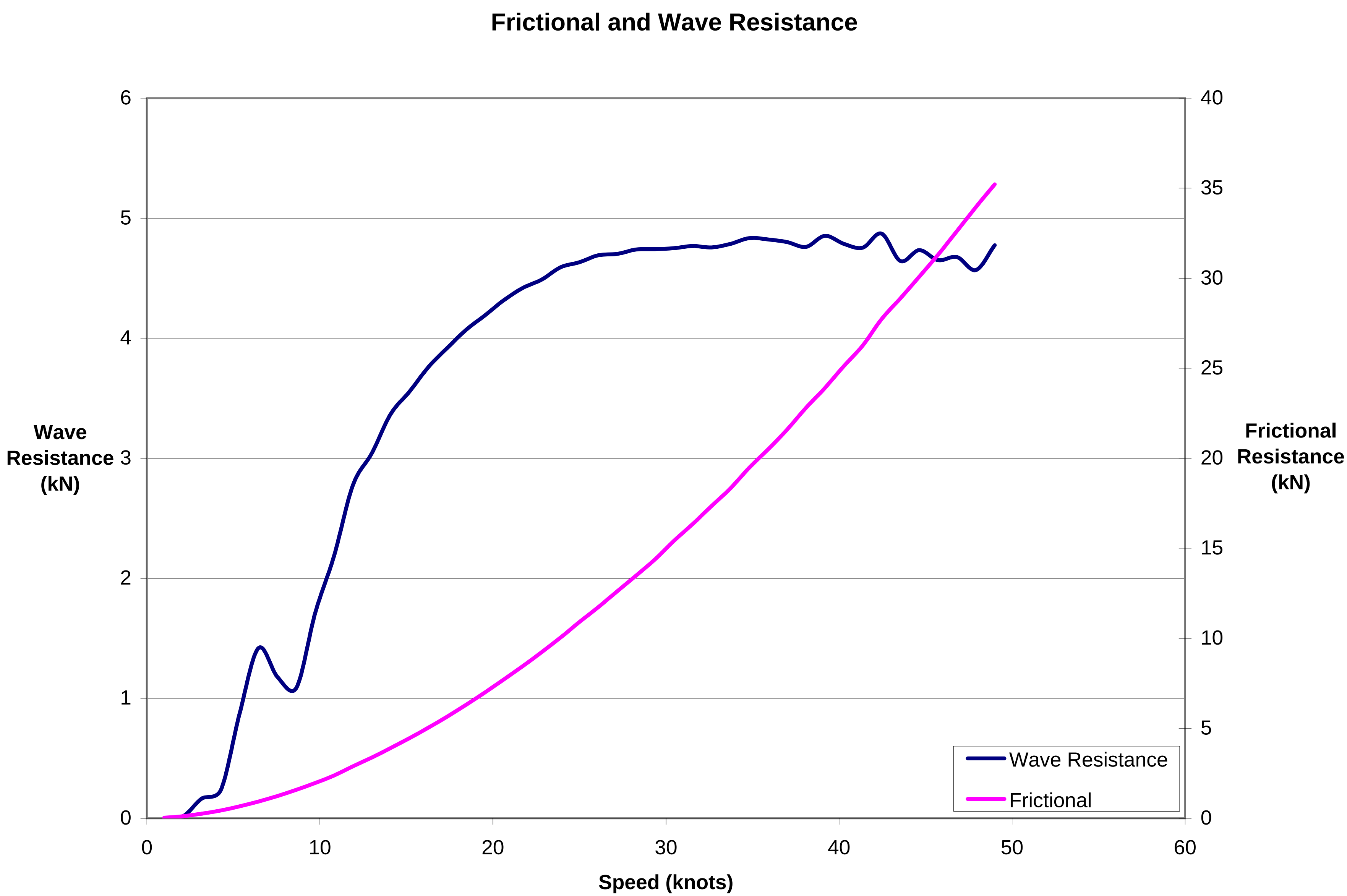
starboard side = +
Port side = -

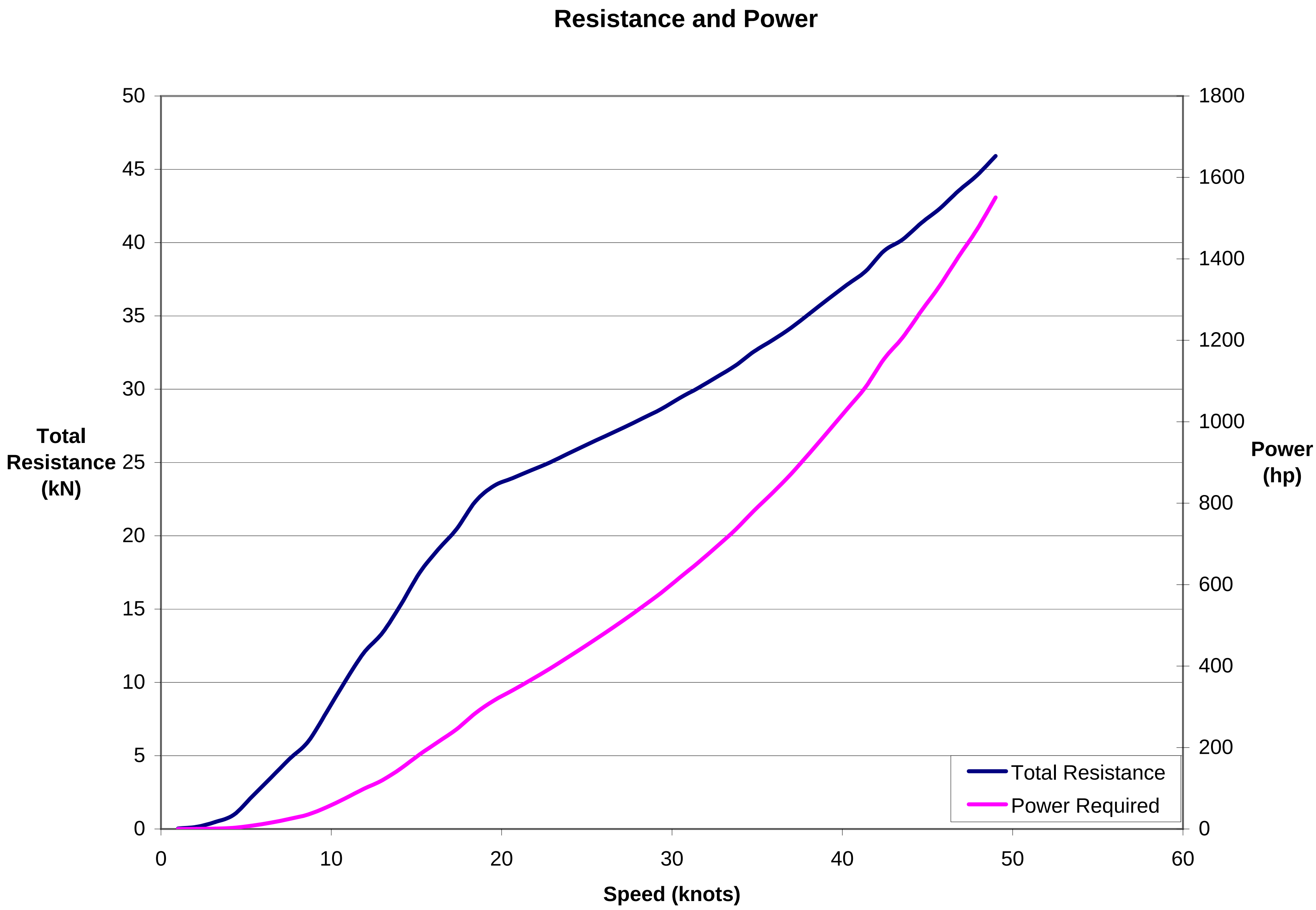
	Weight (kg)	LCG (m)	M*LCG	VCG (m)	M*VCG	TCG (m)	M*TCG
Structure							
Hull Structure:	9363	8.61	80621	1.12	10512.3	0	0
Superstructure:	2037	7.70	15685	3.98	8096.982	0	0
Structure subtotal:	11400						
Machinery							
Engines:	3800	3.74	14212	0.895	3401	0	0
Water Jets:	2110	0.35	739	0.75	1582.5	0	0
Compressor:	544.3	4	2177	2.14	1164.802	-0.944	-513.8192
Compressor Tanks:	544.3	5.6	3048	2.16	1175.688	-1.38	-751.134
Anchor winch (fwd incl. rode)	130	14	1820	1.6	208	0	0
Anchor winch (aft incl. rode)	130	1.5	195	1.6	208	0	0
Lift Winches (x2)	40	0.623	25	1.8	72	0	0
Fuel Pump (x2)	20	11.14	223	0.5	10	0	0
Ballast Pump (x2)	20	11.97	239	0.5	10	0	0
Bilge Pump (x2)	20	3.74	75	0.5	10	0	0
Machinery subtotal:	7358.6						
Tanks							
4 Fuel Tanks	2998	11.14	33398	0.817	2449.366	0	0
2 Ballast Tanks	0	11.97	0	0.817	0	0	0
Fresh Water	957	9.5	9095	0.817	782.1555	2.38	2278.494
Gray Water	287.2	9.5	2728	0.817	234.6466	-2.87	-824.2789
Black Water	287.2	9.5	2728	0.817	234.6466	-1.88	-539.9458
Tank subtotal:	4530						
Electrical and Controls							
Alternator (x2)	60	4.72	283	0.4	24	0	0
Generator	389	6.054	2355	0.895	348.155	2.7925	1086.283
Batteries	300	5.3	1590	1.8	540	1.775	532.5
Wires and Controls	200	8.25	1650	2.25	450	0	0
Electrical subtotal:	949						
Other							
Outfit and Furnishings	3000	8.25	24750	2.75	8250	0	0
Paint	200	8.25	1650	1.1	220	0	0
Other subtotal:	3200						
SubTotal:	**27437**	**7.26** -0.99	199286	**1.46**	39984.24	**0.05**	1268.099
5% Margin	1372						

