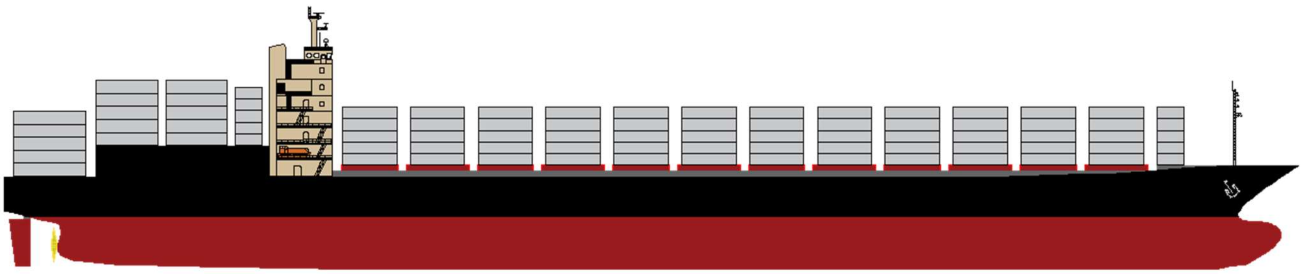
3,750 TEU FEEDER CONTAINER SHIP

DR. JAMES A. LISNYK STUDENT SHIP DESIGN COMPETITION
SPRING 2024



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List of Abbreviations

- ABS – American Bureau of Shipping
- AP – Aft Perpendicular
- ASTM – American Society for Testing and Materials
- CFD – Computational Fluid Dynamics
- COI – Certificate of Inspection
- DNV – Det Norske Veritas Register of Shipping
- EDG – Emergency Diesel Generator
- EEDI – Energy Efficient Design Index
- FP – Forward Perpendicular
- GHS – General Hydrostatics
- HFO – Heavy Fuel Oil
- HT – High Temperature
- HVAC- Heating, Ventilation, and Air Conditioning
- IGF – International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels
- IGG – Inert Gas Generation
- IMO – International Maritime Organization
- ISO – International Organization for Standardization
- LNG – Liquified Natural Gas
- LR – Lloyds Register of Shipping
- LT – Low Temperature
- MARPOL – International Convention for the Prevention of Pollution from Ships
- MARR – Minimum Attractive Rate of Return
- MDO – Marine Diesel Oil
- MGO – Marine Gas Oil
- NG – Natural Gas
- ROA – Response Amplitude Operator
- RPM – Revolutions per minute
- SOLAS – Safety of Life at Sea
- STS – Ship-To-Shore
- TEU – Twenty Foot Equivalent Unit
- USCG – United States Coast Guard

Student Certification

SUNY Maritime College

Dr. James A. Lisnyk Ship Design Competition

Student Design Team Members

The following members were involved in the vessels design:

Faculty Advisor Statement

Dr. James A. Lisnyk Student Design Competition

Faculty Advisor Statement

By this statement, I certify that the work done for this design competition was completed by the listed team members.

Faculty Advisor

Charlie Munsch

Summary

This report documents preliminary design work completed by the Bilge Dwellers Design Group while developing a 3,750 TEU Feeder Container Ship. The vessel was designed in part for Fort Schuyler Ship Design Courses I-III and the 2024 SNAME Dr. James A. Lisnyk Student Design Competition.

Acknowledgements

Collectively we would like to thank the following members of the SUNY Maritime Naval Architecture Faculty. Their expertise, subject-matter knowledge, and commitment to their student's success has been invaluable to both our professional development and our ability to succeed in this preliminary design.

- Dr. Richard Burke
- Professor Charlie Munsch
- Professor Hariharan Balasubramanian
- Professor Dave Gerr

Background

Owners Requirements

A preliminary stock design is to be created for a 3,750 TEU feeder container ship. This type of vessel would transport cargo from major ports to numerous smaller ports. The vessel's range must be suitable for such a route and be capable of carrying an array of container sizes. The container ship shall have a maximum sea speed of 24 knots, have an appropriate endurance for numerous port calls, be economically viable, meet current and projected emissions regulations, and have adequate serviceability to meet a designed lifespan of 20 years. The container vessel must be simple in design and construction, allowing for fast production time and minimal capital expenditures.

Concept Selection

An energy efficient hull utilizing LNG propulsion was selected in order to maximize EEDI efficiency. The vessel is not designed to be self-unloading and will require ship-to-shore (STS cranes) for all loading and discharging processes. The vessel must be designed to ABS and IMO construction and stability requirements.

Route

Ideally the vessel will be designed for use in various trade routes globally. To accomplish this, an example U.S. East Coast/Caribbean route will be used in the design phase. The approximate distance for such a route is 8,000 nautical miles. Although this route is one option, the vessel's large range will allow for its use worldwide. The selected route is based off a homeport of Jacksonville, Florida due to the availability of LNG. The vessel's endurance must allow for a roundtrip route to and from Jacksonville with a factor of safety. The following ports contain necessary ship to shore cranes, are draft and air draft navigable and considered in economic and endurance calculations. A sample voyage plan is provided below in table 1.

Design Voyage Plan			
Stop #	Port Call	Transit Time (Hours)	Transit Distance (nm)
1	Port Canaveral, US		
2	Freeport, Bahamas	7.2	174
3	New Orleans, US	29.0	695
4	Cartagena, Colombia	63.4	1521
5	Caucedo, Dominican Republic	27.2	652
6	NYNJ, US	65.2	1564
7	Norfolk, US	12.7	304
8	Charleston, US	18.1	434
9	Savannah, US	3.6	87
10	Jacksonville, US	5.4	130
11	Port Canaveral, US	3.6	87

Table 1- Design Voyage Plan

Hull Form

Development

The preliminary design of the ship's hull reflected the research done on similar capacity feeder container ships. The original hull's length, beam, and depth were selected based on the average sizes of the researched vessels. As the design process progressed, it was evident that modifications to the length and beam needed to be made to meet safe stability conditions. Specifically, the vessel's beam was increased in order to increase intact BM, improving overall stability. Maximum depth and air clearance were researched for each port to verify that the draft and upper extents of the bridge met these requirements. A table of principal dimensions is provided below in table 2.

Principle Dimensions		
Length, overall	290	m
Length, on waterline	272	m
Breadth	37.2	m
Draft	11.9	m
Draft, Air	49.1	m
Depth	20.9	m

Table 2- Principle Dimensions

Sectional Areas Curve

The container ship's sectional area curve is shown below in figure 1. The curve represents a typical, maximum efficiency hull design for a container ship. The vessel's hull needs to taper smoothly to a wide beam allowing for large cargo holds. The minor convexity shown at the bow represents the bulbous bows increase in area transitioning into the remainder of the hull form. 0 meters is referenced as the aft perpendicular.

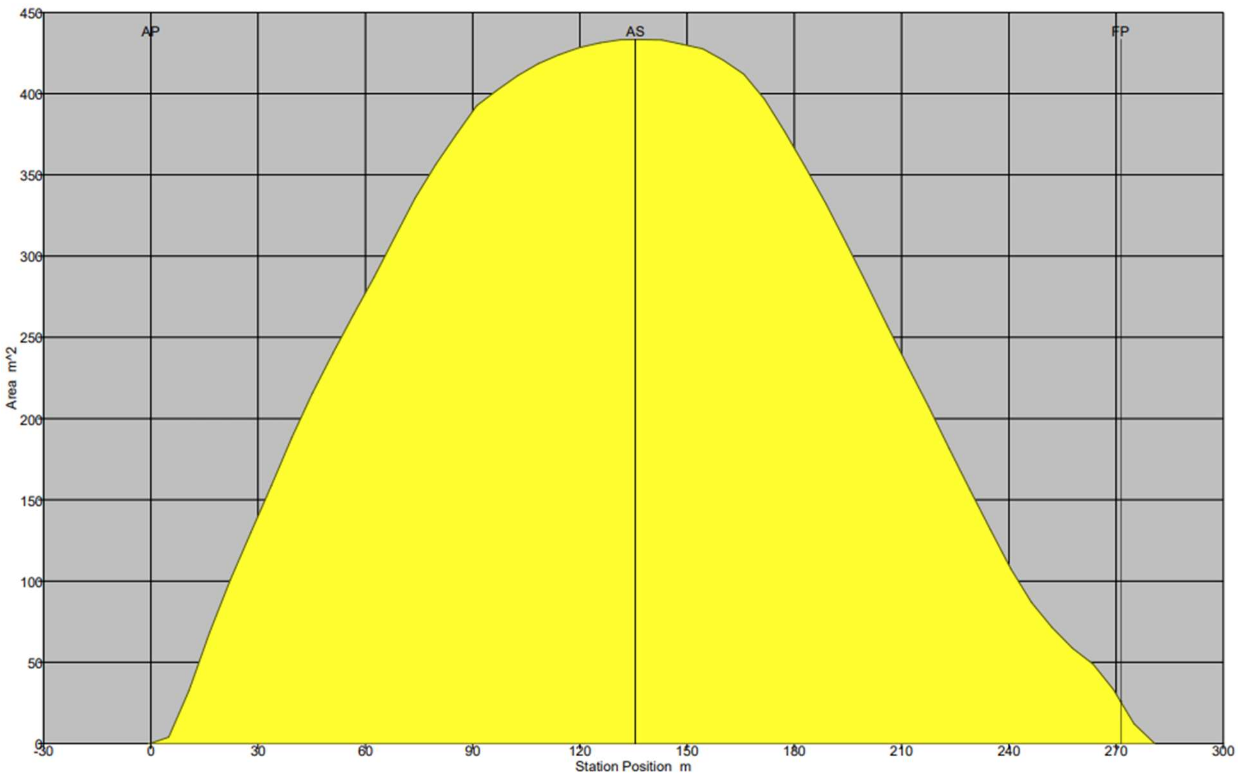

Figure 1- Sectional Area Curve

Curves of Form

Curves of form are shown below in figure 2. These curves were developed in Maxsurf and provide a visual aid for the hydrostatic properties of the vessel. The curves can be used be used to show corresponding properties of the hull between various displacements. A detailed numerical hydrostatics report is included in Appendix D.

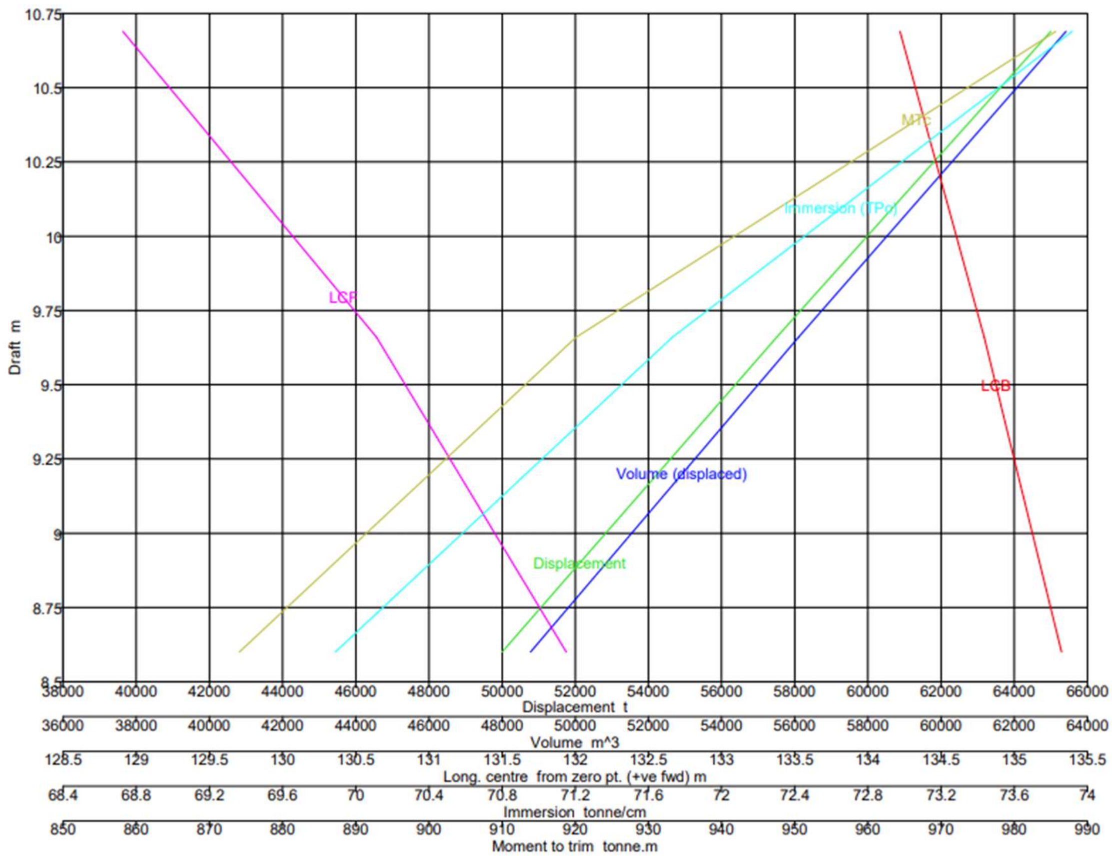

Figure 2- Curves of Form

Capacity Plan

The vessel's capacity plan was developed in accordance with the owner's requirements of a 3,750 TEU capacity ship. The length, breadth, and depth of the vessel were modified from the preliminary design to meet the TEU requirement and optimize available hold space. A significant modification in the capacity plan was made with the decision to store LNG below deck. This allowed for additional space above deck, behind the house, to store containers of various sizes.

In accordance with IMO visibility line requirements, ship stability, cargo and deck space optimization, and container accessibility, the loading of containers follows the below logistics plan:

- 20' standard containers are to be stowed above deck at the forward most cargo bay, due to limited longitudinal space on deck.

- 40' standard containers or 45' high cube containers are to be stowed above deck from bay 2 (forward) all the way aft until bay 42. The stowage of either size container above deck will vary by demand. The alternating of container size is shown in the Appendix J. It is important to note that IMO bridge visibility was calculated for the latter loading plan with 45' high cubes on deck.

- 40' high cube and 45' high cube containers are to be stowed below deck from bay 2 aft until bay 42. Removable container cell guide inserts allow for this variation.

- 40' high cube and 40' standard reefer containers are to be stowed in cargo bay 46 which allows for ease of access, maintenance, and electrical load supply. Extra space is allotted at the forward end of the house to allow for below deck reefer ventilation.

- The 40' standard reefer containers will be stowed above deck, and the 40' high cube reefer containers will be stowed below deck.

- 20' standard, 45' high cube, and 53' high cube containers will be stowed aft of the house to the transom respectively.

Various container sizes are stowable to optimize customer needs. The table below provides the design distribution of container sizes. A detailed capacity plan can be found in the Appendix J.

Container Types	TEU	Quantity Stowed
20' Standard	1	107
40' High	2	804
40' Standard	2	391
45' High Cube	2	551
53' Standard	2.56	70
Total Containers	3,778	1,923

Table 3- Container Size Distribution

The above table assumes all containers are non-refrigerated. If the entirety of bay #46 is loaded with 40' high cube refrigerated containers, the vessels reefer capacity is 264 TEU's (7% reefer capacity). It is possible to increase reefer capacity depending on the trade route by adding containerized refrigeration generators on deck to support increased electrical load.

Structural Design

Applicable Regulations

This vessel, including its hull, machinery, equipment and outfitting, shall be constructed and designed in accordance with the Rules and Regulations set forth by the Classification Society of the American Bureau of Shipping. Structural scantling calculations shall be verified against ABS "Rules for Building and Classing Marine Vessels – Part 3, Hull Construction and Equipment" last updated July 2023. Factors of Safety will be calculated and included with each scantling selection over the ABS requirements. These Factors of Safety will be reasonable to keep structural weights and centers low; however, they will not compromise in any way the safety or structural integrity of the vessel. Factors of Safety will not be permitted in any circumstance, to be below a value of zero.

Framing

A typical longitudinal framing system was selected for this container ship. Longitudinal framing allows for less material to be used to resist large bending moments applied to the hull. Longitudinal stiffeners, girders, and stringers run along the full length of the vessel. Transverse floors and webs are added to resist hull hydrostatic pressure as well as significant weight loads transferred down through the tiers of containers to the tank top. A double bottom layout is required by ABS, with girders placed at transverse locations where highest container weight loading occurs. In this design, although it does run continuously, the hatch coaming is not included in structural scantling and midship section modulus calculations.

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Materials Selected

In accordance with the ABS Rules for Materials and Welding, adequate steel materials will be ABS Grade A or ASTM A36 steel which will be used for most of this vessel's construction. High tensile strength steel plate will be used for the vessel's box girder, to both raise the height of the neutral axis and resist torsional forces applied to the hull. The design operating temperatures for this vessel are in an air temperature not less than 14 degrees Fahrenheit, and a seawater temperature not less than 32 degrees Fahrenheit.

Midship Section Modulus

The nature of container ships requires vast open deck space to accommodate ease of container stowage. This makes container ships a unique ship type, as any structural members located in the transverse center of the vessel would interfere with cargo operations and capacity. Due to the lack of centerline deck structure, high weight, and torsional loads, container ships usually have trouble meeting required section modulus values. Midship section modulus refers to the vessel's ability to resist the bending loads placed on the hull measured at locations of maximum stresses (usually amidships or within 0.4L of amidships).

To achieve sufficient strength, container ships are fitted with box girders underneath the main deck at the outermost extent of the vessel's beam. Container ship box girders are constructed with high tensile steel, of a thickness significantly greater than any other steel on the vessel. Locating longitudinal, high strength, thick steel furthest away from the keel has many benefits. Box girders improve global section modulus, reduce deck stresses, and provide an enclosed, longitudinal passageway for crew under the deck for use in rough seas.

Although material yield strength has a consistent value, to include a safety factor ABS limits the allowable applied stress on steel members. For example, 250 MPA yield high strength steel is limited by ABS to 225 MPA for thicknesses greater than 1", and 235 MPA less than 1".

Transverse bulkheads, both water-tight and non-tight, do not run significant longitudinal distance and are not included in any longitudinal strength calculations. A detailed global section modulus calculation is located in Appendix B. Table 4 below shows abbreviated deck and keel stresses calculated as a result of the designed global section modulus.

Stress Calculations			FOS
Stillwater deck stress	57	MPa	4.1
Stillwater bottom stress	37	MPa	6.4
Hogging deck stress	114	MPa	2.1
Hogging bottom stress	73	MPa	3.2
Sagging deck stress	148	MPa	1.6
Sagging bottom stress	95	MPa	2.5

Table 4- Stress Calculations

An abbreviated table of information from the section modulus calculation in Appendix B is shown below in table 5.

Abbreviated Section Modulus Calculations		
Depth	20.93	m
Height Neutral Axis	8.2	m
Z deck	27.6	m^3
Z keel	42.9	m^3
Stillwater Moment	160	ktonne-m
Sagging Moment	417	ktonne-m
Hogging Moment	320	ktonne-m
Gravity	9.81	m/s/s
Material Yield	250	MPa
ABS Allowable Less than 1"	235	MPa
ABS Allowable Greater than 1"	225	MPa

Table 5- Abbreviated Section Modulus Calculations

General Scantlings

All hull scantling designs were completed in accordance with ABS Rules for Building and Classing marine Vessels – Part 3, Hull Construction and Equipment. ABS minimum required thicknesses are all rounded up to the nearest ½ millimeter. Minimum required thicknesses from ABS encompass a built-in factor of safety. This factor of safety is aimed at reducing potential failures in the material, as well as accounting for corrosion anticipated over the lifespan of the vessel. A detailed list of calculations is included in Appendix B, and an abbreviated table of principle thicknesses is provided in table 6 below.

Principal Scantling Thicknesses		
Outer Bottom Plating	28	mm
Side Shell Plating	25	mm
Inner Bottom Plating	19	mm
Solid Floors	15	mm
CVK	22.5	mm

Table 6- Principle Scantling Thicknesses

Weight Estimate

Lightship Weight

A preliminary lightship weight was developed with Papanikolaou's "Ship Design Methodologies." With the exception of LNG fuel tanks mounted aft of the house, the remainder of lightship structure is typical for a post-panamax container ship. A lightship weight estimate is shown in table 7 below.

Lightship Weight Distribution			
Weight Category	**Weight (Tonnes)**	**VCG (m above BL**	**Vertical Moment (Wt*VCG)**
Lightship Items			
Hull Structure (WH)	20000.0	11.0	220000.0
Superstructure	1600.0	35.0	56000.0
Hatches	1000.0	21.0	21000.0
Outfit	3700.0	18.5	68450.0
Machinery	2000.0	7.9	15800.0
Margin	500.0	11.0	5500.0
Total Lightship	28800.0	13.4	386750.0

Table 7- Lightship Weight Distribution

Deadweight

Difficulties in estimating deadweight tonnage for container ships occur due to the varying nature of cargo container contents. Container box weights are inconsistent and vary from container to container. Until the container is lifted by the gantry crane in port and accurately weighed, the true weight is largely unknown. In order to estimate deadweight tonnage in the preliminary design phase, an average container weight per tier was used. The estimate considers that typical cargo loading plans place lighter boxes above deck and heavier below in order to increase the vessel's stability. Average container weights utilized in the deadweight tonnage estimate and TEU breakdown are included in tables 8 and 9 below. The full breakdown of deadweight tonnage and the vessel's capacity plan can be found in Appendix J.

TEU Distribution	
Above Deck	2170
Below Deck	1608
Sum	3778

Table 8- TEU Distribution

TEU Weight Distribution		
Tier	Weight (MT)	VCG (m above BL)
02	30	3.44
04	30	6.34
06	30	9.24
08	30	12.14
10	25	15.04
12	10	17.94
14	10	20.84
82	10	24.73
84	10	27.63
86	10	30.53
88	5	33.43
90	5	36.33

Table 9- TEU Weight Distribution

Remaining deadweight is shown in table 10 below. Fuel and lube oil capacity are sized appropriately for endurance and engine performance, more information on these items can be found in the endurance calculation section.

Deadweight Items			
Item	Weight (MT)	VCG (m)	Vertical Moment (MT-m)
Cargo DWT	27,010	17.8	480,308
Fuel Oil	2,315	16.8	38,892
Lube Oil	20.5	16	328
Fresh Water	208	11	2,288
Crew + Effects	12	20.3	244
Provisions	5.2	20.3	105
Total Deadweight	29570.7	17.7	522,166

Table 10- Deadweight Items

Stability

Intact

An intact stability analysis was completed in Maxsurf for each of the following load cases.

- Lightship Condition
- Arrival Condition (10% Consumables)
- Full Load Departure Condition (95% Consumables)

Tables 11 and 12 below show the full load condition weight estimate and intact stability results. It is important to note that the metacentric height value is extremely dependent on cargo loading for container ships. It is difficult to estimate values for cargo VCG's as they are inconsistent between trade routes. An average TEU weight is utilized per tier, allowing the heavier boxes to be stowed beneath lighter ones. A full analysis of intact stability including GZ curves for each load case is provided in Appendix G- Intact Stability Analysis.

Full Load Departure Condition

Weight Category	Weight (Tonnes)	VCG (m above BL	Wt* VCG (ton*m
Lightship Items			
Hull Structure (WH)	20000.0	11.0	220000.0
Superstructure	1600.0	35.0	56000.0
Hatches	1000.0	21.0	21000.0
Outfit	3700.0	18.5	68450.0
Machinery	2000.0	7.9	15800.0
Margin	500.0	11.0	5500.0
Total Lightship	28800.0	13.4	386750.0
Deadweight Items			
Cargo DWT	27010.0	17.8	480308.5
Fuel Oil	2315.0	16.8	38892.0
Lube Oil	20.5	16.0	328.0
Fresh Water	208.0	11.0	2288.0
Crew + Effects	12.0	20.3	243.6
Provisions	5.2	20.3	105.6
Ballast Water			0.0
Total Deadweight	29570.7	17.7	522165.6
Total Ship Weight	58370.7	15.6	908915.6
		KG	

Table 11- Full Load Weight Distribution

Full Load Stability		
Displacement	59286	Tonnes
Draft Amidships	9.9	m
Draft at FP	10	m
Draft at AP	9.8	m
Wetted Surface	10365	m^2
Waterplane Area	7034	m^2
KB	5.4	m
KG	15.6	m
BM	10.8	m
KM	16.2	m
TPc	72.1	Tonnes/cm
GM	0.6	m

Table 12- Full Load Stability

The full load departure GM calculated above shows only 0.6 meters. This is sufficient on paper, however in operation would ideally be larger. An empty line item in all KG calculations is left to allow the use of saltwater ballast. The vessel is capable of taking on XX tons of saltwater ballast inside the double bottom (1-meter VCG above the baseline). Since the vessel has such a large double bottom capacity, the overall KG of the vessel can be lowered substantially, even in a fully loaded cargo condition to improve GM.

Saltwater ballast is also essential for the vessel's half-load and lightship load cases in order to improve propeller submergence as well as keep the bulbous bow submerged. The vessel has a natural tendency to trim by the stern as a result of large LNG tanks mounted aft of the house; however, this trim issue can be easily reduced with taking on saltwater ballast towards the bow.

IMO Intact Stability requirements outlined under code A.749 Ch3- Design Criteria Applicable to All Ships, were tested for the full load departure condition. The vessel passed all criteria outlined by IMO and the results and margin are outlined in Appendix G – Intact Stability Analysis.

Floodable Length

Floodable length criteria were tested in Maxsurf and shown below in Figure 3. This container ship has a typical layout of transverse bulkheads at the ends of container bays. Permeabilities based on IMO regulations were entered, and the resulting floodable length curve is shown below. It is evident that the consistent bulkhead spacing leaves plenty of margin between maximum permissible floodable length sections. It is important to note that although there is a transverse bulkhead in between each container bay for cell guides, not all are watertight. Two bays of containers make up one hold, each hold is comprised of watertight bulkheads on both ends. The blue line combines two compartments, reflective of one hold length. Although the margin of safety is reduced, the current layout of watertight bulkheads surrounding holds is both typical and safe.

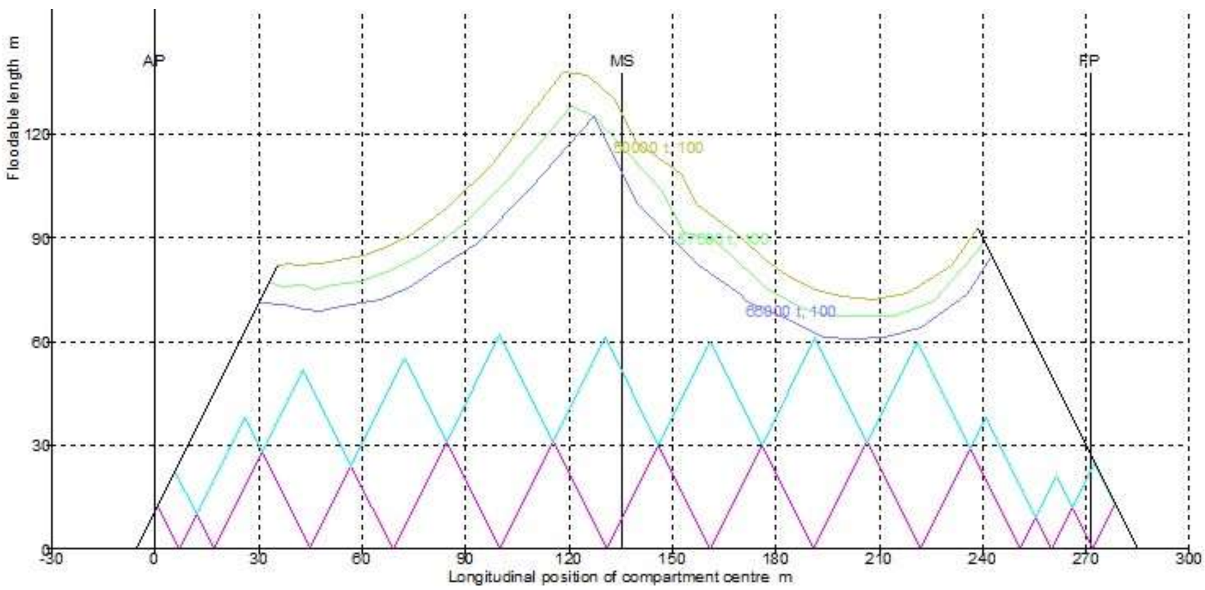


Figure 3- Floodable Length

Damaged

IMO Probabilistic Damage Stability was calculated in GHS. The full damage stability report is attached in Appendix H - Damage Stability Analysis. The vessel's margin line is placed 3 inches below the main deck extent. There are no watertight doors or hatches on the side shell plating, resulting in no down flooding points until the main deck hatch coaming and house entry doors. High, continuous freeboard allows for greater angles of roll and less probability of damage. Much like floodable length, container ships do not typically have an issue with damage stability. The general layout includes many transverse watertight bulkheads, minimizing the ability for holed compartment damage to spread. It is important to note that the GHS damage stability model uses hold compartmentalization that does not distinguish from container space and tank space. Although in practicality it is unlikely that damage would go beyond the double bottom and wing tanks into the cargo space, these values are over-estimated in the sense that GHS treats the space as one. Table 13 below shows the probabilistic indexes for 3 load conditions. The GHS outputs for damage stability analyses are shown in Appendix H.

Damage Stability Overview			
Condition	Draft	Required Index	Attained Index
Lightship	Light, 8.5 meters	0.705	1
Arrival	Intermediate, 10 meters	0.705	0.99
Departure	Deepest, 11.5 meters	0.705	0.97

Table 13- Damage Stability Overview

Propulsion, Speed, and Power

Method of Determining Speed and Power

Since the geometry of the hull form determines the resistance required for the ship to travel through the water at sea speed, and the hull form is determined by the size of cargo and machinery needed to propel the vessel, the speed and power is defined iteratively. Described in the section is how the initial required power of the vessel was defined using example ships and Holtrop analysis, and then how speed and power was determined and verified using CFD Analysis with the final hull.

Initial Values for Design and Holtrop Analysis

To inform the initial design phase, estimation methods and examples are used. These methods include referencing existing example ships of similar operational profiles and Holtrop analysis, which is a mathematical method of estimating vessel performance based on a statistic from existing vessels accounting for key design principle features.

When first blocking out the design of the vessel example vessels of container ships with similar cargo capacity and speed found using several databases. This informed an initial set of principle characteristics for The *MV Dweller*. These characteristics were used to perform a Holtrop Analysis. The results of the Holtrop Analysis yielded a propulsive power of between 38,000 and 42,000.

Overall, the Holtrop analysis revealed a greater power requirement than the vessels identified, mostly due to the fact that although similar vessels could be found to the design profile of the *MV Dweller*, none operated at as high of a speed as outlined in the owner's requirements.

Marine CFD

For vessel design today, the most widely used method of finding hull resistance is Computational Fluid Dynamics, or CFD Modeling. This method involves taking a computer model of the vessel and simulating how fluid interacts with the hull as it travels through the water.

For the *MV Dweller*, CFD testing was used to find hull resistance experienced at design speed due to the accessibility and rapid iteration of design available through Orca3D and Simerics, and the validity of CFD modelling in ship design today. The CFD analysis conducted studied the vessel at the designed daft and even trim under two speed conditions, the designed sea speed of 24 kts, and a reduced speed of 20 kts for endurance calculation.

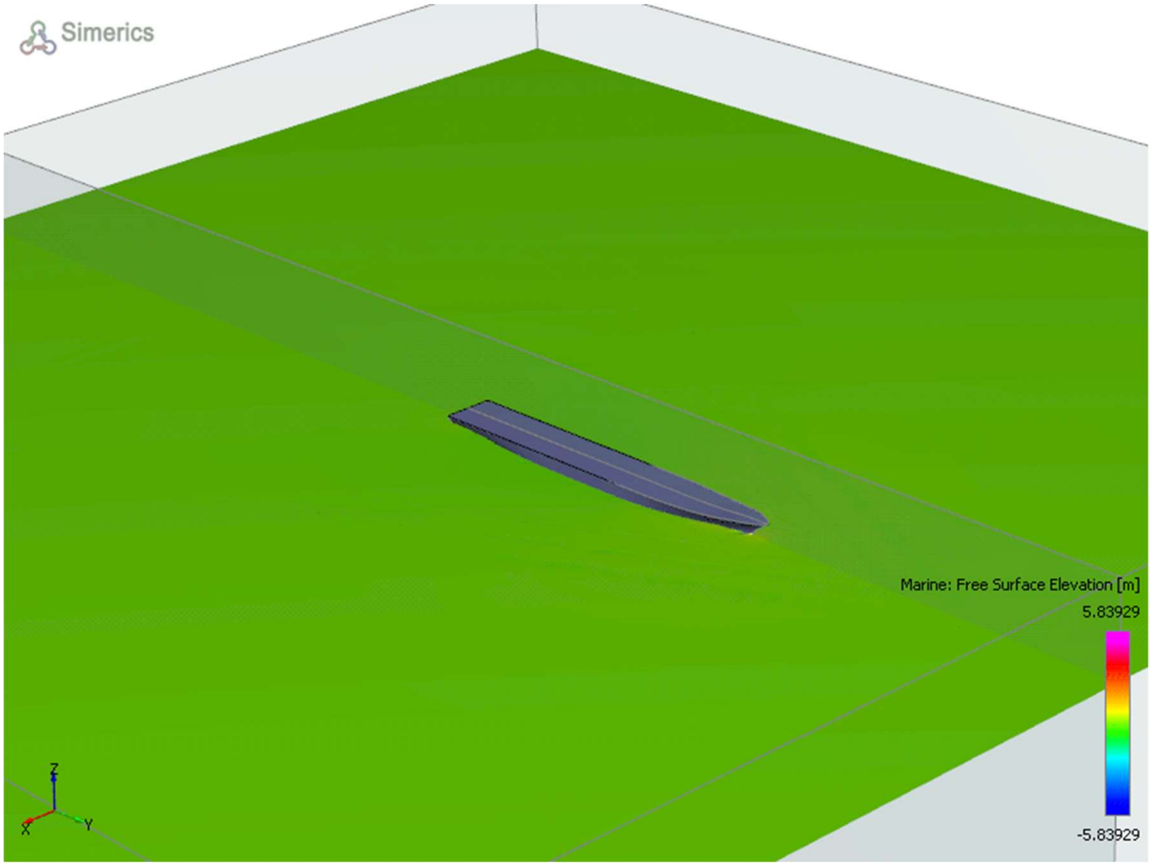


Figure 4- CFD Graphic

From this analysis, the total hull resistance was found to be 1,960,000 N, resulting in a required propulsive power of 24,235 kW. At a sea speed of 20 kts, the hull resistance was dramatically lower, with a resistance of 13,000 kW.

Factoring in Propulsive Losses

Although the hull resistance of the vessel is 24,235 kW, the propulsive power delivered by the propeller is less than the power produced by the engine due to propeller and shaft inefficiency. These losses need to be accounted for to properly size the engine.

Individual Components of Propulsive Losses

Shaft Losses – Being driven by a single propeller, direct driven shaft, the efficiency of the shaft to the propeller can be taken as 97%.

Propeller Efficiency - Based on the propeller characteristics, accounting for propeller diameter, pitch, rpm, and other factors, the propeller efficiency was estimated to be 70%.

Fouling and Erosion – During operation, components in direct contact with sea water can get fouled by marine growth and negatively impact propulsive efficiency. Accounting for this loss also serves as a safety factor for other components of propulsion inefficiency that cannot be accounted for during design. The loss associated with propeller fouling was taken as 10%.

Sum of Propulsion Losses

The total losses associated with the propulsion system is taken as 57%, making the required power output of the engine of 34,080 kW.

Engine Sizing based on Projected Load and Engine Selection

While the propulsive load delivery by the main engine is 34,080 kW, the sizing of the engine must be greater than the required power output, since maximum engine load for continuous use is not tenable due to equipment damage due to overload. Given this, assuming the engine is expected to be run at 80% of maximum continuous rating, the engine size is scaled up 20% from 34,080 kW to 40,700 kW.

With this final value for engine sizing, the engine chosen for the *MV Dweller* is the WinGD X92DF-2.0, a 42,560-kW dual-fuel diesel/LNG powered slow speed diesel engine.

Shipboard Systems

Main Propulsion

Propulsion Plant Selection

The vessel will be propelled by a single slow speed dual-fuel diesel and LNG engine, directly driving a single propeller. The engine specified for this design was selected to be the WinGD X92DF-2.0, a 42,560 kW max operating power slow speed diesel engine. Although this engine is capable of being fueled by either diesel or LNG, it will be primarily run on LNG while underway.

