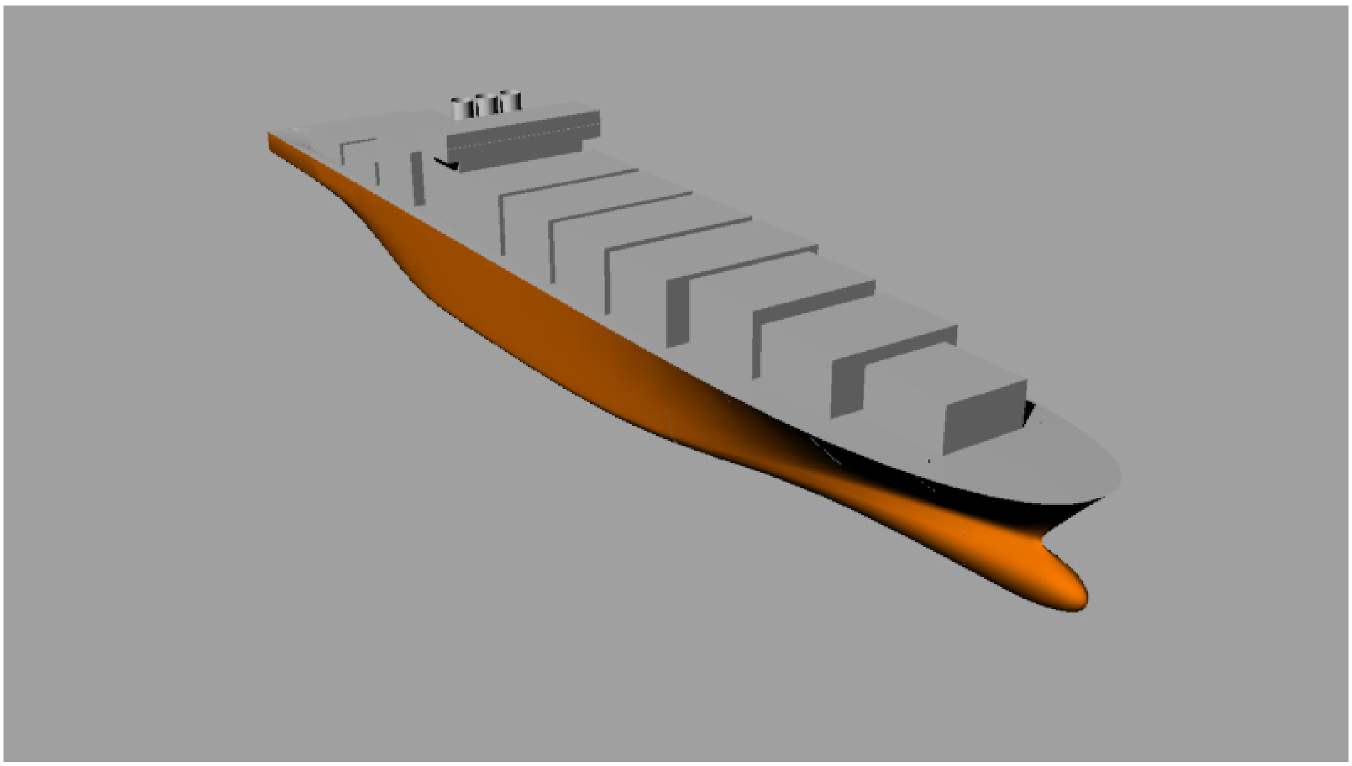
The SS Steel Ducky



Perfection Without Compromise

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December 21, 2020

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1. Executive Summary

Marine transportation is an incredibly important industry in the world that is undeniably the fuel of the modern global economy. Massive unrelenting amounts of trade between giant economic superpowers oceans apart and wars waged from oceans away, have forced the world into a massive steel ship building competition. Especially after the innovation of the standard TEU, the importance and scale of effect container-ships have on the world's population is unfathomable.

With the ever-growing competition a good ship will now not only need to meet the requirements given by the customer, but it will need to be extremely reliable and have a long lifespan. *SS Steel Ducky* is a container ship that keeps this in mind. It is designed to carry 3,500 twenty-foot equivalent unit (TEU) containers along the popular and important trade route between Los Angeles, United States and Shanghai, China. The design was made under the assumption of uniform loading conditions of 12 and 14 tons TEU. This route is approximately 5,800 nautical miles and the ship is designed to complete this route at 20 knots and refuel/restock at the destination. The design is made to meet all the relevant American Bureau of Shipping ABS requirements, which also served as a guide in the design process.

The hull design was configured from a University of Michigan parent hull and parametrized to meet the requirements in the most cost and speed effective way. Initially, this was done through regressions of previous ships with specific attention paid to standard error, but final dimensions were settled on in order to optimize length and stability while still meeting the requirements. The ship was designed to not have permanent ballast at a full load condition, but it does have ballast tanks on the bottom to maintain stability when the load is not full. Table 1.1 contains a summary of the important values of the design.

Table 1.1: Summary of important information for the *SS Steel Ducky* .

Parameter	Value
Length Overall (LOA)	265 m
Length on Water Line (LWL)	250 m
Beam	40.5 m
Draft	11 m
Depth	20.12 m
Block Coefficient (C_b)	0.661
Displacement	75502 tonnes
Design Speed	20 knots
Power	27692.7 KW
TEU Capacity	3500
Range	5700 nm
Endurance	12 days
Accommodations	24 crew

Design programs provided by the University of Michigan influenced the choice of propeller, ideal propeller RPM and necessary power. These results were centered around the required speed 20 knots. 79 RPM was found to be the ideal rotation for the propeller.