	Weight (kg)	LCG (m)	VCG (m)	TCG (m)
Totals:	**28809**	**7.26**	**1.46**	**0.05**

F Resistance

U		Rh	Rf	Rv	Rwtrans	Rwdiv	Rw	Rwtinter	Rwdinter	Rwinter	Rr	Rt	Power	
(m/s)	(knots)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kN)	(kW)	(hp)
0.515	1	0	0.031	0.03	0.00048	0.0001	0	-2E-06	-6E-06	-7E-06	7E-04	0.032	0.016	0.022
1.076	2.0909	0.01	0.118	0.12	0.01041	0.0065	0.02	0.000087	0.000068	0.00016	0.022	0.141	0.151	0.203
1.637	3.1818	0.06	0.255	0.25	0.12299	0.0421	0.17	0.001371	-0.00264	-0.0013	0.223	0.478	0.783	1.049
2.198	4.2728	0.29	0.437	0.44	0.09463	0.1404	0.24	0.013882	-0.0025	0.01139	0.529	0.966	2.124	2.846
2.76	5.3637	0.69	0.665	0.67	0.38866	0.4849	0.87	0.004481	-0.01978	-0.0153	1.559	2.224	6.138	8.225
3.321	6.4546	1.14	0.932	0.93	0.48139	0.937	1.42	0.150387	0.103692	0.25408	2.562	3.494	11.6	15.55
3.882	7.5456	2.37	1.238	1.24	0.55249	0.625	1.18	0.051273	-0.22119	-0.1699	3.545	4.783	18.57	24.88
4.443	8.6365	3.28	1.581	1.58	0.035	1.0509	1.09	0.005078	-0.06263	-0.0575	4.367	5.949	26.43	35.42
5.005	9.7274	4.3	1.961	1.96	0.57444	1.1369	1.71	0.252947	0.093816	0.34676	6.014	7.976	39.92	53.49
5.566	10.818	5.52	2.378	2.38	1.14449	1.0418	2.19	0.511334	0.008843	0.52018	7.701	10.08	56.1	75.18
6.127	11.909	6.36	2.887	2.89	1.57246	1.2023	2.77	0.723158	-0.10097	0.62218	9.13	12.02	73.63	98.66
6.689	13	6.96	3.376	3.38	1.63807	1.4039	3.04	0.771321	-0.13492	0.63641	10	13.38	89.48	119.9
7.25	14.091	8.04	3.906	3.91	1.63697	1.7304	3.37	0.783131	-0.14816	0.63497	11.41	15.32	111	148.8
7.811	15.182	9.47	4.457	4.46	1.55177	2.0049	3.56	0.750857	-0.10166	0.6492	13.02	17.48	136.5	183
8.372	16.273	10.3	5.039	5.04	1.44102	2.3184	3.76	0.702733	-0.07613	0.62661	14.02	19.06	159.6	213.9
8.934	17.364	10.9	5.651	5.65	1.34577	2.5727	3.92	0.660046	-0.02568	0.63436	14.81	20.47	182.8	245
9.495	18.455	12	6.31	6.31	1.22093	2.8498	4.07	0.601285	0.009736	0.61102	16.03	22.34	212.1	284.2
10.06	19.546	12.2	6.998	7	1.13242	3.0583	4.19	0.559428	0.037108	0.59654	16.41	23.4	235.4	315.4
10.62	20.637	11.9	7.712	7.71	1.03459	3.2823	4.32	0.512299	0.076301	0.5886	16.22	23.93	254.1	340.4
11.18	21.728	11.6	8.455	8.46	0.94383	3.4753	4.42	0.468196	0.104045	0.57224	16.01	24.46	273.4	366.4
11.74	22.819	11.3	9.226	9.23	0.8606	3.6281	4.49	0.42751	0.106956	0.53447	15.77	24.99	293.4	393.2
12.3	23.909	11	10.05	10	0.78453	3.807	4.59	0.39015	0.153884	0.54403	15.57	25.61	315.1	422.2
12.86	25	10.7	10.9	10.9	0.71494	3.9175	4.63	0.355856	0.145216	0.50107	15.31	26.21	337.2	451.8
13.42	26.091	10.4	11.73	11.7	0.6508	4.04	4.69	0.32416	0.160961	0.48512	15.07	26.8	359.7	482
13.99	27.182	10.1	12.61	12.6	0.59281	4.109	4.7	0.295446	0.134873	0.43032	14.79	27.39	383.1	513.4
14.55	28.273	9.8	13.48	13.5	0.54024	4.1983	4.74	0.269371	0.14176	0.41113	14.53	28.01	407.5	546.1
15.11	29.364	9.51	14.39	14.4	0.47391	4.2681	4.74	0.236387	0.152509	0.3889	14.25	28.64	432.7	579.8
15.67	30.455	9.23	15.41	15.4	0.44999	4.3002	4.75	0.224529	0.113762	0.33829	13.99	29.39	460.6	617.2
16.23	31.546	8.98	16.34	16.3	0.41169	4.357	4.77	0.205475	0.118758	0.32423	13.74	30.09	488.3	654.4
16.79	32.637	8.73	17.35	17.3	0.36353	4.3924	4.76	0.18148	0.124928	0.30641	13.49	30.84	517.8	693.9
17.35	33.728	8.49	18.33	18.3	0.34668	4.4394	4.79	0.173101	0.114347	0.28745	13.28	31.61	548.5	735.1
17.91	34.819	8.26	19.48	19.5	0.30703	4.5267	4.83	0.15333	0.190246	0.34358	13.09	32.57	583.5	781.8
18.48	35.91	8.03	20.5	20.5	0.29306	4.5294	4.82	0.146371	0.150274	0.29665	12.85	33.35	616.2	825.7
19.04	37.001	7.8	21.59	21.6	0.26973	4.5317	4.8	0.134736	0.136771	0.27151	12.6	34.19	650.9	872.3
19.6	38.091	7.61	22.8	22.8	0.24944	4.5116	4.76	0.124616	0.096389	0.22101	12.37	35.17	689.3	923.6
20.16	39.182	7.41	23.9	23.9	0.23079	4.6226	4.85	0.115306	0.194257	0.30956	12.27	36.16	729	976.9
20.72	40.273	7.22	25.11	25.1	0.21372	4.5729	4.79	0.106786	0.136009	0.2428	12.01	37.12	769.2	1031
21.28	41.364	7.04	26.25	26.3	0.19803	4.5566	4.75	0.098956	0.118148	0.2171	11.79	38.04	809.6	1085
21.84	42.455	6.85	27.72	27.7	0.18379	4.6871	4.87	0.091847	0.247799	0.33965	11.72	39.44	861.6	1155
22.4	43.546	6.68	28.88	28.9	0.17086	4.4721	4.64	0.085389	0.033789	0.11918	11.32	40.21	900.9	1207
22.97	44.637	6.53	30.08	30.1	0.15925	4.5743	4.73	0.079588	0.136108	0.2157	11.26	41.34	949.5	1272
23.53	45.728	6.37	31.31	31.3	0.14852	4.5019	4.65	0.074231	0.067705	0.14194	11.02	42.33	995.9	1334
24.09	46.819	6.22	32.62	32.6	0.13861	4.5371	4.68	0.069278	0.110084	0.17936	10.9	43.52	1048	1405
24.65	47.91	6.07	33.95	34	0.12943	4.4386	4.57	0.064694	0.022311	0.08701	10.64	44.59	1099	1473
25.21	49.001	5.92	35.21	35.2	0.12091	4.6535	4.77	0.060438	0.25199	0.31243	10.7	45.91	1157	1551

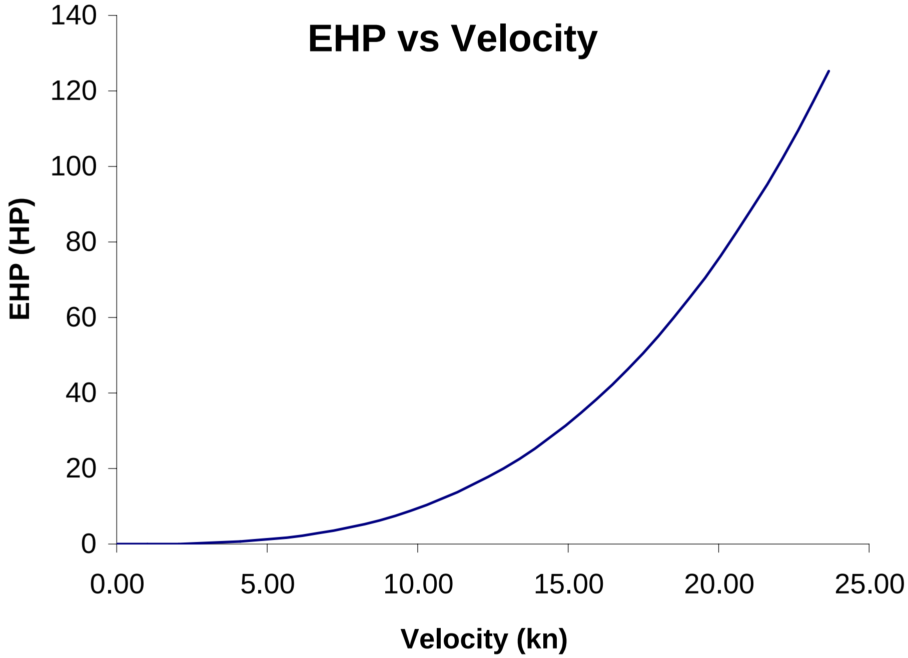

Frictional and Wave Resistance
Wave Resistance (kN)
Frictional Resistance (kN)
Speed (knots)
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
Wave Resistance
Frictional



Resistance and Power
Total Resistance (kN)
Power (hp)
Speed (knots)
0
5
10
15
20
25
30
35
40
45
50
0
200
400
600
800
1000
1200
1400
1600
1800
0
10
20
30
40
50
60
Total Resistance
Power Required

Parameters		
Front Cross Sectional Area	12.23	m^2
Drag Coefficient	0.96	

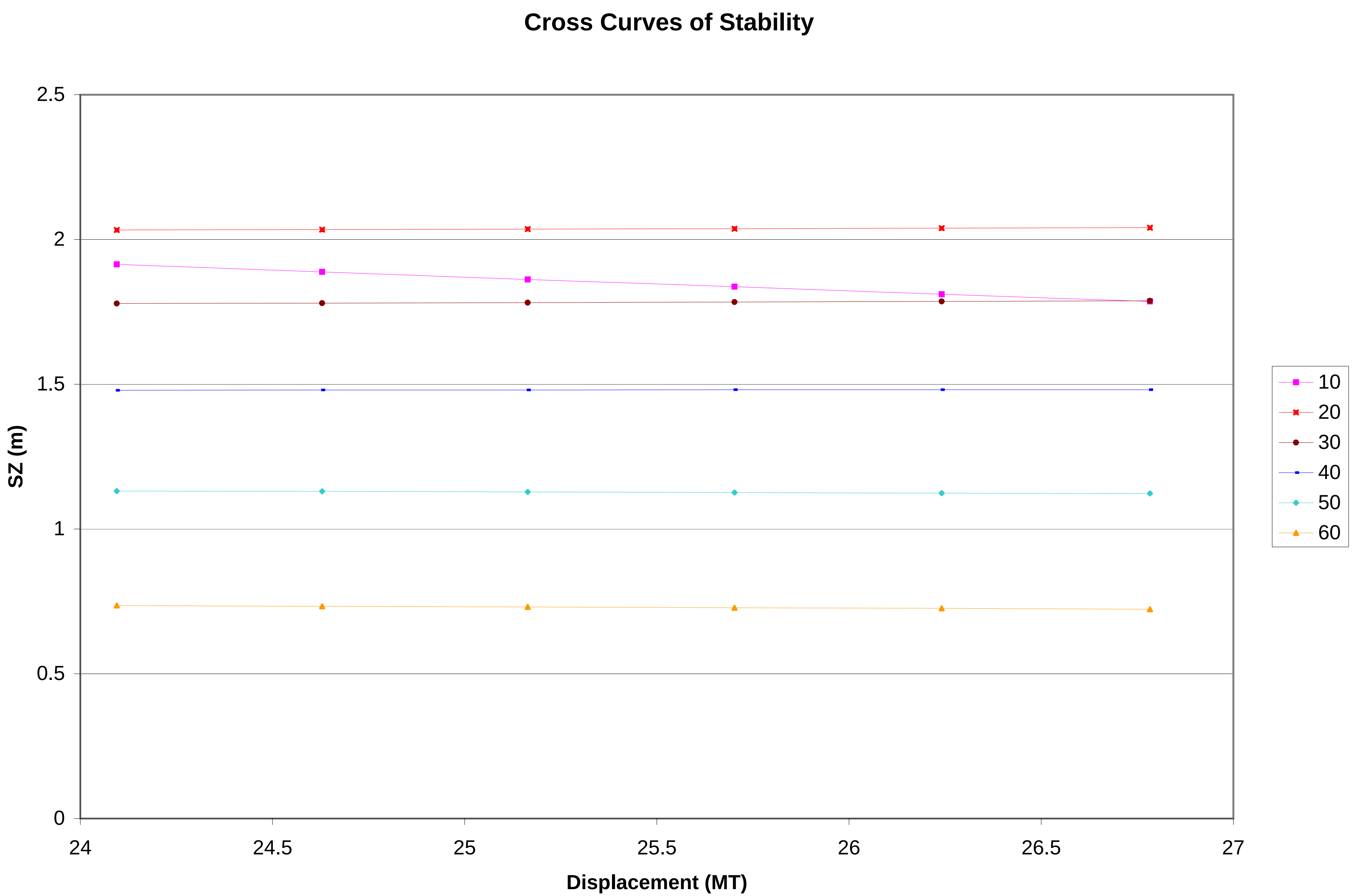
Constants		
Air Density	1.2	kg/m^3



Speed		Resistance	EHP	
kn	m/s	N	kW	HP
0	0.00	0	0	0.0
2	1.03	7	8	0.0
4	2.06	30	61	0.1
6	3.09	67	207	0.3
8	4.12	119	491	0.7
10	5.14	186	959	1.3
12	6.17	268	1657	2.2
14	7.20	365	2632	3.5
16	8.23	477	3928	5.3
18	9.26	604	5593	7.5
20	10.29	746	7673	10.3
22	11.32	902	10213	13.7
24	12.35	1074	13259	17.8
26	13.38	1260	16857	22.6
28	14.40	1462	21054	28.2
30	15.43	1678	25896	34.7
32	16.46	1909	31428	42.1
34	17.49	2155	37697	50.6
36	18.52	2416	44748	60.0
38	19.55	2692	52628	70.6
40	20.58	2983	61382	82.3
42	21.61	3289	71058	95.3
44	22.64	3609	81700	109.6
46	23.66	3945	93355	125.2

Drag Coefficient from http://www.engineeringtoolbox.com/

G Stability Calculations



Cross Curves of Stability
SZ (m)
2.5
2
1.5
1
0.5
0
24
24.5
25
25.5
26
26.5
27
Displacement (MT)
10
20
30
40
50
60

Gravity 9.81 m/s^2
Actual Displacement 25.3 MT

Real VCG 1.54 m
Wind Velocity 95 knots
Projected Area 24 m^2 (area on which the wind acts)
Lever arm of Area 2.75 m (distance between half draft and projected area centroid)
Ship Speed 22.5 m/s
CG to .5T 1.04 m
Turning Radius 141 m

0	Angle	25.5	25	25.3		Area under GZ curve
	0	0	0	0	0	0
1	10	1.862	1.888	1.8724	1.8724	0.163398
2	20	2.036	2.034	2.0352	2.021519	0.843015
3	30	1.782	1.78	1.7812	1.7612	1.833328
4	40	1.48	1.48	1.48	1.454288	2.955746
5	50	1.128	1.13	1.1288	1.098158	4.069461
6	60	0.731	0.733	0.7318	0.697159	5.009486
7	70	0.301	0.303	0.3018	0.264212	5.596755
8	80	-0.144	-0.142	-0.1432	-0.182592	5.653736