Figure 5- WinDG X92DF-2.0 Main Engine Graphic

Propulsion Plant Alternative Analysis

Alternate propulsion options have been considered to power this vessel. In deciding on a propulsion plant, it is important to view the advantages and disadvantages of each. Although various options were investigated for powering the *MV Dweller*, two additional alternative propulsion plants are being viewed as candidates that were considered to be employed on this vessel. In the first design iteration, operating on diesel fuel only was considered. This was quickly decided against due to the vessel's inability to pass stringent EEDI emissions regulations projected for the next 20 years while operating solely on diesel.

Diesel Electric Propulsion Plants

Diesel electric plants involve decoupling the mechanical energy transfer between the engine and propeller. This is done by producing electricity with the main engines, and then using that electrical energy to drive a shaft with propulsive motors. This has the advantage of allowing for redundancy in the propulsive plant, with multiple drive motors and main engines being employed. With smaller equipment it is easier to maintain a diesel electric plant than a large diesel engine. Furthermore, power to drive the shaft can be produced by more than one engine, and they do not need to be oriented on the ship to accommodate a shaft, allowing for flexible design on the machinery arrangement to accommodate a variety of needs. A final advantage of a propulsive plant is its ability to operate optimally through a range of loads and event transient loads associated with maneuvering since engines can be put online and taken offline to accommodate for load changes, and the propulsive motors can be controlled more precisely and effectively.

Diesel electric plants do however come with disadvantages however. Since energy transfer from mechanical to electrical energy occurs between the engine and the shaft, the efficiency of a diesel electric plant is inherently worse than a slow speed diesel engine. Furthermore, there are challenges associated with maintenance of a diesel electric plant that are not necessarily present in other propulsive plants. Due to the high voltage requirements of the main drive motors, high voltage precautions need to be made for operating this type of plant, potentially making it harder to find crew able to run and operate such a vessel.

While the advantages of a diesel electric plant are numerous, the increased performance in transient loads does not suit the operational profile of this vessel which travels relatively large distances between maneuverings. Although the flexibility of engine location can aid in design, and make the vessel easier to operate, in the size of the given vessel, this is something that is not needed for this design. Since the *MV Dweller* can accommodate a larger engine with little difficulty, diesel electric propulsive plants are not the most viable option since more efficient plants can be employed without compromising functionality.

Medium and High-Speed Diesel Engines

Medium and high-speed diesel engines have a higher power to weight ratio than slow speed diesel engines, they are smaller and have higher shaft speeds than slow speeds, requiring reduction gears to reduce engine output RPM to the required propeller RPM. This brings the advantage of having smaller engine components which are easier to fit into a hull form and perform maintenance on. These engines can fit better in smaller and faster ships than a slow speed engine, but have a lower efficiency than engines directly connected to the propeller.

Although medium and high-speed engines are suitable for some applications, the size and ability to fit a larger and more efficient slow speed diesel engine makes utilizing a medium speed or high-speed engine an inferior option to slow speeds.

Electrical Equipment

Analysis of Electrical Equipment Load

While propulsive load is produced by the main engine to move the ship, auxiliary systems that support the running of the main engine, engine room equipment, and hotel loads for making the space habitable for the crew are powered electrically by auxiliary LNG powered Gensets.

Hotel loads

- Lighting
- HVAC
- Potable Water Service
- Hot Water Heating and Circulation
- Culinary/personnel related equipment operation

Machinery Loads

- Pumps/Hydraulic equipment
- Equipment Heaters
- Deck Equipment

Deck and Safety equipment

- Cranes and lifts
- Anchoring equipment
- Mooring winches
- Radar and navigational equipment
- Alarm systems

Loads Associated with Cargo

- Refrigerated Containers

Given the equipment utilized that require electrical power, estimates of hotel loads, and data from existing ships, an electrical power supply of 1,000 kW in hotel loads, and 1,125 kW for the electrical load associated with refrigerated containers. This yields a total electrical load of 2,125 kW.

Generator Selection

Given the expected electrical load of 2,125 kW, a corresponding genset needs to be specified that can match this power demand. For electrical energy, and given the need for redundancy, typically multiple smaller gensets are employed to for these power plants. In this case, four MAN 8L23/30DF will be employed to supply the required electrical power.

This engine is an 8-cylinder, 1,250 kW MCR, dual fuel, LNG, diesel engine. For the purposes of the ships electrical plant, without refrigerated containers, one engine can be used to supply electricity for electrical loads. Under normal operation two generators are run in parallel, and three would be used during periods of peak loading. This engine configuration allows for one redundant engine to be used when other engines are maintained, or in the event of an emergency where one becomes inoperable.

Figure 6- MAN 8L23/30DF Generator Engine Graphic

Emergency Diesel Generator

In the event of a power failure, an emergency diesel generator was selected in order to restore the ships basic essential functions. The emergency diesel generator selected is the Cummins QSB7-DM, with a continuous output rating of 149kW.

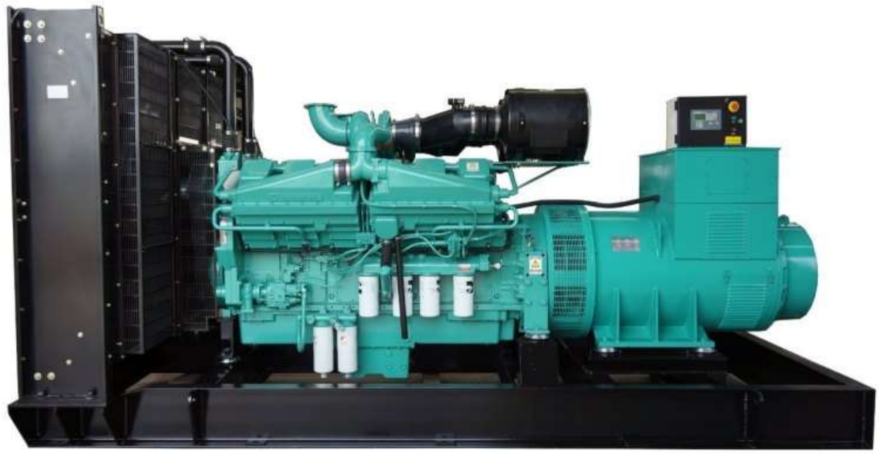


Figure 7- Cummins QSB7-DM Emergency Diesel Generator Graphic

Auxiliaries

Fuel

Overview of LNG as Fuel

LNG, short for Liquified Natural Gas, is the preferred choice of fuel for this vessel due to the vastly improved emissions quality when compared to distillates such as HFO, MDO, and MGO. While LNG produces fewer emissions of CO_2 than traditional fuels, it also has the unique advantage of producing minimal to zero combustion biproducts such as Sulfur Oxides, SOx, and Nitrous Oxides, or NOx. These emissions are produced under the extremely high compression and temperatures associated with diesel engines optimized for fuel efficiency and performance.

LNG vessels differ from a typical diesel-powered vessel by more than the fuel being used to power them. For storage and use by the engines, specialized machinery, equipment, safety procedures, and systems must be employed. In using LNG as fuel, the ship obtains an IMO energy efficiency design index of 0.69 g/dwt/nm. The ship's base energy efficiency design index is 19.82 g/dwt/nm, supporting the fact that the ship produces emissions considerably lower than the acceptable limit. The IMO requires that every five years, ships do not exceed the value of a 10% reduction of the base EEDI value. With the current EEDI and base EEDI, it would take approximately 160 years of service before the ship falls out of regulation.

LNG Storage and Use

Natural gas, the natural state of LNG at atmospheric temperature and pressure, is not economical to store due to the available energy per unit volume of the fuel. For efficient storage LNG must be liquified by cooling to cryogenic temperatures. LNG ships bunker LNG in the liquid form already at cryogenic temperatures, and insulated tanks keep the fuel from evaporating at a rapid rate. This does not prevent evaporation from occurring entirely, and pumps, compressors, heating units, and cooling units are required to handle LNG fuel in both liquid and gas states as a result.

Required equipment for LNG storage:

- LNG Reliquification Plant
- Gas Breaker Vent
- LNG Bunkering Manifold
- Nitrogen Generator System
- Diesel Inert Gas Generator

Required equipment for propulsion plant:

- LNG Service Pump
- LNG Gasifier
- NG Main Engine Compressor
- NG Aux Compressor
- Leak-off Gas Compressor

Considerations for LNG Plant Design

In accordance with PASHA regulations, the following considerations must be made for the design of an LNG powered ship.

- Motors and electrical equipment must be in different spaces than pumps and compressors that will be handling LNG.
- LNG tanks must be vented to atmosphere to allow leaks and spills to expand freely upon evaporation.
- Safety equipment must be located on the ship to vent LNG if over pressurization of the tank occurs.
- LNG handling spaces must be separated from other spaces on the ship by airtight partitions.
- Safety and alarm systems must be in place to take preventative measures, detect, and respond to leaks and other hazards associated with LNG as fuel, including ventilation, gas detectors, water curtains, and other equipment associated with bunkering LNG Fuel
- Piping inside the engine room are double walled, and circulate inert nitrogen gas to contain and detect LNG leaks in the contained fuel delivery system.

Diesel Systems

Although LNG is the preferred fuel of choice for the main engine, the use of diesel is required by the engines for periods of low or transient engine loads. For this reason, and the reliability of diesel as a fuel, diesel must be carried on the vessel for use by the main engine, auxiliary engines, and emergency diesel engine.

Required equipment for diesel use:

- Diesel Storage Tank
- Diesel Settling Tank
- Diesel Service Tank
- Emergency Diesel Generator Day Tank
- Bunkering Manifold
- Service Pumps
- Transfer Pumps
- Fuel Oil Purifiers

Lube Oil

The main engine, generators, and other auxiliary machinery require lubrication oil to reduce friction between moving components and aid in removing heat generated during operation. To accomplish this the vessel must be equipped with a lube oil system. The main engine must have a lube oil circulation loop and other associated systems require their own individual lubrication systems. This entails lube oil storage tanks, transfer pumps, service pumps, purification, coolers, circulation pumps, head tanks, and bunkering stations.

Cooling Systems

The main engine, generators, and other auxiliary machinery generate heat due to friction and other sources which must be removed to avoid equipment damage and failure. Cooling water loops are used to remove the heat generated during operation. To accomplish this, the vessel must be equipped with an HT Cooling system for the main engine, and an LT cooling system for auxiliary machinery where the cooling water passes through the equipment and then passes through a heat exchanger. These loops are ultimately cooled by saltwater collected from the sea chest.

Other Systems

For plant operation and safety, various other systems must be employed which considerations must be made for, outside the scope of the vessels preliminary design. These systems include but are not limited to:

- Stern Tube Sealing
- Firefighting, safety, and detection, alarm, and other associated systems
- Steering gear
- Refrigeration
- HVAC systems
- Compressed air, including control, ship service, and engine start air
- Waste heat recovery and fresh water generation
- Potable water storage, treatment, and heating
- Black and grey water treatment systems
- Ballast water and ballast water treatment
- Bilge holding, purification, and discharge
- Waste management

Deck Equipment

- Cranes and lifts
- Anchoring equipment
- Mooring winches
- Radar and navigational equipment
- Alarm systems
- Lifeboats
- Alarm Systems
- Fire pumps and suppression
- Misc. Safety Systems

Endurance Calculation

Described below details how the fuel tanks are sized to perform shipboard operation at the designed range while having the capacity for additional shipboard operations and safety factors. A theoretical maximum range is found for the vessel accounting for fuel stored with a safety factor, reduced fuel consumption by the engines due to a reduced sea speed, and use of additional diesel fuel typically stored for inert gas production for propulsion.

Initial Fuel Tank Sizing

Methodology for Tank Sizing for Fuel Consumption Underway

The operational profile of the vessel is to have a service range of 8,000 nautical miles. Given the design speed, range, and required power of the vessel, its construction was made specifically to accommodate these requirements burning primarily LNG as fuel. First, the required shaft power and horsepower from the engine must be found at the design speed. This is used to find the fuel consumed by the engine every hour. Then, the time of operation is found for the vessel to travel the designed range at 24 kt. The fuel consumption during this time is the required fuel capacity.

Other consumers of fuel must be considered for the design voyage. For this vessel, the only other component that consumes fuel while underway are the generators for electrical power as all other equipment are electrically operated. Knowing the electrical load and specific fuel consumption given this load, the fuel consumption of these engines can be found. Further detail can be found by accounting for port time, when the main generators are used but the main engine is not.

From the known main engine and generator fuel consumption, the required fuel capacity is found. Both engines are primarily fueled by LNG but require a diesel pilot flame to ensure LNG combustion. Given this, a specific fuel consumption for both fuel types are required and accounted for in sizing the diesel tanks and LNG tanks respectively. The fuel capacity for these tanks are then inflated by 10% for a safety factor to account for losses, inefficiencies, changes in course, and other factors that may increase fuel consumption during a voyage.

Additional Required Fuel Capacity

Although the minimum tank sizes are established for consumption during a voyage, additional fuel storage is still needed as reserve for other shipboard operations to be performed if the need arises. These irregularly used functions include running the EDG and using diesel to inert the LNG tanks for drydock, which is only used when LNG is offloaded, and the nitrogen IGG system cannot meet the demand.

For sizing the tanks for these loads, the diesel day tank requires a cubic meter for ample operating time, but the diesel IGG system requires more considerations. For the Inert gas system to work properly, enough fuel needs to be burned for the combustion product, carbon dioxide to fully fill the LNG tanks and displace any NG vapors. To do this, the mass of vapor required to fill the tank is found using the ideal gas law and the volume of the LNG tanks. This ensures that at above atmospheric pressure and the storage temperature of the LNG of 111.15 degrees K, enough carbon dioxide can be produced to inert these tanks. Once the mass of carbon dioxide is known, the mass ratio of diesel burned to carbon dioxide produced during the combustion reaction is used to determine how much additional diesel capacity is required to perform an inerting procedure for drydock. Similarly, to the fuel used for propulsion, this number is inflated by 10% to account for a factor of safety.

Fuel Tank Sizes

From the analysis above, minimum mass of fuel required for shipboard operations were found to be 2,315 tons, and 72 tons respectively. From here, the volume of the fuel tanks is found using each fuels' respective density, and then increasing the found volume by 2% to account for the maximum allowable fill of 98% for each tank. The following tank sizes are found to be the following.

LNG Tank Sizing			
	LNG	Diesel	Units
Fuel Weight	2,315	72	tons
Volume of Fuel Required/Voyage	3,952	88	m3
Volume of Tank with Max Fill Constraints	4,160	92	m3

Table 14- Tank Sizing LNG

Theoretical Maximum Vessel Range

Establishing Limits to Vessel Range

When viewing the maximum range for a vessel, it is important to consider any consumables required for shipboard operation which may become depleted during a voyage.

Crew Consumables:

- Potable water
- Food Stores

Ship Function Consumables:

- Lubrication Oil
- Maintenance items
- Fuel Oil

Additionally, stores of waste products cannot exceed storage capacity, and if not ethically discharged, must be discharged at port.

Required Discharges:

- Grey and blackwater
- Paper Trash and Food Scraps
- Bilge water slops
- Clean drain tank
- Waste oil and sludge

Of the listed consumables, those such as lubrication oil, stores, and maintenance consumables required capacity and consumption rates are so low that they can easily be stored on board. In the case of water storage, for use by machinery and crew, ample storage of water is available, and water can be produced continuously produced underway. This leaves fuel oil as the only consumable that can be depleted during the duration of one voyage.

As for waste items and discharges, processing plants such as a marine sanitation device for blackwater, oily water separator for bilge water, incinerator for paper waste, and other associated equipment combined with high storage capacity relative to waste production means that waste storage and discharge does not limit the vessels range.

Based on this analysis, since waste management and stores of other consumables do not have an effect on the vessels ability to operate in the time frame of a single voyage, this leaves fuel as being the single limiting factor to vessel range.

Maximum Vessel Range

Given the buffer factors made into the design, the fact that other shipboard functions not typically utilized in a voyage call for extra fuel storage, and allowing for slower sea speeds, the actual range of The *MV Dweller* can be optimized.

Listed below are the combined fuel consumption rates of both the main engine and generators for diesel and LNG. For when burning exclusively diesel fuel the combined fuel consumption of both the main engine and generators is also listed.

Total Fuel Consumption at 20 kt (Main Engine + Generators)		
LNG Operation (LNG Consumption)	2.83	tons/hr
LNG Operation (Diesel Consumption)	0.0021	tons/hr
Diesel Operation Consumption	3.67	tons/hr

Table 15- 20 Knot Fuel Consumption

From the given fuel consumption, the range can be found by tracking the time it takes to deplete each storage tank from full at the given condition. From this analysis, the theoretical maximum range for the MV Dweller is 16,500 nautical miles at 20 kt.

Endurance		
Voyage Start Fuel Capacity LNG	2,315	tons
Voyage Start Fuel Capacity Diesel	79	tons
Hours of Operation	669	hr
Diesel Consumed During Period	1.40	tons
Total Vessel Range		
Total time of Operation	690	hr
Total time of Operation	29	days
Range	16,572	nm

Table 16- Endurance

Seakeeping Analysis

Seakeeping is the study of a vessel's motions when subject to various wave conditions. The purpose of the analysis is to observe the effects of waves on the ship's structure for various degrees of freedom. In order to understand the results of the analysis, the vessel must be viewed as a rigid body and the degrees of freedom shown in figure 8 below. Three linear; surge, sway, heave, and 3 angular; roll, pitch, yaw, degrees of freedom are shown.

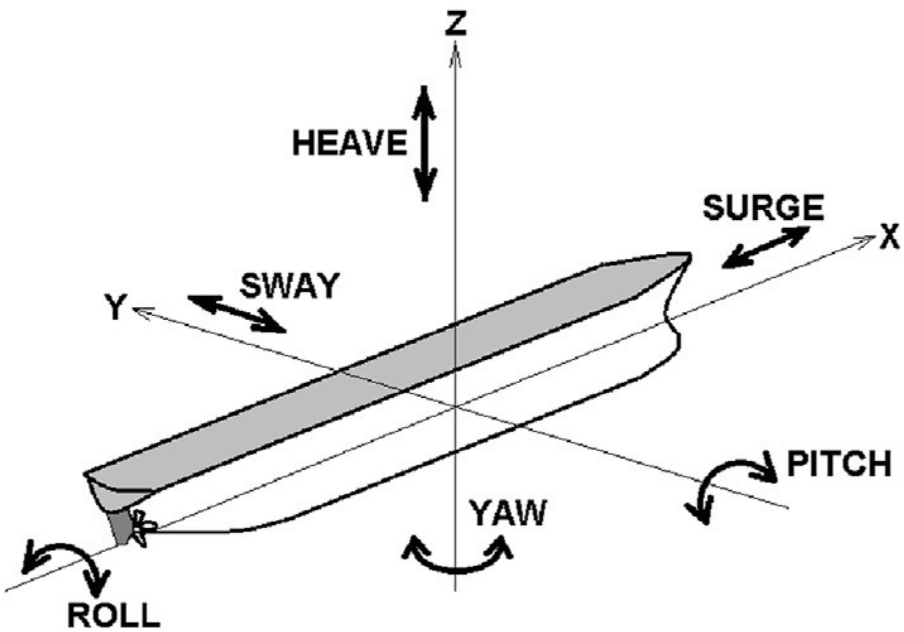


Figure 8- Degrees of Freedom

The analysis was performed using Maxsurf Motions with strip method analysis. Parameters used to run the test are listed in table 17.

Seakeeping Parameters		
Analysis Method	Strip Method	-
Spectrum Type	JONSWAP	-
Wave Height	4	m
Modal Period	9.982	s
Vessel Speed	24	kts
Added Resistance Method	Salvesen	-

Table 17- Seakeeping Parameters

In order to obtain a wide variety of results in various conditions, the following cases were created and tested:

- Vessel Speeds
    - Stopped, 0 kts
    - 1 kt
    - 5 kts
    - 10 kts
    - 15 kts
    - 20 kts
    - Full Speed Ahead, 24 kts
- Wave Headings
    - Following Seas, 0 degrees
    - Stern Quartering, 45 degrees
    - Beam, 90 degrees
    - Bow Quartering, 135 degrees
    - Head Seas, 180 degrees

Strip theory analysis is a method of testing in 2D. This method was developed in the 1970s by Salvesen et al, and is formulated by a function of frequency. Using Maxsurf Motions, once parameters have been inputted, testing is completed by dividing the hull into uniform strips. Hydrodynamic properties are obtained from each, and used to calculate the coupled heave and pitch response of the vessel.

An important factor considered when completing the seakeeping analysis is RAO, the Response Amplitude Operator. This is the response of the vessel as varied frequencies are tested. Heave and pitch RAOs are found in Appendix M. At higher frequencies, the graph tends to trend toward zero. The hull responds very little when many short waves are applied.

The test was ran with an added resistance using the Salvesen method. The added resistance calculated is only due to the vessel's motion in waves. Speed loss due to wind is not accounted for in this analysis. The spectrum type used in the analysis is JONSWAP, Joint North Sea Wave Project. Wave spectrum describes the distribution of energy at different frequencies. JONSWAP uses a peak enhancement factor of 3.3. Strip method results are shown below in table 18.

Seakeeping Results		
Modal Period	9.982	s
Characteristic Wave Height	4	m
Spectrum Type	JONSWAP	-
Number of Sections	41	-
Added Resistance Method	Salvesen	-
Max Added Resistance (stern quarter 45deg)	920	kN
Pitch gyradius	72.593	m
Roll gyradius	16.176	m

Table 18- Seakeeping Results

Manning Estimate

In order for certain design choices to be made and solidified, a manning estimate must be established. Such items include accommodation space design, consumables, and operational expenses calculations. Based on USCG COI manning requirements for the size of the ship, the following crewing arrangements were made:

Crew Complement	24 Persons
Deck Department	
Master	1 Person
Chief Mate	1 Person
2nd Mate	1 Person
3rd Mate	1 Person
Able Bodied Seamen	5 Person
Ordinary Seamen	5 Person
Engineering Department	
Chief Engineer	1 Person
1st Assistant Engineer	1 Person
2nd Assistant Engineer	1 Person
3rd Assistant Engineer	1 Person
Oiler	1 Person
Wiper	2 Person
Other	
Chief Cook	1 Person
Chief Steward	1 Person
Steward's Assistant	1 Person

Table 19- Crew Compliment

Financial Analysis

Capital Expenses

The vessels capital expense was developed utilizing the Caryette estimation. Caryette's method accounts for a shipyard profit margin of 10%, overhead expenses, and shipyard wastage and disposal of unused materials. The capital expense calculation is created by using the vessel's principle characteristics and carrying capacity with empirical formulas. The breakdown of the capital expenditure calculation is shown in table 20.

CAPEX Caryette Method	
Profit margin (%)	10.0
Overheads (%)	100
Wastage (%)	10
Steelwork labor coef., A'	2,156
Steelwork material coef., B'	708
Outfit labor coef., C'	25,691
Outfit material coef., D'	12,420
Machinery labor coef., F'	994
Machinery material coef. G'	5,520
Steelwork labor cost (million $)	10.55
Steelwork material cost (million $)	8.22
Outfit labor cost (million $)	6.08
Outfit material cost (million $)	30.02
Machinery labor cost (million $)	7.99
Machinery material cost (million $)	44.38
Total ship building cost (million $)	107.25

Table 20- Caryette Capital Expenses

Using a 6% interest rate, the table 21 below outlines a calculation completed to determine the added cost of paying the principal over a chosen 10 years.

Principle Cost Recovery	
Item	Value
MARR, percent	0.06
Principle Cost of Ship	$101,664,794.72
Time to Pay Principle, Years	10
Total Cost of Loan	$182,066,163.44
Annual Principle Recovery Cost	$18,206,616.34

Table 21- Principle Cost Recovery

Vessel Operational Expense

Annual operational expenses include all expenses accrued as a result of operating the vessel. Although it is impossible to predict all operating expenses a shipowner could experience, the following categories have been used to account for an expected year of service.

- Fuel Cost – Includes LNG propulsive fuel for main engines and generators. A breakdown of consumption is shown in table 22 below. The expected total annual fuel cost based on $842/MT of LNG and $855/MT of diesel is $19,825,000.

Annual Fuel Consumption			
	LNG	MDO	Units
Mass of Fuel Consumed [tons]	23448.4	94.8	tons/year
Cost	$19,743,587	$81,032	

Table 22- Annual Fuel Consumption

- Lube Oil Cost – Includes annual cost for the propulsion plants lube oil. Lube oil is bunkered infrequently, and is estimated to cost $120,000 annually.

- Upkeep/Misc. Repairs – An estimate of $1,000,000 was created for supplies and materials utilized by the crew for repairs at sea, as well as minor drydocking repairs.

- Port Costs – Incurred port costs include pilots' fees, wharfage, docking, and miscellaneous regulatory fees imposed by local ports - $210,000.

- Crew Wages – The ship must be staffed by qualified mariners to satisfy USCG requirements. Table 23 below outlines the calculation for crew wages.

Crew Wages			
Position	Positions	$/Year	Total per Position
Deck			
Master	1	$250,000.00	$250,000.00
Chief Mate	1	$189,000.00	$189,000.00
2nd Mate	1	$175,000.00	$175,000.00
3rd Mate	1	$165,000.00	$165,000.00
AB	5	$120,000.00	$600,000.00
OS	5	$80,000.00	$400,000.00
Engine			
Chief Engineer	1	$220,000.00	$220,000.00
1st A/E	1	$189,000.00	$189,000.00
2nd A/E	1	$175,000.00	$175,000.00
3rd A/E	1	$165,000.00	$165,000.00
Oiler	1	$110,000.00	$110,000.00
Wiper	2	$90,000.00	$180,000.00
Other			
Chief Cook	1	$90,000.00	$90,000.00
Chief Steward	1	$80,000.00	$80,000.00
Stewards Assistant	1	$75,000.00	$75,000.00
Total Crew	24	SUM	$3,063,000.00

Table 23- Crew Wages

In summary, the expected operational expenses incurred annually are as follows in table 24.

Annual Operational Expenses	
Expense	**Value**
Total	$24,307,619.00
Yearly LNG Cost	$19,743,587.00
Yearly Diesel Cost	$81,032.00
Lube Oil Consumption	$210,000.00
Crew Wages	$3,063,000.00
Cost of Upkeep	$1,000,000.00
Port Cost	$210,000.00

Table 24- Annual Operational Expenses

Minimum Required Freight Rate

The minimum required freight rate outlines how much should be charged for each TEU transported in order for the ship to be an economical investment. This is defined by determining the costs associated with and dividing this number by the number of TEU the vessel transports in a given year.

To find the number of TEU delivered every year, the number of times the route is completed in a year must be calculated. This is done by evaluating how long the vessel takes to complete the designed route, accounting for the time spent in port while performing cargo operations. The expected operational time of operation during the year of 320 day divided by the time to complete a voyage yields 12 voyages per year. Assuming that during a voyage, the full capacity of cargo 3,750 TEU is delivered, a total of 45,000 TEU are delivered every year.

Given the expenses every year of $42,242,235 and an expected 45,000 TEU to be delivered every year, the minimum required freight rate is $944/TEU.

Total Expense Overview	
Cargo carried per year (TEU)	45,000
Total Yearly Operating cost (Million $)	$24,217,620
Annual capital charges (Million $)	$18,206,616
Total Annual cost (Million $)	$42,424,236
Required Freight rate ($/TEU)	$942.76

Table 25- Total Expense Overview

Profit of Vessel During Operational Lifespan

After the initial pay-off period, no accrued debt has to be paid related to the vessel. For the rest of the vessels operation, profit is defined as the number of containers delivered multiplied by the freight rate, minus the cost of operation.

Projected Vessel Profit		
	Value	Units
Vessel Design Lifespan	20	years
Time of investment deficit	10	years
Net Earnings Over Design Lifespan	$594	$ (Million)
Value of Principle over design lifespan	$326	$ (Million)
Earnings Compared to Principle	$268	$ (Million)
% Return on Initial Investment Total	264	%

Table 26- Projected Vessel Profit

Risk Assessment

There are several categories of risk associated with this vessel and similar vessels in general. Physical ship hazards pose an immediate risk to crew and effects, while economic and logistic factors pose a more long-term risk.

Typical container ship risks include:

- Serious injury or death of crew due to slips, trips, and falls
- Container loss due to rough seas, and or faulty lashing equipment
- Inherent stability risk for heavy loads of cargo
- Mis-declared cargo, and potential for transportation of hazardous or non-legal materials

LNG hazards:

- Cryogenic material handling
- Flash expansion explosion from LNG vaporization
- Crew asphyxiation by gaseous fuel

LNG risks (economic/logistics):

- Potential limit to route options and range due to lack of LNG bunkering stations
- Potential crewing issues due to training and certification requirements.

Appendices

Appendix A – Owners Requirements

OWNER'S REQUIREMENTS FOR A 3,750 TEU CONTAINER SHIP

Introduction

A preliminary shipyard stock design is to be created for a 3,750 TEU feeder container ship. This type of vessel would transport cargo from major ports to numerous smaller ports. The vessel's range must be suitable for such a route and be capable of carrying an array of container sizes. The container ship shall have a maximum speed of 24 knots, have an appropriate endurance for calling at numerous ports, be economically viable, meet current and projected emissions regulations, and have adequate serviceability to meet a designed lifespan of 20 years. The container vessel must be simple in design and construction, allowing for fast production time and minimal capital expenditures.

Trade Route

Ideally the vessel will be designed for use in many trade routes globally. To accomplish this, an example U.S. East Coast/Caribbean route will be used in the design phase. The approximate distance for such a route is 8,000 nautical miles. Although this route is one option, the vessels' large range will allow for its use worldwide.

Principal Cargo Types – Loading & Discharging

Approximate carrying capacity of 3,750 TEU with a suitable array of container types. The vessel is not designed to be self-unloading and will require ship-to-shore (STS cranes) for all loading and discharging processes.

1. ISO standard 40-ft containers.
2. ISO 20-ft high-cube containers.
3. ISO 40-ft high-cube containers.
4. ISO 40-ft high-cube refrigerated containers.
5. ISO standard 40-ft refrigerated containers.

The vessel will also be designed to accommodate containers of varying widths.

6. ISO standard 48-ft containers.
7. ISO standard 53-ft containers.

Speed & Range

For the vessel to accomplish the designed route and use case, it should have a range of approximately 8,000 nautical miles at a maximum speed of 24 knots.

Classification
ABS, LR, or DNV. The choice of class shall be supported by a specific owner. The vessel is designed to ABS construction standards and will be American flagged.

Complement
Crewing requirements to be consistent with classification society requirements and be suitable for safe navigation of the vessel. Spare accommodation for temporary crew such as technicians, owners, or persons other than the permanent crew.

Special Design Considerations
The vessel shall be capable of operating as a typical feeder container ship in numerous trade routes while carrying various container types. The vessel shall accommodate a wide range of constraints imposed by the vessel's maximum speed, size and draft limitations, emission regulations, and range.

Applicable Regulations
- General: ABS, DNV, LR
- USCG Code of Federal Regulations
- LNG: Pasha, IGF Code
- MARPOL
- IMO EEDI
- SOLAS

Appendix B – ABS Structural Calculations

ABS Scantling Calculations - M/V Dweller				
Component	**ABS Section**	**Formula**	**Min Thickness (mm)**	**Selected Thickness (mm)**
Side Shell Plate	3-2-2/ 3.9.3 Steel Vessel Side Shell Plate	t=(s/Cs1)Sqrt((L-Cl1)(d/Ds)+C	25.0	25.0
Bottom Plate	3-2-2/ 3.15.1 Steel Vessel Outer Bottom Shell Plate	Tlong2=(s/508)sqrt((L-62.5)(d-Ds)+2.5mm	28.3	28.0
Inner Bottom Plate	3-2-4/ 9.1.1 Steel Vessel Inner Bottom Shell Plate	t=.037L+.009s-c	19.4	19.0
Solid Floor Thickness	3-2-4/5.1 Steel Vessel Floors	Tmin= .036L+4.7+1.5	14.9	15.0
Center Girder Thickness	3-2-5/3.15.2 Steel Vessel Center Girder	tlongmin= .056*L+5.5	19.1	22.5

ABS Midship Bending Calculations - M/V Dweller					
ABS Midship Wave Bending Moments			Section 3-2-1/3.5.1		
Sagging Moment=-k1c1L62B(Cb+.7)*10^3					
Hogging Moment= k2c2L^2BCb*10^3					
Constants			Moments	KN-m	ktonne-m
k1=	110	[-]	Sagging Moment	4089204	456
k2=	190	[-]	Hogging Moment	3139187	320
c1=	10.72	[-]			
L=	272	m			
B=	37.2	m			
Cb=	0.56	[-]			

M/V Dweller - Global Hull Girder Section Modulus and Bending Stress

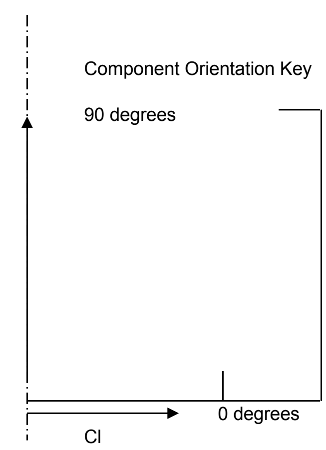
Units (USCS/SI):	SI	(USCS, SI)
Height of Deck:	20.9	m

Plating (Major components) (one-half of ship)

Component	# of items	Plate wt #	Width	Thickness	Angle	Total Area (a)	Height wrt BL (h)	1st Moment (ah)	2nd Moment (ah^2)	Local Moment (i)
		kg/m^2	m	m	deg	m^2	m	m^3	m^4	m^4
CVK 22.5MM PLATE	1.0	177.0	0.0	0.0225	90.00	0.0005	1.00	0.00	0.00	0.000000021
OUTER BOTTOM PLATE 28MM	1.0	220.0	13.670	0.0280	0.00	0.3828	0.02	0.01	0.00	0.000025007
INNER BOTTOM PLATE 22.5MM	1.0	149.0	18.500	0.0225	0.00	0.4163	1.98	0.82	1.63	0.000017561
GIRDER 2 15MM	1.0	118.0	0.015	0.0150	90.00	0.0002	1.00	0.00	0.00	0.000000004
GIRDER 5 15MM	1.0	118.0	0.015	0.0150	90.00	0.0002	1.00	0.00	0.00	0.000000004
GIRDER 8 15MM	1.0	118.0	0.015	0.0150	90.00	0.0002	1.00	0.00	0.00	0.000000004
GIRDER 11 15MM	1.0	118.0	0.015	0.0150	90.00	0.0002	1.00	0.00	0.00	0.000000004
GIRDER 14 15MM	1.0	118.0	0.015	0.0150	90.00	0.0002	1.00	0.00	0.00	0.000000004
LOWER TANK SIDE SHELL 22.5MM	1.0	177.0	0.023	0.0225	90.00	0.0005	2.40	0.00	0.00	0.000000021
LOWER TANK TOP 22.5MM	1.0	177.0	4.900	0.0225	0.00	0.1103	4.86	0.54	2.60	0.000004651
OUTER SIDE SHELL 25MM	1.0	196.0	0.025	0.0225	90.00	0.0006	8.65	0.00	0.04	0.000000029
INNER SIDE SHELL 25MM	1.0	196.0	0.025	0.0225	90.00	0.0006	8.65	0.00	0.04	0.000000029
STRINGER 11 20MM	1.0	157.0	2.450	0.0200	0.00	0.0490	10.80	0.53	5.72	0.000001633
BOX GIRDER DECK 75mm	1.0	589.0	2.450	0.0750	0.00	0.1838	20.90	3.84	80.26	0.000086133
BOX GIRDER BOTTOM 75mm	1.0	589.0	2.450	0.0750	0.00	0.1838	17.90	3.29	58.88	0.000086133
BOX GIRDER OUTER SHELL 75mm	1.0	589.0	0.075	0.0750	90.00	0.0056	19.10	0.11	2.05	0.000002637
BOX GIRDER INNER SHELL 75mm	1.0	589.0	0.075	0.0750	90.00	0.0056	19.10	0.11	2.05	0.000002637
					Sum	1.3		9.3	153.3	0.0

Longitudinals (Small components) (one-half of ship)

Component	# of items	Area	Total Area (a)	Height wrt BL (h)	1st Moment (ah)	2nd Moment (ah^2)
		m^2	m^2	m	m^3	m^4
OUTER BOTTOM LONG.	12.0	0.01000	0.12	0.33	0.0396	0.0131
INNER BOTTOM LONG	12.0	0.01000	0.12	1.73	0.0173	0.0299
LOWER TANK INNER AND OUTER LONG 1-2	2.0	0.01000	0.02	2.60	0.0520	0.1352
LOWER TANK INNER LONG 3-4	2.0	0.01000	0.02	3.43	0.0686	0.2353
LOWER TANK INNER AND OUTER LONG 5-6	2.0	0.01000	0.02	4.27	0.0854	0.3647
LOWER TANK INNER AND OUTER LONG 7-8	2.0	0.01000	0.02	4.63	0.0926	0.4287
SIDE SHELL LONG 9-10	2.0	0.01000	0.02	5.78	0.1156	0.6682
SIDE SHELL LONG 11-12	2.0	0.01000	0.02	7.14	0.1428	1.0196
SIDE SHELL LONG 13-14	2.0	0.01000	0.02	8.50	0.1700	1.4450
SIDE SHELL LONG 15-16	2.0	0.01000	0.02	9.86	0.1972	1.9444
SIDE SHELL LONG 17	2.0	0.01000	0.02	10.57	0.2114	2.2345
SIDE SHELL LONG 18-19	2.0	0.01000	0.02	12.18	0.2436	2.9670
SIDE SHELL LONG 20-21	2.0	0.01000	0.02	13.55	0.2710	3.6721
SIDE SHELL LONG 22-23	2.0	0.01000	0.02	14.90	0.2980	4.4402
SIDE SHELL LONG 24-25	2.0	0.01000	0.02	16.26	0.3252	5.2878
			0.00		0.0000	0.0000
BOX GIRDER BOTTOM STIFF	3.0	0.03000	0.09	17.72	1.5948	28.2599
BOX GIFRDER LONG 1	2.0	0.03000	0.06	18.37	1.1022	20.2474
BOX GIRDER LONG 2	2.0	0.03000	0.06	18.98	1.1388	21.6144
BOX GIRDER LONG 3	2.0	0.03000	0.06	19.57	1.1742	22.9791
BOX GIRDER LONG 4	2.0	0.03000	0.06	20.15	1.2090	24.3614
BOX GIRDER DECK STIFF	3.0	0.03000	0.09	20.66	1.8594	38.4152
	Sum		0.92		10.4	180.8



Curved Plating (one-half of ship)

Component	# of items	wt #	Curve Radius	Circle Fraction	Thickness	Total Area (a)	Height wrt BL (h)	1st Moment (ah)	2nd Moment (ah^2)	Local Moment (i)
		kg/m^2	m	%	m	m^2	m	m^3	m^4	m^4
BILGE RADIUS	1.0	30.0	2.0	25.0	0.0191	0.0594	2.0	0	0	0
					Sum	0.1		0.1	0.2	0.0
					TOTAL SUM	2.3		19.8	334.3	0.0

Half-Ship Values

h_{NA}	8.5	m
$1/2\ I_{ZZ}$	334.3	m^4
$A \times h^2_{NA}$	168.7	m^4
1/2 I	165.7	m^4
% ht of NA abv BL	41%	

Note: The goal is as close to 50% as is practical.

Full Ship Values

Area	2.7	m^2
I	331.3	m^4
Z_{deck}	26.8	m^3
Z_{keel}	38.9	m^3

Stillwater Moment	160	ktonne-m
Hogging Moment	351	ktonne-m
Sagging Moment	406	ktonne-m
DAF	1	[-]

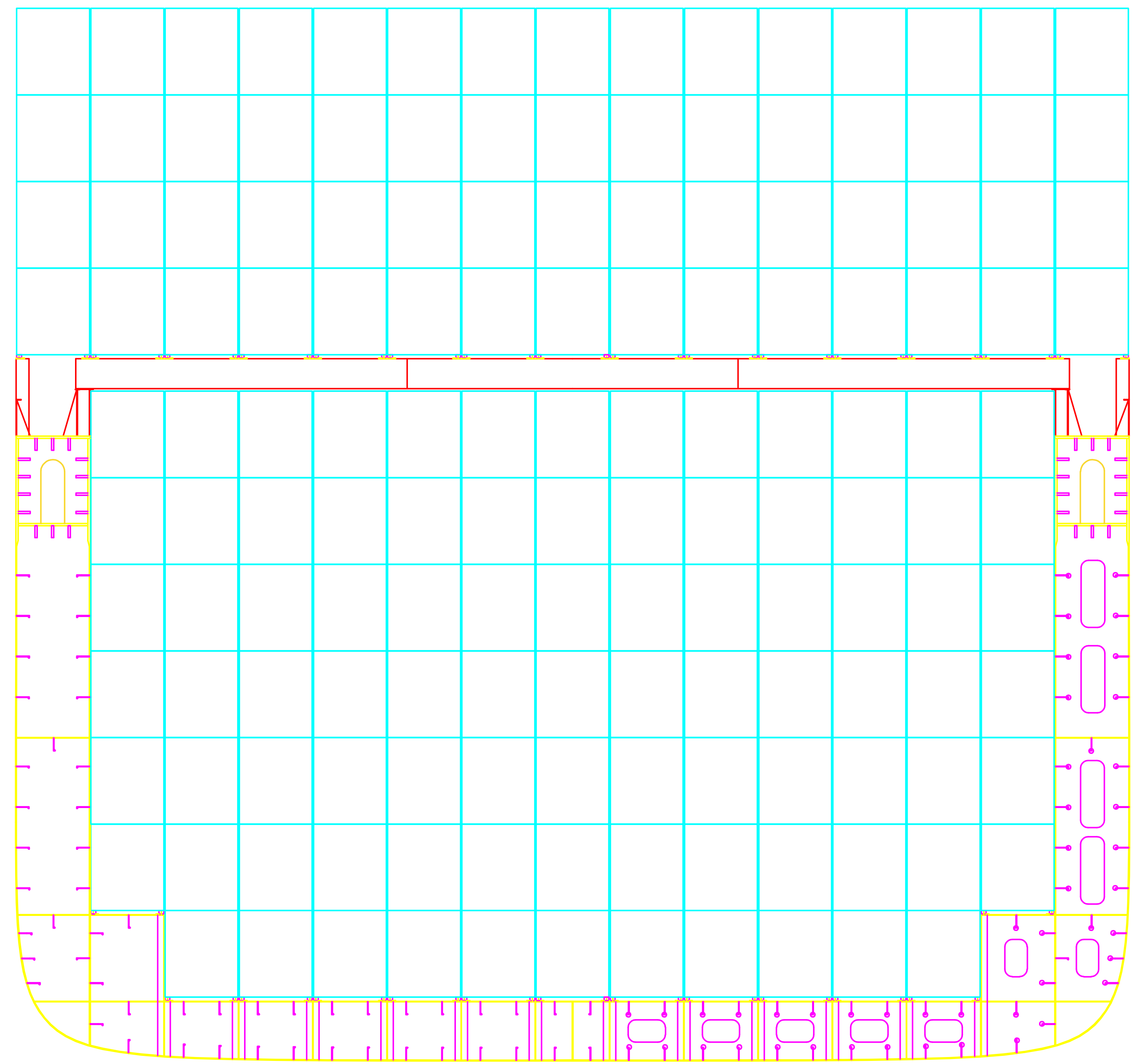
Material yield	250	Mpa	ABS Grade A, ASTM A36
Allowable FOS	1.5		
Material allowable	167	Mpa	

			Actual FOS	OK?
Stillwater deck stress	59	Mpa	4.3	OK
Stillwater bottom stress	40	Mpa	6.2	OK
Hogging deck stress	129	Mpa	1.9	OK
Hogging bottom stress	89	Mpa	2.8	OK
Sagging deck stress	149	Mpa	1.7	OK
Sagging bottom stress	103	Mpa	2.4	OK

Appendix C- Structural Midship Section Drawing

PRINCIPLE CHARACTERISTICS		
Length, Overall	290	meters
Length, On waterline	272	meters
Breadth	37.2	meters
Draft	11.9	meters
Draft, Air	49.1	meters
Depth	20.9	meters

PRINCIPLE SCANTLINGS	
Component	Thickness (mm)
Side Shell Plating	25
Bottom Plate	28
Inner Bottom Plate	19
Solid Floor Thickness	15
Center Girder Thickness	22.5



Bilge Dweller Designs ©

SUNY MARITIME COLLEGE

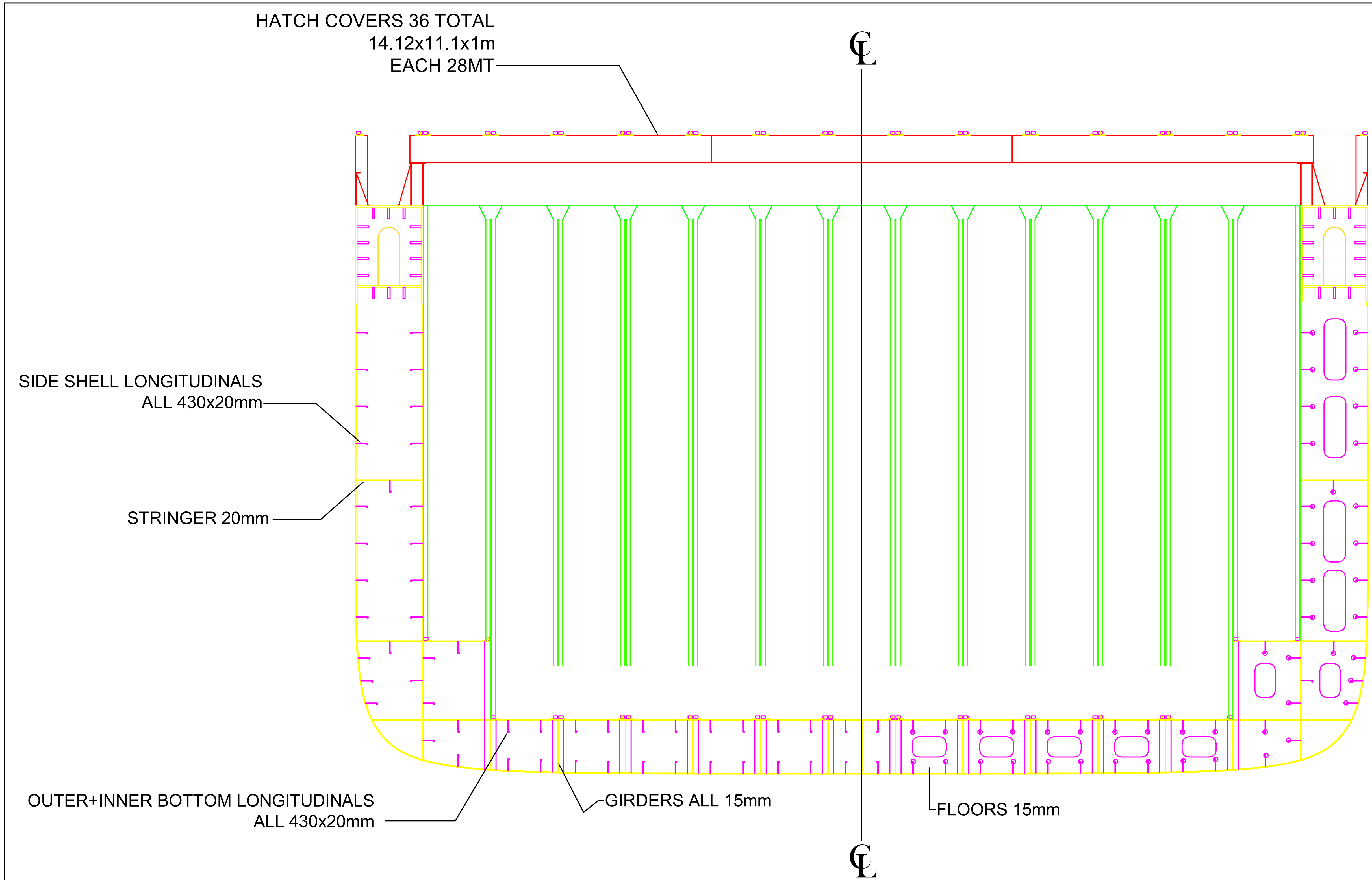
HCH- SD III
TYPICAL MIDSHIP HOLD

5-6-2024

SCALE: 1:5

SHEET 1 OF 4

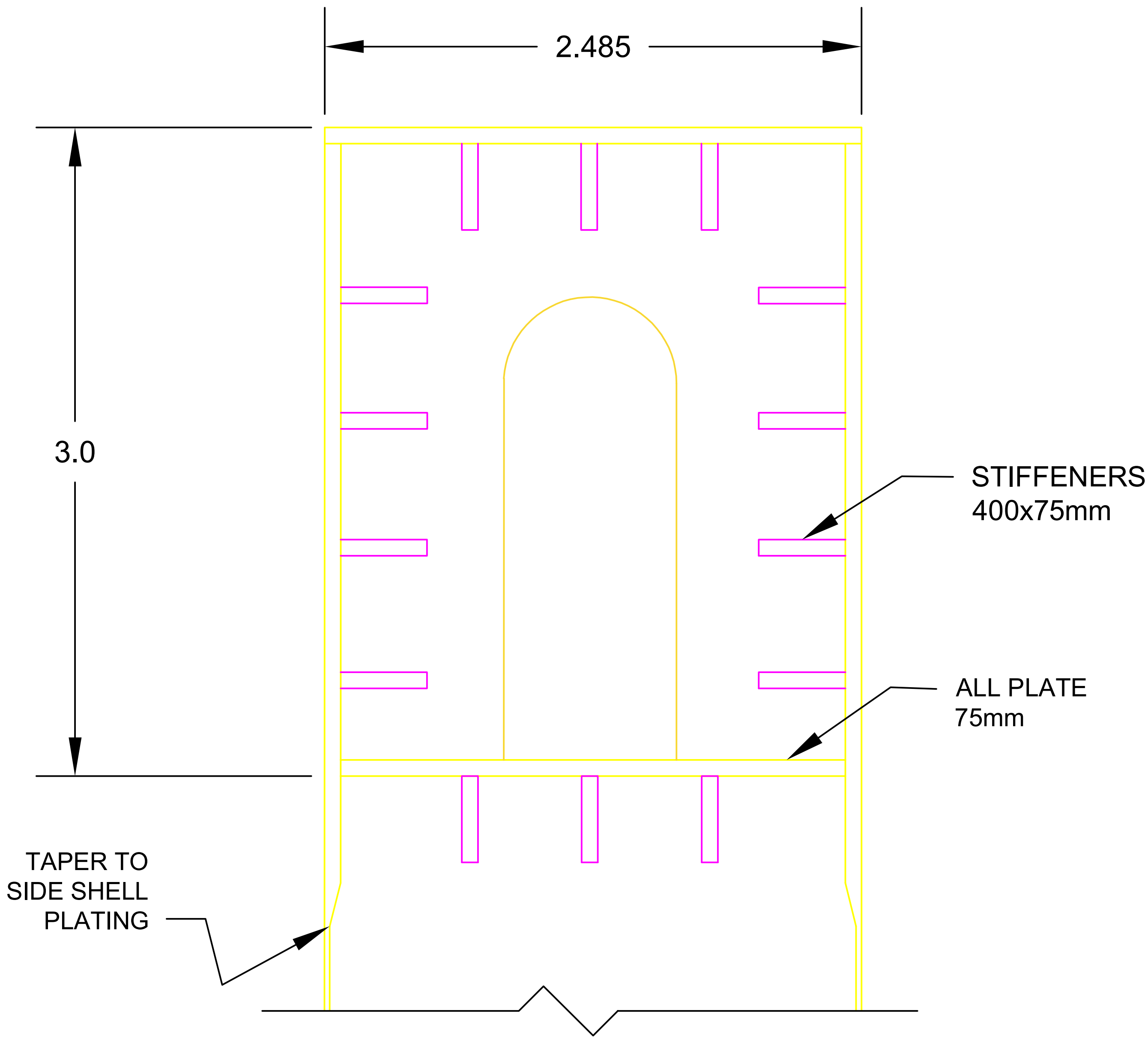
REV 3



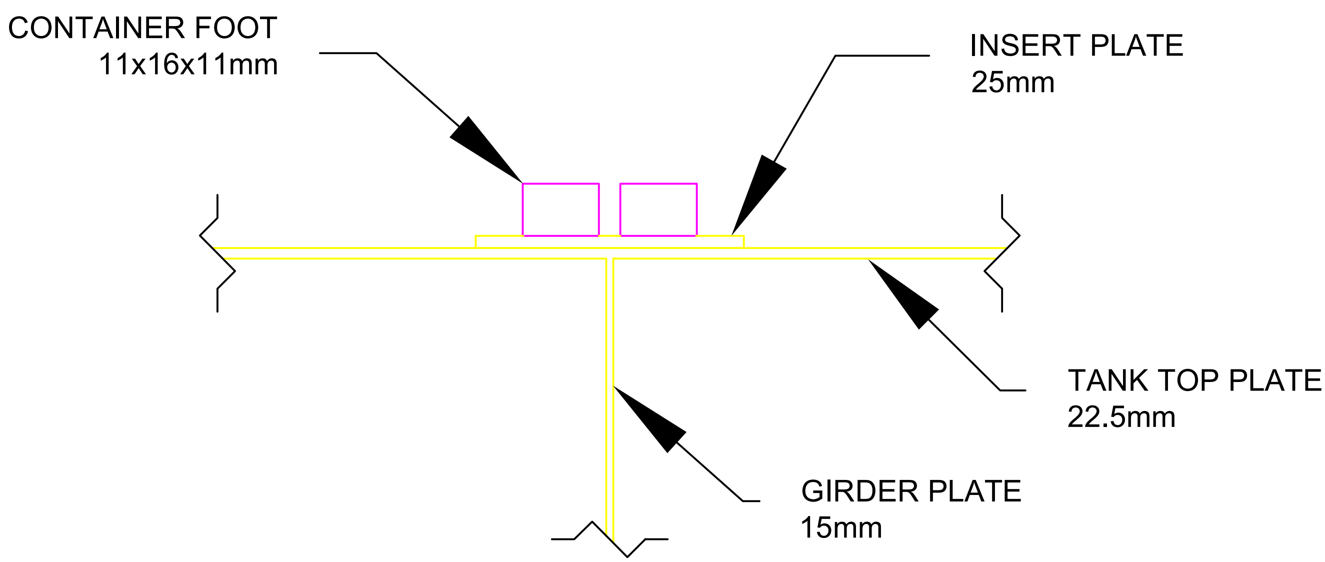
TYPICAL INTERMEDIATE FRAME

TYPICAL WEB FRAME

Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	HCH- SD III TYPICAL MIDSHIP HOLD	5-6-2024
		SCALE: 1:4	SHEET 2 OF 4 / REV 3



Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III BOX GIRDER DETAIL	5-6-2024
		SCALE: NTS	SHEET 3 OF 4 / REV 3



Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CONTAINER FOOTING DETAIL	5-6-2024	
		SCALE: NTS	SHEET 4 OF 4	REV 3

Appendix D- Hydrostatics Report

GHS Hydrostatics by Draft

HYDROSTATIC PROPERTIES at No Trim, No Heel, Fixed VCG = 13.500

Draft@ 7.500a	Displacement Weight(MT)	Buoyancy-Ctr. LCB	VCB	Weight/ cm	LCF	Moment/ Deg trim	KML	KMT
8.000	45,903.54	135.554f	4.396	69.01	132.643f	407811	522.47	17.320
9.000	52,883.78	135.107f	4.938	70.62	131.641f	425141	474.06	16.641
9.500	56,436.41	134.869f	5.210	71.49	130.994f	435904	456.00	16.407
10.000	60,034.35	134.615f	5.482	72.43	130.277f	448176	441.19	16.234
10.500	63,681.46	134.343f	5.757	73.49	129.394f	463406	430.40	16.119
11.000	67,385.16	134.045f	6.032	74.67	128.427f	481543	422.90	16.054
11.500	71,153.76	133.718f	6.309	76.10	127.292f	506044	420.95	16.046
12.000	75,004.79	133.347f	6.589	77.94	125.721f	540871	426.63	16.095
12.500	78,962.55	132.904f	6.874	80.16	123.663f	586354	438.92	16.200

Draft is from Baseline.

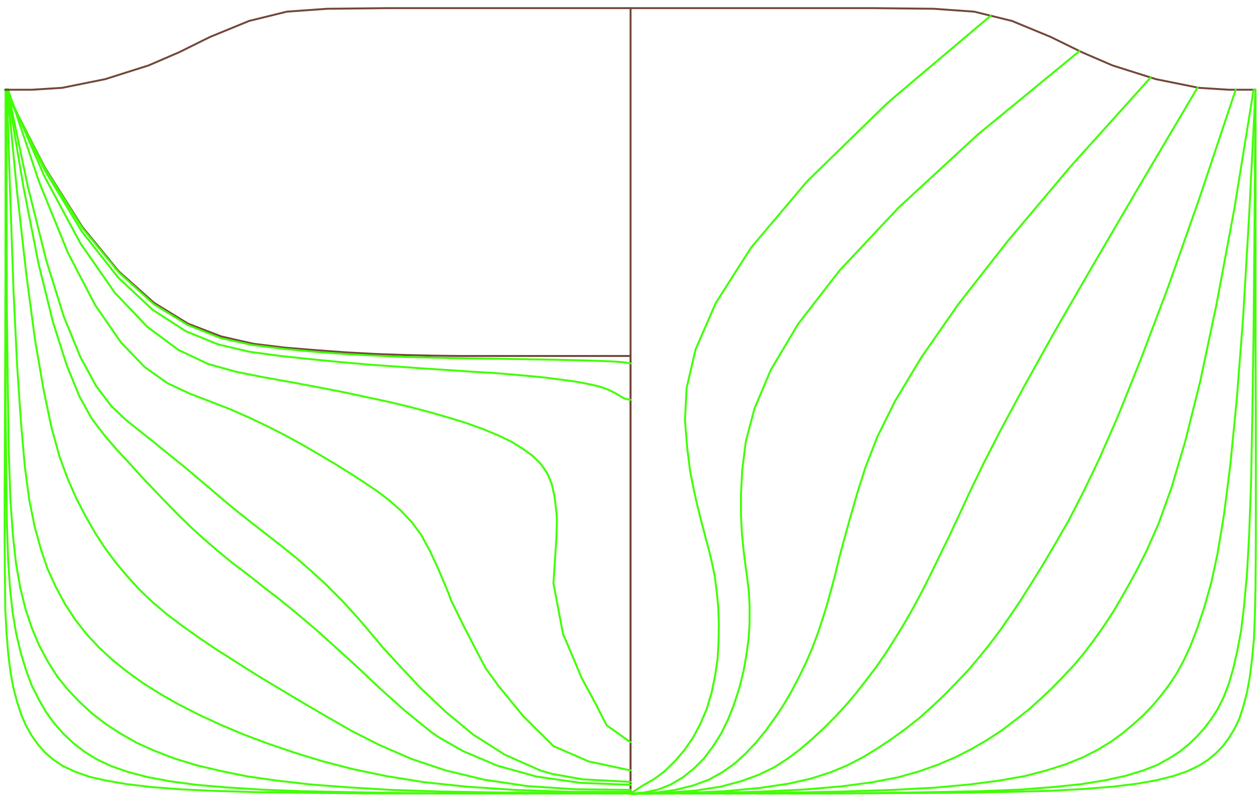
Maxsurf Hydrostatics by Load case

Lightship Condition		
Displacement	28534	Tonnes
Draft Amidship	5.36	m
Draft at FP	2.189	m
Draft at AP	8.463	m
Wetted Surface	7535	m^2
Waterplane Area	6292	m^2
Cp	0.524	[-]
Cb	0.392	[-]
KB	3.2	m
KG	13.5	m
BM	18.5	m
KM	21.7	m
TPc	64.5	Tonnes/cm
GM	8.2	m

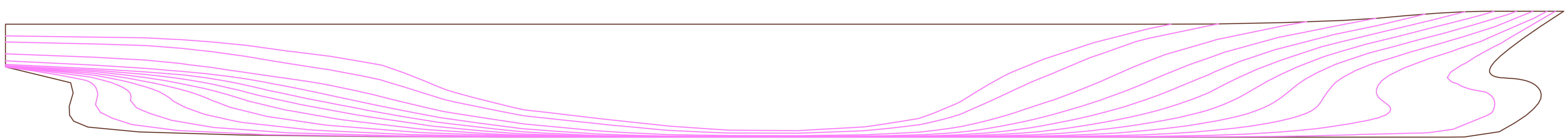
Arrival Condition		
Displacement	59094.5	Tonnes
Draft Amidship	10	m
Draft at FP	10.1	m
Draft at AP	9.8	m
Wetted Surface	10429	m^2
Waterplane Area	7054	m^2
Cp	0.59	[-]
Cb	0.57	[-]
KB	5.5	m
KG	14.8	m
BM	10.7	m
KM	16.2	m
TPc	72.3	Tonnes/cm
GM	1.4	m

Departure Condition		
Displacement	59286	Tonnes
Draft Amidship	9.9	m
Draft at FP	10	m
Draft at AP	9.8	m
Wetted Surface	10365	m^2
Waterplane Area	7034	m^2
Cp	0.59	[-]
Cb	0.57	[-]
KB	5.4	m
KG	15.6	m
BM	10.8	m
KM	16.2	m
TPc	72.1	Tonnes/cm
GM	0.6	m

Appendix E- Lines Plan



Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III HULL FORM	4-2-2024	
		SCALE: NTS	SHEET 1 OF 3	REV 3



Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	HCH- SD III BUTTOCKS LINES	4-2-2024	
		SCALE: 1:20	SHEET 2 OF 3	REV 1

Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	HCH- SD III WATERLINE PLAN VIEW	4-2-2024	
		SCALE: 1:20	SHEET 3 OF 3	REV 1

Appendix F- Resistance Reports

Project:	MV DWELLER
Description:	20 Knot CFD Analysis
Date:	4/30/2024 12:59

Design Characteristics:	
Lwl (m)	271.262
Bwl (m)	37.201
Tx (m)	11.900
Swet (m^2)	11783.330
Displacement (kgf)	74395874
LCG (m)	133.388
TCG (m)	0.000
VCG (m)	0.000
Sinkage (m)	11.900
Trim (deg)	0.000
Heel (deg)	0.000
RhoW (kg/m^3)	1025.900
RhoA (kg/m^3)	1.225
NuW (m^2/s)	1.188E-06
g (m/s^2)	9.806
Samples	10

Speed (kt)	Heave (m)	Pitch (deg)	Rcfd (N)	Rtot (N)	Petot (kW)
20.000	-0.259	0.059	1293982.7	1293983	13313.7

Speed (kt)	Fn	Rn	Cf	Cf_ITTC	Cr	Ct
20.000	0.199	2.349E+09	1.165E-05	1.380E-03	-5.972E-01	2.022E-03

Notes

1. Cf is computed from the sum of the longitudinal shear forces in the CFD simulation. It includes shear forces on geometry in air as well as water.

2. Cr is computed from the sum of the longitudinal pressure forces in the CFD simulation. It includes pressure forces on geometry in air as well as water.

3. Ct includes Ca, Caa, Crough, Cenv, and margin as specified.

4. Cr, Cf, and Ct are normalized by the wetted surface of the CFD model, Swet, which does not include any additional wetted surface of geometry that was not explicitly represented in the CFD model (e.g., appendages).

Project:	MV Dweller
Description:	24 Knot CFD Analysis
Date:	4/11/2024 9:45

Design Characteristics:	
Lwl (m)	271.000
Bwl (m)	37.201
Tx (m)	11.900
Swet (m^2)	11783.330
Displacement (kgf)	74395874
LCG (ft)	437.625
TCG (ft)	0.000
VCG (ft)	0.000
Sinkage (ft)	39.042
Trim (deg)	0.000
Heel (deg)	0.000
RhoW (kg/m^3)	1025.900
RhoA (kg/m^3)	1.225
NuW (m^2/s)	1.188E-06
g (m/s^2)	9.807
Samples	10

Speed (kt)	**Heave (ft)**	**Pitch (deg)**	**Rcfd (N)**	**Rtot (N)**	**Petot (kW)**
24.000	-1.274	0.092	1963352.0	1963352	24240.9

Speed (kt)	**Fn**	**Rn**	**Cf**	**Cf_ITTC**	**Cr**	**Ct**
24.000	0.434	8.583E+08	1.205E-05	1.6E-03	-4.2E-01	2.13E-03

Notes

1. Cf is computed from the sum of the longitudinal shear forces in the CFD simulation. It includes shear forces on geometry in air as well as water.

2. Cr is computed from the sum of the longitudinal pressure forces in the CFD simulation. It includes pressure forces on geometry in air as well as water.

3. Ct includes Ca, Caa, Crough, Cenv, and margin as specified.

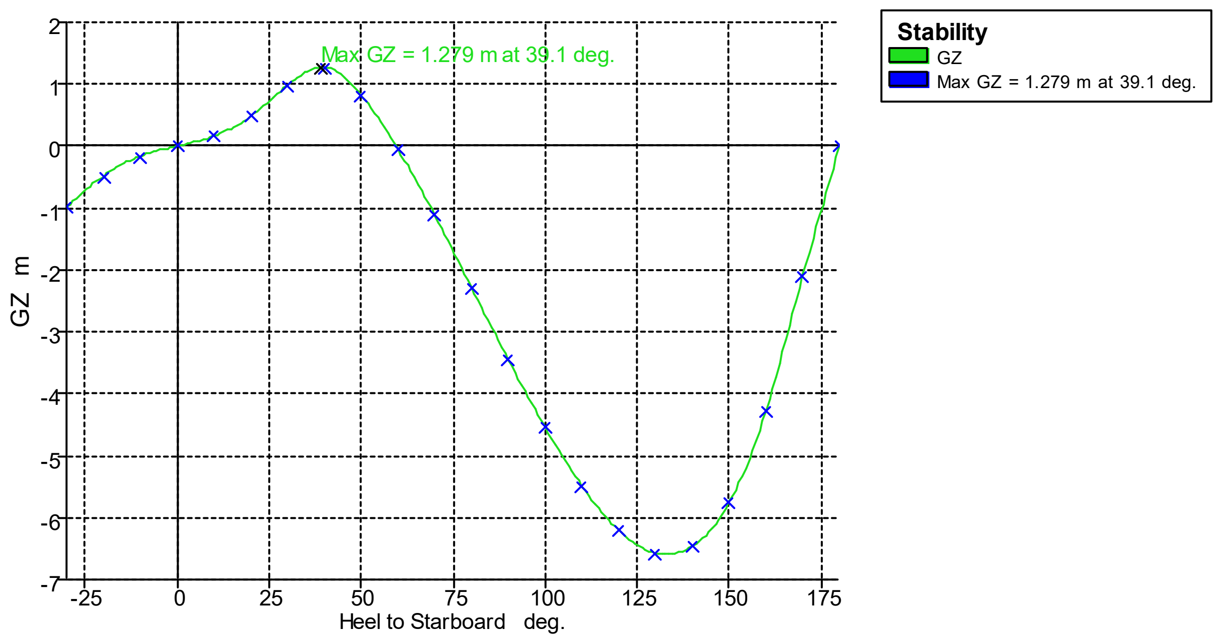
4. Cr, Cf, and Ct are normalized by the wetted surface of the CFD model, Swet, which does not include any additional wetted surface of geometry that was not explicitly represented in the CFD model (e.g., appendages).