Interpolation Value	0.6	
	0	0
GM	10.72806	10.72806

Wind Forces

Angle of Heel (degrees)	GZ (m)	Wind Heeling Arm (m)	
0	0	0.459098	-0.459098
10	1.8724	0.445254	1.427146
20	2.021519	0.405394	1.616126
30	1.7612	0.344323	1.416877
40	1.454288	0.26941	1.184879
50	1.098158	0.189688	0.90847
60	0.697159	0.114774	0.582385
70	0.264212	0.053704	0.210508
80	-0.18259	0.013843	-0.196436

Criteria 1
angle of steady heel does not exceed 10 degrees
Criteria Passed

Criteria 2

Heeling arm at intersection is no more then 60 percent of maximum Righting arm

C	2.447451
GZ $_{@ C}$	0.458261
H.A. $_{@C}$	0.458261
MAX GZ	2.021519
	Criteria Passed

Criteria 3

Residual righting energy is not less than 40 percent of the total area

Angle (degrees)	GZ-H.A (m)	S.M	
2.447451	0		
20	1.616126	1	1.616126
30	1.416877	4	5.667507
40	1.184879	2	2.369758
50	0.90847	4	3.63388
60	0.582385	2	1.164769
70	0.210508	4	0.842032
80	0	1	0
			15.29407

A1 65.1638

Angle (degrees)	GZ-H.A (m)	S.M	
2.447451	0	0	0
0	-0.4591	1	-0.459098
-10	-2.31765	4	-9.270617
-20	-2.42691	2	-4.853826
-30	-2.10552	4	-8.422093
-40	-1.7237	1	-1.723698
-22.55255	-2.46721	0	0
			-24.72933

A2 46.43257

Criteria Passed

High Speed Turns

Angle of Heel (degrees)	GZ (m)	Turn Heeling Arm (m)	
0	0	0.380636	-0.380636
10	1.8724	0.374854	1.497546
20	2.021519	0.357681	1.663838
30	1.7612	0.329641	1.431559
40	1.454288	0.291584	1.162704
50	1.098158	0.244668	0.85349
60	0.697159	0.190318	0.506841
70	0.264212	0.130185	0.134027
80	-0.182592	0.066097	-0.248689

Criteria 1

angle of steady heel does not exceed 10 degrees

Criteria Passed

Criteria 2

Heeling arm at intersection is no more then 60 percent of maximum Righting arm

C 2.031602

$GZ_{@\,C}$ 0.380397

$H.A._{@C}$ 0.380397

MAX GZ 2.021519

Criteria Passed

Criteria 3

Residual righting energy is not less than 40 percent of the total area

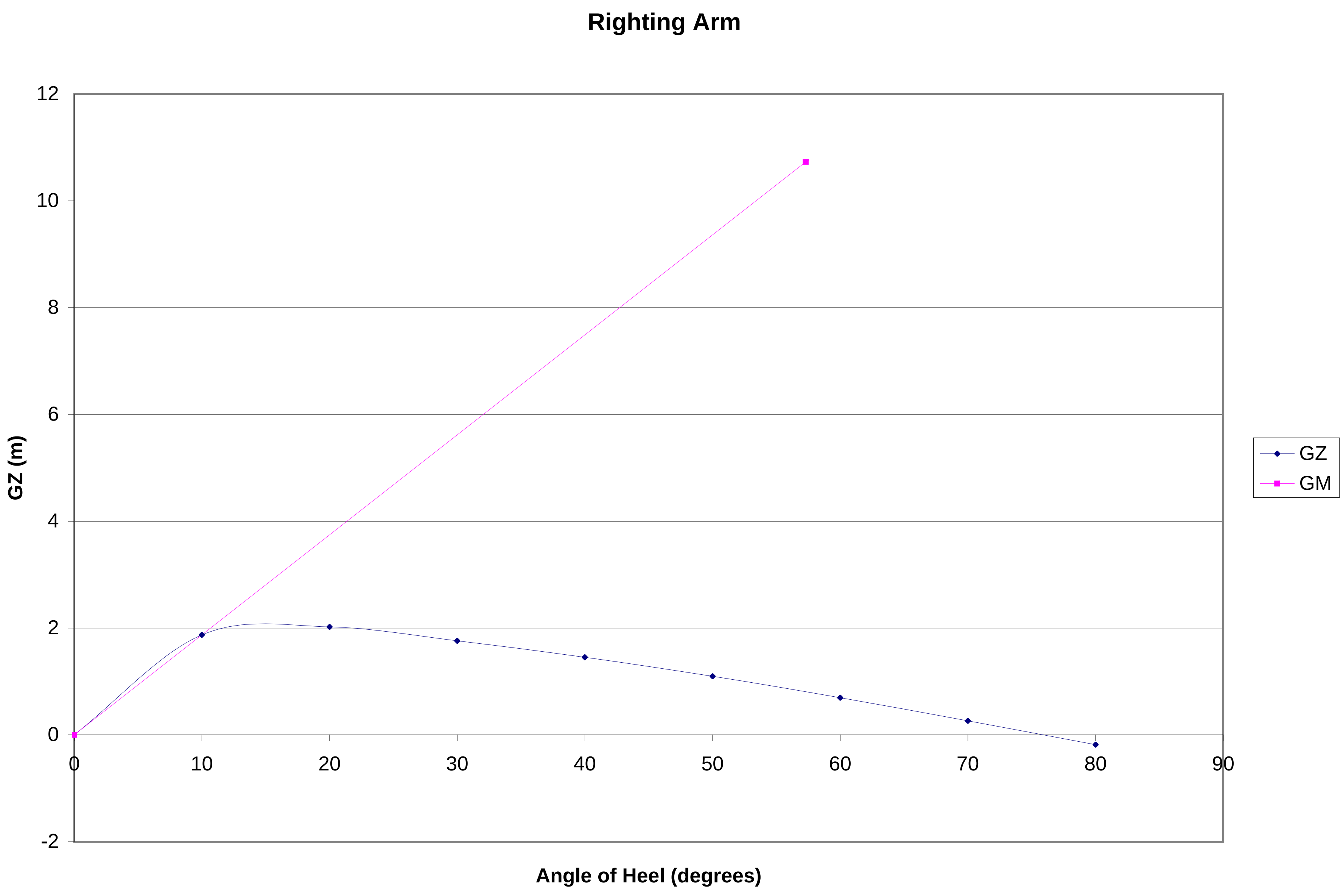
Angle (degrees)	GZ-H.A (m)	S.M	
2.031602	0		
20	1.663838	1	1.663838
30	1.431559	4	5.726237
40	1.162704	2	2.325408
50	0.85349	4	3.41396
60	0.506841	2	1.013682
70	0.134027	4	0.536108
80	0	1	0
			14.67923

A1 63.87903

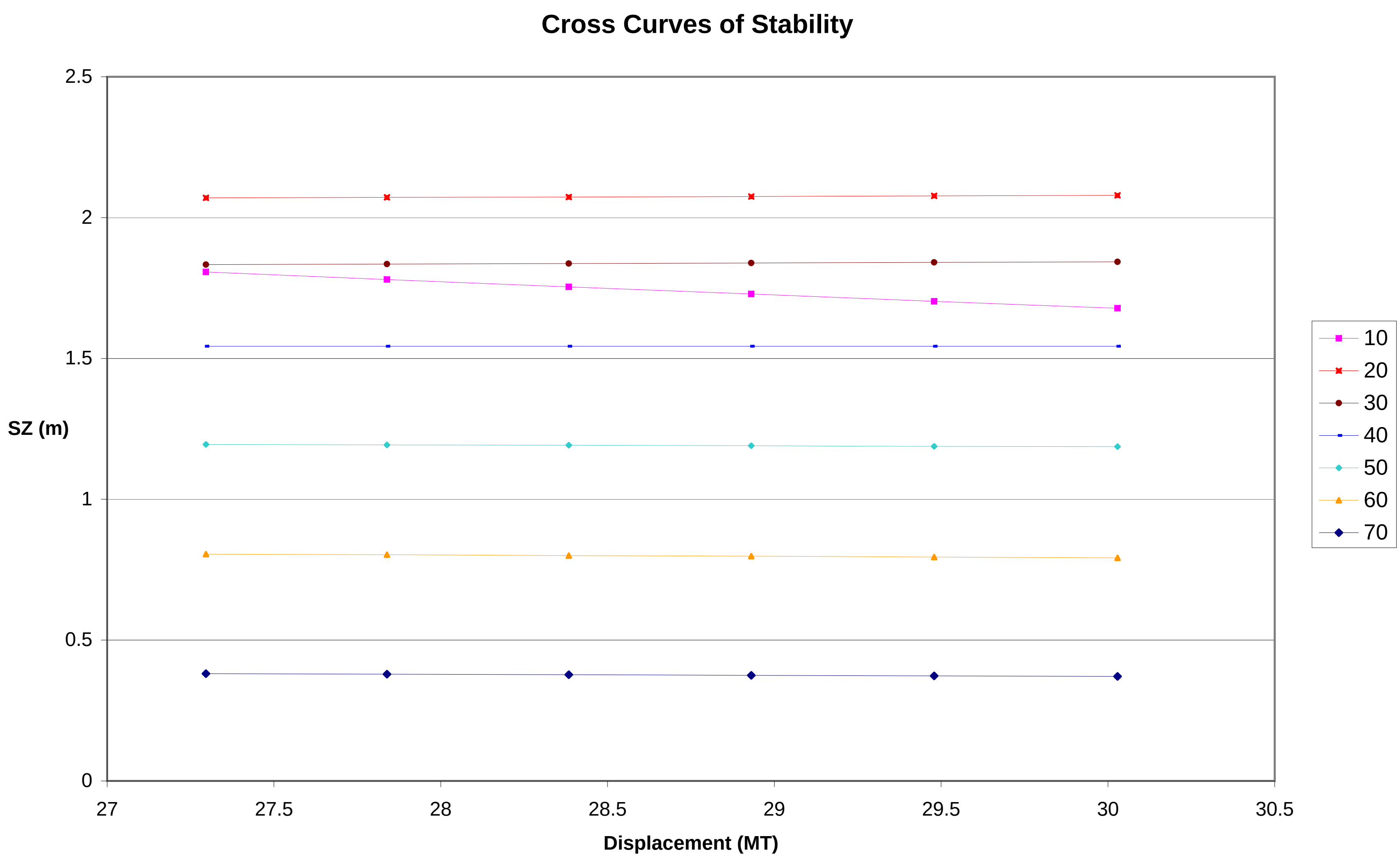
Angle (degrees)	GZ-H.A (m)	S.M	
2.031602	0	0	0
0	-0.380636	1	-0.380636
-10	-2.247254	4	-8.989014
-20	-2.3792	2	-4.758401
-30	-2.090841	4	-8.363363
-40	-1.745873	1	-1.745873
-22.9684	-2.450024	0	0
			-24.23729

A2 45.44618

Criteria Passed



Righting Arm
GZ (m)
Angle of Heel (degrees)
12
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
70
80
90
GZ
GM



Cross Curves of Stability
SZ (m)
2.5
2
1.5
1
0.5
0
27
27.5
28
28.5
29
29.5
30
30.5
Displacement (MT)
10
20
30
40
50
60
70

Gravity	9.81	m/s^2

Actual Displacement	28.5	MT	
Real VCG	1.46	m	
Wind Velocity	80	knots	
Projected Area	24	m^2	(area on which the wind acts)
Lever arm of Area	2.75	m	(distance between half draft and projected area centroid)
Ship Speed	22.5	m/s	
CG to .5T	1.04	m	
Turning Radius	141	m	

0	Angle	28.5	28	28.5		Area under GZ curve
	0	0	0	0	0	0
1	10	1.754	1.754	1.754	1.754	0.153065
2	20	2.073	2.073	2.073	2.073	0.821003
3	30	1.837	1.837	1.837	1.837	1.844638
4	40	1.543	1.543	1.543	1.543	3.024481
5	50	1.192	1.192	1.192	1.192	4.21785
6	60	0.8	0.8	0.8	0.8	5.260859
7	70	0.377	0.377	0.377	0.377	5.979847
8	80	-0.063	-0.063	-0.063	-0.063	6.19906

Interpolation Value	1	
	0	0
GM	10.04968	10.04968

Wind Forces

Angle of Heel (degrees)	GZ (m)	Wind Heeling Arm (m)	
0	0	0.289011	-0.289011
10	1.754	0.280296	1.473704
20	2.073	0.255203	1.817797
30	1.837	0.216758	1.620242
40	1.543	0.169598	1.373402
50	1.192	0.119412	1.072588
60	0.8	0.072253	0.727747
70	0.377	0.033808	0.343192
80	-0.063	0.008715	-0.071715

Criteria 1

angle of steady heel does not exceed 10 degrees

Criteria Passed

Criteria 2

Heeling arm at intersection is no more then 60 percent of maximum Righting arm

C	1.646362
$GZ_{@C}$	0.288772
$H.A._{@C}$	0.288772
MAX GZ	2.073

Criteria Passed

Criteria 3

Residual righting energy is not less than 40 percent of the total area

Angle (degrees)	GZ-H.A (m)	S.M	
1.646362	0		
20	1.817797	1	1.817797
30	1.620242	4	6.480968
40	1.373402	2	2.746803
50	1.072588	4	4.290351
60	0.727747	2	1.455495
70	0.343192	4	1.372769
80	0	1	0
			18.16418