Appendix G – Intact Stability Analysis

Full Load Condition

Specific gravity = 1.025; (Density = 1.025 tonne/m^3)

Item Name	Total Mass tonne	Total Volume m^3	Long. Arm m-AP	Trans. Arm m	Vert. Arm m-BL
Full Load Condition	59286.000	57840	133.000	0.000	15.600

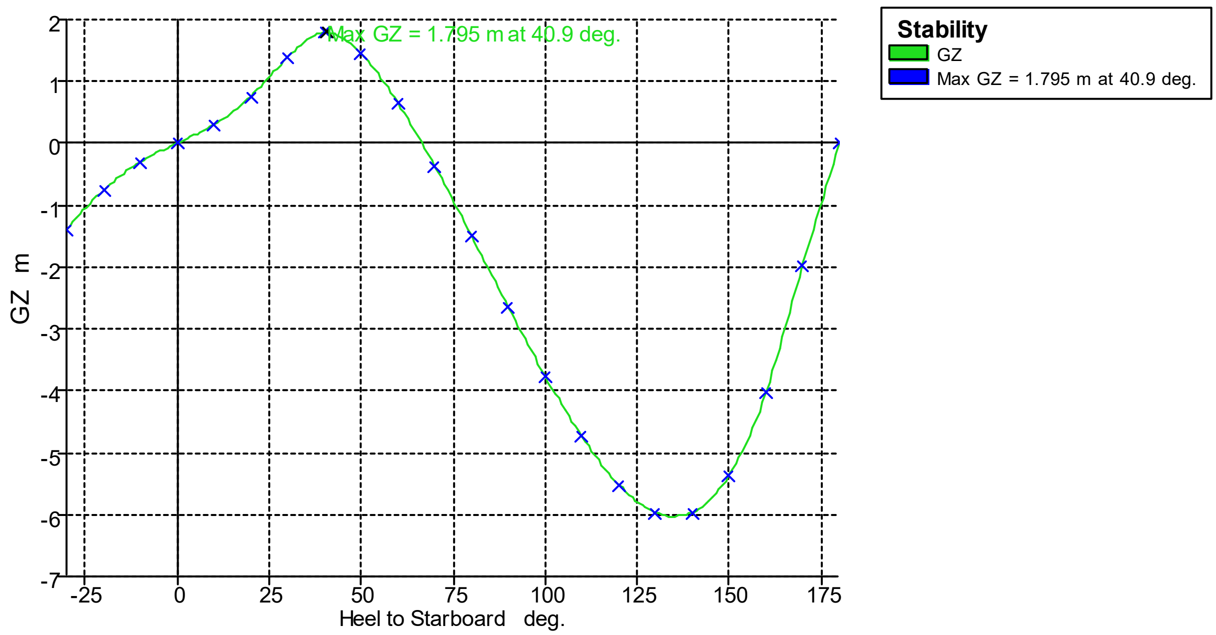


Heel to Starboard deg	0.0	10.0	20.0	40.0	50.0	70.0	90.0
GZ m	0	0.162	0.484	1.277	0.825	-1.120	-3.450
Area under GZ curve m.deg	0.0000	0.7348	3.7890	22.8363	33.8978	32.3425	-13.3546
Displacement t	59286	59286	59285	59287	59286	59286	59286
Draft at FP m	9.362	9.395	9.523	9.360	8.865	6.624	n/a
Draft at AP m	10.408	10.254	9.685	6.897	4.851	-3.553	n/a
WL Length m	274.470	273.860	285.258	285.345	285.756	286.038	289.330
Beam max extents on WL m	37.210	37.775	39.284	32.530	27.322	23.145	22.120
Wetted Area m^2	10364	10451.465	10696	11214	11477	11685.	11747
Waterpl. Area m^2	7088.894	7241.172	7650	7433	6679	5803	5388
Prismatic coeff. (Cp)	0.588	0.593	0.583	0.619	0.627	0.634	0.634
Block coeff. (Cb)	0.564	0.465	0.366	0.377	0.435	0.518	0.568
LCB from zero pt. (+ve fwd) m	132.960	132.967	132.980	133.077	133.101	133.137	133.156
LCF from zero pt. (+ve fwd) m	129.413	128.561	126.249	128.006	131.661	139.794	143.997
Max deck inclination deg	0.2211	10.0016	20.0000	40.0017	50.0022	70.0017	90.0000

Arrival Condition

Specific gravity = 1.025; (Density = 1.025 tonne/m^3)

Item Name	Total Mass tonne	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m
Arrival Condition	59094.000	57652	133.000	0.000	14.800

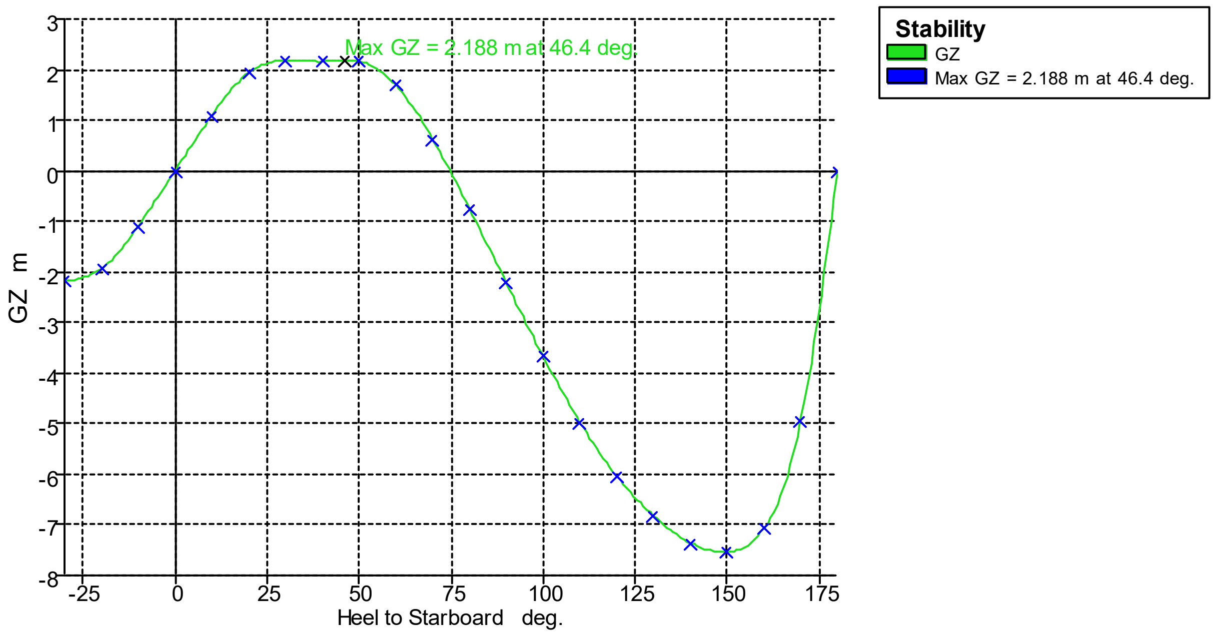


Heel to Starboard deg	0.0	10.0	20.0	40.0	50.0	70.0	90.0
GZ m	0.000	0.302	0.760	1.795	1.445	-0.361	-2.647
Area under GZ curve m.deg	0.0000	1.4377	6.5793	33.6309	50.3950	62.7699	32.8515
Displacement t	59094	59094	59093	59095	59094	59094	59094
Draft at FP m	9.332	9.365	9.491	9.322	8.819	6.542	n/a
Draft at AP m	10.385	10.231	9.665	6.869	4.809	-3.660	n/a
WL Length m	274.398	273.794	285.291	285.385	285.786	285.997	289.306
Beam max extents on WL m	37.211	37.775	39.277	32.531	27.322	23.173	22.093
Wetted Area m^2	10347.866	10433.004	10678.246	11191.746	11454.868	11659.402	11723.264
Waterpl. Area m^2	7083.577	7234.328	7643.777	7435.614	6681.665	5798.961	5383.108
Prismatic coeff. (Cp)	0.588	0.593	0.582	0.618	0.626	0.634	0.634
Block coeff. (Cb)	0.564	0.465	0.366	0.376	0.434	0.517	0.568
LCB from zero pt. (+ve fwd) m	132.963	132.969	132.980	133.073	133.099	133.134	133.157
LCF from zero pt. (+ve fwd) m	129.457	128.623	126.283	127.999	131.665	139.826	143.959
Max deck inclination deg	0.2222	10.0016	20.0000	40.0016	50.0022	70.0017	90.0000
Trim angle (+ve by stern) deg	0.2222	0.1830	0.0367	-0.5180	-0.8471	-2.1542	n/a

Lightship Condition

Specific gravity = 1.025; (Density = 1.025 tonne/m^3)

Item Name	Total Mass tonne	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m
Lightship Condition	28534.000	27838	133.000	0.000	14.800



Heel to Starboard deg	0.0	10.0	20.0	40.0	50.0	70.0	90.0
GZ m	0.000	1.094	1.943	2.159	2.165	0.624	-2.219
Area under GZ curve m.deg	0.0000	5.5378	21.1238	63.8910	85.6606	117.4172	102.1824
Displacement t	28534	28534	28534	28534	28532	28535	28534
Draft at FP m	4.680	4.650	4.471	2.839	1.047	-8.393	n/a
Draft at AP m	6.122	5.976	5.451	2.150	-1.794	-21.656	n/a
WL Length m	272.079	272.090	271.938	269.603	278.481	265.531	281.399
Beam max extents on WL m	37.180	37.241	33.965	28.203	27.361	22.273	20.909
Wetted Area m^2	7608.534	7599.229	7452.672	7138.449	7272.930	7235.255	7442.892
Waterpl. Area m^2	6294.150	6276.861	6076.880	5852.379	5959.000	4675.574	4238.567
Prismatic coeff. (Cp)	0.534	0.541	0.556	0.542	0.512	0.540	0.534
Block coeff. (Cb)	0.487	0.363	0.310	0.300	0.295	0.420	0.478
LCB from zero pt. (+ve fwd) m	132.938	132.942	132.956	133.014	133.090	133.218	133.287
LCF from zero pt. (+ve fwd) m	133.419	133.481	133.226	130.727	128.648	130.335	132.228
Max deck inclination deg	0.3046	10.0038	20.0009	40.0001	50.0011	70.0029	90.0000
Trim angle (+ve by stern) deg	0.3046	0.2800	0.2071	-0.1455	-0.6003	-2.7997	n/a

M/V Dweller Intact Stability IMO Criteria Analysis

IMO Code A.749(18) Ch3 - Design criteria applicable to all ships

Criteria	Value	Units	Actual	Status	Margin
3.1.2.1: Area 0 to 30				Pass	
from the greater of					
spec. heel angle	0	deg	0		
to the lesser of					
spec. heel angle	30	deg	30		
angle of vanishing stability	59.4	deg			
shall not be less than (>=)	3.1513	m.deg	10.3175	Pass	227.41
3.1.2.1: Area 0 to 40				Pass	
from the greater of					
spec. heel angle	0	deg	0		
to the lesser of					
spec. heel angle	40	deg	40		
first flooding angle of the DownfloodingPoints	n/a	deg			
angle of vanishing stability	59.4	deg			
shall not be less than (>=)	5.1566	m.deg	21.6826	Pass	320.48
3.1.2.1: Area 30 to 40				Pass	
from the greater of					
spec. heel angle	30	deg	30		
to the lesser of					
spec. heel angle	40	deg	40		
first flooding angle of the DownfloodingPoints	n/a	deg			
angle of vanishing stability	59.4	deg			
shall not be less than (>=)	1.7189	m.deg	11.365	Pass	561.18
3.1.2.2: Max GZ at 30 or greater				Pass	
in the range from the greater of					
spec. heel angle	30	deg	30		
to the lesser of					
spec. heel angle	90	deg			
angle of max. GZ	39.1	deg	39.1		
shall not be less than (>=)	0.2	m	1.241	Pass	520.5
Intermediate values					
angle at which this GZ occurs		deg	39.1		
3.1.2.3: Angle of maximum GZ				Pass	
shall not be less than (>=)	25	deg	39.1	Pass	56.36
3.1.2.4: Initial GMt				Pass	
spec. heel angle	0	deg			
shall not be less than (>=)	0.15	m	0.688	Pass	358.67
3.1.2.5: Passenger crowding: angle of equilibrium				Pass	
Pass. crowding arm = nPass M / disp. D cos^n(phi)					
number of passengers: nPass =	0				

passenger mass: M =	0.075	tonne			
distance from centre line: D =	0	m			
cosine power: n =	0				
shall not be greater than (<=)	10	deg	0	Pass	100
Intermediate values					
Heel arm amplitude		m	0		

3.1.2.6: Turn: angle of equilibrium				Pass	
Turn arm = a v^2 / (R g) h cos^n(phi)					
constant: a =	0.9996				
vessel speed: v =	0	kn			
turn radius, R, as percentage of Lwl	510	%			
h = KG - mean draft / 2	10.644	m			
cosine power: n =	0				
shall not be greater than (<=)	10	deg	0	Pass	100
Intermediate values					
Heel arm amplitude		m	0		

3.2.2: Severe wind and rolling				Pass	
Wind arm = a P A (h - H) / (g disp.) cos^n(phi)					
constant: a =	0.99966				
wind pressure: P =	504	Pa			
area centroid height (from zero point): h =	6	m			
additional area: A =	50	m^2			
H = vert. centre of projected lat. u'water area	5.074	m			
cosine power: n =	0				
gust ratio	1.5				
Area2 integrated to the lesser of					
roll back angle from equilibrium (with steady heel arm)	25.0 (-22.6	deg	-22.6		
Area 1 upper integration range, to the lesser of:					
spec. heel angle	50	deg	50		
first flooding angle of the DownfloodingPoints	n/a	deg			
angle of vanishing stability (with gust heel arm)	58.9	deg			
Angle for GZ(max) in GZ ratio, the lesser of:					
angle of max. GZ	39.1	deg	39.1		
Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
Criteria:				Pass	
Angle of steady heel shall not be greater than (<=)	16	deg	2.4	Pass	84.7
Angle of steady heel / Deck edge immersion angle shall not be gr	80	%	7.69	Pass	90.39
Area1 / Area2 shall not be less than (>=)	100	%	521.65	Pass	421.65
Intermediate values					
Model windage area		m^2	3222.363		
Model windage area centroid height (from zero point)		m	15.626		
Total windage area		m^2	3272.363		
Total windage area centroid height (from zero point)		m	15.479		
Heel arm amplitude		m	0.03		
Equilibrium angle with steady heel arm		deg	2.4		
Equilibrium angle with gust heel arm		deg	3.6		
Deck edge immersion angle		deg	31.8		
Area1 (under GZ), from 3.6 to 50.0 deg.		m.deg	32.3577		
Area1 (under HA), from 3.6 to 50.0 deg.		m.deg	2.0529		

Area1, from 3.6 to 50.0 deg.	m.deg	30.3048
Area2 (under GZ), from -22.6 to 3.6 deg.	m.deg	-4.6513
Area2 (under HA), from -22.6 to 3.6 deg.	m.deg	1.1582
Area2, from -22.6 to 3.6 deg.	m.deg	5.8094

Appendix H – Damage Stability Analysis

Damage Stability Analysis
GHS DAMSTAB2 Wizard version 18.90
GHS DAMSTAB2 Library version 18.90

Probabilistic Damage

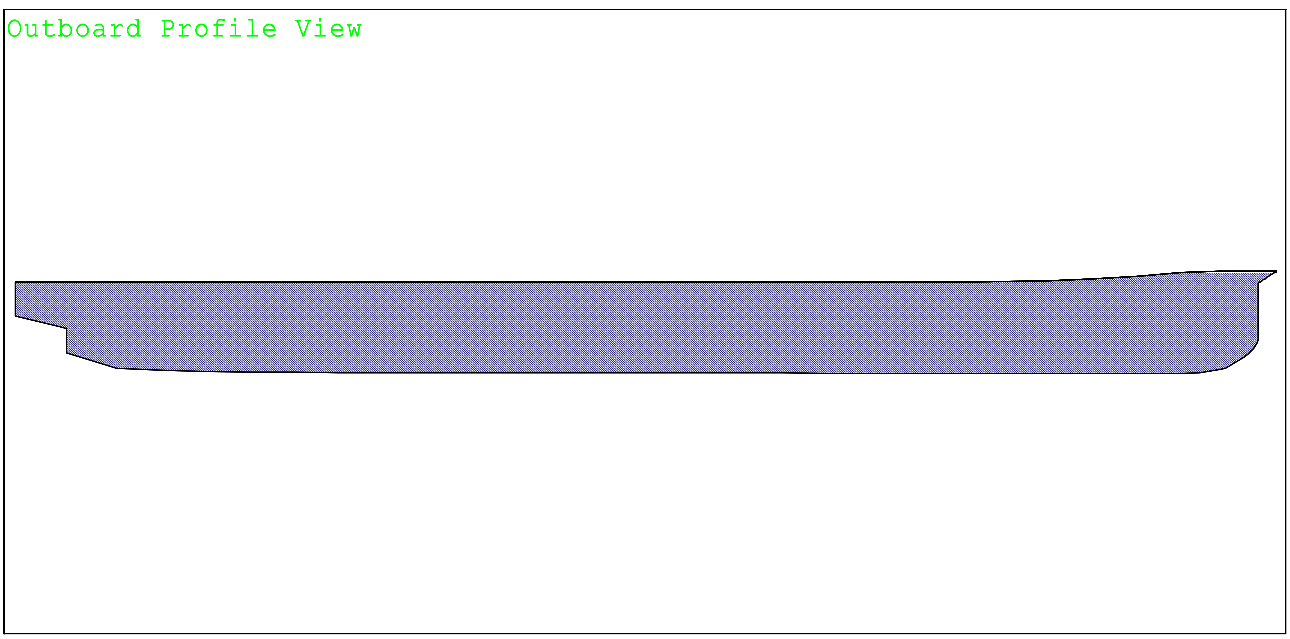
Lightship Condition

STARBOARD-side Probabilistic Cargo SOLAS 2009

Stability checked in both directions

Light-service draft (dl)

Condition Graphic



DIVISION definitions

Division	Fwd End	Aft End	Wing	HBhd	Parts
1	277.000f	260.000f			FPT.C
2	260.000f	249.189f			HOLD1.C HOLD1DB.P HOLD1DB.S
3	249.189f	223.000f			HOLD1.C HOLD1DB.S HOLD1WING.S
4	223.000f	193.000f			HOLD2.C HOLD2DB.S HOLD2WING.S
5	193.000f	162.000f			HOLD3.C HOLD3DB.S HOLD3WING.S
6	162.000f	132.000f			HOLD4.C HOLD4DB.S HOLD4WING.S
7	132.000f	101.000f			HOLD5.C HOLD5DB.S HOLD5WING.S
8	101.000f	69.000f			HOLD6.C HOLD6DB.S HOLD6WING.S
9	69.000f	45.000f			FWDER.C
10	45.000f	17.000f			AFTER.C LOWERER.C
11	17.000f	5.000a			APT.C

Distances in METERS.

Executing DAMSTAB /sdi216C /side:STARBOARD /L:-277,5 /B:37.221 /DLL:11.5 /macro:PROBSURV

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 282.000 Terminals: 277.000f, 5.000a
Breadth: 37.221 Draft: 8.500
Subdivision load line draft: 11.500

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	8.500	0.00	0.08s	79.35	1.018
1	0.03961	1.000*	0.040	0.040	8.217	0.15f	0.07s	79.54	2.784
2	0.00806	1.000*	0.008	0.048	7.046	0.82f	0.05s	77.75	2.856
3	0.04139	1.000*	0.041	0.089	7.114	0.79f	0.13s	77.67	2.843
4	0.05239	1.000*	0.052	0.141	6.875	1.06f	0.48s	77.29	2.575
5	0.05540	1.000*	0.055	0.197	7.547	0.95f	3.27s	80.54	2.488
6	0.05239	1.000*	0.052	0.249	8.910	0.33f	7.04s	85.07	2.562
7	0.05540	1.000*	0.055	0.305	10.377	0.29a	6.24s	84.68	2.628
8	0.05846	1.000*	0.058	0.363	11.782	0.90a	2.71s	81.28	2.710
9	0.03546	1.000*	0.035	0.399	11.193	0.86a	0.03s	78.66	2.779
10	0.04652	1.000*	0.047	0.445	13.006	1.55a	0.02s	79.74	3.094
11	0.05418	1.000*	0.054	0.499	8.500	0.00	0.08s	78.13	2.662
		1-division damage:		**0.499**		**Probability of damage:**		**0.499**	
1+2	0.02463	1.000*	0.025	0.524	6.614	1.06f	0.04s	78.07	2.889
2+3	0.02487	1.000*	0.025	0.549	7.044	0.82f	0.05s	77.75	2.856
3+4	0.04634	1.000*	0.046	0.595	3.810	2.83f	0.57s	75.59	2.534
4+5	0.04937	1.000*	0.049	0.644	5.104	2.67f	4.57s	79.64	2.347
5+6	0.04937	1.000*	0.049	0.694	7.813	1.49f	12.73s	88.10	2.341
6+7	0.04937	1.000*	0.049	0.743	10.641	0.17f	13.90s	90.00	2.459
7+8	0.05039	1.000*	0.050	0.794	13.622	1.05a	7.99s	84.14	2.589
8+9	0.04552	1.000*	0.046	0.839	14.693	1.75a	2.43s	79.39	2.718
9+10	0.04336	1.000*	0.043	0.882	15.292	2.23a	0.01s	79.68	3.331
10+11	0.04713	1.000*	0.047	0.930	13.180	1.61a	0.02s	78.47	2.998
		2-division damage:		**0.430**		**Probability of damage:**		**0.430**	
1+2+3	0.02338	1.000*	0.023	0.953	6.614	1.06f	0.04s	78.07	2.889
2+3+4	0.00539	1.000*	0.005	0.958	3.715	2.88f	0.47s	75.64	2.545
3+4+5	0.00514	1.000*	0.005	0.964	-1.449	6.63f	7.89s	71.33	1.532
4+5+6	0.00462	1.000*	0.005	0.968	5.866	3.27f	12.37s	86.51	2.124
5+6+7	0.00515	1.000*	0.005	0.973	10.088	1.31f	16.79s	89.93	2.362
6+7+8	0.00462	1.000*	0.005	0.978	14.196	0.53a	13.93s	86.46	2.505
7+8+9	0.00412	1.000*	0.004	0.982	16.982	1.95a	7.90s	82.23	2.506
8+9+10	0.00940	1.000*	0.009	0.991	18.504	2.94a	1.92s	82.42	3.246
9+10+11	0.00618	1.000*	0.006	0.998	16.563	2.68a	0.01s	77.94	3.106
		3-division damage:		**0.068**		**Probability of damage:**		**0.068**	
1+2+3+4	0.00224	1.000*	0.002	1.000	3.156	3.19f	0.47s	75.85	2.574
2+3+4+5	0.00001	1.000*	0.000	1.000	-1.693	6.78f	7.85s	71.07	1.513
3+4+5+6	0.00000	0.000*	0.000	1.000	-80.909	72.74f	162.87s	0.00	
4+5+6+7	0.00000	0.000*	0.000	1.000	-23.158	10.85f	168.15s	0.00	

continued next page

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
5+6+7+8	0.00000	1.000*	0.000	1.000	14.373	0.61f	15.23s	84.73	2.712
6+7+8+9	0.00000	1.000*	0.000	1.000	18.306	1.55a	14.34s	85.21	2.348
7+8+9+10	0.00001	1.000*	0.000	1.000	21.329	3.23a	7.43s	88.92	2.580
8+9+10+11	0.00010	1.000*	0.000	1.000	22.190	4.20a	2.77s	79.53	2.509
			4-division damage:	**0.002**			**Probability of damage:**	**0.002**	
1+2+3+4+5	0.00000	1.000*	0.000	1.000	-3.350	7.71f	8.27s	69.36	1.379
2+3+4+5+6	0.00000	0.000*	0.000	1.000	-80.976	73.65f	162.69s	0.00	
3+4+5+6+7	0.00000	0.000*	0.000	1.000	-49.557	86.22f	147.80s	0.00	
4+5+6+7+8	0.00000	0.000*	0.000	1.000	-29.495	75.36f	132.98s	0.00	
5+6+7+8+9	0.00000	0.000*	0.000	1.000	0.800	0.83a	135.15s	0.00	
6+7+8+9+10	0.00000	0.000*	0.000	1.000	28.233	10.62a	153.64s	0.00	
7+8+9+10+11	0.00000	0.000*	0.000	1.000	40.494	16.37a	170.43s	0.00	
			5-division damage:	**0.000**			**Probability of damage:**	**0.000**	

Attained index in this condition: 1.000 **Total probability of damage: 1.000**
Required index: 0.705
Values marked with * computed by macro.

Distances in METERS. Angles in deg.

====== Summary Data ======

Calculation method: SDI216C
Condition name: Light-service draft (dl) (code 0)
Damage side: Starboard

Displacement: 49373.6 METRIC TONS
Trim: 0.00 degrees
VCG: 13.600 METERS
Free surface moment: 0.0 METRIC TONS-METERS
Environment: 1.025

Attained index: 1.000
Minimim index needed for this draft: 0.353
Overall Required index: 0.705

Damage Stability Analysis
GHS DAMSTAB2 Wizard version 18.90
GHS DAMSTAB2 Library version 18.90

Probabilistic Damage

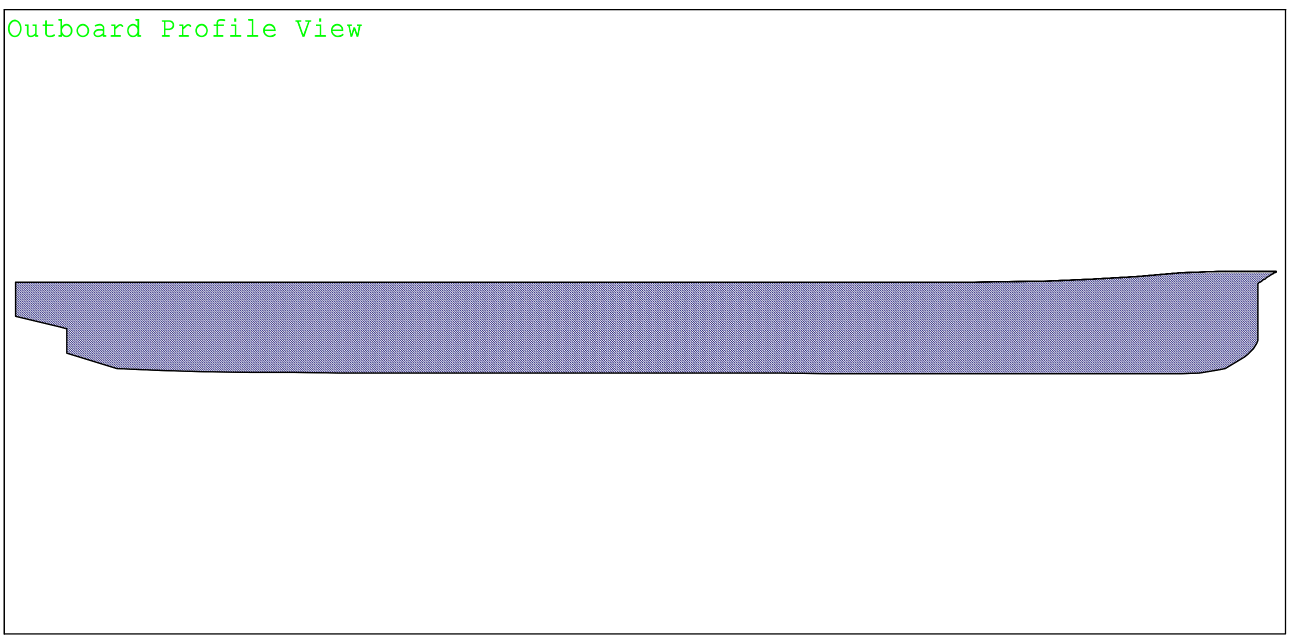
Arrival Condition

STARBOARD-side Probabilistic Cargo SOLAS 2009

Stability checked in both directions

Intermediate draft (dp)

Condition Graphic



DIVISION definitions

Division	Fwd End	Aft End	Wing	HBhd	Parts
1	277.000f	260.000f			FPT.C
2	260.000f	249.189f			HOLD1.C HOLD1DB.P HOLD1DB.S
3	249.189f	223.000f			HOLD1.C HOLD1DB.S HOLD1WING.S
4	223.000f	193.000f			HOLD2.C HOLD2DB.S HOLD2WING.S
5	193.000f	162.000f			HOLD3.C HOLD3DB.S HOLD3WING.S
6	162.000f	132.000f			HOLD4.C HOLD4DB.S HOLD4WING.S
7	132.000f	101.000f			HOLD5.C HOLD5DB.S HOLD5WING.S
8	101.000f	69.000f			HOLD6.C HOLD6DB.S HOLD6WING.S
9	69.000f	45.000f			FWDER.C
10	45.000f	17.000f			AFTER.C LOWERER.C
11	17.000f	5.000a			APT.C

Distances in METERS.

Executing DAMSTAB /sdi216C /side:STARBOARD /L:-277,5 /B:37.221 /DLL:11.5 /macro:PROBSURV

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 282.000 Terminals: 277.000f, 5.000a
Breadth: 37.221 Draft: 10.000
Subdivision load line draft: 11.500

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	10.000	0.00	0.19s	65.98	0.533
1	0.03961	1.000*	0.040	0.040	9.699	0.16f	0.18s	66.68	1.794
2	0.00806	1.000*	0.008	0.048	8.314	0.97f	0.11s	65.48	1.775
3	0.04139	1.000*	0.041	0.089	8.379	0.94f	0.26s	65.49	1.769
4	0.05239	1.000*	0.052	0.141	8.119	1.26f	1.08s	65.00	1.567
5	0.05540	1.000*	0.055	0.197	8.849	1.09f	7.48s	70.64	1.533
6	0.05239	1.000*	0.052	0.249	10.105	0.45f	12.07s	75.33	1.608
7	0.05540	1.000*	0.055	0.305	11.666	0.19a	9.61s	72.87	1.665
8	0.05846	1.000*	0.058	0.363	13.192	0.83a	3.87s	67.14	1.703
9	0.03546	1.000*	0.035	0.399	12.845	0.90a	0.02s	64.46	1.747
10	0.04652	1.000*	0.047	0.445	13.865	1.32a	0.01s	67.29	2.142
11	0.05418	1.000*	0.054	0.499	9.999	0.00	0.20s	64.19	1.652
		1-division damage:		**0.499**		**Probability of damage:**		**0.499**	
1+2	0.02463	1.000*	0.025	0.524	7.911	1.19f	0.09s	65.84	1.785
2+3	0.02487	1.000*	0.025	0.549	8.315	0.97f	0.10s	65.48	1.775
3+4	0.04634	1.000*	0.046	0.595	4.746	3.24f	1.31s	61.87	1.285
4+5	0.04937	1.000*	0.049	0.644	6.533	2.82f	7.95s	68.89	1.238
5+6	0.04937	1.000*	0.049	0.694	9.131	1.61f	15.98s	76.16	1.440
6+7	0.04937	1.000*	0.049	0.743	11.757	0.36f	16.61s	76.39	1.614
7+8	0.05039	1.000*	0.050	0.794	14.876	0.89a	10.73s	70.18	1.616
8+9	0.04552	1.000*	0.046	0.839	16.179	1.68a	3.92s	65.04	1.577
9+10	0.04336	1.000*	0.043	0.882	16.338	2.05a	0.00	67.07	2.148
10+11	0.04713	1.000*	0.047	0.930	14.327	1.49a	0.01s	65.36	1.973
		2-division damage:		**0.430**		**Probability of damage:**		**0.430**	
1+2+3	0.02338	1.000*	0.023	0.953	7.911	1.19f	0.09s	65.84	1.785
2+3+4	0.00539	1.000*	0.005	0.958	4.674	3.28f	1.14s	61.75	1.288
3+4+5	0.00514	0.000*	0.000	0.958	-28.556	10.99f	177.78s	0.00	
4+5+6	0.00462	0.000*	0.000	0.958	-22.117	8.14f	175.76s	0.00	
5+6+7	0.00515	1.000*	0.005	0.964	11.412	1.53f	18.66s	74.93	1.668
6+7+8	0.00462	1.000*	0.005	0.968	15.650	0.37a	15.36s	70.50	1.814
7+8+9	0.00412	1.000*	0.004	0.972	18.648	1.90a	10.90s	66.79	1.348
8+9+10	0.00940	1.000*	0.009	0.982	19.858	2.82a	2.62s	67.59	1.673
9+10+11	0.00618	1.000*	0.006	0.988	18.145	2.69a	0.00	64.07	1.766
		3-division damage:		**0.058**		**Probability of damage:**		**0.068**	
1+2+3+4	0.00224	1.000*	0.002	0.990	4.234	3.52f	1.18s	61.52	1.277
2+3+4+5	0.00001	0.000*	0.000	0.990	-28.895	11.23f	177.79s	0.00	
3+4+5+6	0.00000	0.000*	0.000	0.990	-66.813	90.00f	0.09p	0.00	
4+5+6+7	0.00000	0.000*	0.000	0.990	-48.682	66.84f	160.53s	0.00	

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Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
5+6+7+8	0.00000	0.000*	0.000	0.990	-10.678	2.26f	164.25s	0.00	
6+7+8+9	0.00000	0.000*	0.000	0.990	4.360	3.80a	165.94s	0.00	
7+8+9+10	0.00001	0.000*	0.000	0.990	15.867	8.12a	173.47s	0.00	
8+9+10+11	0.00010	1.000*	0.000	0.990	26.779	5.21a	9.08s	61.92	0.780
		4-division damage:		**0.002**		**Probability of damage:**		**0.002**	
1+2+3+4+5	0.00000	0.000*	0.000	0.990	-31.191	12.77f	177.61s	0.00	
2+3+4+5+6	0.00000	0.000*	0.000	0.990	-66.657	90.00f	0.25p	0.00	
3+4+5+6+7	0.00000	0.000*	0.000	0.990	-28.883	85.17f	158.96s	0.00	
4+5+6+7+8	0.00000	0.000*	0.000	0.990	2.447	84.68f	145.71s	0.00	
5+6+7+8+9	0.00000	0.000*	0.000	0.990	150.871	37.85a	145.26s	0.00	
6+7+8+9+10	0.00000	0.000*	0.000	0.990	209.655	73.54a	152.45s	0.00	
7+8+9+10+11	0.00000	0.000*	0.000	0.990	179.285	69.93a	167.87s	0.00	
		5-division damage:		**0.000**		**Probability of damage:**		**0.000**	

Attained index in this condition: 0.990 **Total probability of damage: 1.000**
Required index: 0.705
Values marked with * computed by macro.

Distances in METERS. Angles in deg.

====== Summary Data ======

```
Calculation method: SDI216C
Condition name: Intermediate draft (dp) (code 1)
Damage side: Starboard

Displacement: 60034.4 METRIC TONS
Trim: 0.00 degrees
VCG: 14.800 METERS
Free surface moment: 0.0 METRIC TONS-METERS
Environment: 1.025


Attained index: 0.990
Minimim index needed for this draft: 0.353
Overall Required index: 0.705
```

Damage Stability Analysis
GHS DAMSTAB2 Wizard version 18.90
GHS DAMSTAB2 Library version 18.90

Probabilistic Damage

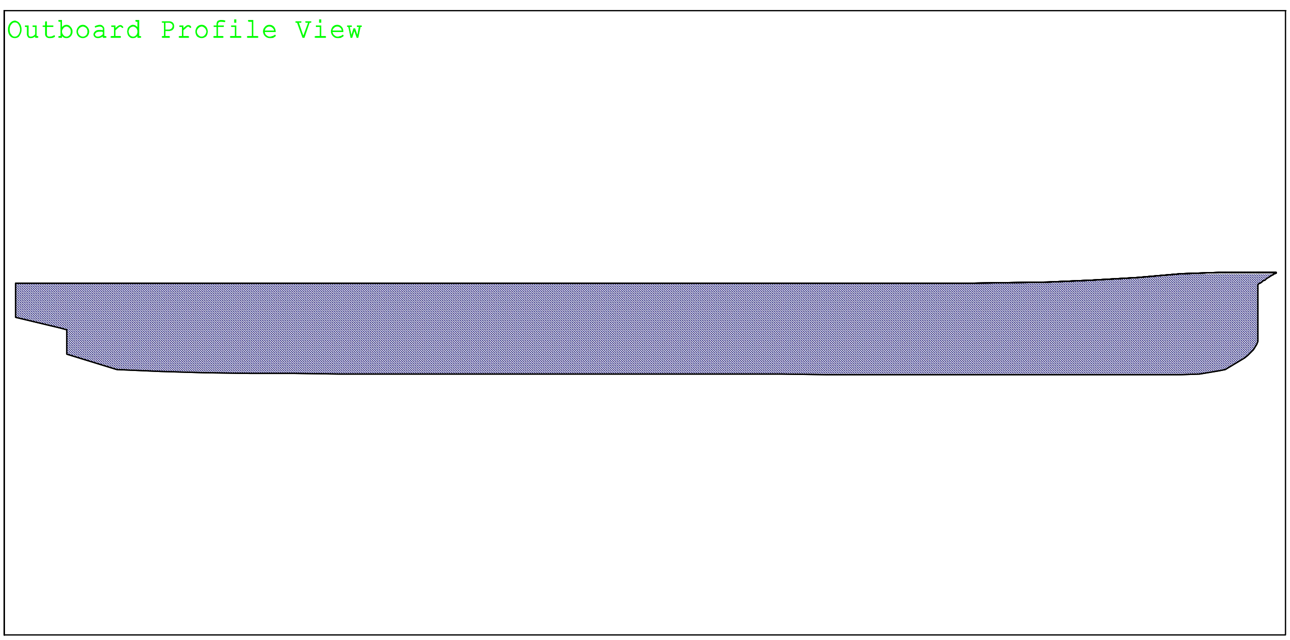
Full Load Condition

STARBOARD-side Probabilistic Cargo SOLAS 2009

Stability checked in both directions

Deepest draft (ds)

Condition Graphic



DIVISION definitions

Division	Fwd End	Aft End	Wing	HBhd	Parts
1	277.000f	260.000f			FPT.C
2	260.000f	249.189f			HOLD1.C HOLD1DB.P HOLD1DB.S
3	249.189f	223.000f			HOLD1.C HOLD1DB.S HOLD1WING.S
4	223.000f	193.000f			HOLD2.C HOLD2DB.S HOLD2WING.S
5	193.000f	162.000f			HOLD3.C HOLD3DB.S HOLD3WING.S
6	162.000f	132.000f			HOLD4.C HOLD4DB.S HOLD4WING.S
7	132.000f	101.000f			HOLD5.C HOLD5DB.S HOLD5WING.S
8	101.000f	69.000f			HOLD6.C HOLD6DB.S HOLD6WING.S
9	69.000f	45.000f			FWDER.C
10	45.000f	17.000f			AFTER.C LOWERER.C
11	17.000f	5.000a			APT.C

Distances in METERS.

Executing DAMSTAB /sdi216C /side:STARBOARD /L:-277,5 /B:37.221 /DLL:11.5 /macro:PROBSURV

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 282.000 Terminals: 277.000f, 5.000a
Breadth: 37.221 Draft: 11.499
Subdivision load line draft: 11.500

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	11.499	0.00	0.00	54.96	0.261
1	0.03961	1.000*	0.040	0.040	11.238	0.15f	0.00	55.36	1.093
2	0.00806	1.000*	0.008	0.048	9.704	1.08f	0.36s	53.22	0.970
3	0.04139	1.000*	0.041	0.089	9.761	1.04f	0.73s	53.50	0.967
4	0.05239	1.000*	0.052	0.141	9.509	1.37f	4.43s	56.73	0.818
5	0.05540	1.000*	0.055	0.197	10.055	1.17f	12.63s	63.95	0.841
6	0.05239	1.000*	0.052	0.249	11.180	0.57f	15.35s	66.72	0.971
7	0.05540	1.000*	0.055	0.305	12.763	0.05a	12.60s	63.82	1.009
8	0.05846	1.000*	0.058	0.363	14.428	0.71a	6.05s	57.11	0.971
9	0.03546	1.000*	0.035	0.399	14.176	0.82a	0.00	52.47	0.977
10	0.04652	1.000*	0.047	0.445	14.779	1.11a	0.00	56.81	1.377
11	0.05418	1.000*	0.054	0.499	11.499	0.00	0.00	52.23	0.932
		1-division damage:		**0.499**		**Probability of damage:**		**0.499**	
1+2	0.02463	1.000*	0.025	0.524	9.348	1.27f	0.28s	54.38	0.971
2+3	0.02487	1.000*	0.025	0.549	9.704	1.07f	0.33s	53.22	0.970
3+4	0.04634	1.000*	0.046	0.595	6.179	3.39f	3.20s	45.00	0.388
4+5	0.04937	0.883*	0.044	0.639	7.837	2.91f	13.98s	17.50	0.073
5+6	0.04937	1.000*	0.049	0.688	10.413	1.73f	18.10s	65.00	0.887
6+7	0.04937	1.000*	0.049	0.737	13.176	0.46f	17.16s	64.18	1.162
7+8	0.05039	1.000*	0.050	0.788	16.187	0.77a	12.89s	58.67	1.050
8+9	0.04552	1.000*	0.046	0.833	17.713	1.64a	5.95s	52.17	0.750
9+10	0.04336	1.000*	0.043	0.877	17.491	1.90a	0.00	54.61	1.181
10+11	0.04713	1.000*	0.047	0.924	15.597	1.41a	0.00	53.70	1.132
		2-division damage:		**0.425**		**Probability of damage:**		**0.430**	
1+2+3	0.02338	1.000*	0.023	0.947	9.348	1.27f	0.28s	54.38	0.971
2+3+4	0.00539	1.000*	0.005	0.953	6.135	3.41f	2.84s	44.51	0.387
3+4+5	0.00514	0.000*	0.000	0.953	-47.891	28.61f	177.27s	0.00	
4+5+6	0.00462	0.000	0.000	0.953	NO EQUILIBRIUM FOUND				
5+6+7	0.00515	0.000*	0.000	0.953	-15.039	4.28f	174.34s	0.00	
6+7+8	0.00462	0.000*	0.000	0.953	-8.277	0.31f	172.41s	0.00	
7+8+9	0.00412	0.000*	0.000	0.953	3.721	4.12a	175.18s	0.00	
8+9+10	0.00940	1.000*	0.009	0.962	21.740	2.90a	5.83s	48.07	0.601
9+10+11	0.00618	1.000*	0.006	0.968	19.908	2.76a	0.02p	47.51	0.705
		3-division damage:		**0.044**		**Probability of damage:**		**0.068**	
1+2+3+4	0.00224	1.000*	0.002	0.970	5.866	3.57f	2.36s	42.73	0.374
2+3+4+5	0.00001	0.000*	0.000	0.970	-49.812	30.42f	177.21s	0.00	
3+4+5+6	0.00000	0.000*	0.000	0.970	-48.888	81.04f	171.32s	0.00	
4+5+6+7	0.00000	0.000*	0.000	0.970	-26.746	79.55f	164.98s	0.00	

continued next page

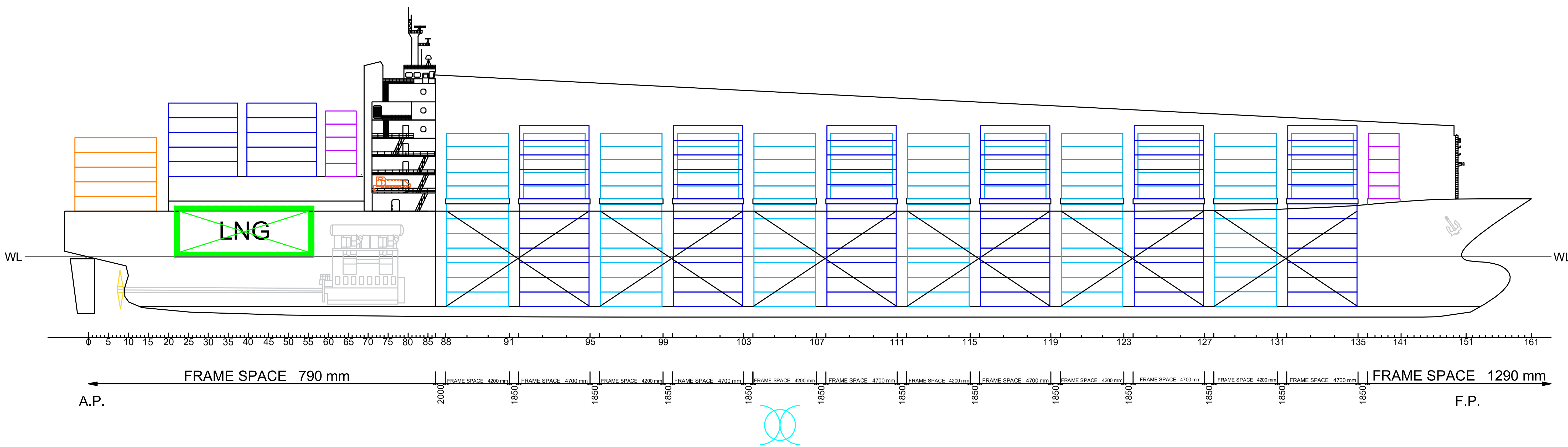
Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
5+6+7+8	0.00000	0.000*	0.000	0.970	-15.303	16.54f	162.39s	0.00	
6+7+8+9	0.00000	0.000*	0.000	0.970	87.472	25.28a	164.26s	0.00	
7+8+9+10	0.00001	0.000*	0.000	0.970	93.239	30.36a	171.30s	0.00	
8+9+10+11	0.00010	0.000*	0.000	0.970	21.114	10.05a	178.19s	0.00	
		4-division damage:		**0.002**		**Probability of damage:**		**0.002**	
1+2+3+4+5	0.00000	0.000*	0.000	0.970	-59.251	40.13f	177.08s	0.00	
2+3+4+5+6	0.00000	0.000*	0.000	0.970	-48.657	81.12f	171.34s	0.00	
3+4+5+6+7	0.00000	0.000	0.000	0.970	SUNK				
4+5+6+7+8	0.00000	0.000	0.000	0.970	SUNK				
5+6+7+8+9	0.00000	0.000	0.000	0.970	SUNK				
6+7+8+9+10	0.00000	0.000*	0.000	0.970	252.479	82.74a	161.03s	0.00	
7+8+9+10+11	0.00000	0.000*	0.000	0.970	207.902	78.04a	171.14s	0.00	
		5-division damage:		**0.000**		**Probability of damage:**		**0.000**	
		Attained index in this condition:		**0.970**		**Total probability of damage:**			**1.000**
	Required index:			**0.705**					
	Values marked with * computed by macro.								

Distances in METERS. Angles in deg.

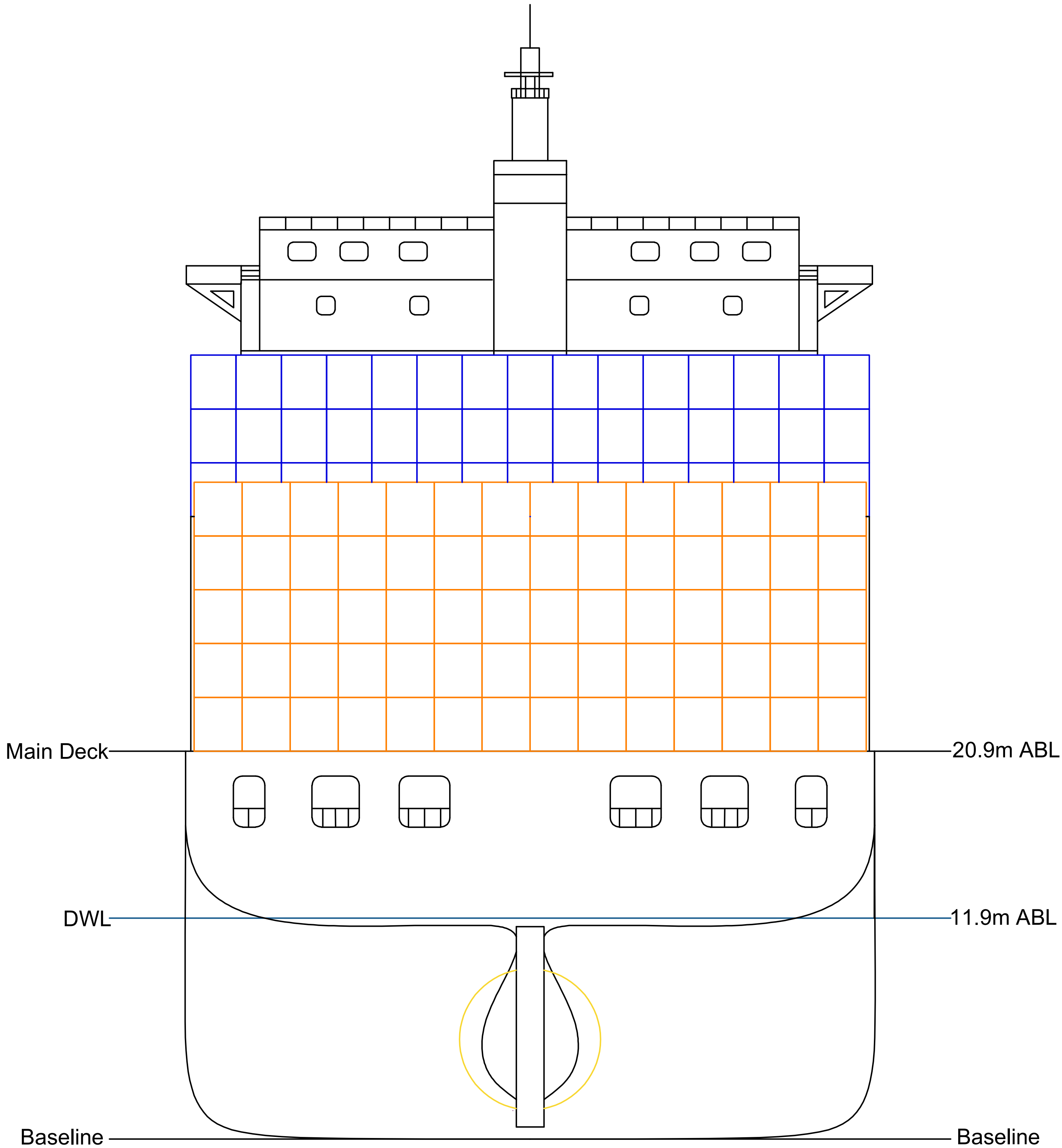
====== Summary Data ======

```
Calculation method: SDI216C
Condition name: Deepest draft (ds) (code 2)
Damage side: Starboard

Displacement: 71153.8 METRIC TONS
Trim: 0.00 degrees
VCG: 15.600 METERS
Free surface moment: 0.0 METRIC TONS-METERS
Environment: 1.025


Attained index: 0.970
Minimim index needed for this draft: 0.353
Overall Required index: 0.705
```

Appendix I – General Arrangements



Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	HCH- SD III PROFILE VIEW	4-2-2024	
		SCALE: 1:5	SHEET 1 OF 3	REV 1



Bilge Dweller Designs

SUNY MARITIME COLLEGE

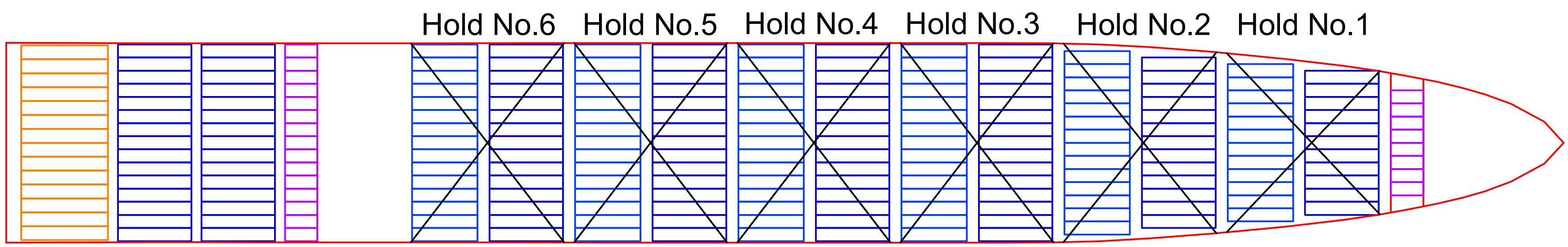
HCH- SD III
STERN VIEW

4-2-2024

SCALE: NTS

SHEET 2 OF 3

REV 3



Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	HCH- SD III CARGO PLAN VIEW	4-2-2024
		SCALE: 1:5	SHEET 3 OF 3 REV 1

Appendix J – Cargo Capacity Plan

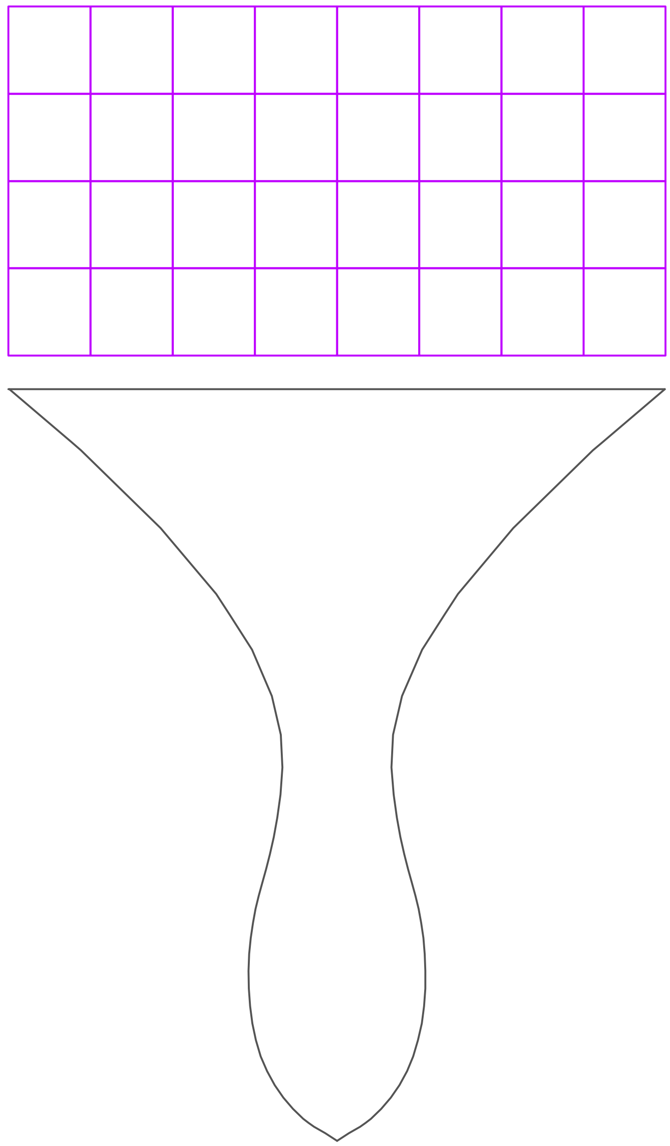
Capacity Plan Summary		
Cargo DWT	27010.00	MT
Sum Moment T	480308.45	MT-m
Sum Moment L	3706102.25	MT-m
Cargo KG	17.78	m-BL
Cargo LCG	137.2	m FWD-AP
TEU Count	3778.20	TEU

Container Types	TEU	Quantity Stowed
20S	1	107
40H	2	804
40S	2	391
45H	2	551
53H	2.56	70
Total Containers	3778	1923

M/V Dweller Capacity Plan

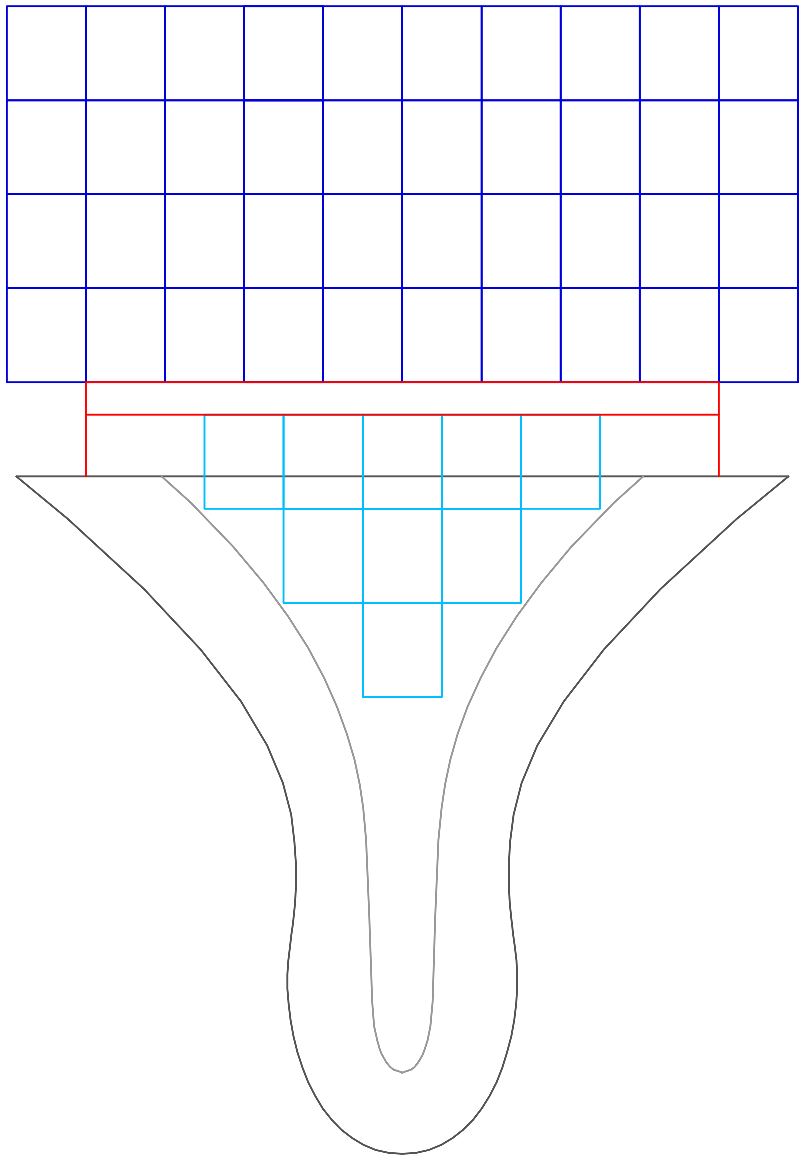
HOLD	BAY	Tier	TEU Count	TYPE	COUNT	BOX WEIGHT (MT)	WEIGHT TOTAL (MT)	KG (m)	TMOMENT (MT*m)	LCG (m) F-AP	LMOMENT (MT*m)
0	00	02	0.00	0.00	0	30.00	0.00	3.44	0.00	256.42	0.00
	00	04	0.00	0.00	0	30.00	0.00	6.34	0.00	256.42	0.00
	00	06	0.00	0	0	30.00	0.00	9.24	0.00	256.42	0.00
	00	08	0.00	0	0	30.00	0.00	12.14	0.00	256.42	0.00
	00	10	0.00	0	0	25.00	0.00	15.04	0.00	256.42	0.00
	00	12	0.00	0	0	10.00	0.00	17.94	0.00	256.42	0.00
	00	14	0.00	0	0	10.00	0.00	20.84	0.00	256.42	0.00
	00	82	8.00	20S	8	10.00	80.00	24.73	1978.40	256.42	20513.60
	00	84	8.00	20S	8	10.00	80.00	27.63	2210.40	256.42	20513.60
	00	86	8.00	20S	8	10.00	80.00	30.53	2442.40	256.42	20513.60
	00	88	8.00	20S	8	5.00	40.00	33.43	1337.20	256.42	10256.80
	00	90	0.00	0	0	5.00	0.00	36.33	0.00	256.42	0.00
1	02	02	0.00	40H	0	30.00	0.00	3.44	0.00	244.28	0.00
	02	04	0.00	40H	0	30.00	0.00	6.34	0.00	244.28	0.00
	02	06	0.00	40H	0	30.00	0.00	9.24	0.00	244.28	0.00
	02	08	0.00	40H	0	30.00	0.00	12.14	0.00	244.28	0.00
	02	10	2.00	40H	1	25.00	25.00	15.04	376.00	244.28	6107.00
	02	12	6.00	40H	3	10.00	30.00	17.94	538.20	244.28	7328.40
	02	14	10.00	40H	5	10.00	50.00	20.84	1042.00	244.28	12214.00
	02	82	20.00	45H	10	10.00	100.00	24.73	2473.00	244.28	24428.00
	02	84	24.00	45H	12	10.00	120.00	27.63	3315.60	244.28	29313.60
	02	86	24.00	45H	12	10.00	120.00	30.53	3663.60	244.28	29313.60
	02	88	24.00	45H	12	5.00	60.00	33.43	2005.80	244.28	14656.80
	02	90	0.00	45H	0	5.00	0.00	36.33	0.00	244.28	0.00
	06	02	2.00	40H	1	30.00	30.00	3.44	103.20	229	6870.00
	06	04	2.00	40H	1	30.00	30.00	6.34	190.20	229	6870.00
	06	06	6.00	40H	3	30.00	90.00	9.24	831.60	229	20610.00
	06	08	6.00	40H	3	30.00	90.00	12.14	1092.60	229	20610.00
	06	10	10.00	40H	5	25.00	125.00	15.04	1880.00	229	28625.00
	06	12	14.00	40H	7	10.00	70.00	17.94	1255.80	229	16030.00
	06	14	18.00	40H	9	10.00	90.00	20.84	1875.60	229	20610.00
	06	82	20.00	40S	10	10.00	100.00	24.73	2473.00	229	22900.00
	06	84	24.00	40S	12	10.00	120.00	27.63	3315.60	229	27480.00
	06	86	24.00	40S	12	10.00	120.00	30.53	3663.60	229	27480.00
	06	88	24.00	40S	12	5.00	60.00	33.43	2005.80	229	13740.00
	06	90	0.00	40S	0	5.00	0.00	36.33	0.00	229	0.00
2	10	02	2.00	40H	1	30.00	30.00	3.44	103.20	213.87	6416.10
	10	04	6.00	40H	3	30.00	90.00	6.34	570.60	213.87	19248.30
	10	06	10.00	40H	5	30.00	150.00	9.24	1386.00	213.87	32080.50
	10	08	14.00	40H	7	30.00	210.00	12.14	2549.40	213.87	44912.70
	10	10	14.00	40H	7	25.00	175.00	15.04	2632.00	213.87	37427.25
	10	12	18.00	40H	9	10.00	90.00	17.94	1614.60	213.87	19248.30
	10	14	22.00	40H	11	10.00	110.00	20.84	2292.40	213.87	23525.70
	10	82	22.00	45H	11	10.00	110.00	24.73	2720.30	213.87	23525.70
	10	84	26.00	45H	13	10.00	130.00	27.63	3591.90	213.87	27803.10
	10	86	26.00	45H	13	10.00	130.00	30.53	3968.90	213.87	27803.10
	10	88	26.00	45H	13	5.00	65.00	33.43	2172.95	213.87	13901.55
	10	90	26.00	45H	13	5.00	65.00	36.33	2361.45	213.87	13901.55
	14	02	4.00	40H	2	30.00	60.00	3.44	206.40	198.67	11920.20
	14	04	12.00	40H	6	30.00	180.00	6.34	1141.20	198.67	35760.60
	14	06	16.00	40H	8	30.00	240.00	9.24	2217.60	198.67	47680.80
	14	08	20.00	40H	10	30.00	300.00	12.14	3642.00	198.67	59601.00
	14	10	20.00	40H	10	25.00	250.00	15.04	3760.00	198.67	49667.50
	14	12	24.00	40H	12	10.00	120.00	17.94	2152.80	198.67	23840.40
	14	14	24.00	40H	12	10.00	120.00	20.84	2500.80	198.67	23840.40
	14	82	24.00	40S	12	10.00	120.00	24.73	2967.60	198.67	23840.40
	14	84	28.00	40S	14	10.00	140.00	27.63	3868.20	198.67	27813.80
	14	86	28.00	40S	14	10.00	140.00	30.53	4274.20	198.67	27813.80
	14	88	28.00	40S	14	5.00	70.00	33.43	2340.10	198.67	13906.90
	14	90	28.00	40S	14	5.00	70.00	36.33	2543.10	198.67	13906.90
3	18	02	6.00	40H	3	30.00	90.00	3.44	309.60	183.46	16511.40
	18	04	18.00	40H	9	30.00	270.00	6.34	1711.80	183.46	49534.20
	18	06	22.00	40H	11	30.00	330.00	9.24	3049.20	183.46	60541.80
	18	08	22.00	40H	11	30.00	330.00	12.14	4006.20	183.46	60541.80
	18	10	26.00	40H	13	25.00	325.00	15.04	4888.00	183.46	59624.50
	18	12	26.00	40H	13	10.00	130.00	17.94	2332.20	183.46	23849.80
	18	14	26.00	40H	13	10.00	130.00	20.84	2709.20	183.46	23849.80
	18	82	26.00	45H	13	10.00	130.00	24.73	3214.90	183.46	23849.80
	18	84	30.00	45H	15	10.00	150.00	27.63	4144.50	183.46	27519.00
	18	86	30.00	45H	15	10.00	150.00	30.53	4579.50	183.46	27519.00
	18	88	30.00	45H	15	5.00	75.00	33.43	2507.25	183.46	13759.50
	18	90	30.00	45H	15	5.00	75.00	36.33	2724.75	183.46	13759.50
	22	02	14.00	40H	7	30.00	210.00	3.44	722.40	168.26	35334.60
	22	04	22.00	40H	11	30.00	330.00	6.34	2092.20	168.26	55525.80
	22	06	26.00	40H	13	30.00	390.00	9.24	3603.60	168.26	65621.40
	22	08	26.00	40H	13	30.00	390.00	12.14	4734.60	168.26	65621.40
	22	10	26.00	40H	13	25.00	325.00	15.04	4888.00	168.26	54684.50
	22	12	26.00	40H	13	10.00	130.00	17.94	2332.20	168.26	21873.80
	22	14	26.00	40H	13	10.00	130.00	20.84	2709.20	168.26	21873.80
	22	82	26.00	40S	13	10.00	130.00	24.73	3214.90	168.26	21873.80
	22	84	30.00	40S	15	10.00	150.00	27.63	4144.50	168.26	25239.00
	22	86	30.00	40S	15	10.00	150.00	30.53	4579.50	168.26	25239.00
	22	88	30.00	40S	15	5.00	75.00	33.43	2507.25	168.26	12619.50
	22	90	30.00	40S	15	5.00	75.00	36.33	2724.75	168.26	12619.50
4	26	02	18.00	40H	9	30.00	270.00	3.44	928.80	153.05	41323.50
	26	04	26.00	40H	13	30.00	390.00	6.34	2472.60	153.05	59689.50
	26	06	26.00	40H	13	30.00	390.00	9.24	3603.60	153.05	59689.50
	26	08	26.00	40H	13	30.00	390.00	12.14	4734.60	153.05	59689.50
	26	10	26.00	40H	13	25.00	325.00	15.04	4888.00	153.05	49741.25
	26	12	26.00	40H	13	10.00	130.00	17.94	2332.20	153.05	19896.50
	26	14	26.00	40H	13	10.00	130.00	20.84	2709.20	153.05	19896.50
	26	82	26.00	45H	13	10.00	130.00	24.73	3214.90	153.05	19896.50
	26	84	30.00	45H	15	10.00	150.00	27.63	4144.50	153.05	22957.50
	26	86	30.00	45H	15	10.00	150.00	30.53	4579.50	153.05	22957.50
	26	88	30.00	45H	15	5.00	75.00	33.43	2507.25	153.05	11478.75
	26	90	30.00	45H	15	5.00	75.00	36.33	2724.75	153.05	11478.75
	30	02	22.00	40H	11	30.00	330.00	3.44	1135.20	137.85	45490.50
	30	04	26.00	40H	13	30.00	390.00	6.34	2472.60	137.85	53761.50
	30	06	26.00	40H	13	30.00	390.00	9.24	3603.60	137.85	53761.50
	30	08	26.00	40H	13	30.00	390.00	12.14	4734.60	137.85	53761.50
	30	10	26.00	40H	13	25.00	325.00	15.04	4888.00	137.85	44801.25
	30	12	26.00	40H	13	10.00	130.00	17.94	2332.20	137.85	17920.50
	30	14	26.00	40H	13	10.00	130.00	20.84	2709.20	137.85	17920.50
	30	82	26.00	40S	13	10.00	130.00	24.73	3214.90	137.85	17920.50
	30	84	30.00	40S	15	10.00	150.00	27.63	4144.50	137.85	20677.50
	30	86	30.00	40S	15	10.00	150.00	30.53	4579.50	137.85	20677.50
	30	88	30.00	40S	15	5.00	75.00	33.43	2507.25	137.85	10338.75
	30	90	30.00	40S	15	5.00	75.00	36.33	2724.75	137.85	10338.75

HOLD	BAY	Tier	TEU Count	TYPE	COUNT	BOX WEIGHT (MT)	WEIGHT TOTAL (MT)	KG (m)	TMOMENT (MT*m)	LCG (m) F-AP	LMOMENT (MT*m)
5	0.00	02	22.00	40H	11	30.00	330.00	0.00	0.00	122.64	40471.20
	0.00	04	26.00	40H	13	30.00	390.00	0.00	0.00	122.64	47829.60
	0.00	06	26.00	40H	13	30.00	390.00	0.00	0.00	122.64	47829.60
	0.00	08	26.00	40H	13	30.00	390.00	0.00	0.00	122.64	47829.60
	0.00	10	26.00	40H	13	25.00	325.00	0.00	0.00	122.64	39858.00
	0.00	12	26.00	40H	13	10.00	130.00	0.00	0.00	122.64	15943.20
	0.00	14	26.00	40H	13	10.00	130.00	0.00	0.00	122.64	15943.20
	0.00	82	26.00	45H	13	10.00	130.00	0.00	0.00	122.64	15943.20
	0.00	84	30.00	45H	15	10.00	150.00	0.00	0.00	122.64	18396.00
	0.00	86	30.00	45H	15	10.00	150.00	0.00	0.00	122.64	18396.00
	0.00	88	30.00	45H	15	5.00	75.00	0.00	0.00	122.64	9198.00
	0.00	90	30.00	45H	15	5.00	75.00	0.00	0.00	122.64	9198.00
	0.00	02	18.00	40H	9	30.00	270.00	0.00	0.00	107.44	29008.80
	0.00	04	26.00	40H	13	30.00	390.00	0.00	0.00	107.44	41901.60
	0.00	06	26.00	40H	13	30.00	390.00	0.00	0.00	107.44	41901.60
	0.00	08	26.00	40H	13	30.00	390.00	0.00	0.00	107.44	41901.60
	0.00	10	26.00	40H	13	25.00	325.00	0.00	0.00	107.44	34918.00
	0.00	12	26.00	40H	13	10.00	130.00	0.00	0.00	107.44	13967.20
	0.00	14	26.00	40H	13	10.00	130.00	0.00	0.00	107.44	13967.20
	0.00	82	26.00	40S	13	10.00	130.00	0.00	0.00	107.44	13967.20
	0.00	84	30.00	40S	15	10.00	150.00	0.00	0.00	107.44	16116.00
	0.00	86	30.00	40S	15	10.00	150.00	0.00	0.00	107.44	16116.00
	0.00	88	30.00	40S	15	5.00	75.00	0.00	0.00	107.44	8058.00
	0.00	90	30.00	40S	15	5.00	75.00	0.00	0.00	107.44	8058.00
6	0.00	02	10.00	40H	5	30.00	150.00	0.00	0.00	92.2	13830.00
	0.00	04	22.00	40H	11	30.00	330.00	0.00	0.00	92.2	30426.00
	0.00	06	26.00	40H	13	30.00	390.00	0.00	0.00	92.2	35958.00
	0.00	08	26.00	40H	13	30.00	390.00	0.00	0.00	92.2	35958.00
	0.00	10	26.00	40H	13	25.00	325.00	0.00	0.00	92.2	29965.00
	0.00	12	26.00	40H	13	10.00	130.00	0.00	0.00	92.2	11986.00
	0.00	14	26.00	40H	13	10.00	130.00	0.00	0.00	92.2	11986.00
	0.00	82	26.00	45H	13	10.00	130.00	0.00	0.00	92.2	11986.00
	0.00	84	30.00	45H	15	10.00	150.00	0.00	0.00	92.2	13830.00
	0.00	86	30.00	45H	15	10.00	150.00	0.00	0.00	92.2	13830.00
	0.00	88	30.00	45H	15	5.00	75.00	0.00	0.00	92.2	6915.00
	0.00	90	30.00	45H	15	5.00	75.00	0.00	0.00	92.2	6915.00
	0.00	02	0.00	40H	0	30.00	0.00	0.00	0.00	77.03	0.00
	0.00	04	18.00	40H	9	30.00	270.00	0.00	0.00	77.03	20798.10
	0.00	06	26.00	40H	13	30.00	390.00	0.00	0.00	77.03	30041.70
	0.00	08	26.00	40H	13	30.00	390.00	0.00	0.00	77.03	30041.70
	0.00	10	26.00	40H	13	25.00	325.00	0.00	0.00	77.03	25034.75
	0.00	12	26.00	40H	13	10.00	130.00	0.00	0.00	77.03	10013.90
	0.00	14	26.00	40H	13	10.00	130.00	0.00	0.00	77.03	10013.90
	0.00	82	26.00	40S	13	10.00	130.00	0.00	0.00	77.03	10013.90
	0.00	84	30.00	40S	15	10.00	150.00	0.00	0.00	77.03	11554.50
	0.00	86	30.00	40S	15	10.00	150.00	0.00	0.00	77.03	11554.50
	0.00	88	30.00	40S	15	5.00	75.00	0.00	0.00	77.03	5777.25
	0.00	90	0.00	40S	0	5.00	0.00	0.00	0.00	77.03	0.00
7	0.00	02	0.00	0.00	0	30.00	0.00	0.00	0.00	50	0.00
	0.00	04	0.00	0.00	0	30.00	0.00	0.00	0.00	50	0.00
	0.00	06	0.00	0.00	0	30.00	0.00	0.00	0.00	50	0.00
	0.00	08	0.00	0.00	0	30.00	0.00	0.00	0.00	50	0.00
	0.00	10	0.00	0.00	0	25.00	0.00	0.00	0.00	50	0.00
	0.00	12	0.00	0.00	0	10.00	0.00	0.00	0.00	50	0.00
	0.00	14	0.00	0.00	0	10.00	0.00	0.00	0.00	50	0.00
	0.00	82	15.00	20S	15	10.00	150.00	0.00	0.00	50	7500.00
	0.00	84	15.00	20S	15	10.00	150.00	0.00	0.00	50	7500.00
	0.00	86	15.00	20S	15	10.00	150.00	0.00	0.00	50	7500.00
	0.00	88	15.00	20S	15	5.00	75.00	0.00	0.00	50	3750.00
	0.00	90	15.00	20S	15	5.00	75.00	0.00	0.00	50	3750.00
	0.00	02	0.00	0.00	0	30.00	0.00	0.00	0.00	38.2	0.00
	0.00	04	0.00	0.00	0	30.00	0.00	0.00	0.00	38.2	0.00
	0.00	06	0.00	0.00	0	30.00	0.00	0.00	0.00	38.2	0.00
	0.00	08	0.00	0.00	0	30.00	0.00	0.00	0.00	38.2	0.00
	0.00	10	0.00	0.00	0	25.00	0.00	0.00	0.00	38.2	0.00
	0.00	12	0.00	0.00	0	10.00	0.00	0.00	0.00	38.2	0.00
	0.00	14	0.00	0.00	0	10.00	0.00	0.00	0.00	38.2	0.00
	0.00	82	30.00	45H	15	10.00	150.00	0.00	0.00	38.2	5730.00
	0.00	84	30.00	45H	15	10.00	150.00	0.00	0.00	38.2	5730.00
	0.00	86	30.00	45H	15	10.00	150.00	0.00	0.00	38.2	5730.00
	0.00	88	30.00	45H	15	5.00	75.00	0.00	0.00	38.2	2865.00
	0.00	90	30.00	45H	15	5.00	75.00	0.00	0.00	38.2	2865.00
	0.00	02	0.00	0.00	0	30.00	0.00	0.00	0.00	22.65	0.00
	0.00	04	0.00	0.00	0	30.00	0.00	0.00	0.00	22.65	0.00
	0.00	06	0.00	0.00	0	30.00	0.00	0.00	0.00	22.65	0.00
	0.00	08	0.00	0.00	0	30.00	0.00	0.00	0.00	22.65	0.00
	0.00	10	0.00	0.00	0	25.00	0.00	0.00	0.00	22.65	0.00
	0.00	12	0.00	0.00	0	10.00	0.00	0.00	0.00	22.65	0.00
	0.00	14	0.00	0.00	0	10.00	0.00	0.00	0.00	22.65	0.00
	0.00	82	30.00	45H	15	10.00	150.00	0.00	0.00	22.65	3397.50
	0.00	84	30.00	45H	15	10.00	150.00	0.00	0.00	22.65	3397.50
	0.00	86	30.00	45H	15	10.00	150.00	0.00	0.00	22.65	3397.50
	0.00	88	30.00	45H	15	5.00	75.00	0.00	0.00	22.65	1698.75
	0.00	90	30.00	45H	15	5.00	75.00	0.00	0.00	22.65	1698.75
	0.00	02	0.00	0.00	0	30.00	0.00	0.00	0.00	5.4	0.00
	0.00	04	0.00	0.00	0	30.00	0.00	0.00	0.00	5.4	0.00
	0.00	06	0.00	0.00	0	30.00	0.00	0.00	0.00	5.4	0.00
	0.00	08	0.00	0.00	0	30.00	0.00	0.00	0.00	5.4	0.00
	0.00	10	0.00	0.00	0	25.00	0.00	0.00	0.00	5.4	0.00
	0.00	12	0.00	0.00	0	10.00	0.00	0.00	0.00	5.4	0.00
	0.00	14	0.00	0.00	0	10.00	0.00	0.00	0.00	5.4	0.00
	0.00	82	35.84	53H	14	10.00	140.00	0.00	0.00	5.4	756.00
	0.00	84	35.84	53H	14	10.00	140.00	0.00	0.00	5.4	756.00
	0.00	86	35.84	53H	14	10.00	140.00	0.00	0.00	5.4	756.00
	0.00	88	35.84	53H	14	5.00	70.00	0.00	0.00	5.4	378.00
	0.00	90	35.84	53H	14	5.00	70.00	0.00	0.00	5.4	378.00