A1 77.22888

Angle (degrees)	GZ-H.A (m)	S.M	
1.646362	0	0	0
0	-0.28901	1	-0.289011
-10	-2.0343	4	-8.137183
-20	-2.3282	2	-4.656405
-30	-2.05376	4	-8.215032
-40	-1.7126	1	-1.712598
-23.35364	-2.37088	0	0
			-23.01023

A2 42.95111

Criteria Passed

High Speed Turns

Angle of Heel (degrees)	GZ (m)	Turn Heeling Arm (m)	
0	0	0.380636	-0.380636
10	1.754	0.374854	1.379146
20	2.073	0.357681	1.715319
30	1.837	0.329641	1.507359
40	1.543	0.291584	1.251416
50	1.192	0.244668	0.947332
60	0.8	0.190318	0.609682
70	0.377	0.130185	0.246815
80	-0.063	0.066097	-0.129097

Criteria 1

angle of steady heel does not exceed 10 degrees

Criteria Passed

Criteria 2

Heeling arm at intersection is no more then 60 percent of maximum Righting arm

C	2.16855
$GZ_{@\,C}$	0.380364
$H.A._{@C}$	0.380364
MAX GZ	2.073

Criteria Passed

Criteria 3

Residual righting energy is not less than 40 percent of the total area

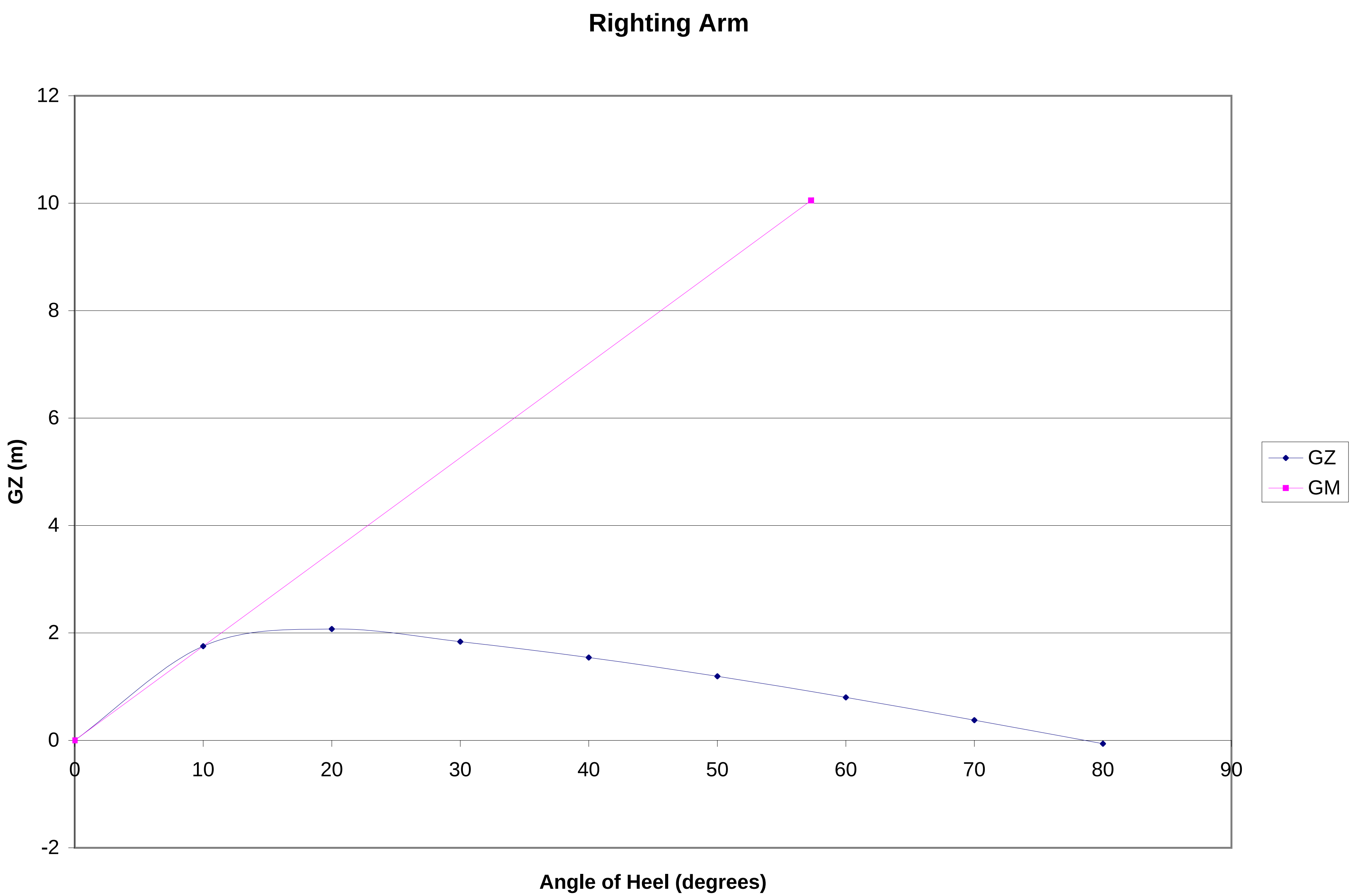
Angle (degrees)	GZ-H.A (m)	S.M	
2.16855	0		
20	1.715319	1	1.715319
30	1.507359	4	6.029437
40	1.251416	2	2.502831
50	0.947332	4	3.789327
60	0.609682	2	1.219364
70	0.246815	4	0.987259
80	0	1	0
			16.24354

A1 69.43843

Angle (degrees)	GZ-H.A (m)	S.M	
2.16855	0	0	0
0	-0.380636	1	-0.380636
-10	-2.128854	4	-8.515414
-20	-2.430681	2	-4.861362
-30	-2.166641	4	-8.666563
-40	-1.834584	1	-1.834584
-22.83145	-2.391113	0	0
			-24.25856

A2 45.00003

Criteria Passed



Righting Arm
12
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
70
80
90
GZ (m)
Angle of Heel (degrees)
GZ
GM

Assume flooded compartment is at extreme end of vessel

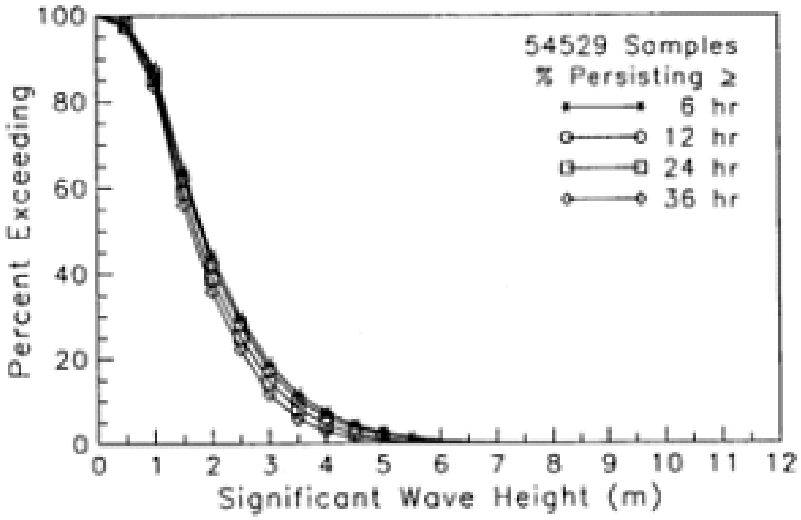
density	1.025	kg/m^3
Area of Midship	1.056	m^2
Floodable length	15.9912112	m
TPI	0.0532467	
MCT(m)	0.619	
MCH	0.16826	
Trim	0.122879081	m
Squat	0.325069666	
Heel	0.452051295	
Aft end sinkage	0.900000042	

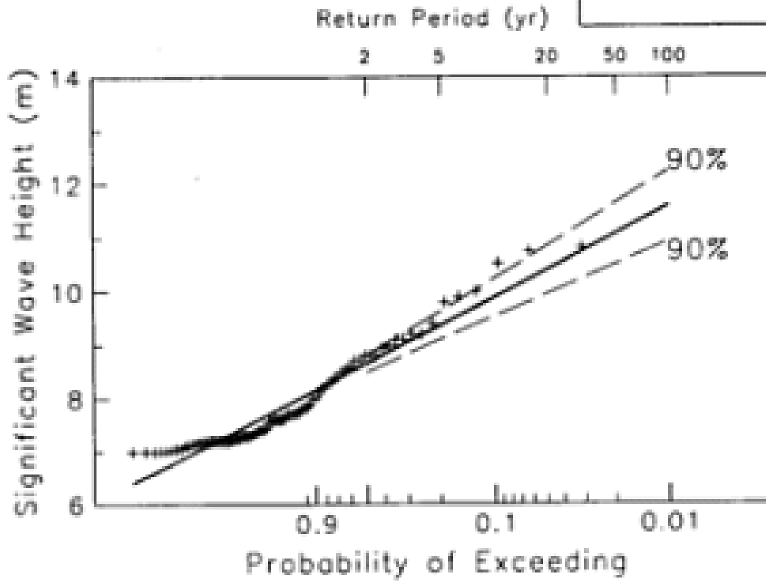
H Seakeeping Calculations

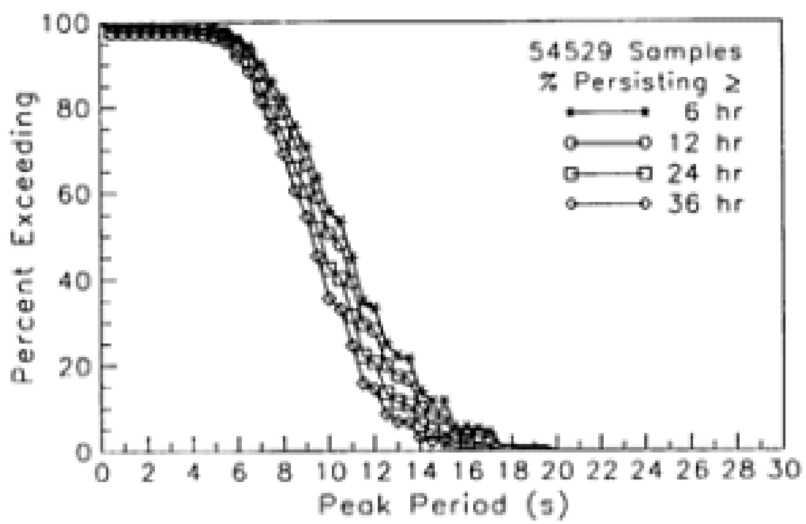
Please note that measured wave spectrum data was obtained from Department of Fisheries and Oceans.
http://www.meds-sdmm.dfo-mpo.gc.ca/alphapro/wave/TDCAtlas/TDCProducts.htm