Bay:	00
On Deck:	32 @ 20' Standard
Below Deck:	0

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 1 OF 17 REV 3



Bay: 02
On Deck: 40 @ 45' High Cube
Below Deck: 9 @ 40' High Cube

Bilge Dweller Designs

SUNY MARITIME COLLEGE

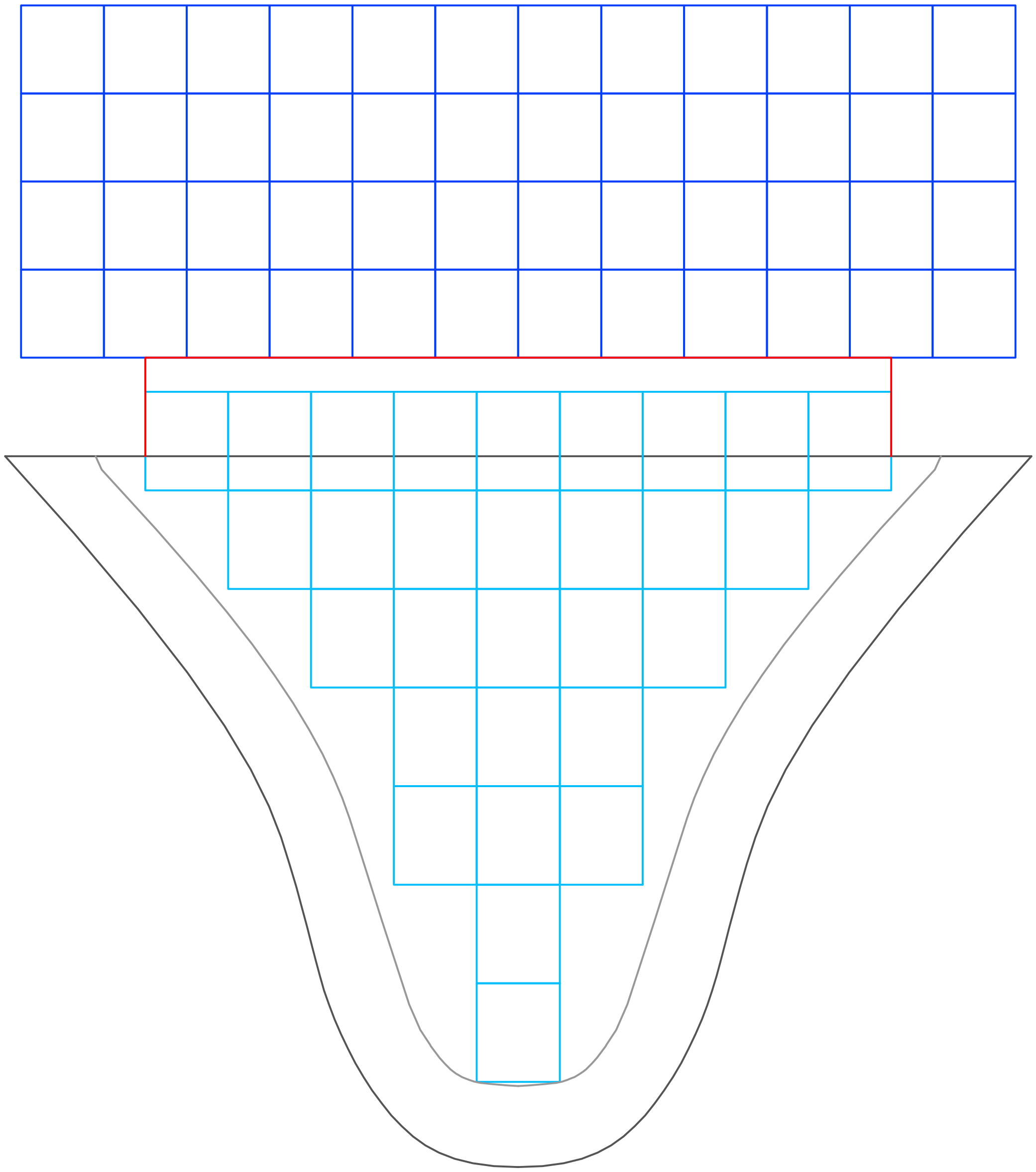
HCH- SD III CARGO ARRANGEMENTS

4-2-2024

SCALE: NTS

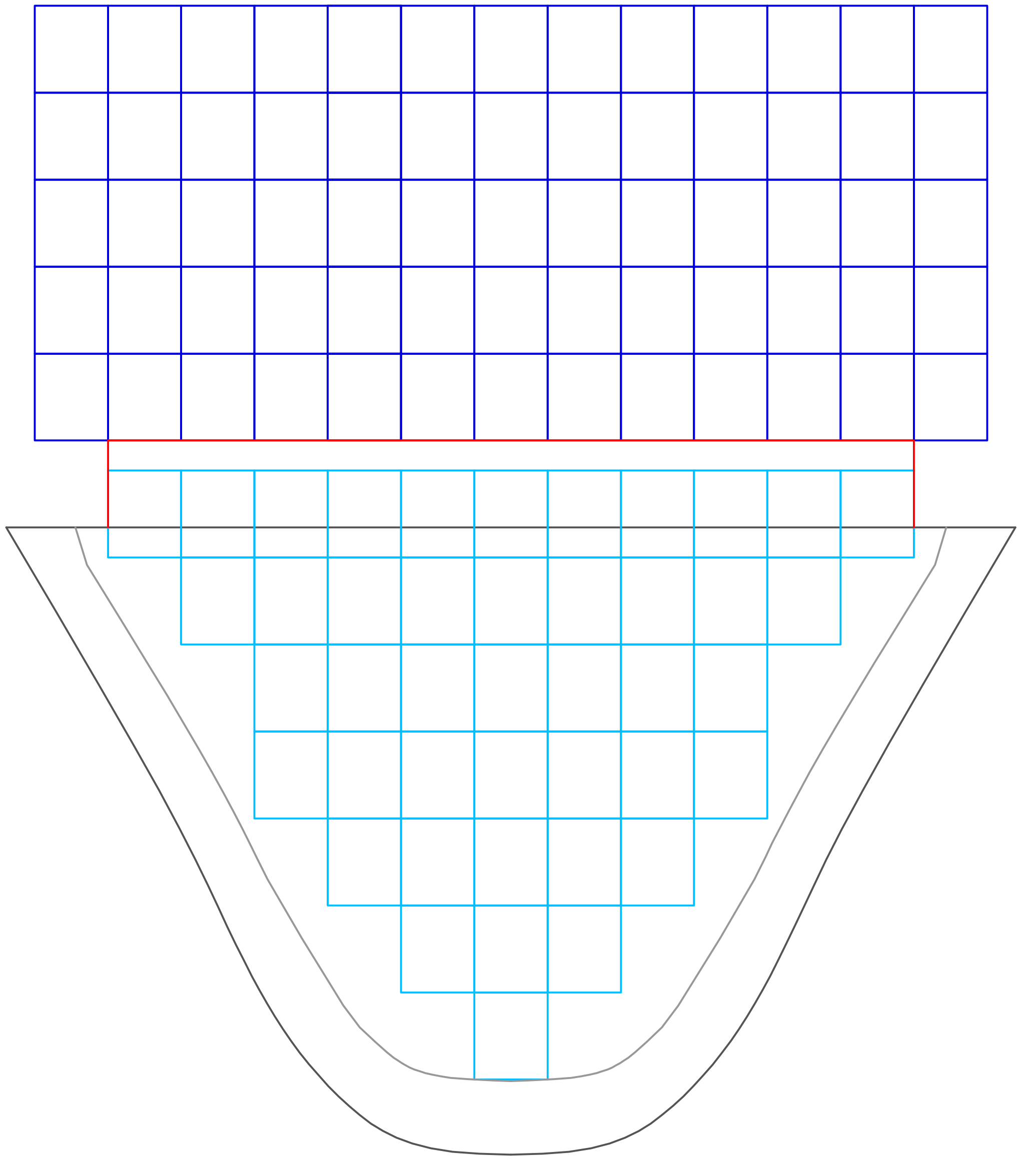
SHEET 2 OF 17

REV 3



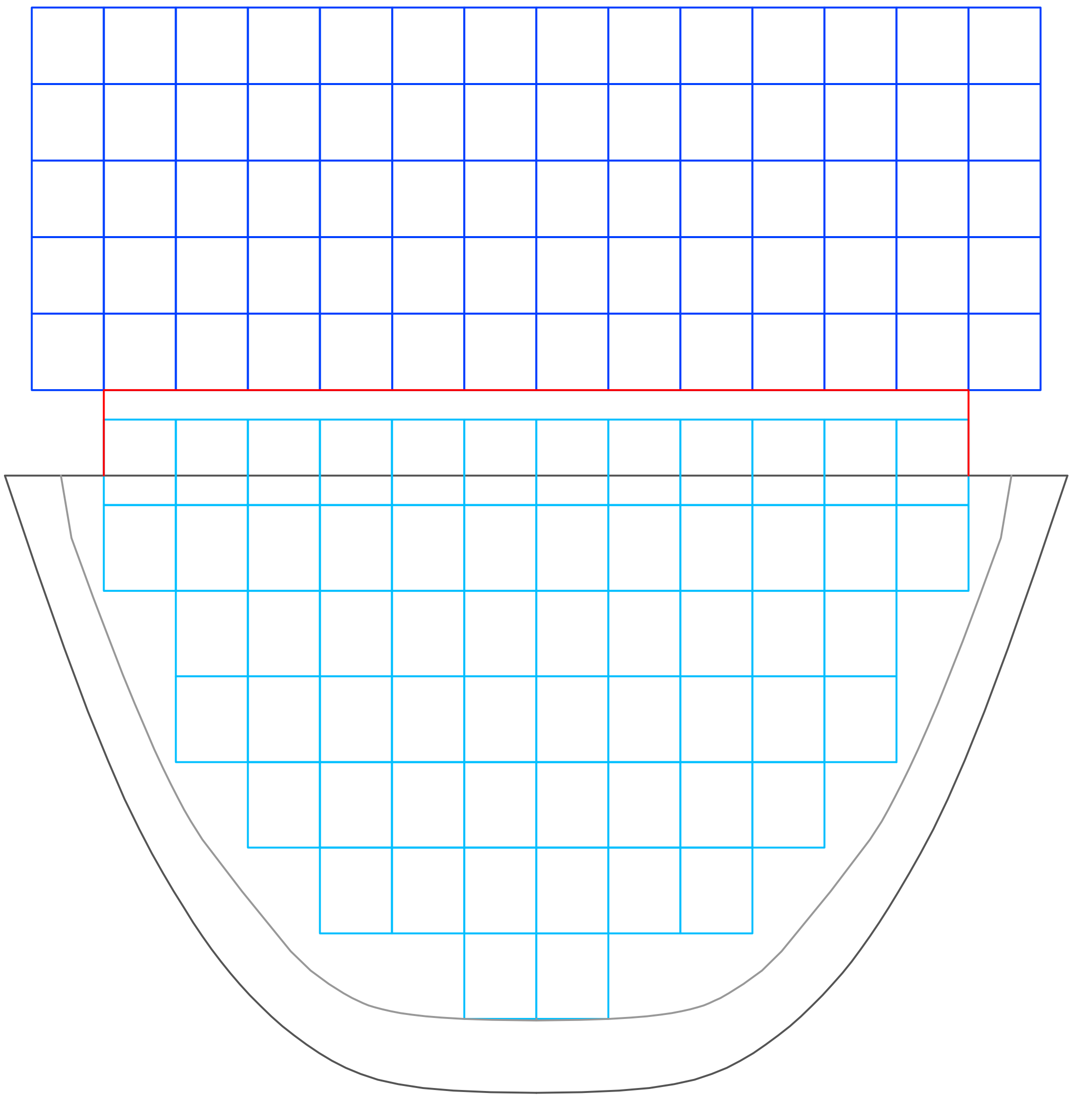
Bay: 06
On Deck: 46 @ 40' Standard
Below Deck: 29 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024	
		SCALE: NTS	SHEET 3 OF 17	REV 3



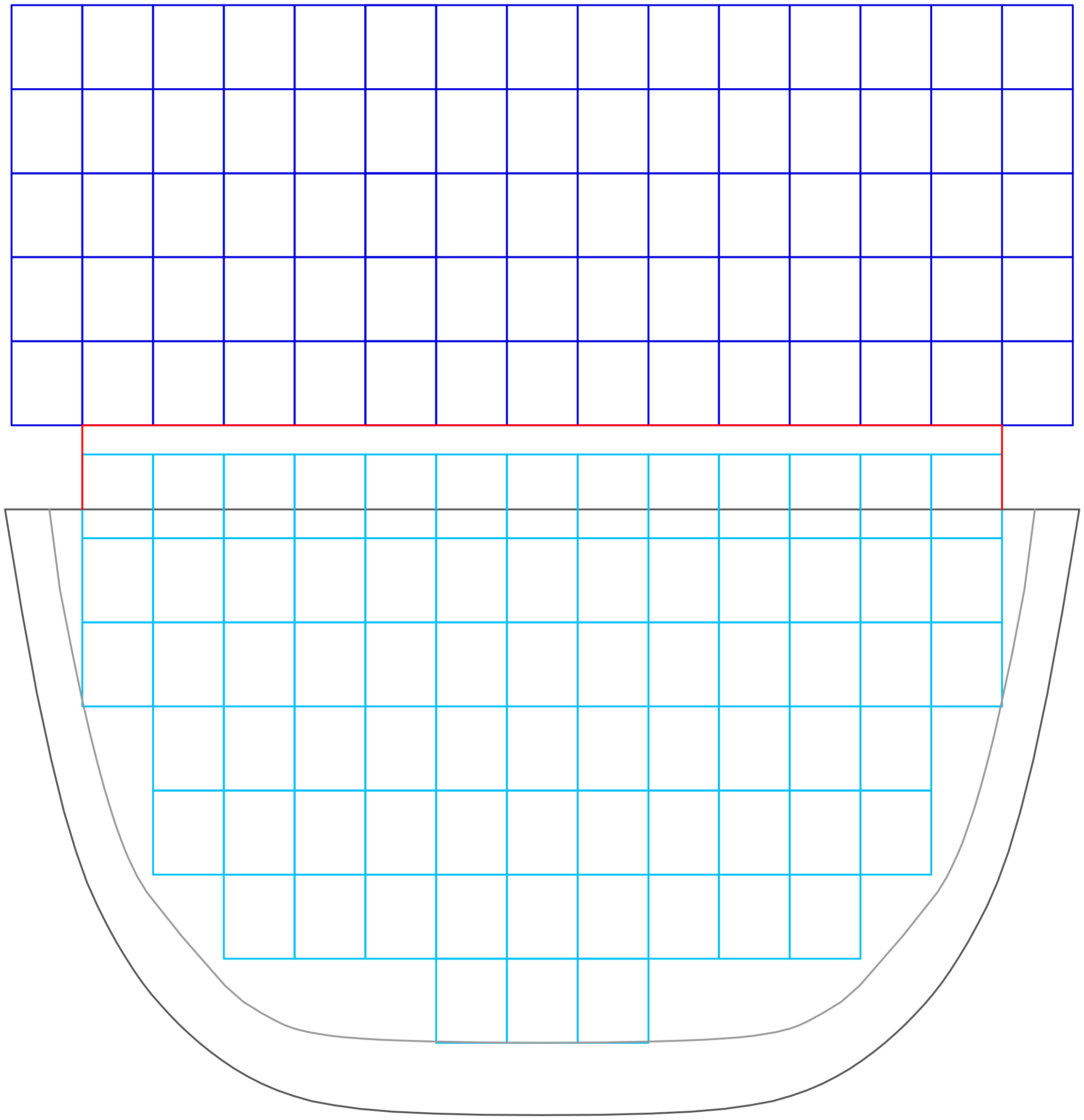
Bay: 10
On Deck: 63 @ 45' High Cube
Below Deck: 43 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 4 OF 17 REV 3



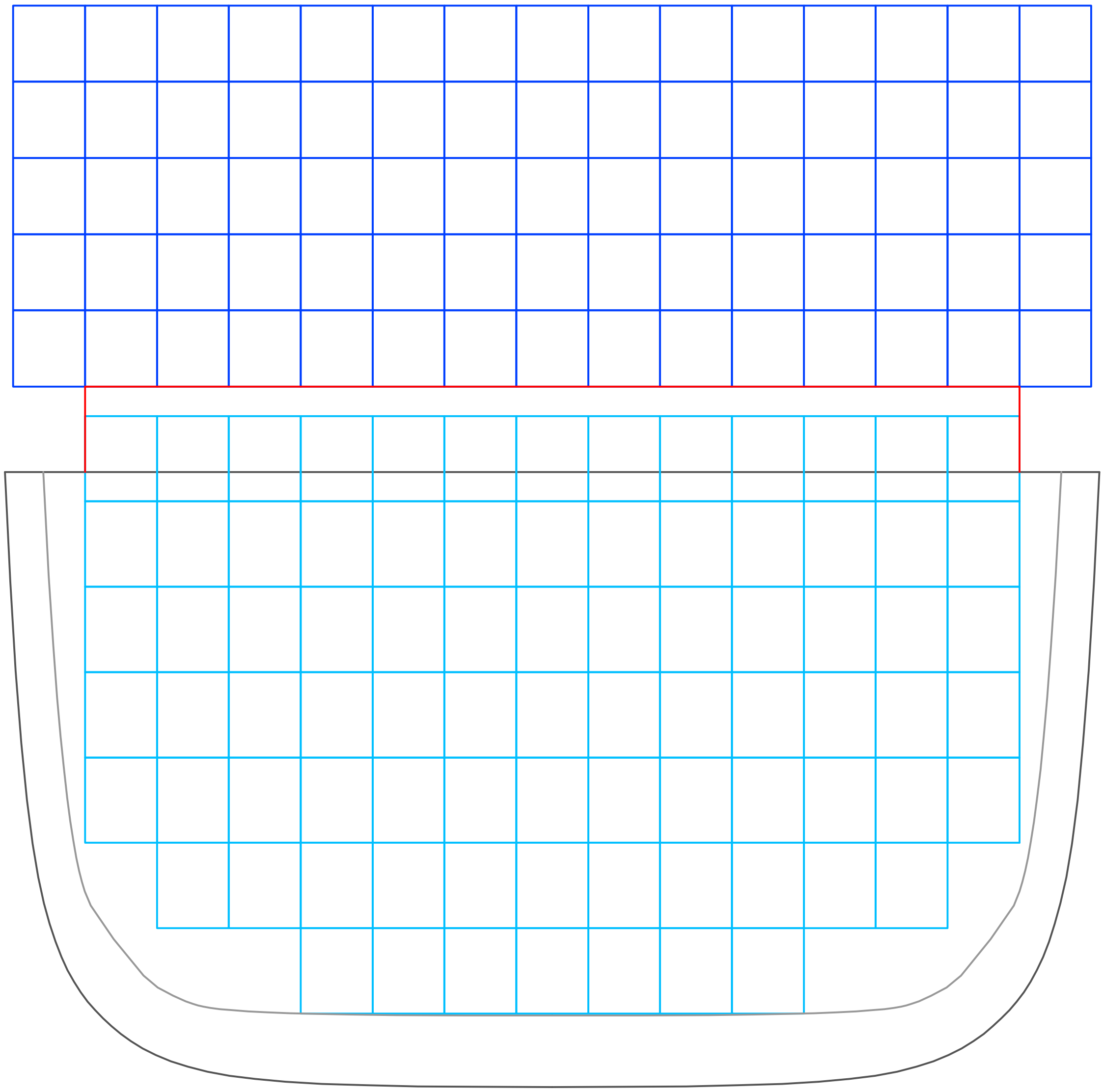
Bay: 14
On Deck: 68 @ 40' Standard
Below Deck: 60 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 5 OF 17 / REV 3



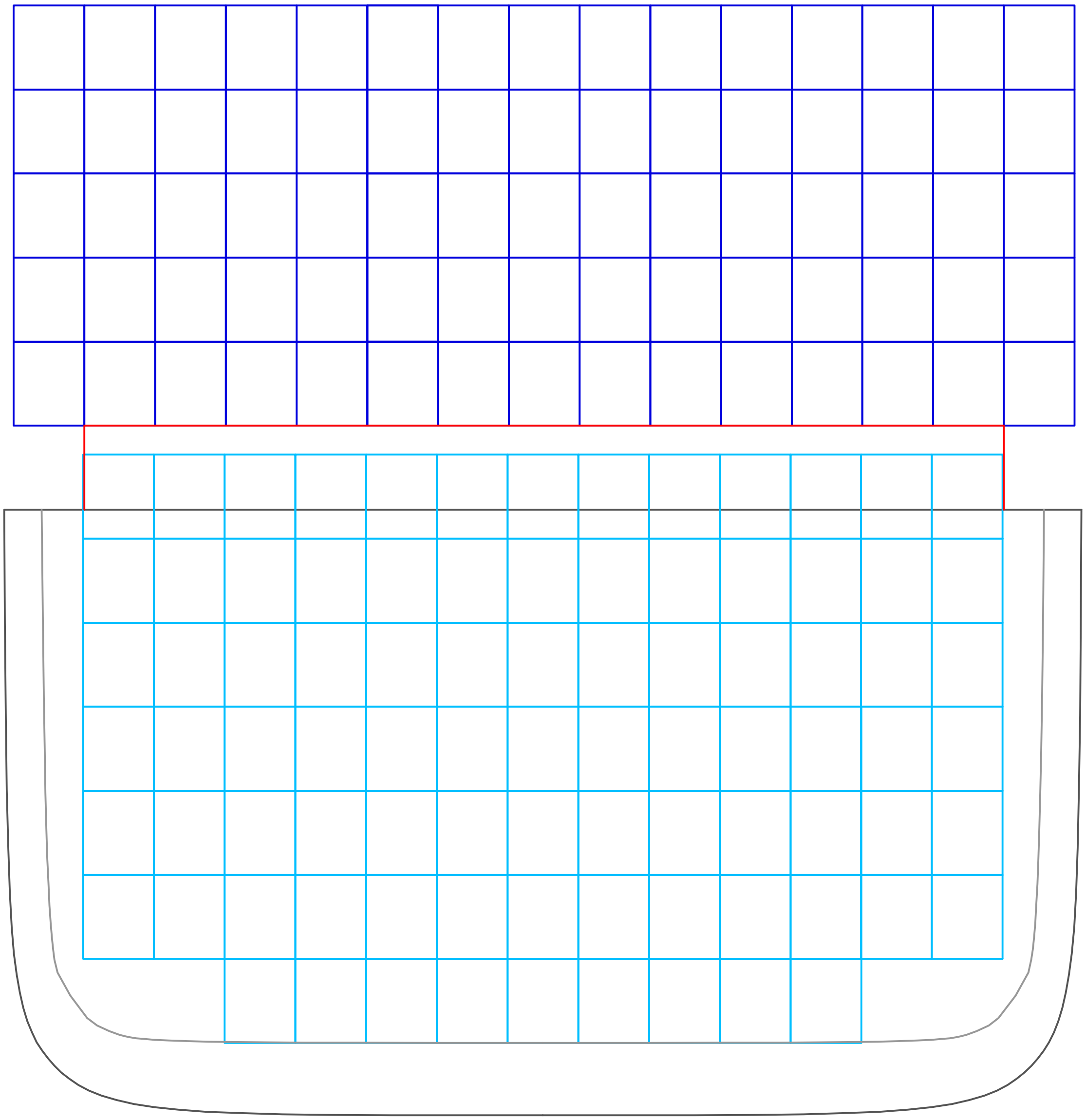
Bay: 18
On Deck: 73 @ 45' High Cube
Below Deck: 73 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024	
		SCALE: NTS	SHEET 6 OF 17	REV 3



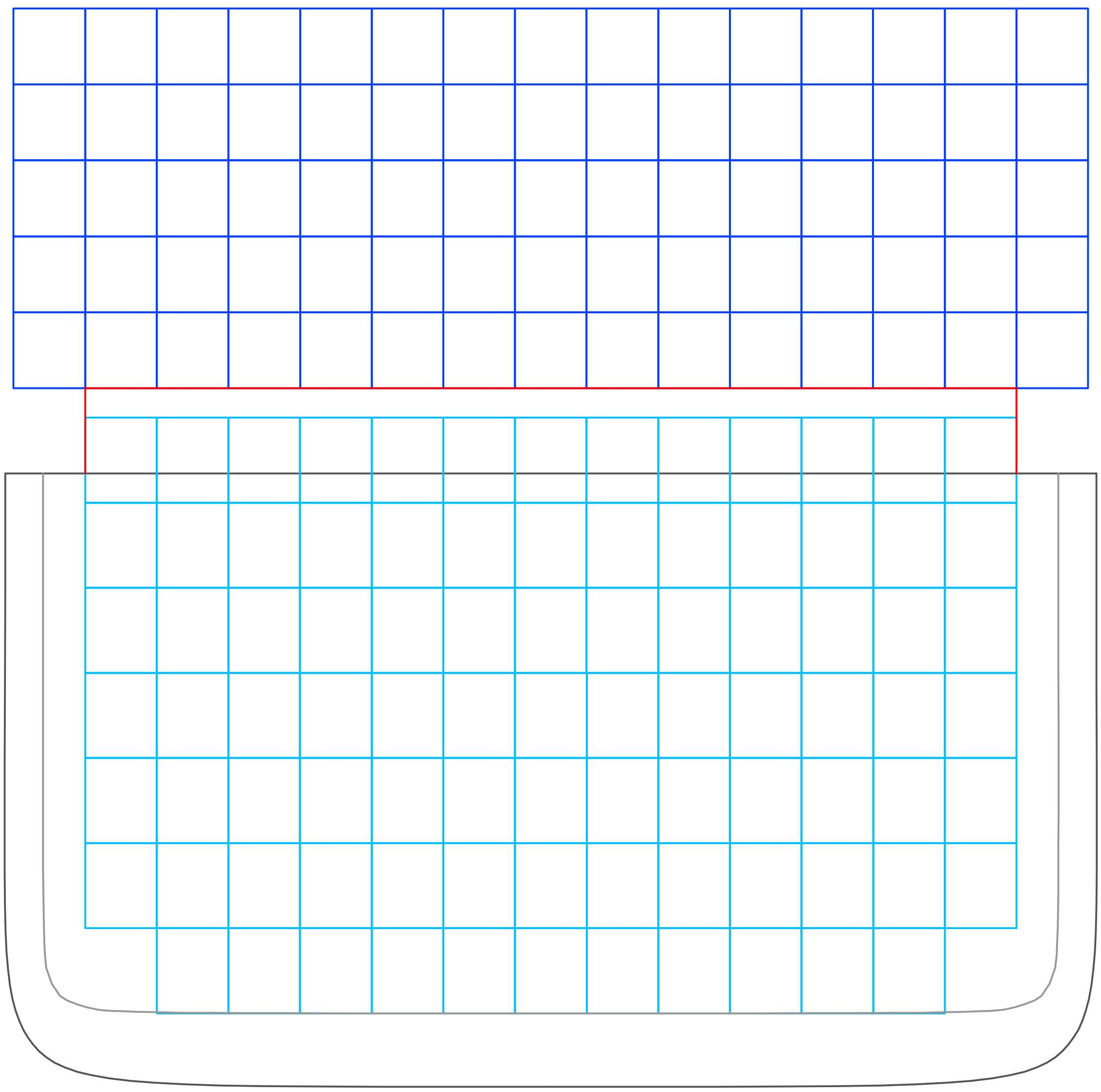
Bay: 22	
On Deck: 73 @ 40' Standard	
Below Deck: 83 @ 40' High Cube	

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 7 OF 17 REV 3



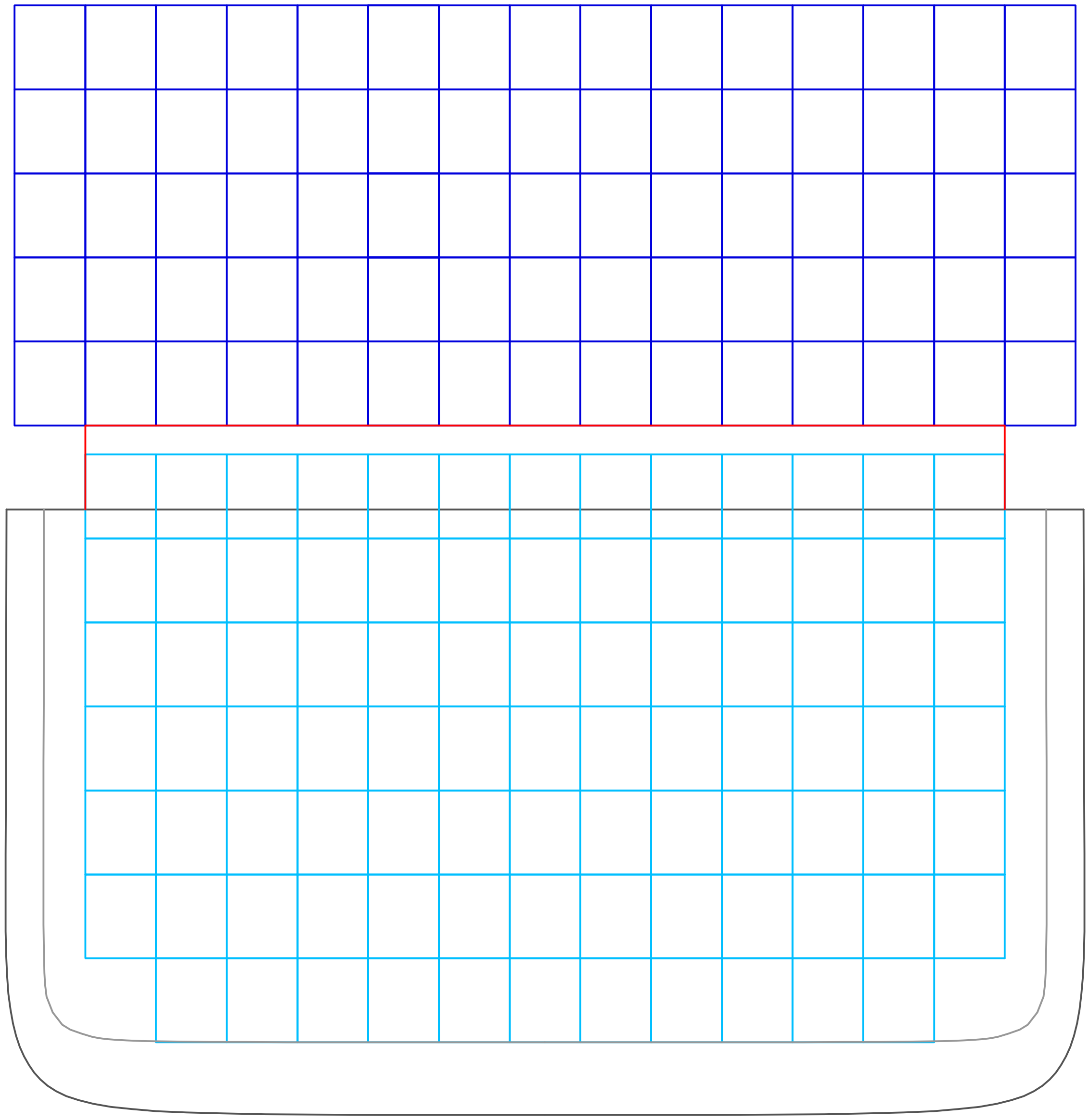
Bay:	26
On Deck:	73 @ 45' High Cube
Below Deck:	87 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024		
		SCALE: NTS	SHEET 8 OF 17		REV 3