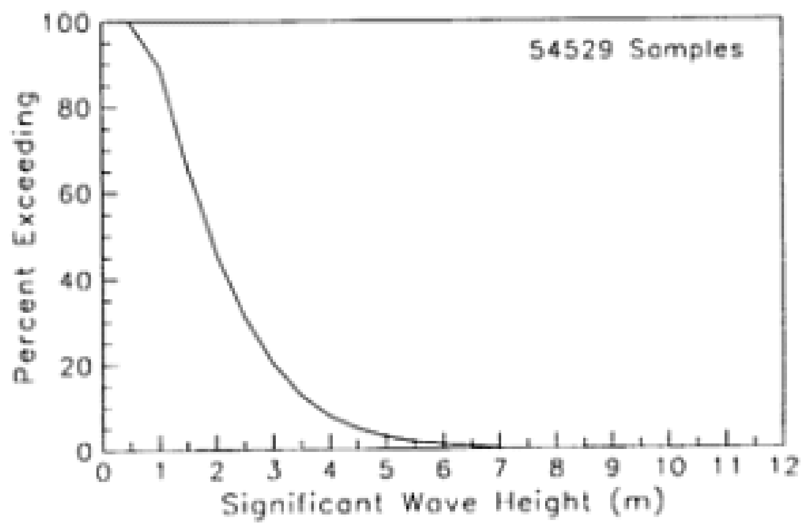
ANNUAL WAVE STATISTICS

WEST COAST AREA 1 – WEST VANCOUVER ISLAND









MOST PROBABLE SPECTRA

WEST COAST AREA 1 – WEST VANCOUVER ISLAND

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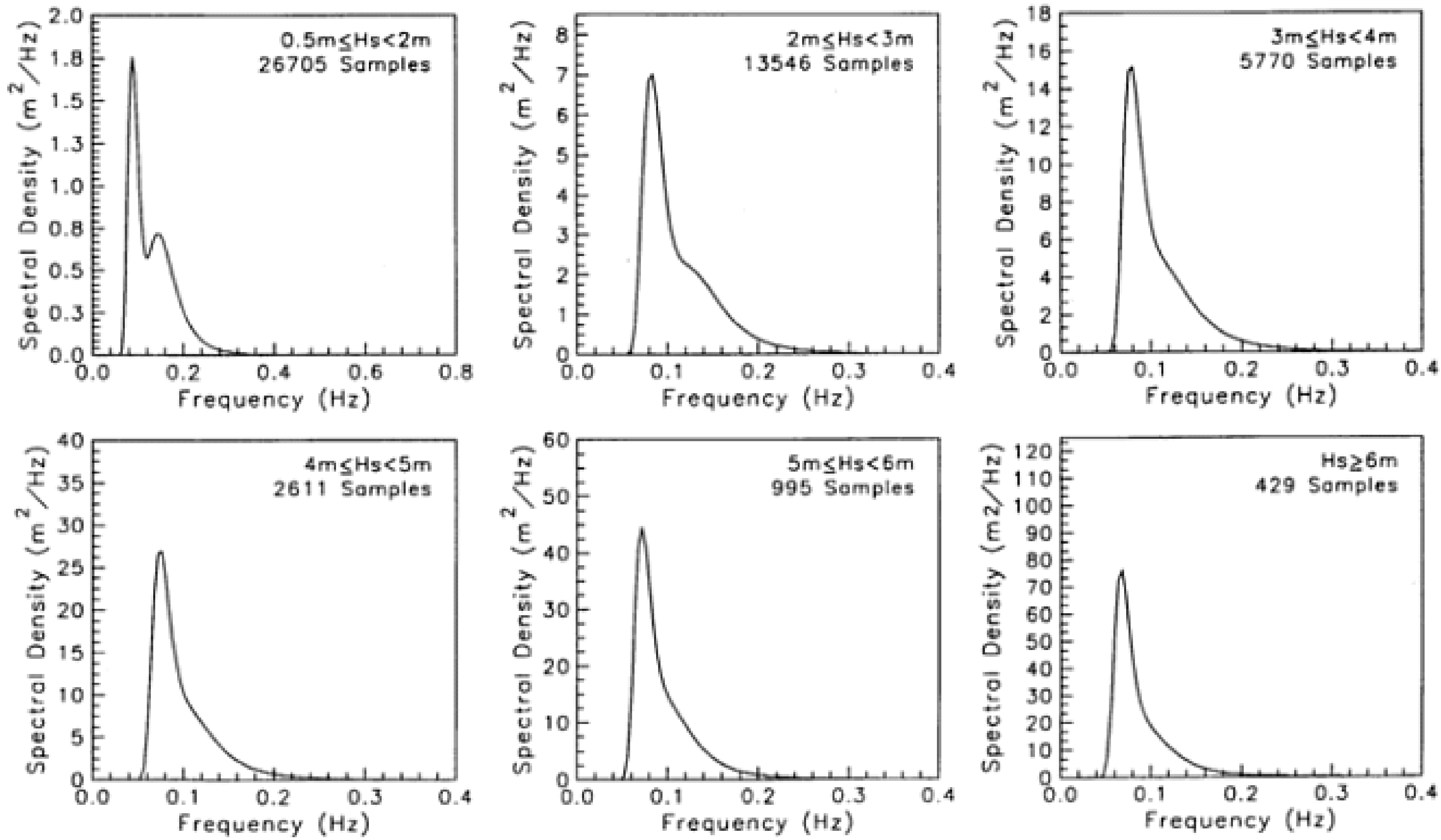


A Time-Domain Seakeeping Simulation for Fast Ships

D.C. Kring, D.A. Mantzaris, G.B. Tcheou, and P.D. Sclavounos
Massachusetts Institute of Technology
Cambridge, MA, USA

To appear at the FAST97 conference, Sydney, Australia

1 Introduction

Advanced marine vehicles such as semi-displacement ships, catamarans, SWATH, and SES pose many new technical challenges that are beyond the realm of conventional displacement ship design. These advanced vessels are characterized by more complex geometric configurations and operation at higher speeds. The geometric complications include transom sterns, multiple hulls, and appendages. They operate throughout the range from zero to high speeds ($F_n = U/\sqrt{gL} = 0.8$ and higher).

Since a more limited base of experience exists for advanced marine vehicles than for conventional displacement ships, experimental or numerical modeling techniques are of increased value to a designer. Experimentation, while useful to evaluate concepts and provide ultimate validation, may be too expensive to apply at the conceptual or preliminary stages of design. So, a flexible, robust, and accurate numerical simulation of ship hydrodynamics is necessary for the practical analysis of advanced marine vehicle performance and safety.

Some of the performance issues that a numerical method must address include residuary resistance, wave added resistance, and seakeeping. Seakeeping is also the primary consideration for the issue of safety. The simulation of ship motion in waves allows the prediction of accelerations and structural loads and also provides a description of the wave patterns necessary for determining relative motions and slamming.

In the simulation of seakeeping for high speed vessels, while the linear interaction of waves with the ship dominates this problem, the effect of lift, viscosity, and nonlinearity must be considered. These extensions to a seakeeping model also enable a simulation of active and passive ride control systems. Active control systems, such as movable control fins and trim tabs, and passive control systems, such as skegs or struts, are very important for high speed, advanced vehicles. Structural loads and motion in extreme seas will also depend strongly on nonlinearity in the wave-body interaction.

In order to address these issues this paper presents a sample of calm water and seakeeping

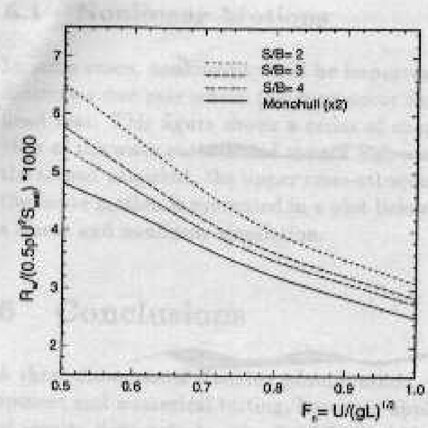


Figure 7: Wave resistance coefficient as a function of speed for a catamaran with various demi-hull separation ratios.

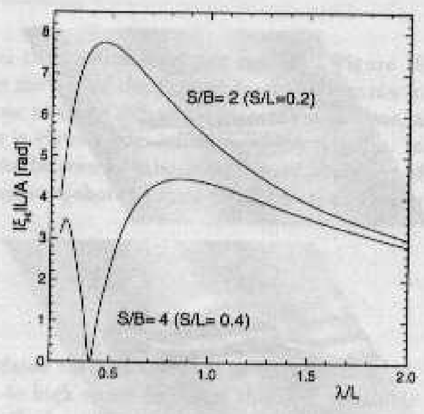


Figure 8: Roll RAO for a catamaran at $F_n = 0.8$ for two separation ratios.

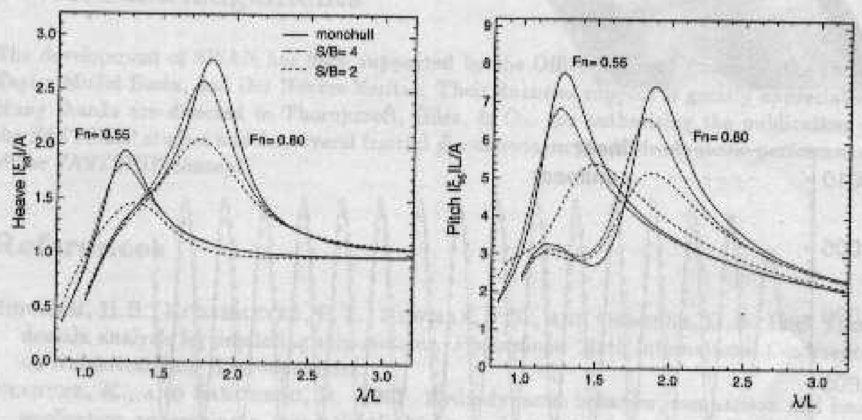


Figure 9: Heave and pitch RAOs for a catamaran at various separation ratios and speeds.

I.T.T.C. Spectrum

Significant Wave Height (Hs):	2.5	m
Vessel Waterline Length (LWL):	16.4	m
Froude Number (Fn):	0.6	
Vessel Speed (Vel):	7.61	m/s
Vessel Speed:	14.79	kn
Vessel Heading:	180	deg
Vessel Heading (Head):	3.14	rad

Wave spectrum as recommended by I.T.T.C.: $S(\omega_w) =$ $A/\omega^5 * exp(-B/\omega^4)$

where:

A = $8.1E-03*g^2$

A = 0.7795124

g = 9.81 m/s^2

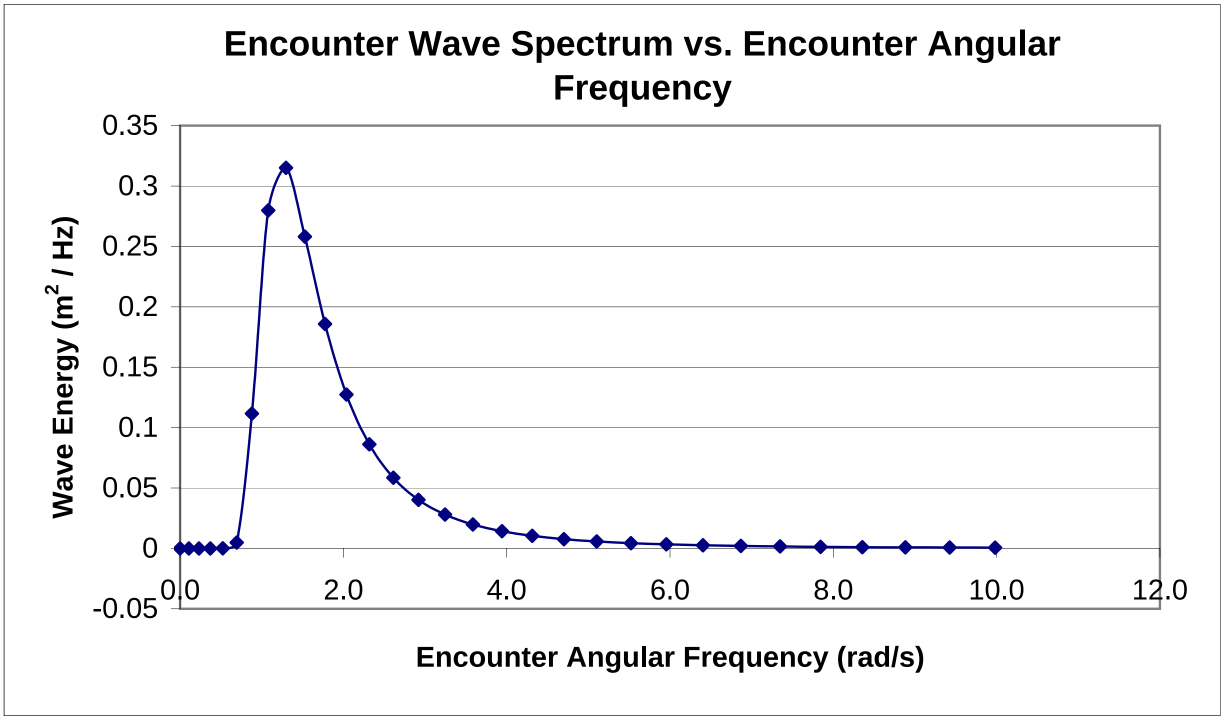
B = $3.11 / Hs^2$

B = 0.4976

$\omega_e =$ $\omega_w(1 - \omega_w*V*cos(Head)/g)$

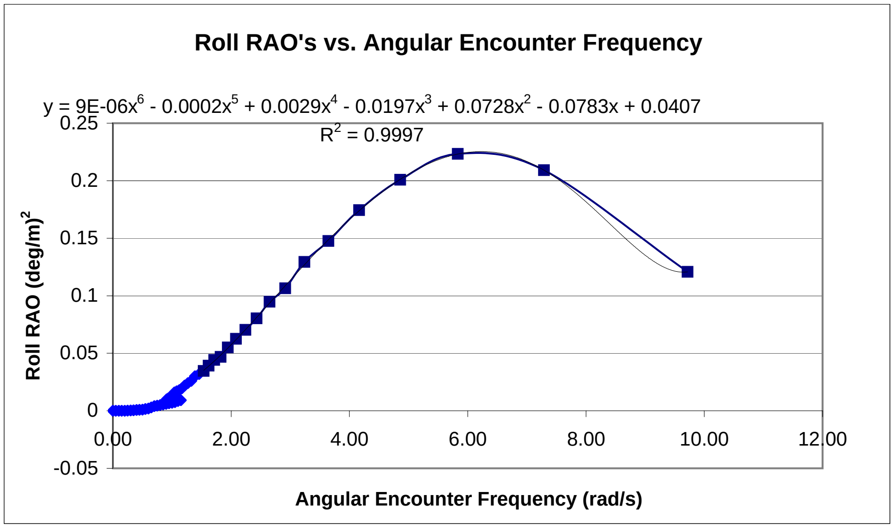
$S(\omega_e) =$ $S(\omega_w) / sqrt(1 - 4*\omega_e*V/g*cos(Head))$

ω_w (rad/s)	$Freq_w$ (Hz)	$S(\omega)$	ω_e (rad/s)	$S(\omega_e)$
0	0.000	0	0.000	0
0.1	0.016	0	0.108	0
0.2	0.032	0	0.231	0
0.3	0.048	6.708E-25	0.370	4.5774E-25
0.4	0.064	2.7537E-07	0.524	1.69919E-07
0.5	0.080	0.00869549	0.694	0.004896715
0.6	0.095	0.21557105	0.879	0.11164069
0.7	0.111	0.5838088	1.080	0.279857615
0.8	0.127	0.70594873	1.296	0.314980158
0.9	0.143	0.61834726	1.528	0.258031278
1	0.159	0.47393425	1.776	0.185742916
1.1	0.175	0.34455379	2.039	0.127295861
1.2	0.191	0.24643338	2.317	0.086109143
1.3	0.207	0.17637699	2.611	0.0584605
1.4	0.223	0.12732948	2.921	0.040139368
1.5	0.239	0.09304207	3.246	0.027962893
1.6	0.255	0.06890459	3.586	0.019785974
1.7	0.271	0.05172543	3.942	0.014219453
1.8	0.286	0.03934363	4.314	0.010373217
1.9	0.302	0.03030209	4.701	0.007675369
2	0.318	0.02361383	5.103	0.005755091
2.1	0.334	0.01860436	5.521	0.004368988
2.2	0.350	0.01480759	5.955	0.003355119
2.3	0.366	0.01189766	6.404	0.00260423
2.4	0.382	0.00964391	6.868	0.002041582
2.5	0.398	0.00788117	7.349	0.001615358
2.6	0.414	0.00648974	7.844	0.001289167
2.7	0.430	0.00538193	8.355	0.001037137
2.8	0.446	0.0044928	8.882	0.00084066
2.9	0.462	0.00377379	9.424	0.000686203
3	0.477	0.00318822	9.982	0.00056382
3.1	0.493	0.00270816	10.555	0.000466134
3.2	0.509	0.00231213	11.144	0.000387617
3.3	0.525	0.00198349	11.748	0.000324093
3.4	0.541	0.00170927	12.368	0.000272381
3.5	0.557	0.00147925	13.003	0.000230039
3.6	0.573	0.00128536	13.654	0.000195176
3.7	0.589	0.00112114	14.320	0.000166323
3.8	0.605	0.00098145	15.002	0.000142323
3.9	0.621	0.00086212	15.700	0.000122267
4	0.637	0.00075976	16.412	0.000105431
4.1	0.653	0.00067164	17.141	9.12386E-05
4.2	0.668	0.0005955	17.885	7.92252E-05

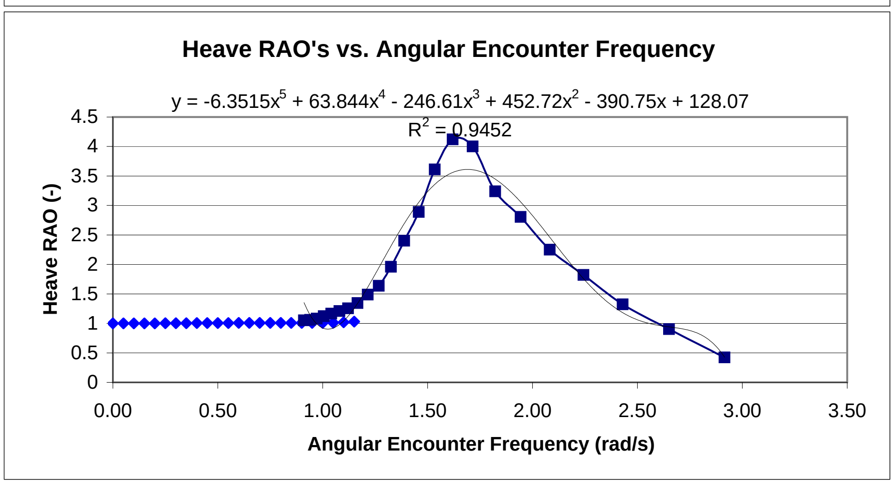

Encounter Wave Spectrum vs. Encounter Angular Frequency
Wave Energy (m2 / Hz)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Encounter Angular Frequency (rad/s)

ITTC RAO's

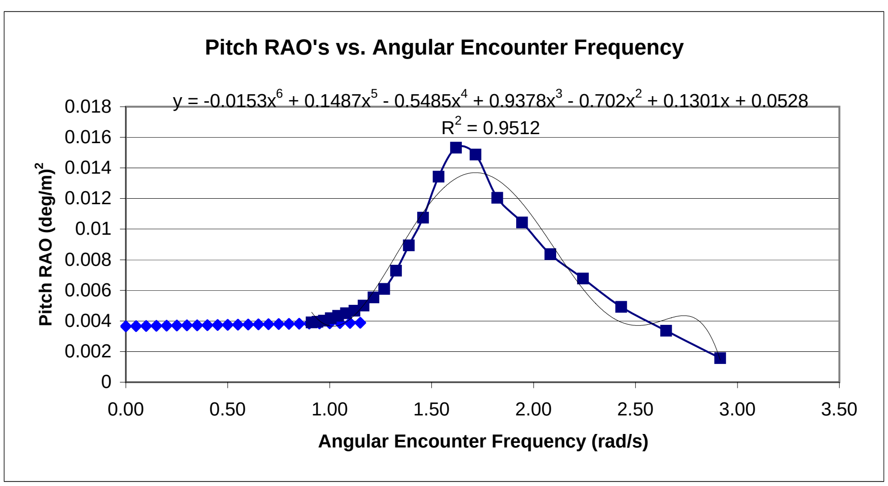
λ_e / L	ω_e	RRW's at S/B = 2			RAO's at S/B = 2		
		Roll	Heave	Pitch	Roll	Heave	Pitch
		(E*L/A)	(E/A)	(E*L/A)	$(E/A)^2$	$(E/A)^2$	$(E/A)^2$
		(rad)	(-)	(rad)	$(rad/m)^2$	$(-)^2$	$(rad/m)^2$
	0.00				0	1	0.00365
	0.05				0	1	0.00366
	0.10				0	1	0.00367
	0.15				0	1	0.00368
	0.20				0.00009	1	0.00369
	0.25				0.0001	1.002	0.0037
	0.30				0.0003	1.003	0.00371
	0.35				0.0005	1.004	0.00372
	0.40				0.0007	1.005	0.00373
	0.45				0.0009	1.006	0.00374
	0.50				0.001	1.0065	0.00375
	0.55				0.0015	1.0068	0.00376
	0.60				0.002	1.0072	0.00377
	0.65				0.003	1.0075	0.00378
	0.70				0.004	1.0078	0.00379
	0.75				0.0045	1.0079	0.0038
	0.80				0.005	1.008	0.00381
	0.85				0.0055	1.0081	0.00382
	0.90				0.006	1.0082	0.00383
	0.95				0.0065	1.0085	0.00384
	1.00				0.007	1.009	0.00385
	1.05				0.0075	1.01	0.00386
	1.10				0.0085	1.02	0.00387
	1.15				0.0092	1.03	0.00388
3.2	0.91		1.025	2.4	0.01	1.050625	0.003906
3.1	0.94		1.03	2.4	0.011	1.0609	0.003944
3	0.97		1.04	2.5	0.012	1.0816	0.004021
2.9	1.01		1.06	2.55	0.013	1.1236	0.004178
2.8	1.04		1.08	2.7	0.016	1.1664	0.004337
2.7	1.08		1.1	2.85	0.017	1.21	0.004499
2.6	1.12		1.12	3	0.018	1.2544	0.004664
2.5	1.17		1.16	3.2	0.0195	1.3456	0.005003
2.4	1.21		1.22	3.45	0.022	1.4884	0.005534
2.3	1.27		1.28	3.75	0.024	1.6384	0.006092
2.2	1.33		1.4	4.2	0.026	1.96	0.007287
2.1	1.39		1.55	4.55	0.03	2.4025	0.008933
2	1.46		1.7	4.95	0.032	2.89	0.010745
1.9	1.53	3.05	1.9	5.15	0.034587	3.61	0.013422
1.8	1.62	3.25	2.03	4.95	0.039272	4.1209	0.015322
1.7	1.72	3.45	2	4.45	0.044254	4	0.014872
1.6	1.82	3.55	1.8	3.55	0.046856	3.24	0.012046
1.5	1.94	3.85	1.675	3.1	0.05511	2.805625	0.010431
1.4	2.08	4.1	1.5	2.85	0.0625	2.25	0.008366
1.3	2.24	4.35	1.35	2.85	0.070354	1.8225	0.006776
1.2	2.43	4.65	1.15	3	0.080393	1.3225	0.004917
1.1	2.65	5.05	0.95	2.8	0.094819	0.9025	0.003356
1	2.92	5.35	0.65	2.4	0.106419	0.4225	0.001571
0.9	3.24	5.9			0.129424		
0.8	3.64	6.3			0.147568		
0.7	4.17	6.85			0.174459		
0.6	4.86	7.35			0.200857		
0.5	5.83	7.75			0.223314		
0.4	7.29	7.5			0.209139		
0.3	9.72	5.7			0.120799		
0.2	14.58	1			0.003718		
0.1	29.16						
0							



Roll RAO's vs. Angular Encounter Frequency
y = 9E-06x6 - 0.0002x5 + 0.0029x4 - 0.0197x3 + 0.0728x2 - 0.0783x + 0.0407
R2 = 0.9997
Roll RAO (deg/m)2
0.25
0.2
0.15
0.1
0.05
0
-0.05
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Angular Encounter Frequency (rad/s)



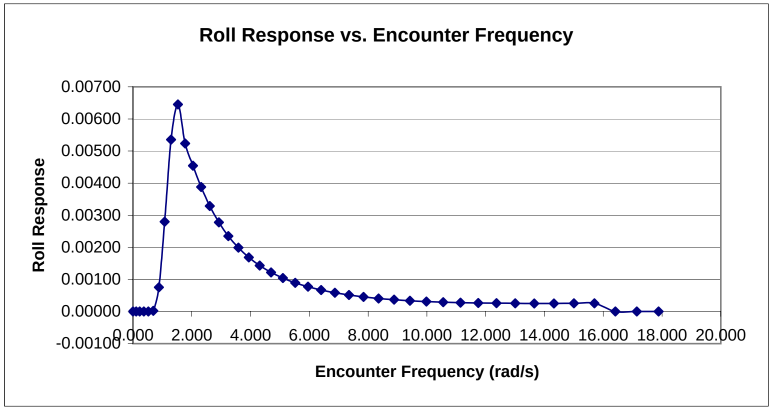
Heave RAO's vs. Angular Encounter Frequency
y = -6.3515x5 + 63.844x4 - 246.61x3 + 452.72x2 - 390.75x + 128.07
R2 = 0.9452
Heave RAO (-)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Angular Encounter Frequency (rad/s)



Pitch RAO's vs. Angular Encounter Frequency
y = -0.0153x6 + 0.1487x5 - 0.5485x4 + 0.9378x3 - 0.702x2 + 0.1301x + 0.0528
R2 = 0.9512
Pitch RAO (deg/m)2
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Angular Encounter Frequency (rad/s)