Bay: 30	
On Deck: 73 @ 40' Standard	
Below Deck: 89 @ 40' High Cube	

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 9 OF 17 REV 3



Bay: 34	
On Deck: 73 @ 45' High Cube	
Below Deck: 89 @ 40' High Cube	

Bilge Dweller Designs

SUNY MARITIME COLLEGE

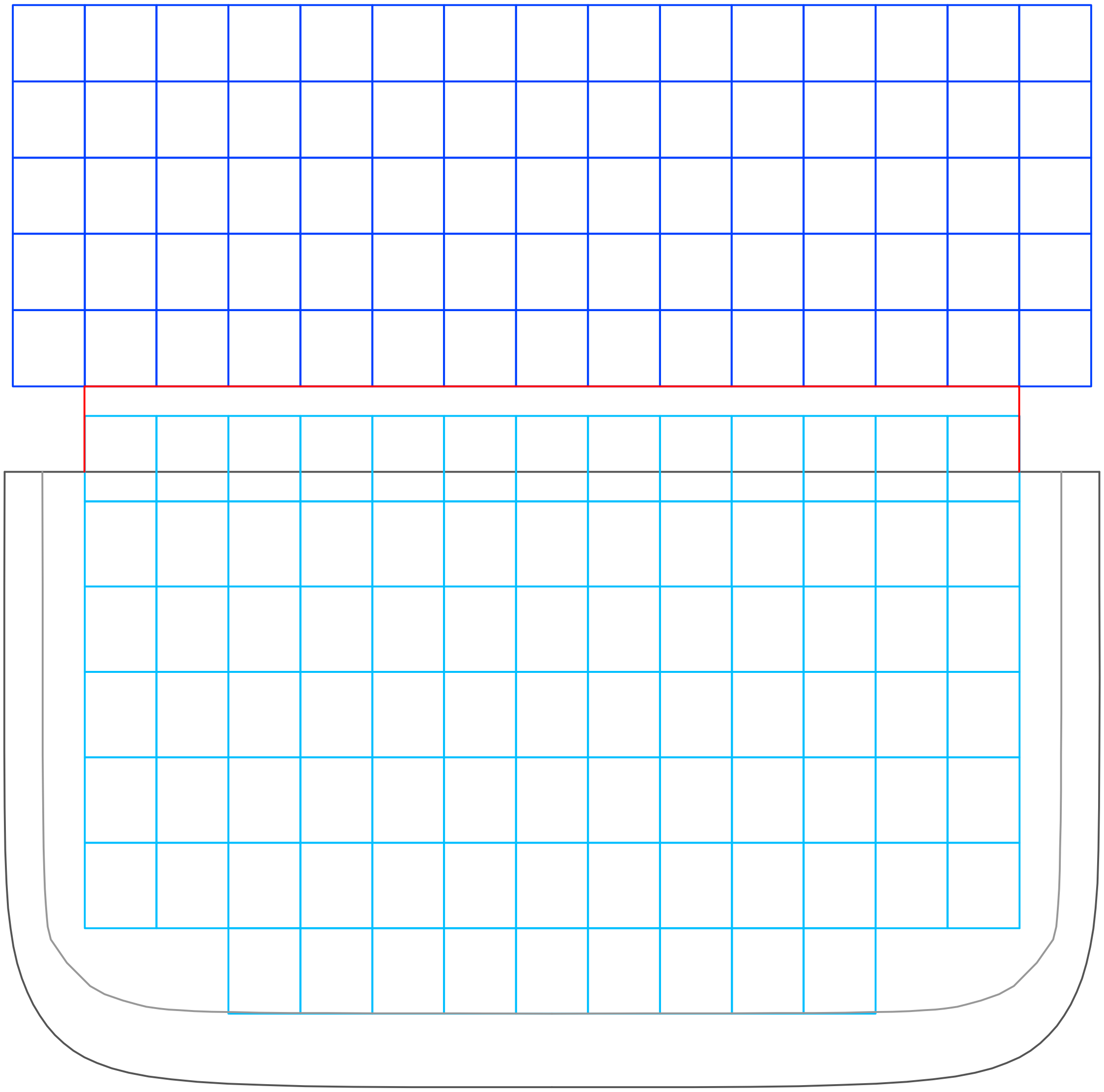
HCH- SD III CARGO ARRANGEMENTS

4-2-2024

SCALE: NTS

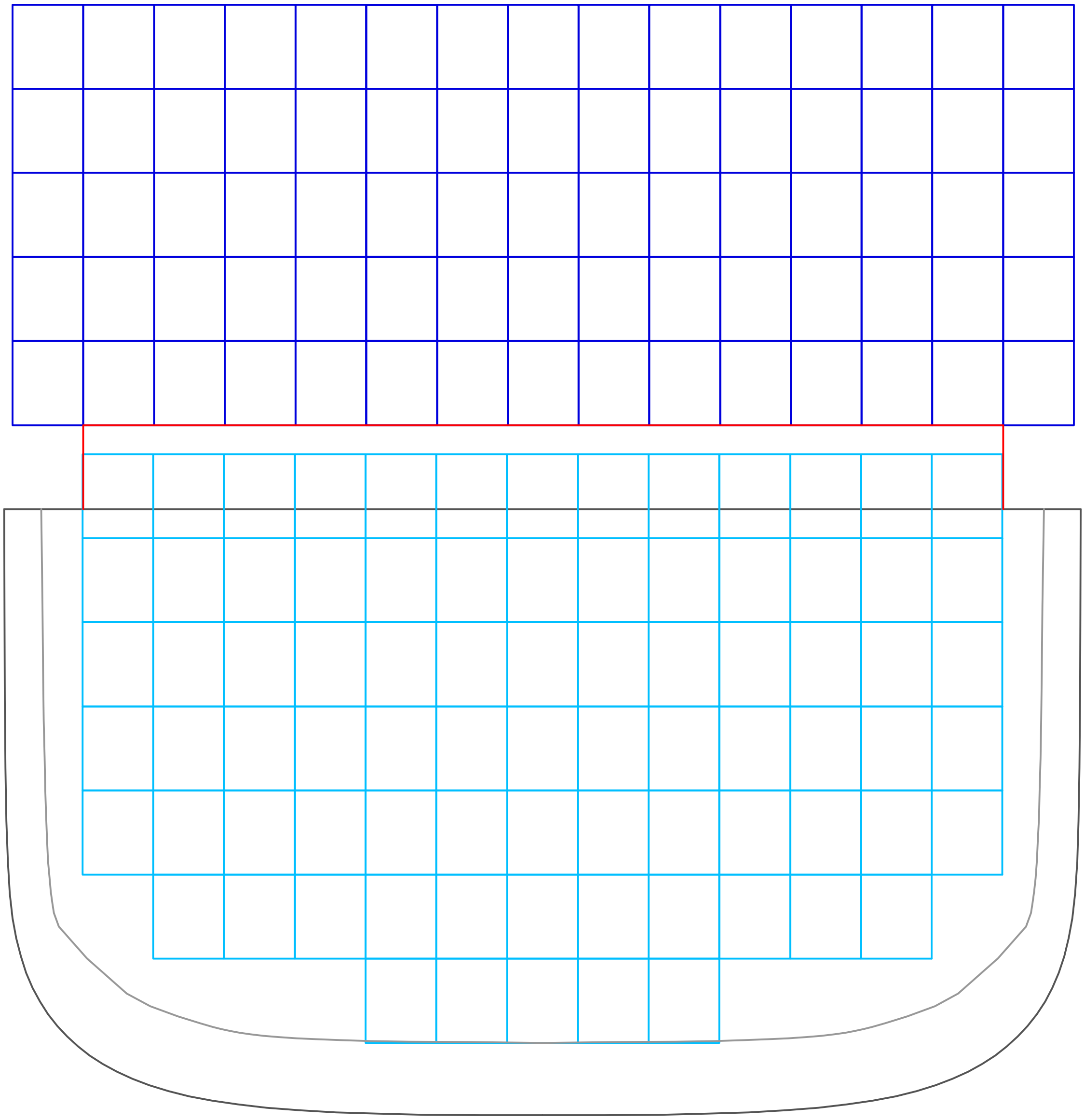
SHEET 10 OF 17

REV 3

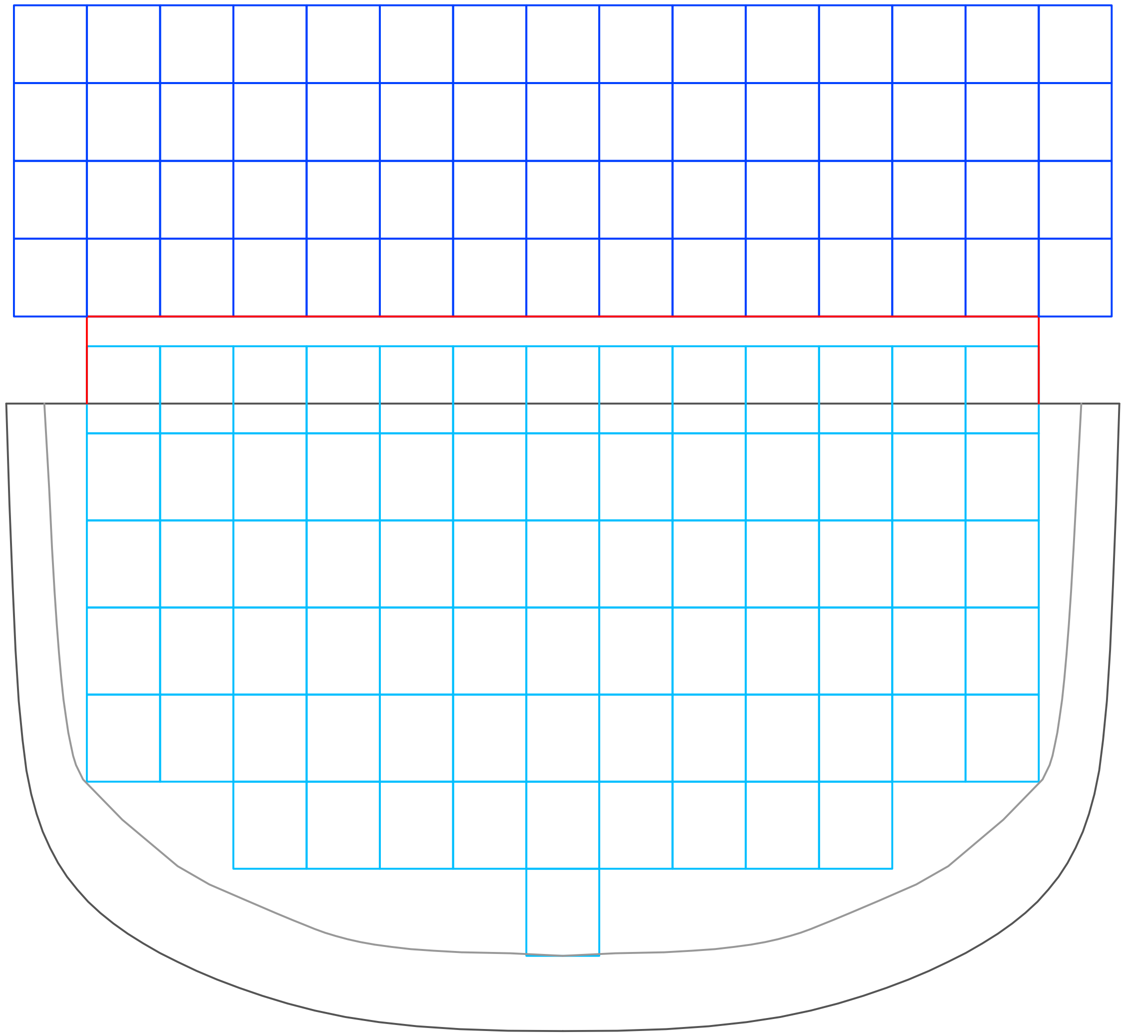


Bay: 38	
On Deck: 73 @ 40' Standard	
Below Deck: 87 @ 40' High Cube	

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 11 OF 17 REV 3

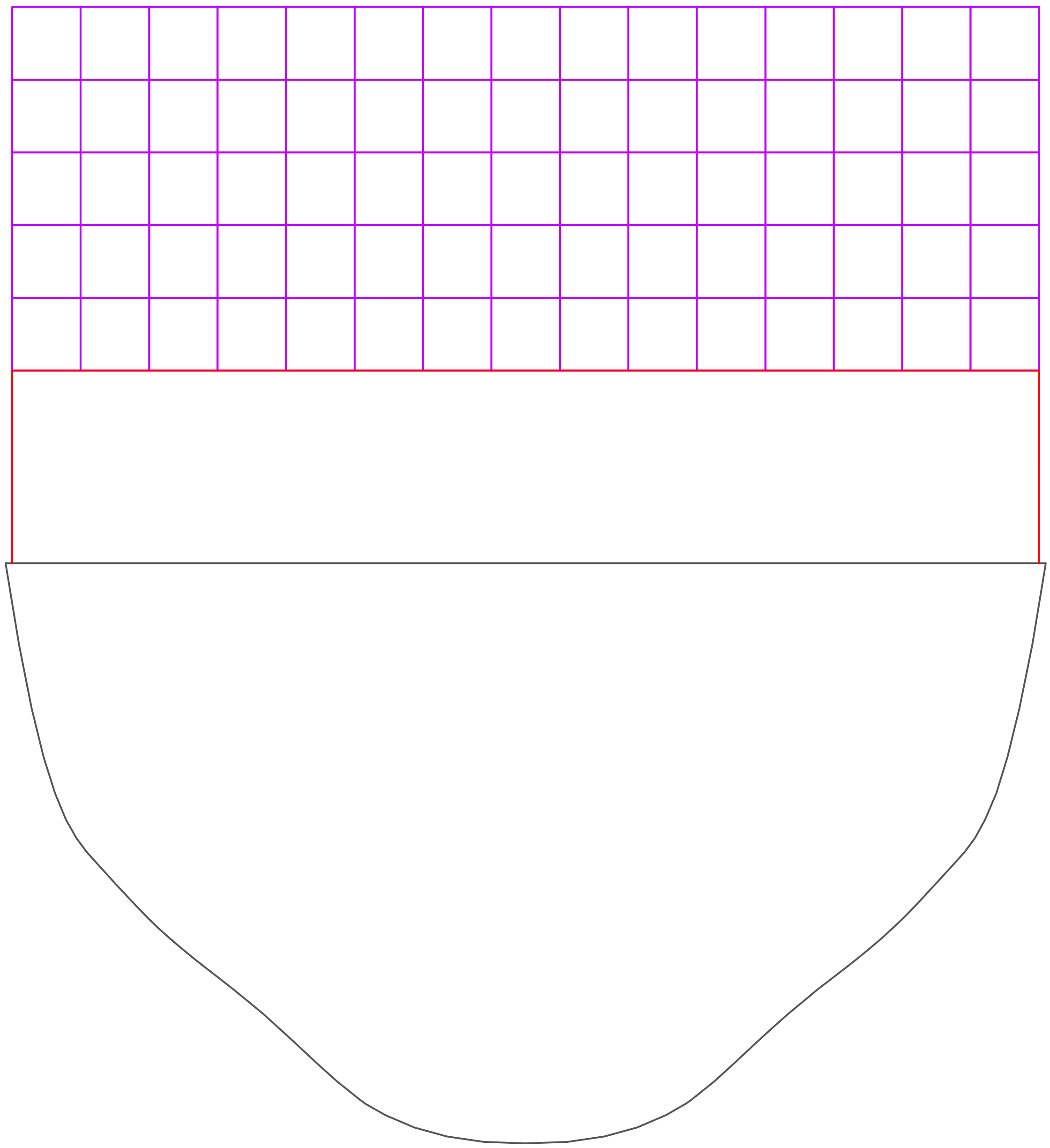


Bay: 42	
On Deck: 73 @ 45' High Cube	
Below Deck: 81 @ 40' High Cube	



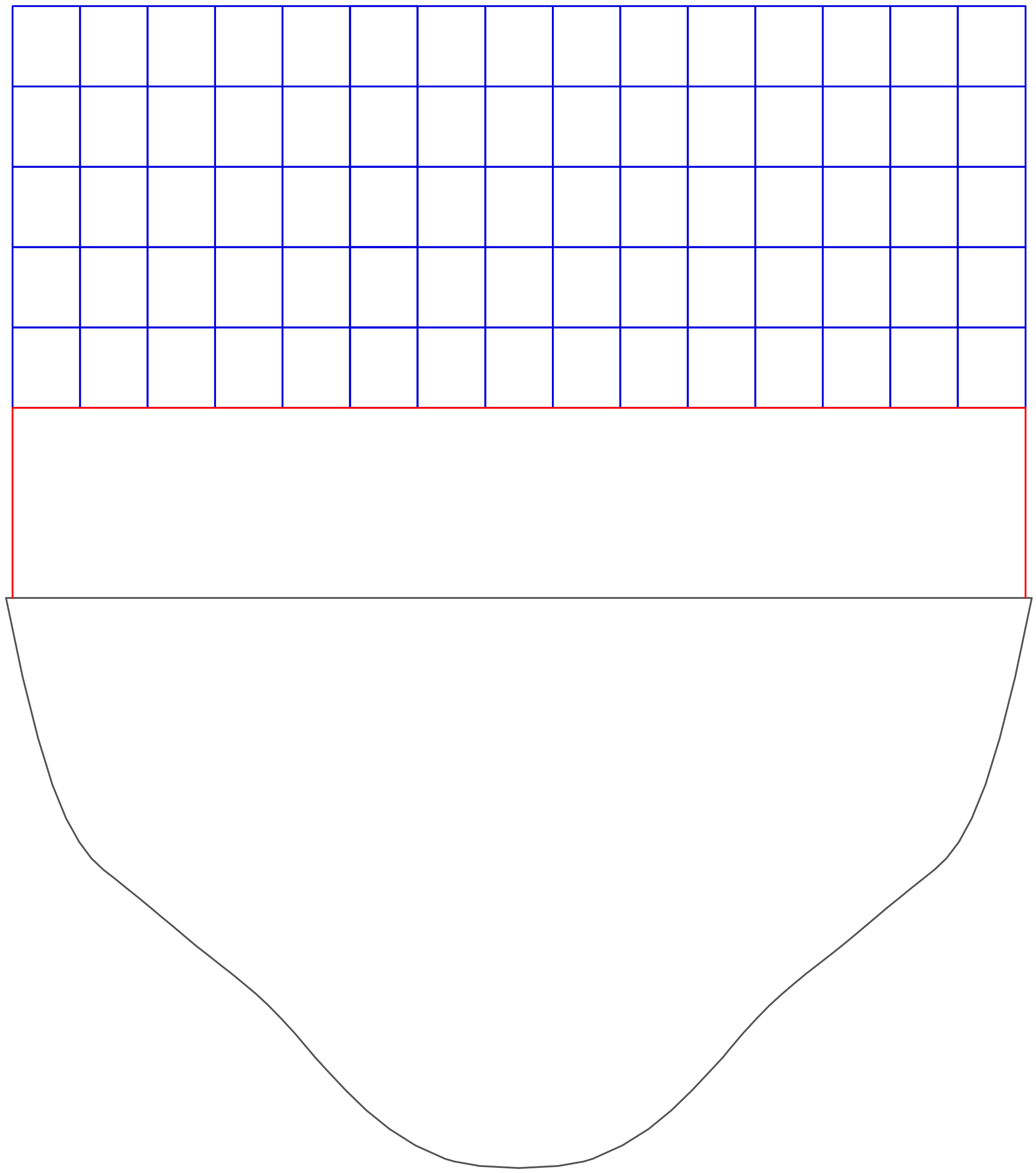
Bay: 46 (All Reefer)
On Deck: 58 @ 40' Standard
Below Deck: 74 @ 40' High Cube

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 13 OF 17 REV 3



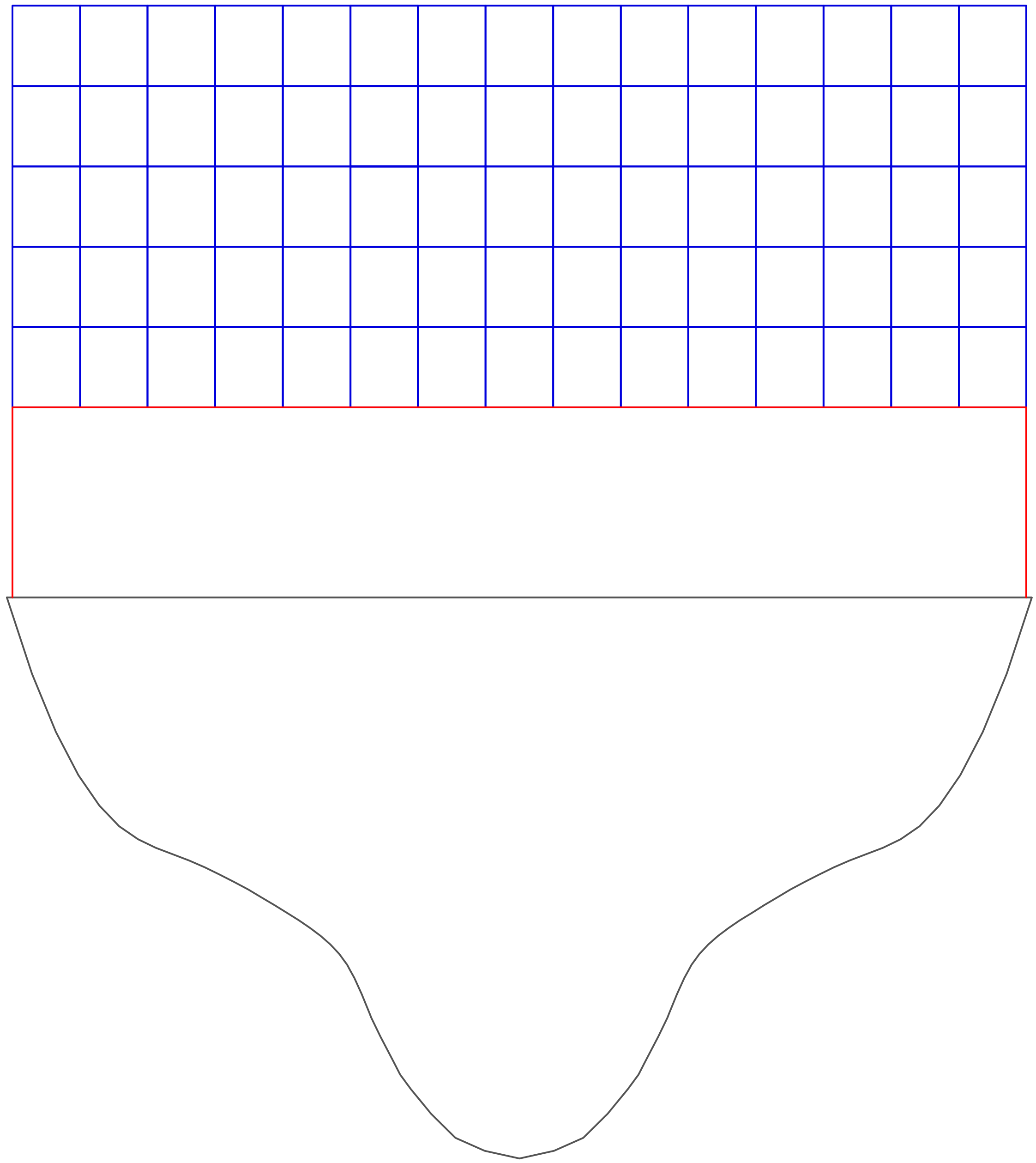
Bay: 48	
On Deck: 75 @ 20' Standard	
Below Deck: 0	

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 14 OF 17 / REV 3



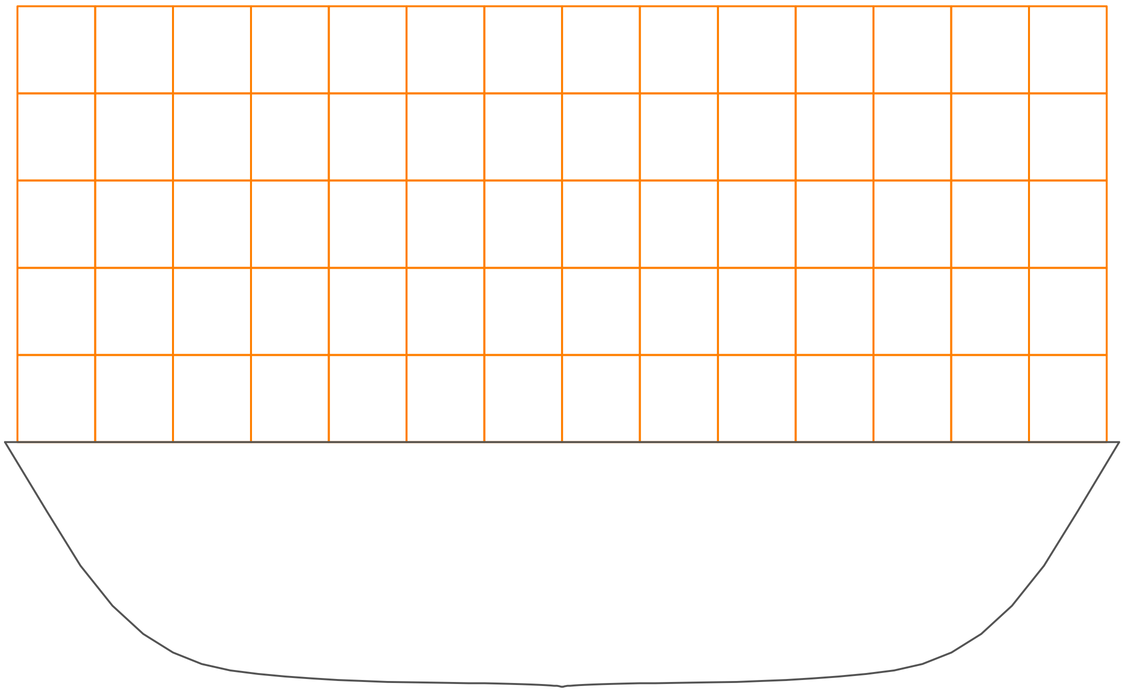
Bay: 50
On Deck: 75 @ 45' High Cube
Below Deck: 0

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 15 OF 17 REV 3



Bay: 52
On Deck: 75 @ 45' High Cube
Below Deck: 0

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 16 OF 17 REV 3



Bay:	54
On Deck:	70 @ 53' High Cube
Below Deck:	0

Bilge Dweller Designs	SUNY MARITIME COLLEGE	HCH- SD III CARGO ARRANGEMENTS	4-2-2024
		SCALE: NTS	SHEET 17 OF 17 REV 3

Appendix K- Tank Capacity Plan

M/V Dweller Tank Plan

Tank	Volume (m^3)	Weight 95% Full (MT)	Weight 50% Full (MT)	Weight 10% Full (MT)	Fluid Type	Density (tonnes/m^3)
LNG	4160	1897	948.5	189.7	LNG	0.48
No. 1 DB SWB P	99.5	102.0	53.7	10.74	Sea Water	1.025
No. 1 DB SWB S	99.5	102.0	53.7	10.74	Sea Water	2.025
No. 1 Lower SWB P	404.2	414.3	218.1	43.612	Sea Water	3.025
No. 1 Lower SWB S	404.2	414.3	218.1	43.612	Sea Water	4.025
No. 1 Upper SWB P	634.7	650.6	342.4	68.485	Sea Water	5.025
No. 1 Upper SWB S	634.7	650.6	342.4	68.485	Sea Water	6.025
No. 2 DB SWB P	270.0	276.7	145.6	29.127	Sea Water	7.025
No. 2 DB SWB S	270.0	276.7	145.6	29.127	Sea Water	8.025
No. 2 Lower SWB P	498.9	511.4	269.2	53.831	Sea Water	9.025
No. 2 Lower SWB S	498.9	511.4	269.2	53.831	Sea Water	10.025
No. 2 Upper SWB P	462.2	473.7	249.3	49.865	Sea Water	11.025
No. 2 Upper SWB S	462.2	473.7	249.3	49.865	Sea Water	12.025
No. 3 DB SWB P	571.3	585.6	308.2	61.638	Sea Water	13.025
No. 3 DB SWB S	571.3	585.6	308.2	61.638	Sea Water	14.025
No. 3 Lower SWB P	499.5	512.0	269.5	53.897	Sea Water	15.025
No. 3 Lower SWB S	499.5	512.0	269.5	53.897	Sea Water	16.025
No. 3 Upper SWB P	359.3	368.3	193.8	38.765	Sea Water	17.025
No. 3 Upper SWB S	359.3	368.3	193.8	38.765	Sea Water	18.025
No. 4 DB SWB P	785.3	805.0	423.7	84.733	Sea Water	19.025
No. 4 DB SWB S	785.3	805.0	423.7	84.733	Sea Water	20.025
No. 4 Lower SWB P	422.9	433.4	228.1	45.623	Sea Water	21.025
No. 4 Lower SWB S	422.9	433.4	228.1	45.623	Sea Water	22.025
No. 4 Upper SWB P	341.1	349.6	184.0	36.802	Sea Water	23.025
No. 4 Upper SWB S	341.1	349.6	184.0	36.802	Sea Water	24.025
No. 5 DB SWB P	725.4	743.5	391.3	78.265	Sea Water	25.025
No. 5 DB SWB S	725.4	743.5	391.3	78.265	Sea Water	26.025
No. 5 Lower SWB P	468.0	479.7	252.5	50.491	Sea Water	27.025
No. 5 Lower SWB S	468.0	479.7	252.5	50.491	Sea Water	28.025
No. 5 Upper SWB P	340.4	348.9	183.6	36.729	Sea Water	29.025
No. 5 Upper SWB S	340.4	348.9	183.6	36.729	Sea Water	30.025
No. 6 DB SWB P	422.7	433.3	228.1	45.61	Sea Water	31.025
No. 6 DB SWB S	422.7	433.3	228.1	45.61	Sea Water	32.025
No. 6 Lower SWB P	774.0	793.4	417.6	83.515	Sea Water	33.025
No. 6 Lower SWB S	774.0	793.4	417.6	83.515	Sea Water	34.025
No. 6 Upper SWB P	384.3	393.9	207.3	41.464	Sea Water	35.025
No. 6 Upper SWB S	384.3	393.9	207.3	41.464	Sea Water	36.025
FPT	970.3	970.3	510.7	102.139	Sea Water	37.025
Potable P	142.5	142.5	75.0	15.0	Fresh Water	1
Potable S	142.5	142.5	75.0	15.0	Fresh Water	1
LO Sett P	24.0	22.1	11.1	1.7	Lube Oil	0.92
LO Sett S	24.0	22.1	11.1	2.2	Lube Oil	0.92
LO Serv P	24.0	22.1	11.1	2.2	Lube Oil	0.92
LO Serv S	24.0	22.1	11.1	2.2	Lube Oil	0.92
Diesel Stor Tank P	142.9	135.0	67.5	28.5	Fuel Oil	0.84
Diesel Stor Tank S	142.9	135.0	67.5	13.5	Fuel Oil	0.84
SUM	22725	20861	10920	2199		

Appendix L – Machinery Arrangements

M/V Dweller Engine Room Equipment

Machinery: Main Engine, Generators, EDG, Transformers, and Distribution Switchboard

Air System: Start Air, Control Air, Deck Air, and Emergency Air Compressors, Cross-Over, and Receivers

Fuel Oil: Storage Tanks, Day Tank, Bunkering Station, Fuel Oil Transfer and Storage Pumps, FO Heaters and Coolers, and Fuel Oil Purifiers

Lube Oil: Lube Oil Storage and Settling Tanks, Bunkering Station, Lube Oil Transfer and Service Pump, Coolers and Heaters, and Circulation Pump

Cooling Water: Heat Exchangers, Circulation Pumps, Head Tanks for HT and LT Cooling Systems

Saltwater: Saltwater Main, High and Low Sea Chest, and Saltwater Pumps

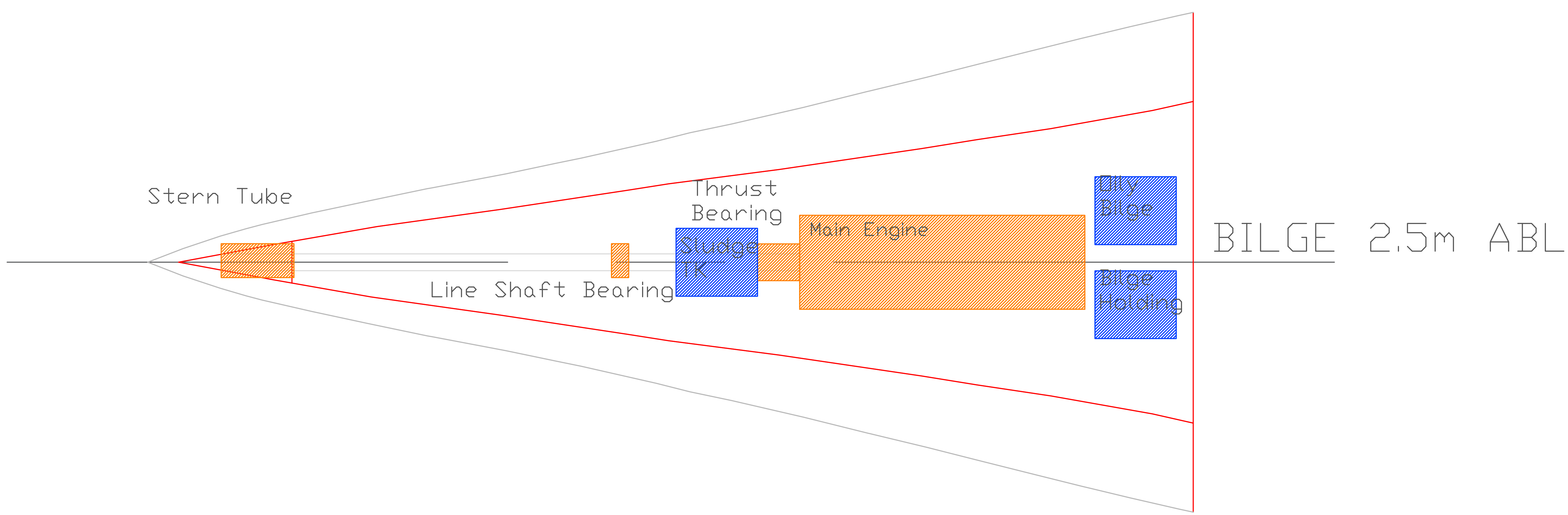
Bilge: Bilge Wells, Bilge Pumps, and Bilge Storage Tank

Waste Management: Incinerator, Sludge Tank, Grey/Blackwater Pumps, and MSD

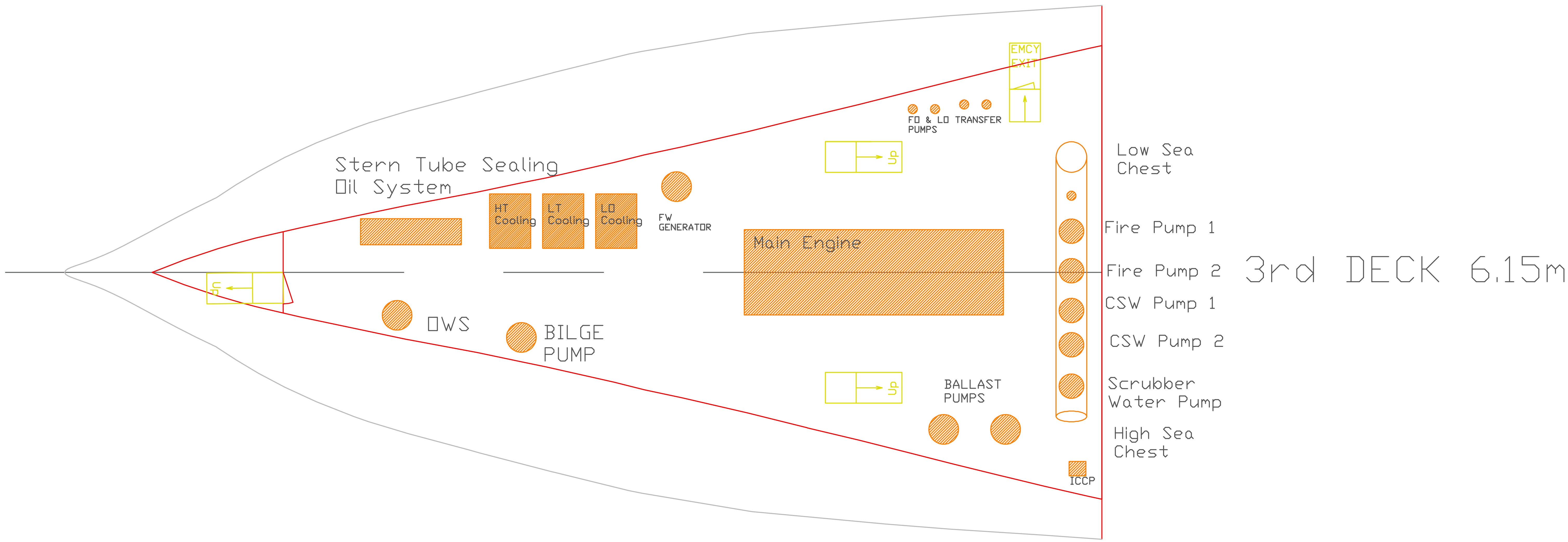
Misc: ICCP, Shaft Bearing and Sealing, and Steering Gear Equipment, Fire Pumps, Watermaker, CO2 Static Firefighting System, Water Mist System

HVAC: Compressors, Reefer Refrigeration Equipment, and AHU

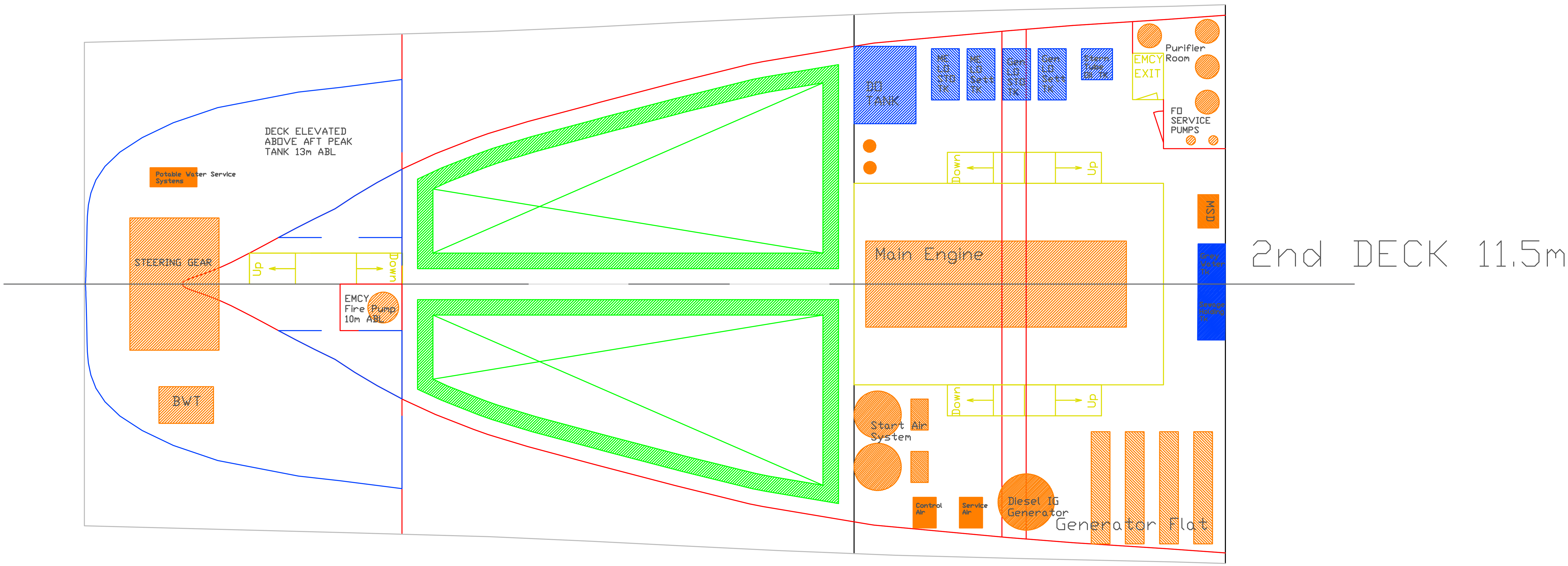
LNG Equipment: Gasification Plant, Nitrogen Inert Gas System, Diesel Inert Gas System, Water Cascade, Reliquification Plant, and Ventilation and over-pressurization system