ITTC Responses

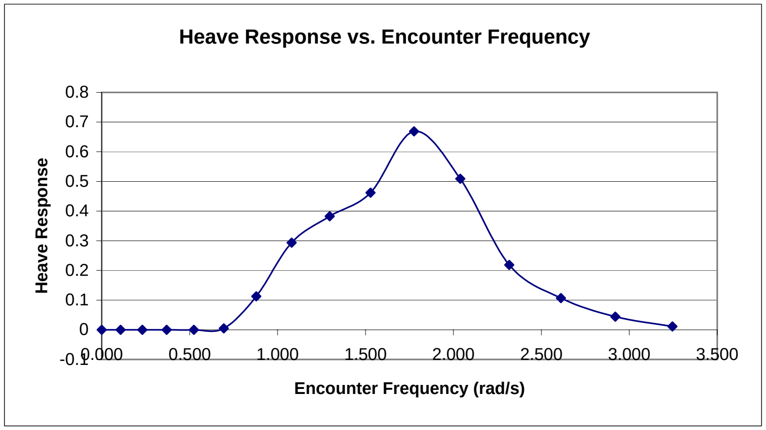
		RAO's			Responses			Areas Under Response		
ω_e (rad/s)	$S(\omega_e)$	Roll $(E/A)^2$ $(rad/m)^2$	Heave $(E/A)^2$ $(-)^2$	Pitch $(E/A)^2$ $(rad/m)^2$	Roll RAO*$S(\omega_e)$	Heave RAO*$S(\omega_e)$	Pitch RAO*$S(\omega_e)$	Roll	Heave	Pitch
0.000	0	0	1	0.00365	0.00000	0	0			
0.108	0	0	1	0.00367	0.00000	0	0	0	0	0
0.231	0	0.0001	1.002	0.0037	0.00000	0	0	0	0	0
0.370	4.5774E-25	0.0007	1.005	0.00373	0.00000	4.60029E-25	1.70737E-27	2.22352E-29	3.19235E-26	1.18482E-28
0.524	1.69919E-07	0.00155	1.00685	0.00376	0.00000	1.71083E-07	6.38895E-10	2.03199E-11	1.31994E-08	4.92922E-11
0.694	0.004896715	0.0045	1.0079	0.0038	0.00002	0.004935399	1.86075E-05	1.87104E-06	0.00041908	1.58002E-06
0.879	0.11164069	0.00675	1.0087	0.003845	0.00075	0.112611965	0.000429258	7.18741E-05	0.010892868	4.15028E-05
1.080	0.279857615	0.01	1.05	0.003906	0.00280	0.293850496	0.001093124	0.000356727	0.040819281	0.000152886
1.296	0.314980158	0.017	1.215	0.0045	0.00535	0.382700891	0.001417411	0.000882046	0.073191705	0.000271598
1.528	0.258031278	0.025	1.79	0.0066	0.00645	0.461875988	0.001703006	0.001368739	0.097921353	0.000361785
1.776	0.185742916	0.028198	3.6	0.013	0.00524	0.668674496	0.002414658	0.001445846	0.139848095	0.000509351
2.039	0.127295861	0.035693	4	0.0134	0.00454	0.509183443	0.001705765	0.001285805	0.154837574	0.000541658
2.317	0.086109143	0.045037	2.54	0.009	0.00388	0.218717223	0.000774982	0.001172419	0.101334487	0.000345356
2.611	0.0584605	0.056234	1.83	0.011629	0.00329	0.106982715	0.000679865	0.00105314	0.047868941	0.000213823
2.921	0.040139368	0.069253	1.1	0.00425	0.00278	0.044153305	0.000170592	0.000938783	0.023385325	0.000131592
3.246	0.027962893	0.084031	0.4	0.002	0.00235	0.011185157	5.59258E-05	0.000833486	0.008991843	3.68065E-05
3.586	0.019785974	0.100487			0.00199			0.000738525	0.001904227	9.52114E-06
3.942	0.014219453	0.118523			0.00169			0.000653908		
4.314	0.010373217	0.138046			0.00143			0.000579077		
4.701	0.007675369	0.15898			0.00122			0.000513255		
5.103	0.005755091	0.181288			0.00104			0.000455603		
5.521	0.004368988	0.204991			0.00090			0.000405305		
5.955	0.003355119	0.230201			0.00077			0.000361601		
6.404	0.00260423	0.257142			0.00067			0.000323804		
6.868	0.002041582	0.286187			0.00058			0.000291299		
7.349	0.001615358	0.317893			0.00051			0.000263541		
7.844	0.001289167	0.353033			0.00046			0.00024005		
8.355	0.001037137	0.392639			0.00041			0.000220398		
8.882	0.00084066	0.438036			0.00037			0.000204209		
9.424	0.000686203	0.49089			0.00034			0.000191148		
9.982	0.00056382	0.553237			0.00031			0.000180915		
10.555	0.000466134	0.62753			0.00029			0.00017324		
11.144	0.000387617	0.716668			0.00028			0.000167881		
11.748	0.000324093	0.824031			0.00027			0.000164616		
12.368	0.000272381	0.953504			0.00026			0.000163241		
13.003	0.000230039	1.109499			0.00026			0.000163569		
13.654	0.000195176	1.296961			0.00025			0.000165423		
14.320	0.000166323	1.521371			0.00025			0.000168637		
15.002	0.000142323	1.788731			0.00025			0.000173055		
15.700	0.000122267	2.105532			0.00026			0.000178527		
16.412	0.000105431				0.00000			9.17593E-05		
17.141	9.12386E-05				0.00000			0		
17.885	7.92252E-05				0.00000			0		
							Totals:	0.0166	0.701	0.002617

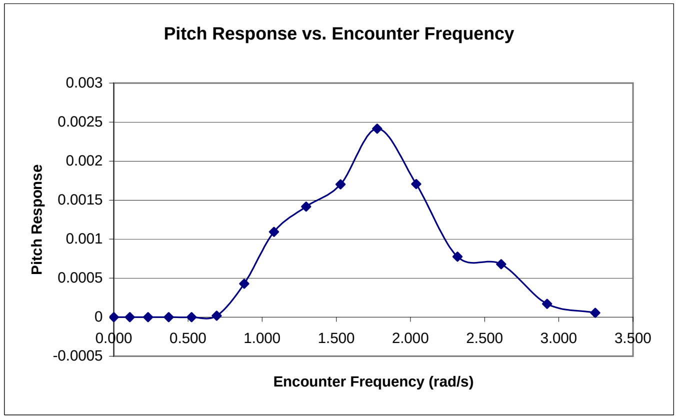


Significant Response: 0.258 (rad) 1.675 (m) 0.102 (rad)

Roll (deg)	Heave (m)	Pitch (deg)
14.8	1.675	5.9

Heading (deg)	Roll (deg)	Heave (m)	Pitch (deg)
0	19.3	1.677	17.5
45	13.4	1.819	11.5
90	9.7	1.675	5.7
135	14.4	1.675	5.9
180	17.1	1.675	5.8

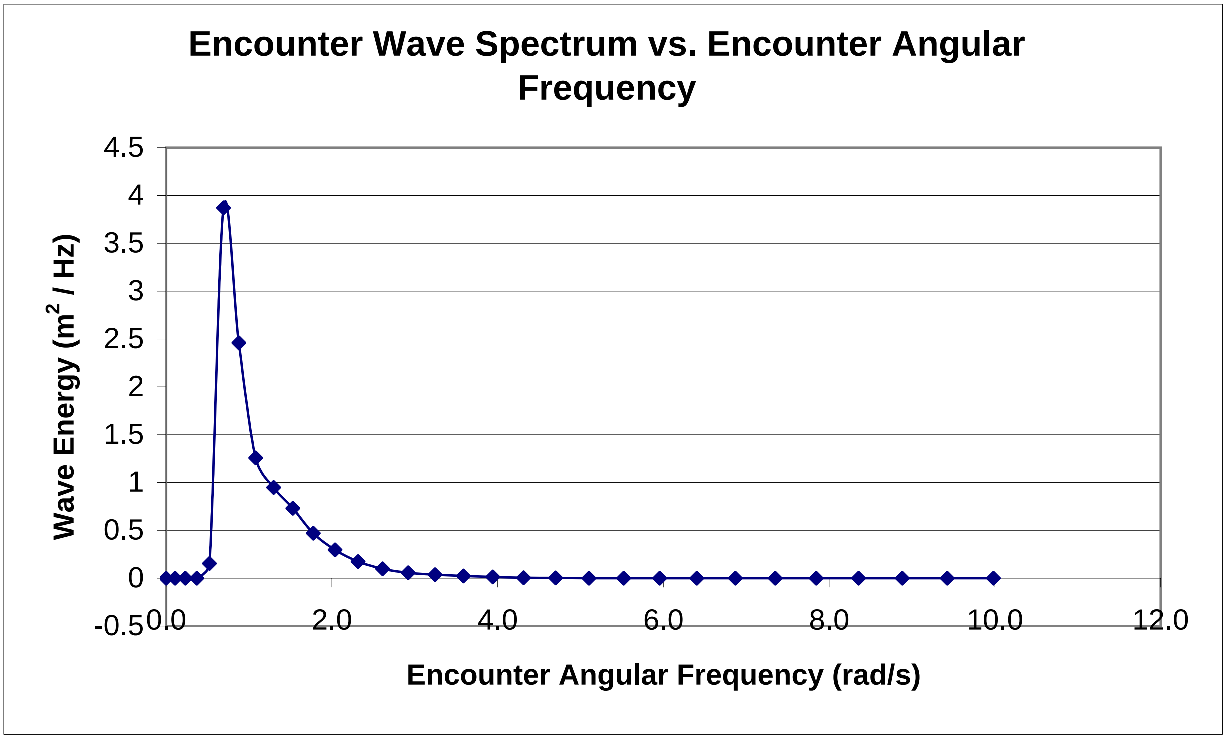




West Coast Spectrum (2 < Hs < 3)

Vessel Waterline Length (LWL):	16.4	m
Froude Number (Fn):	0.6	
Vessel Speed (Vel):	7.61	m/s
Vessel Speed:	14.79	kn
Vessel Heading:	180	deg
Vessel Heading (Head):	3.14	rad

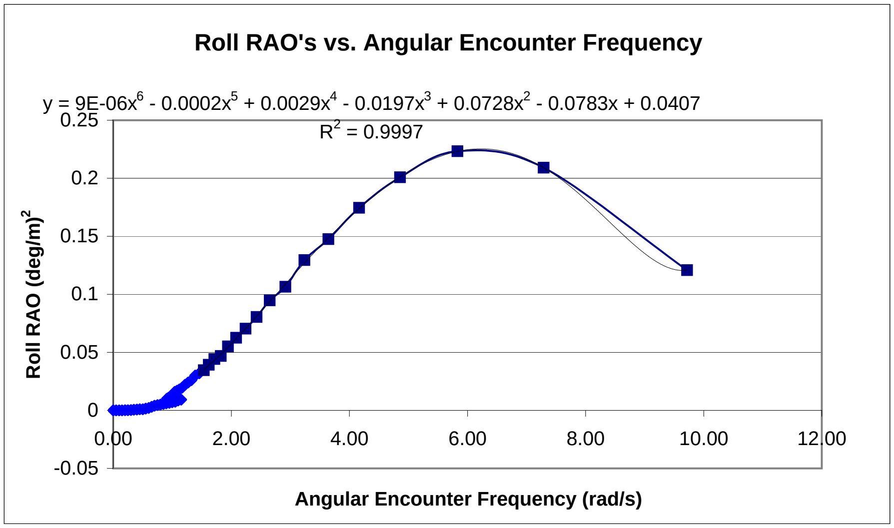
ω_w (rad/s)	$Freq_w$ (Hz)	$S(\omega_w)$	ω_e (rad/s)	$S(\omega_e)$
0	0.000	0	0.000	0
0.1	0.016	0	0.108	0
0.2	0.032	0	0.231	0
0.3	0.048	0	0.370	0
0.4	0.064	0.25	0.524	0.15426156
0.5	0.080	6.875	0.694	3.87153778
0.6	0.095	4.75	0.879	2.45994664
0.7	0.111	2.625	1.080	1.25833363
0.8	0.127	2.125	1.296	0.94813236
0.9	0.143	1.75	1.528	0.73026075
1	0.159	1.2	1.776	0.47030046
1.1	0.175	0.8	2.039	0.29556108
1.2	0.191	0.5	2.317	0.17471079
1.3	0.207	0.3	2.611	0.09943559
1.4	0.223	0.18	2.921	0.05674323
1.5	0.239	0.125	3.246	0.03756754
1.6	0.255	0.08	3.586	0.02297203
1.7	0.271	0.05	3.942	0.01374513
1.8	0.286	0.02	4.314	0.00527314
1.9	0.302	0.01	4.701	0.00253295
2	0.318	0	5.103	0
2.1	0.334	0	5.521	0
2.2	0.350	0	5.955	0
2.3	0.366	0	6.404	0
2.4	0.382	0	6.868	0
2.5	0.398	0	7.349	0
2.6	0.414	0	7.844	0
2.7	0.430	0	8.355	0
2.8	0.446	0	8.882	0
2.9	0.462	0	9.424	0
3	0.477	0	9.982	0
3.1	0.493	0	10.555	0
3.2	0.509	0	11.144	0
3.3	0.525	0	11.748	0
3.4	0.541	0	12.368	0
3.5	0.557	0	13.003	0
3.6	0.573	0	13.654	0
3.7	0.589	0	14.320	0
3.8	0.605	0	15.002	0
3.9	0.621	0	15.700	0
4	0.637	0	16.412	0
4.1	0.653	0	17.141	0
4.2	0.668	0	17.885	0