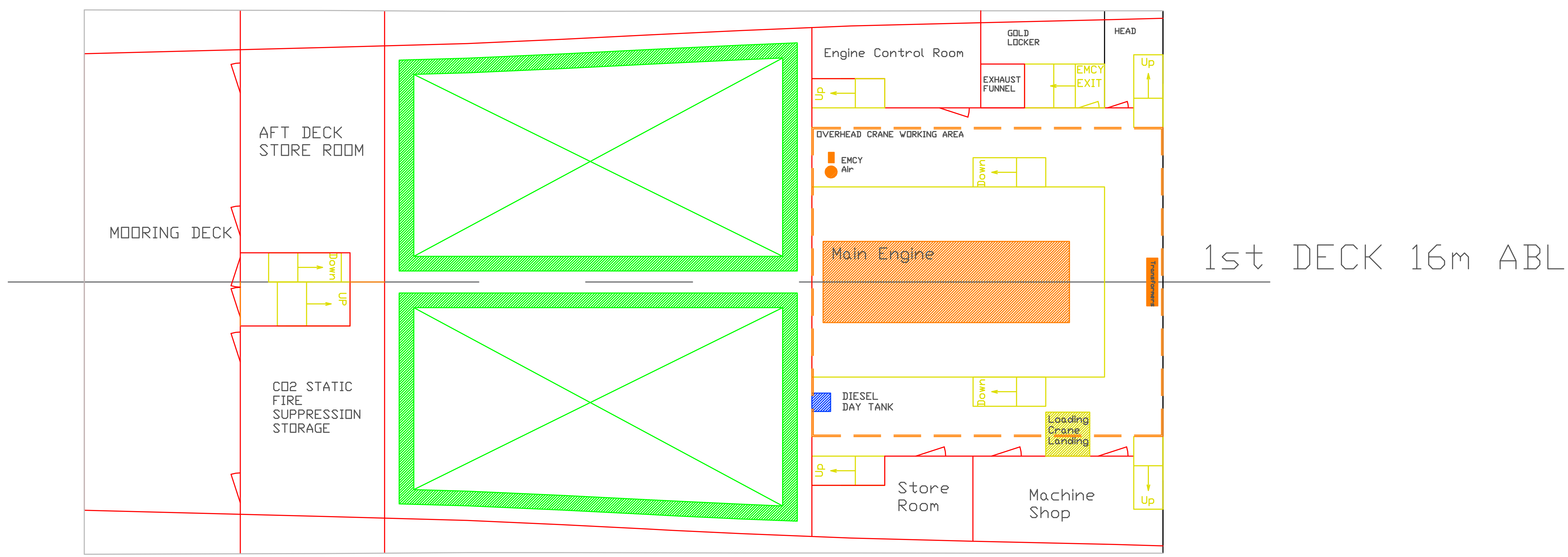
Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	ENGINE ROOM ARRANGEMENT 2.5m ABL	5-10-2024	
		SCALE: NTS	SHEET 1 OF 5	REV 3



Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	ENGINE ROOM ARRANGEMENT 6.15m ABL	5-10-2024	
		SCALE: NTS	SHEET 2 OF 5	REV 3



Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	ENGINE ROOM ARRANGEMENT 11.5m ABL	5-10-2024	
		SCALE: NTS	SHEET 3 OF 5	REV 3



Bilge Dweller Designs ©

SUNY MARITIME COLLEGE

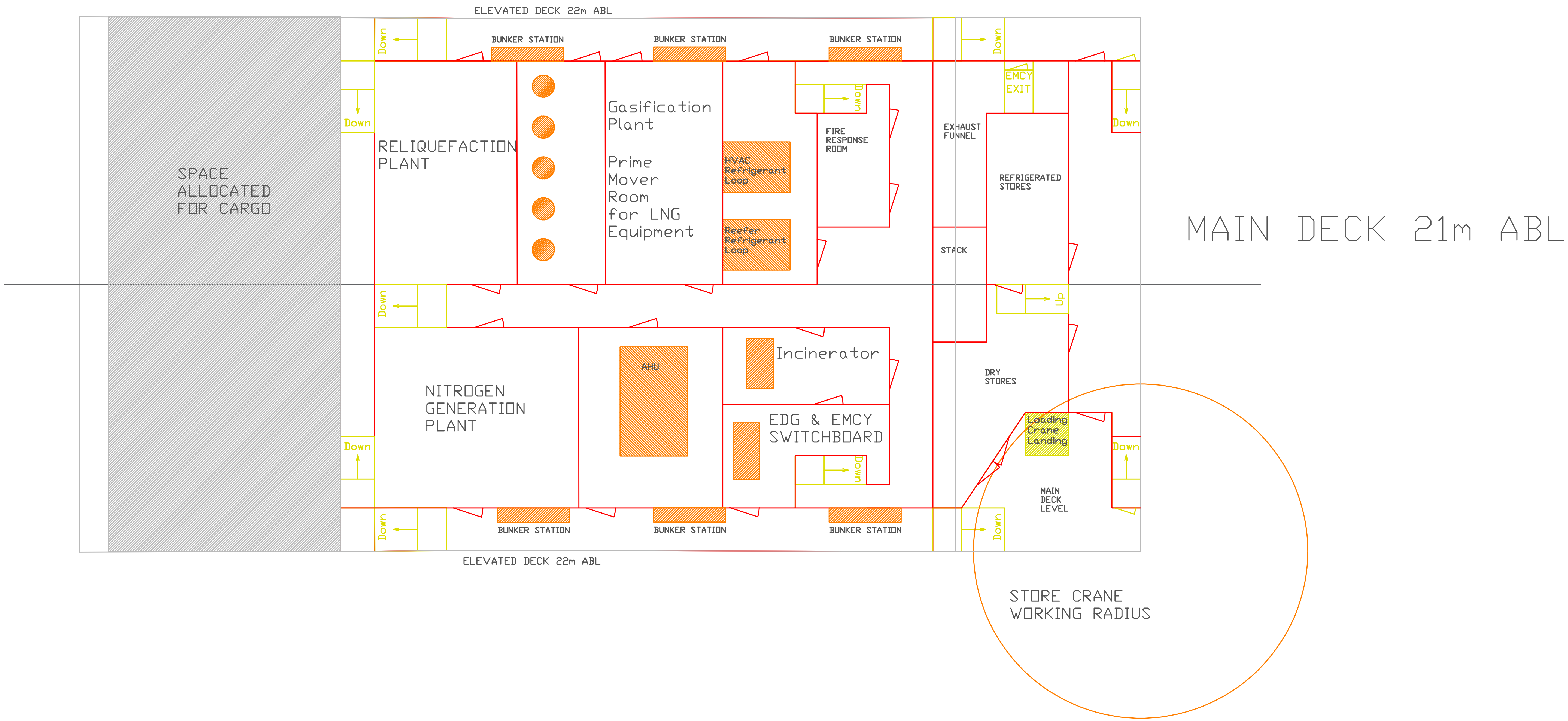
ENGINE ROOM ARRANGEMENT 16m ABL

5-10-2024

SCALE: NTS

SHEET 4 OF 5

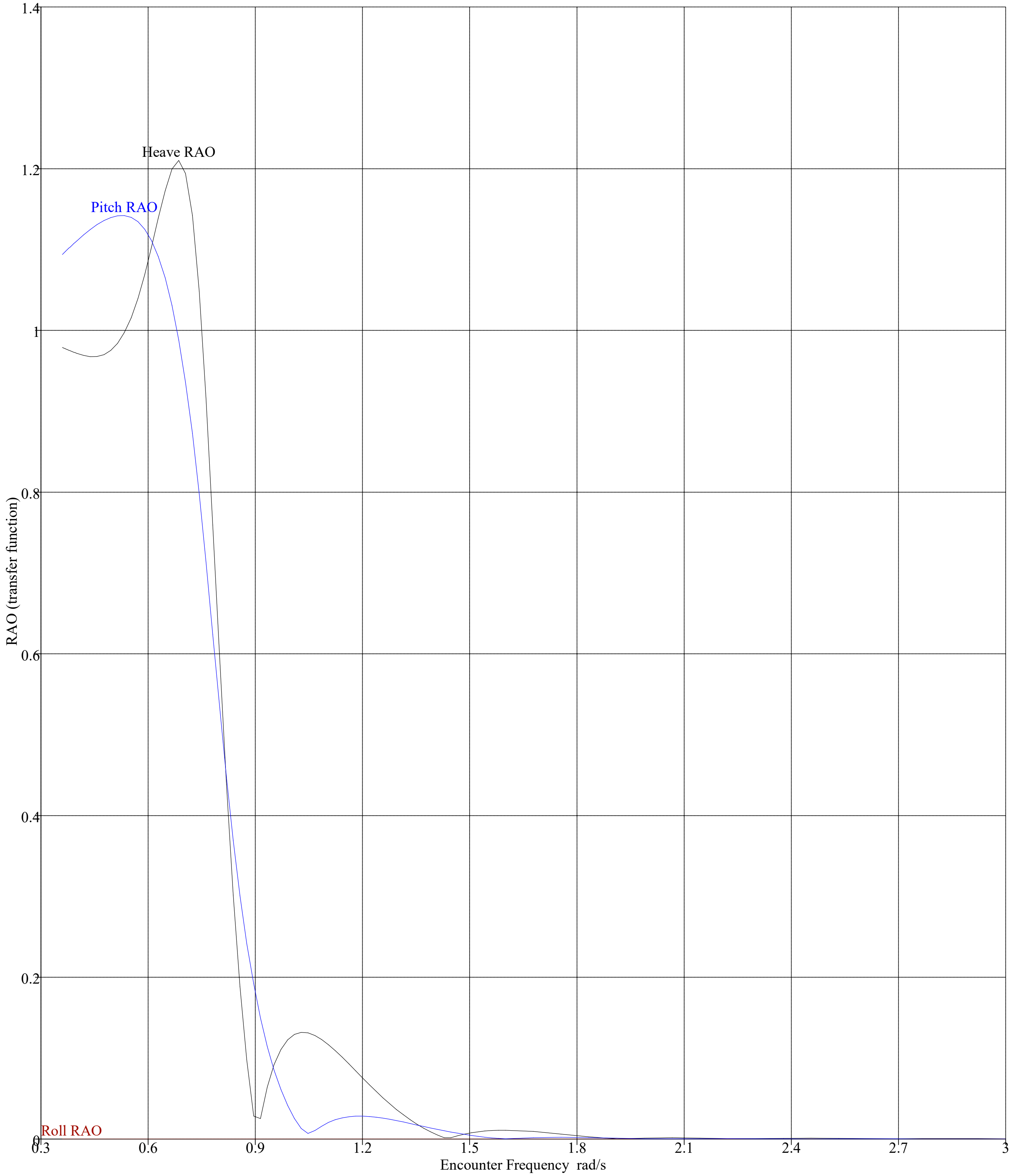
REV 3



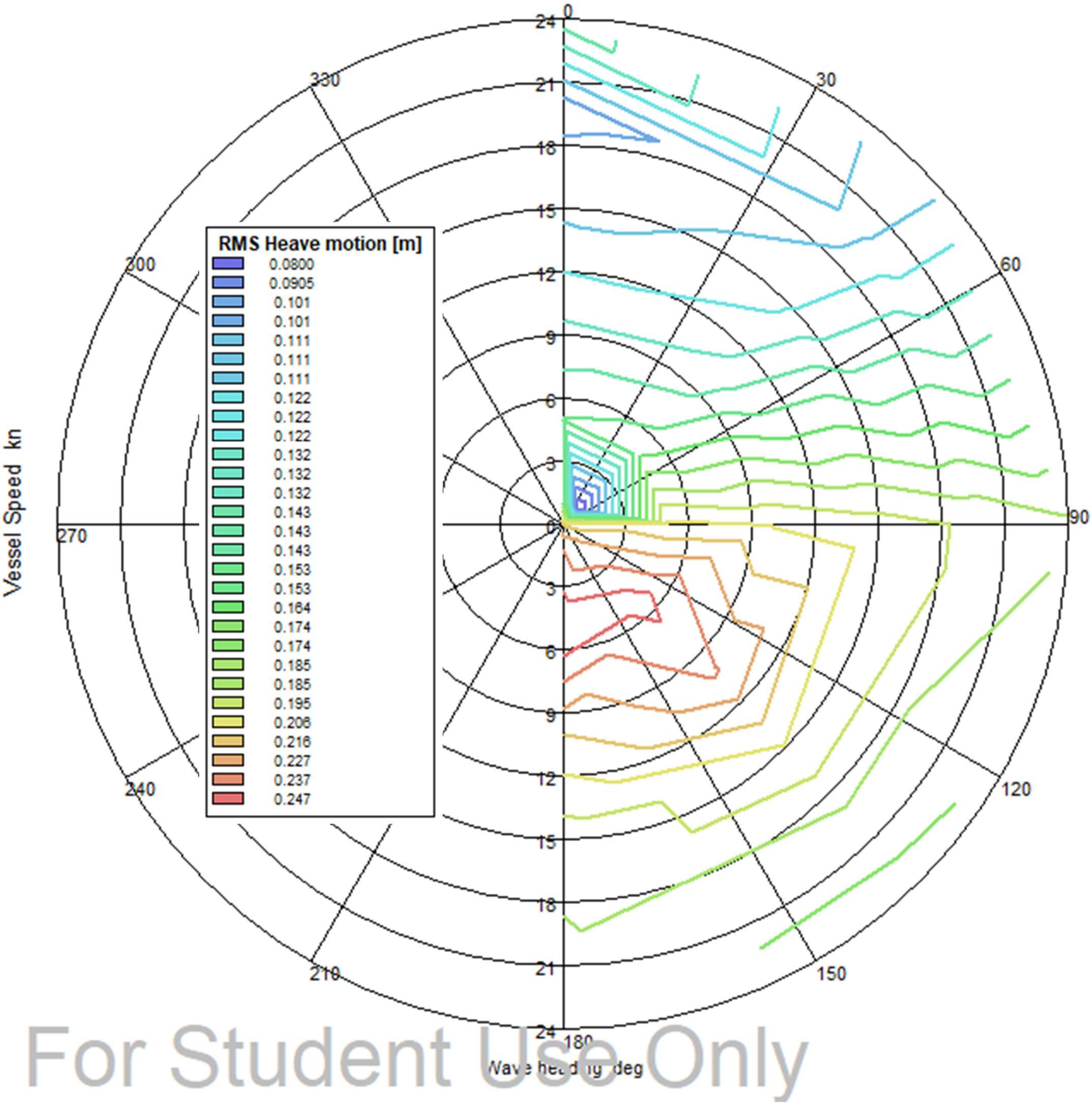
Bilge Dweller Designs ©	SUNY MARITIME COLLEGE	ENGINE ROOM ARRANGEMENT 21m ABL	5-10-2024
		SCALE: NTS	SHEET 5 OF 5 — REV 3

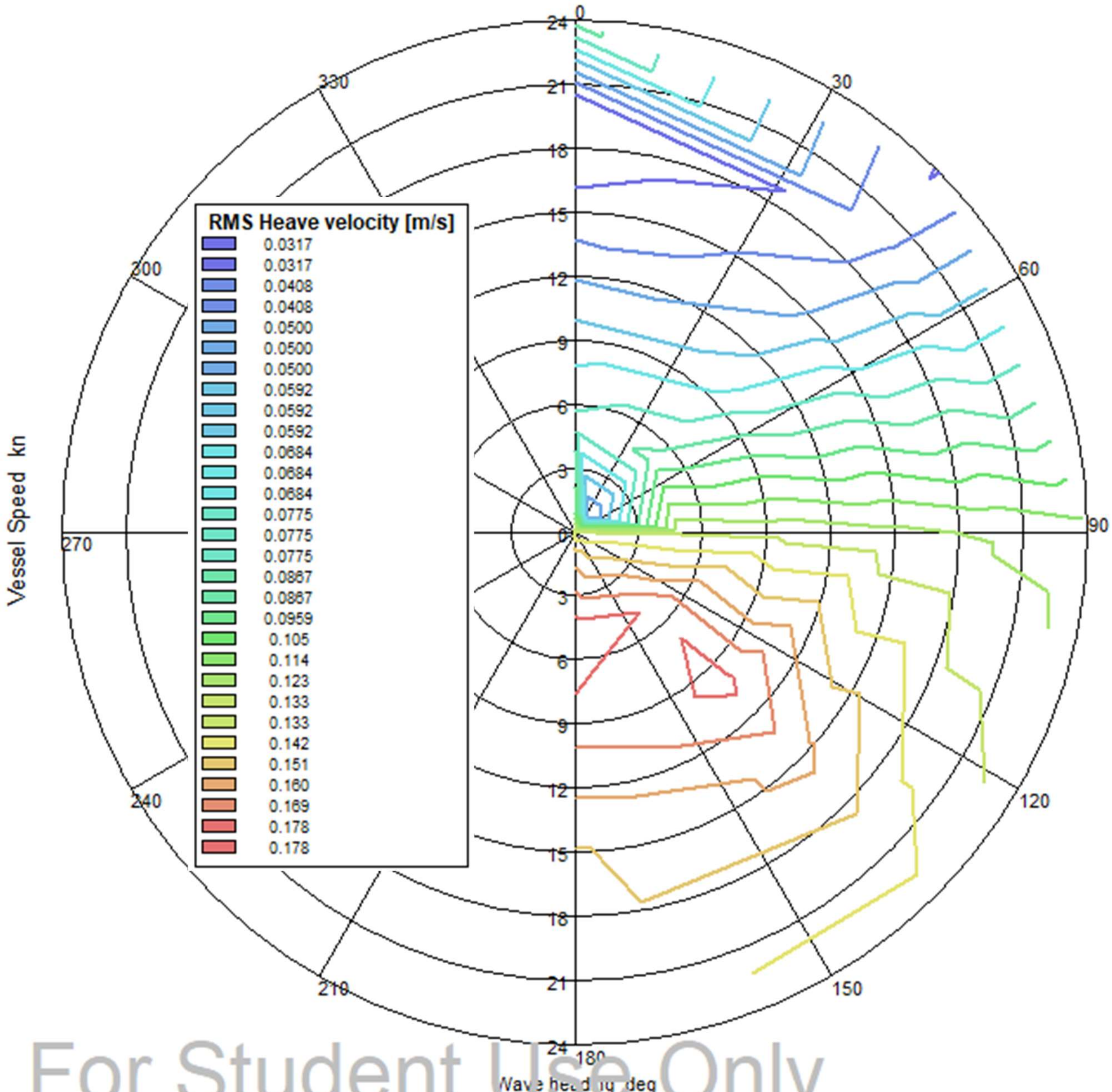
Appendix M – Seakeeping Analysis

RAO Graph

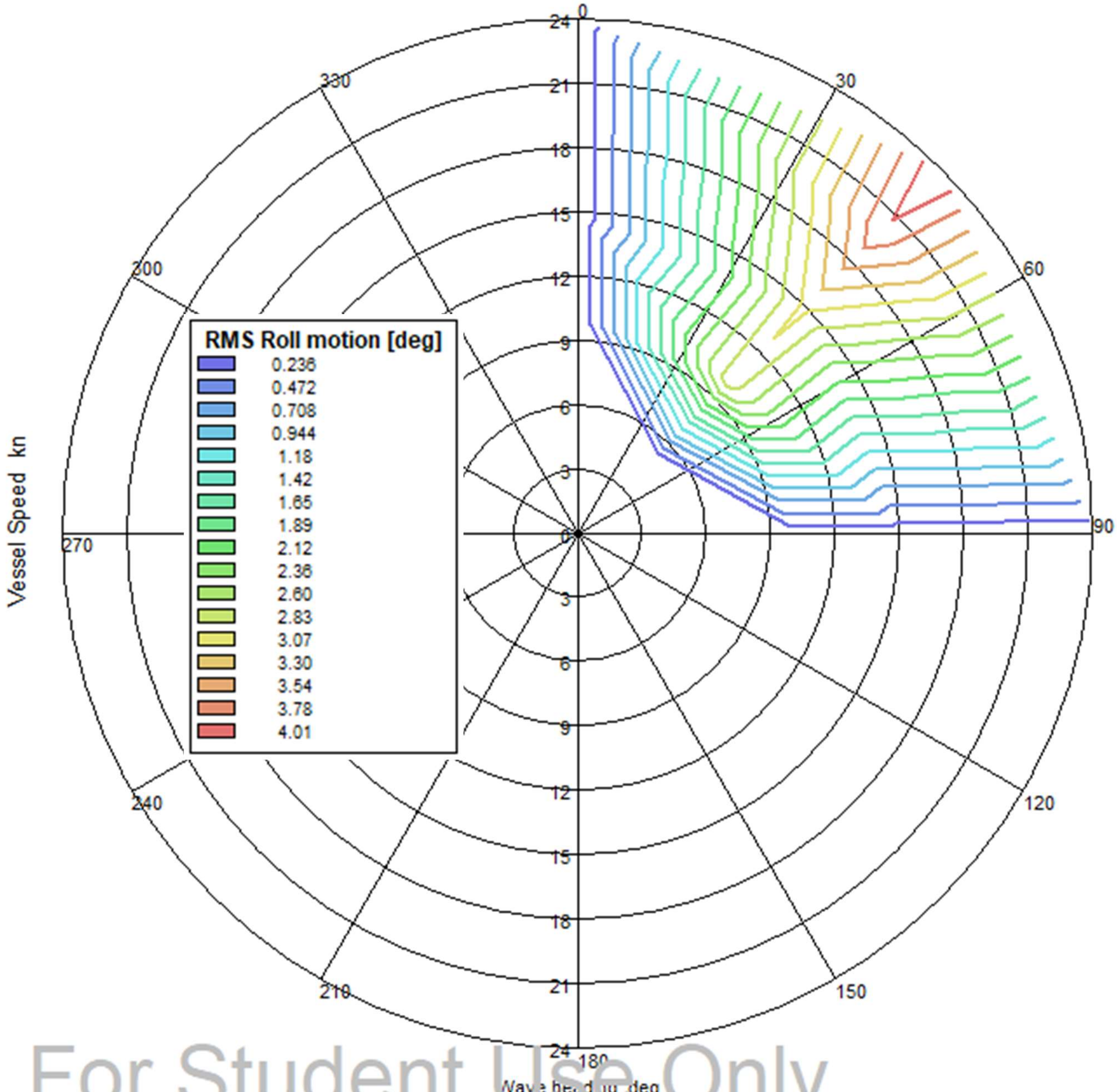

Heave RAO
Pitch RAO
Roll RAO
RAO (transfer function)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3
Encounter Frequency rad/s

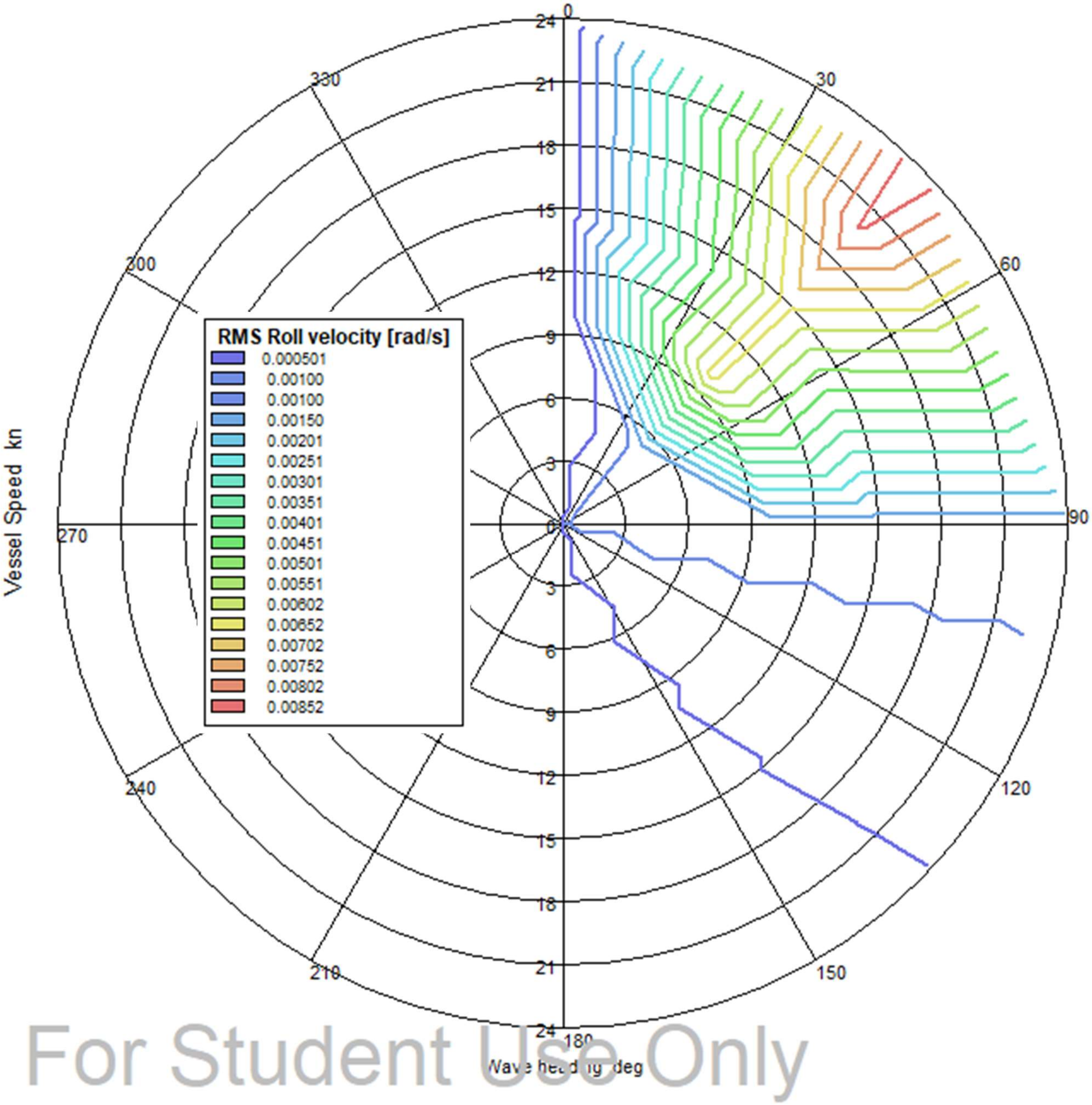
Heave Motion & Velocity



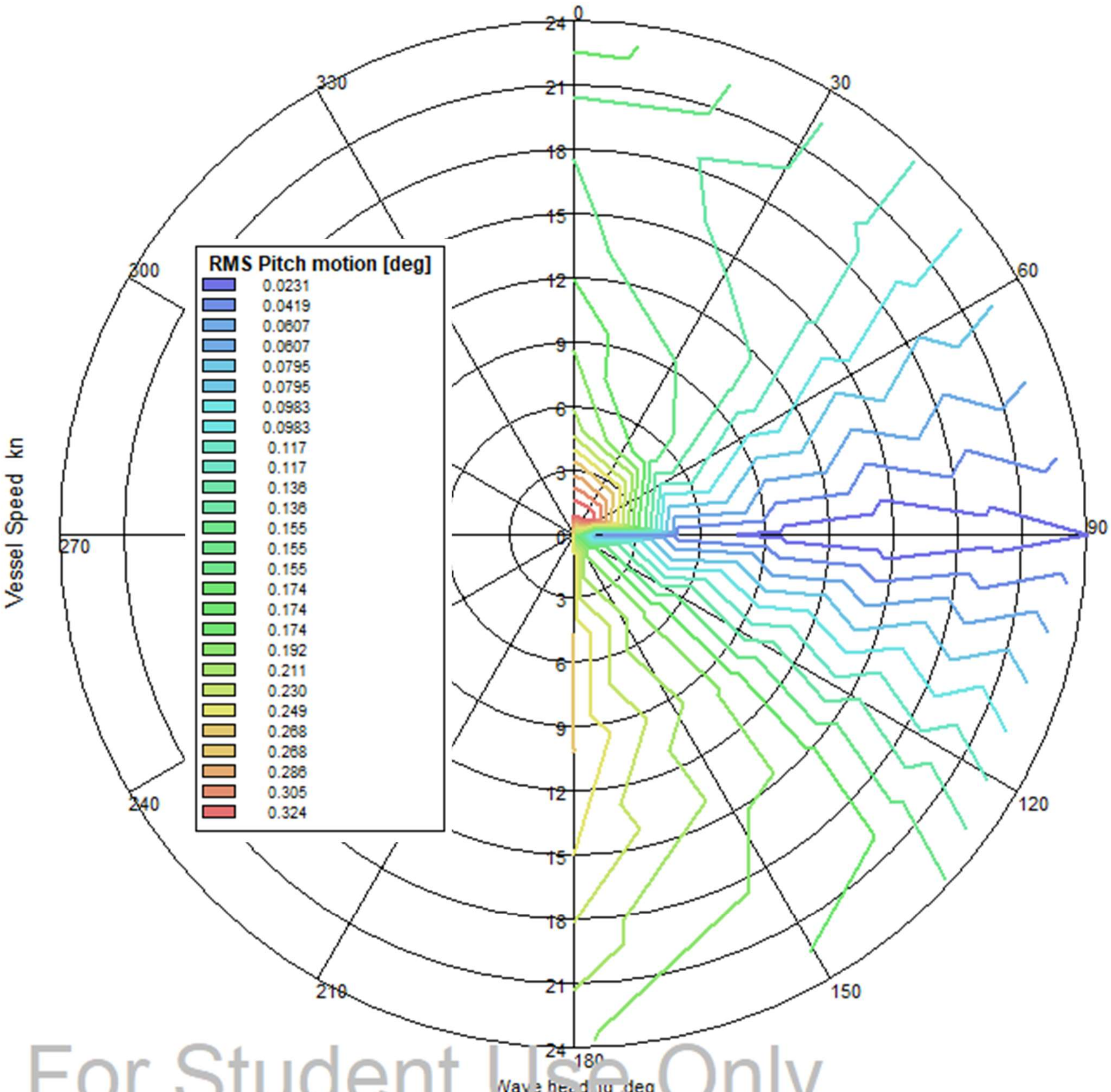

RMS Heave velocity [m/s]
0.0317
0.0317
0.0408
0.0408
0.0500
0.0500
0.0500
0.0592
0.0592
0.0592
0.0684
0.0684
0.0684
0.0775
0.0775
0.0775
0.0867
0.0867
0.0959
0.105
0.114
0.123
0.133
0.133
0.142
0.151
0.160
0.169
0.178
0.178
Vessel Speed kn
Wave heading deg
0
30
60
90
120
150
180
210
240
270
300
330
0
3
6
9
12
15
18
21
24

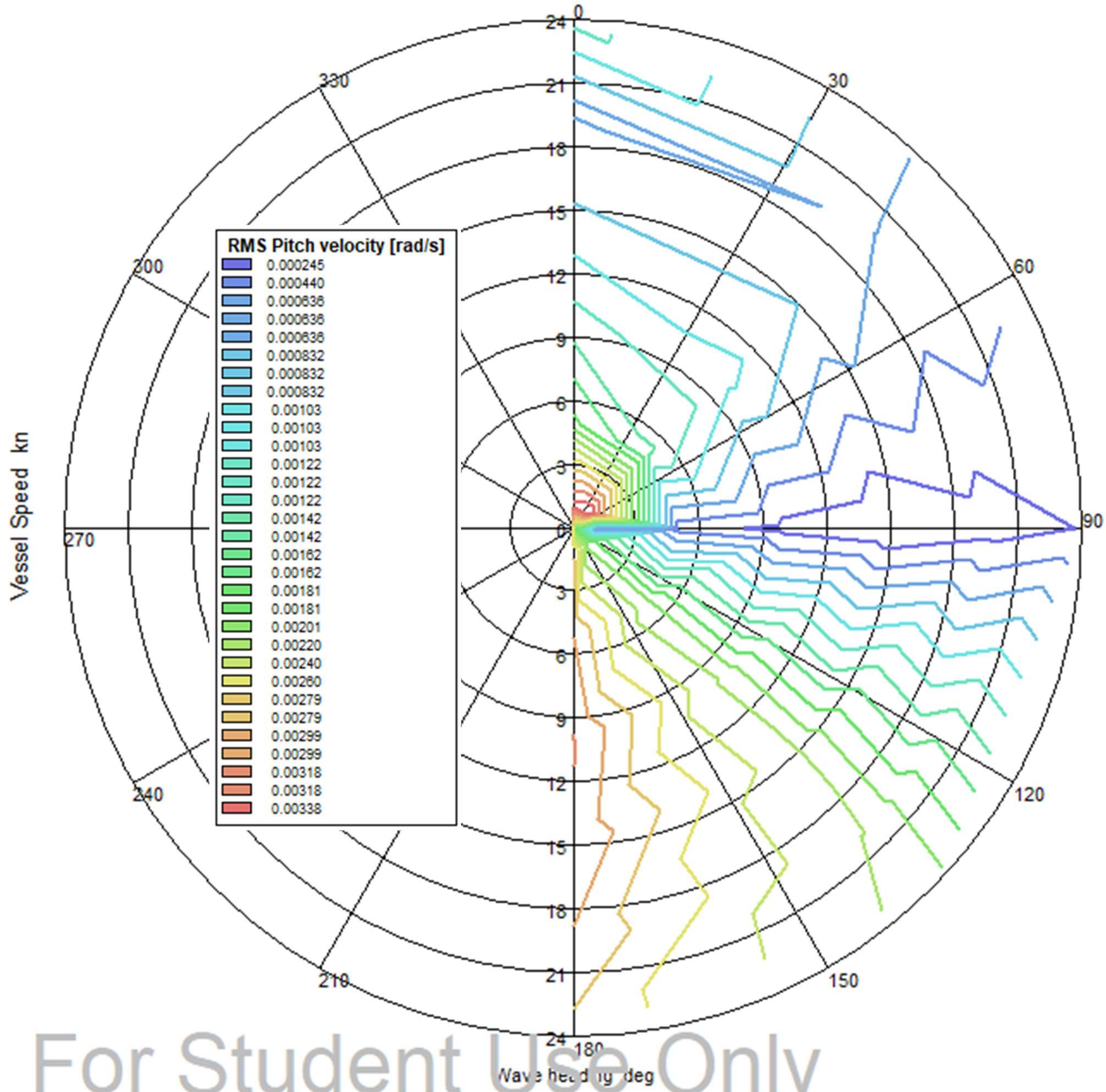
Roll Motion & Velocity




RMS Roll velocity [rad/s]
0.000501
0.00100
0.00100
0.00150
0.00201
0.00251
0.00301
0.00351
0.00401
0.00451
0.00501
0.00551
0.00602
0.00652
0.00702
0.00752
0.00802
0.00852
Vessel Speed kn
Wave heading deg
0
30
60
90
120
150
180
210
240
270
300
330

Pitch Motion & Velocity





RMS Pitch velocity [rad/s]
0.000245
0.000440
0.000636
0.000636
0.000636
0.000832
0.000832
0.000832
0.00103
0.00103
0.00103
0.00122
0.00122
0.00122
0.00142
0.00142
0.00162
0.00162
0.00181
0.00181
0.00201
0.00220
0.00240
0.00260
0.00279
0.00279
0.00299
0.00299
0.00318
0.00318
0.00338
Vessel Speed kn
Wave heading deg
0
30
60
90
120
150
180
210
240
270
300
330