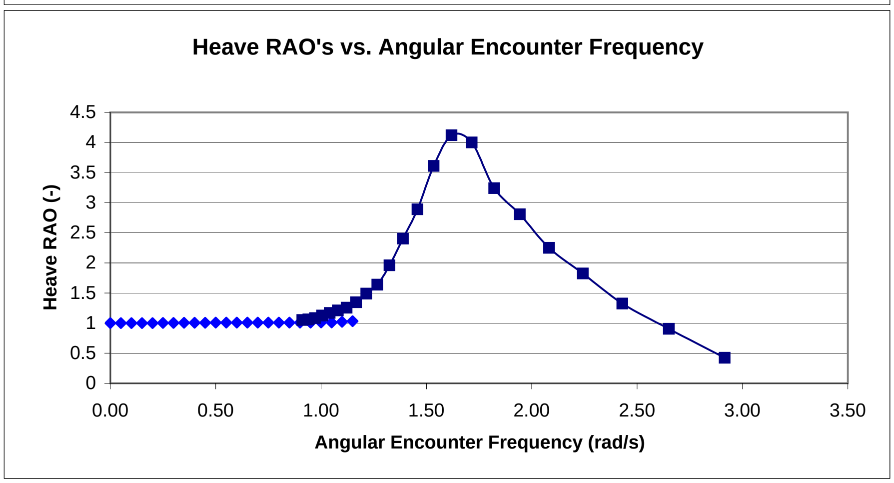


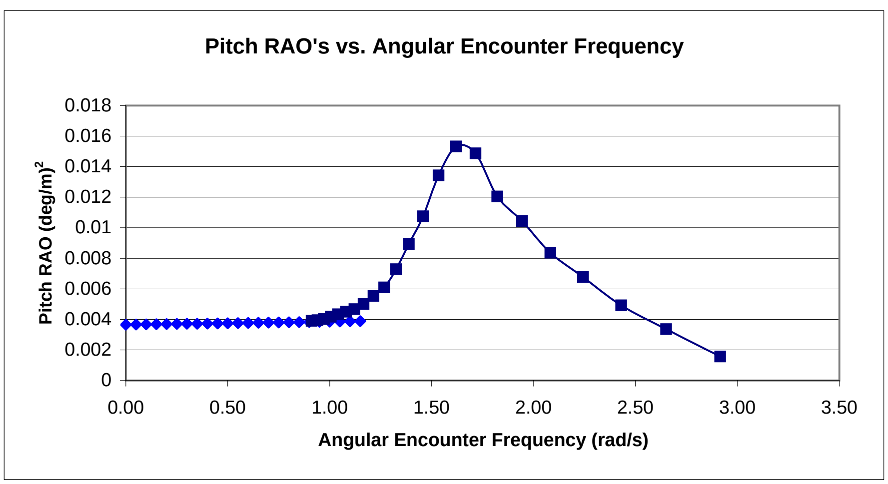
Encounter Wave Spectrum vs. Encounter Angular Frequency
Wave Energy (m² / Hz)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Encounter Angular Frequency (rad/s)

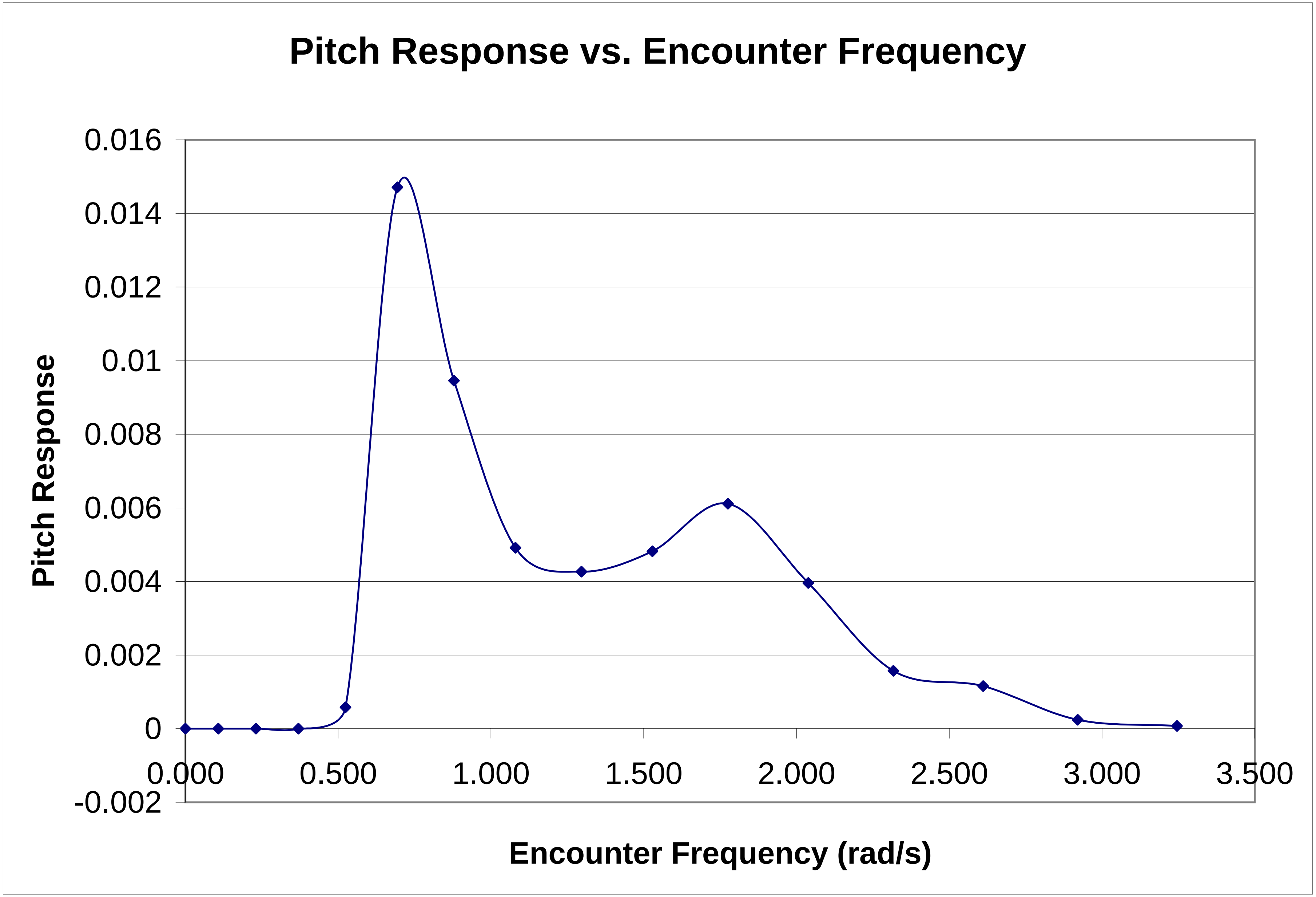
West Coast RAOs

λ_e / L	ω_e	RRW's at S/B = 2			RAO's at S/B = 2		
		Roll	Heave	Pitch	Roll	Heave	Pitch
		(E*L/A)	(E/A)	(E*L/A)	$(E/A)^2$	$(E/A)^2$	$(E/A)^2$
		(rad)	(-)	(rad)	$(rad/m)^2$	$(-)^2$	$(rad/m)^2$
	0.00				0	1	0.00365
	0.05				0	1	0.00366
	0.10				0	1	0.00367
	0.15				0	1	0.00368
	0.20				0.00009	1	0.00369
	0.25				0.0001	1.002	0.0037
	0.30				0.0003	1.003	0.00371
	0.35				0.0005	1.004	0.00372
	0.40				0.0007	1.005	0.00373
	0.45				0.0009	1.006	0.00374
	0.50				0.001	1.0065	0.00375
	0.55				0.0015	1.0068	0.00376
	0.60				0.002	1.0072	0.00377
	0.65				0.003	1.0075	0.00378
	0.70				0.004	1.0078	0.00379
	0.75				0.0045	1.0079	0.0038
	0.80				0.005	1.008	0.00381
	0.85				0.0055	1.0081	0.00382
	0.90				0.006	1.0082	0.00383
	0.95				0.0065	1.0085	0.00384
	1.00				0.007	1.009	0.00385
	1.05				0.0075	1.01	0.00386
	1.10				0.0085	1.02	0.00387
	1.15				0.0092	1.03	0.00388
3.2	0.91		1.025	2.4	0.01	1.050625	0.003906
3.1	0.94		1.03	2.4	0.011	1.0609	0.003944
3	0.97		1.04	2.5	0.012	1.0816	0.004021
2.9	1.01		1.06	2.55	0.013	1.1236	0.004178
2.8	1.04		1.08	2.7	0.016	1.1664	0.004337
2.7	1.08		1.1	2.85	0.017	1.21	0.004499
2.6	1.12		1.12	3	0.018	1.2544	0.004664
2.5	1.17		1.16	3.2	0.0195	1.3456	0.005003
2.4	1.21		1.22	3.45	0.022	1.4884	0.005534
2.3	1.27		1.28	3.75	0.024	1.6384	0.006092
2.2	1.33		1.4	4.2	0.026	1.96	0.007287
2.1	1.39		1.55	4.55	0.03	2.4025	0.008933
2	1.46		1.7	4.95	0.032	2.89	0.010745
1.9	1.53	3.05	1.9	5.15	0.0345869	3.61	0.013422
1.8	1.62	3.25	2.03	4.95	0.0392716	4.1209	0.015322
1.7	1.72	3.45	2	4.45	0.0442538	4	0.014872
1.6	1.82	3.55	1.8	3.55	0.0468564	3.24	0.012046
1.5	1.94	3.85	1.675	3.1	0.0551104	2.805625	0.010431
1.4	2.08	4.1	1.5	2.85	0.0625	2.25	0.008366
1.3	2.24	4.35	1.35	2.85	0.0703543	1.8225	0.006776
1.2	2.43	4.65	1.15	3	0.080393	1.3225	0.004917
1.1	2.65	5.05	0.95	2.8	0.0948189	0.9025	0.003356
1	2.92	5.35	0.65	2.4	0.1064192	0.4225	0.001571
0.9	3.24	5.9			0.1294244		
0.8	3.64	6.3			0.1475684		
0.7	4.17	6.85			0.174459		
0.6	4.86	7.35			0.200857		
0.5	5.83	7.75			0.2233139		
0.4	7.29	7.5			0.2091389		
0.3	9.72	5.7			0.1207986		
0.2	14.58	1			0.003718		
0.1	29.16						
0							


Roll RAO's vs. Angular Encounter Frequency
y = 9E-06x6 - 0.0002x5 + 0.0029x4 - 0.0197x3 + 0.0728x2 - 0.0783x + 0.0407
R2 = 0.9997
Roll RAO (deg/m)2
0.25
0.2
0.15
0.1
0.05
0
-0.05
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Angular Encounter Frequency (rad/s)


Heave RAO's vs. Angular Encounter Frequency
Heave RAO (-)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Angular Encounter Frequency (rad/s)


Pitch RAO's vs. Angular Encounter Frequency
Pitch RAO (deg/m)2
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Angular Encounter Frequency (rad/s)


Pitch Response vs. Encounter Frequency
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
Pitch Response
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
Encounter Frequency (rad/s)

I Electrical Load

120/240V AC Systems		
Domestic Systems		
Wheelhouse Heaters	1500	W
Deckhouse Heaters	2500	W
Kitchen Appliances	3000	W
Lighting	1500	W
Water Heater	2000	W
Operation Systems		
Computer	500	W
Search Light	2500	W
Floodlights	4000	W
Block Heaters	2400	W
Battery Chargers	1200	W
Total Power	**21100**	**W**
Total Current	**88**	**A**

12V Systems		
Loudhailer	90	W
Autopilot	120	W
GPS	90	W
Radios	360	W
Map Table Lighting	100	W
Total Power	**760**	**W**
Total Current	**63**	**A**

24V Systems		
Bilge Pump	1400	W
Anchor Windlas	1200	W
Wipers	140	W
Horn	250	W
Radar	120	W
Navigation Lights	200	W
Engine Controls	550	W
Alarms	550	W
Total Power	**4410**	**W**
Total Current	**184**	**A**
Total DC Current @ 24V	**215**	

J Cost Estimate

Item	Unit Cost	Units	Quantity	Cost
	Structure			
Aluminium	$5,500	$/MT	11.4	$62,700
+25% Scrap	$5,500	$/MT	2.85	$15,675
+18% Consumables	$5,500	$/MT	2.052	$11,286
Labour	$65	$/hour	3135	$203,775
NC work	$25,000	Fixed	1	$25,000
Paint	$650	$/MT	1	$650
Outfitting	$10,000	Fixed	1	$10,000
Subtotal				$329,086
	Deck Equipment			
Compressor	$15,527	Each	1	$15,527
Cascade Air System	$8,225	Each	1	$8,225
Specialized Medical Equipment	$50,000	Fixed	1	$50,000
Winch	$700	Each	4	$2,800
Anchor	$100	Each	2	$200
Chain	$20	m	20	$400
Subtotal				$77,152
	Machinery			
Main engines	$105,600	Each	2	$211,200
Waterjets	$230,000	Each	2	$460,000
Fuel System	$12,000	Fixed	1	$12,000
Machinery Cooling and Exhaust	$35,000	Fixed	1	$35,000
Misc	$20,000	Fixed	1	$20,000
Subtotal				$738,200
	Electrical			
Alternator	$300	Each	2	$600
Generator	$10,000	Each	1	$10,000
Wiring	$5,000	Fixed	1	$5,000
Subtotal				$15,600
	Miscellaneous			
Navigation Equipment	$200,000	Fixed	1	$200,000
Communication Equipment	$320,000	Fixed	1	$320,000
Plumbing	$5,000	Fixed	1	$5,000
During Construction Insurance	$33,600	Fixed	1	$33,600
Classification Survey & Approval	$25,000	Fixed	1	$25,000
Subtotal				$583,600
	Summary			
Structural				$329,086
Deck Equipment				$77,152
Machinery				$738,200
Electrical				$15,600
Miscellaneous				$583,600
Engineering	10% of of Structural,			$116,004
10% Contingency				$185,964
Total			**CAD**	**$2,045,606**