Due to the short length of the ship and narrow beam, the necessary propulsion is relatively low for a cargo ship at approximately 19,400 kW to turn the propeller at is optimal RPM of 79. This allows for more availability of cargo, and has allowed the engine to be optimally operated at a large range of higher speeds and lower speeds to adjust for necessary maneuvering.

A low speed WinGD-Diesel engine was selected as the prime mover. The 8 cylinder WinGD X72-B allows the engine to operate in an optimal capacity while still spinning the propeller at the optimal 78 RPM. The power needed to be generated by the engine is 27692.7 kW, the engine chosen can go up to 28851 kW while still performing at an optimal level. Further, it has an output range of up to 31360 kW but it will begin to operate less efficiently. This is very good compared to previous designs as it is a low amount of power and as a result the engine will not weigh as much. This is useful because it will allow the customer to make up for any unexpected delays during certain aspects of the trip such as offloading.

In order, to meet the required capabilities of the ship the generator must provided power for 400 containers which are to be refrigerated requiring 440V plugs and 4.75kW per container, requiring a total of 1,500 kW. The generator will have to provide 1079 kW for auxiliary loads besides refrigeration. This means that the generator will have a total power requirement of 2,979 kW. This was after applying a 33% service marigin. Two Wartsila Genset 20 9L20 were chosen to fulfill this requirement. A smaller emergency Wartsila

Ballast tanks and cargo bays were placed with the thought of the bulkheads in mind, and keeping the ship even whilst bringing down center of gravity. The bulkheads were arranged to follow ABS standards with the forward collision bulkhead at a placing determine by ABA requirements (12.5.2). This will ensure easier design of the ship and the safety of the cargo and crew in multiple damage cases.

As specified by the owner's requirements the vessel was tested and analyzed with departure and arrival conditions of a 14 ton and 12 ton TEU loadcases. The stability for each case was compared to the USCG stability requirements. The *SS Steel Ducky* was found to pass intact stability requirements for each load case however in a damage scenario the ship does not meet some regulations in the 14 ton arrival and departure load cases, this will have to be adjusted in future work on the design.

In order to test for damage stability capabilities, 25 load cases were run on the 12 ton TEU departure load case. This included 13 on single hull flooding and 12 on adjacent hull flooding. In this load case it was found that each test case met the USCG and SOLAS requirements. However, because of an initial problem with trim, the containers weight on the ship was shifted towards the center and the VCG was raised as containers were stacked. For this reason, the 14 ton loadcases do not meet USCG requirements in all damage scenario's.

To meet ABS structural requirements, a midship section design was developed and longitudinal strength analysis was done. However, this full analysis is incomplete and does not yet show that the *SS Steel Ducky* meets ABS structural requirements in still water bending moments and wave induced bending moments, this will also have to be addressed in future design work. At this point the midship section is designed well to handle the moments that were received from the longitudinal strength analysis when compared to ships of a similar operating characteristics.

The initial arrangement plans show that the *SS Steel Ducky* has more than enough room to hold 3500 containers. The initial container placement design should be reconsidered in future work to assure that the ship meets stability requirements for each load case from the necessary regulatory bodies. The height of the deck house was based on ABS visibility requirements, and the ship comfortably passes the minimum visibility requirements set forth by ABS with 503 meters of visibility from the deck house to the waterline. Currently, the *SS Steel Ducky* has not been analysed for hull frequency or seakeeping, this will also need to be done in future work. A seakeeping analysis will have to be done to determine roll, pitch, and heave motions and accelerations, and it should be tested against NORDFORSK criterion.

The preliminary cost analysis shows that the build cost will be approximately $195.68 million dollars. This a cost effective design when compared to other ships with similar principle characteristics. The cost can be decreased by decreasing the overall length of the ship. This is feasible due to the current choice of container placement.

Safety was a priority when designing the *SS Steel Ducky* . Regulations from the American Bureau of Shipping (ABS), United States Coast Gaurd (USCG), Lloyd's Register, MARPOL, and the International Maritime Organization, were researched and followed to guide the design of the *SS Steel Ducky* . The name of the ship was inspired by the event in 1992 when 28,000 rubber ducky's fell off of a container ship on the path between the USA and China. This event provided scientists studying ocean currents with valuable information.

2. Technical Summary

This section details the technical aspects of the Steel Ducky's design and why the design choices were made. Container ships are regulated by many different organizations the following are the regulatory bodies and regulations that informed the design of the Steel Ducky: American Bureau of Shipping (ABS), United States Coast Guard (USCG), Lloyd's Register, MARPOL, the Jones Act, and the International Maritime Organization (IMO). This is a brief summary of important aspect of the design all aspects are expanded on to the necessary level of detail in their respective sections.

2.1 Requirements

The customer required The Steel Ducky to have a total load of 3500 TEU. These were meant to be loaded under two homogeneously loaded conditions of containers that weigh 12 tons and 14 tons. 400 containers were required to be refrigerated using 440 V plugs and 4.75 kW of power for each container. This ship must operate on the 5,800 journey from LA to Shanghai. A one way trip was considered as the ship will be reloaded on each end of the trip. Because the ship will fly under the United States flag it is designed to meet all ABS standards.

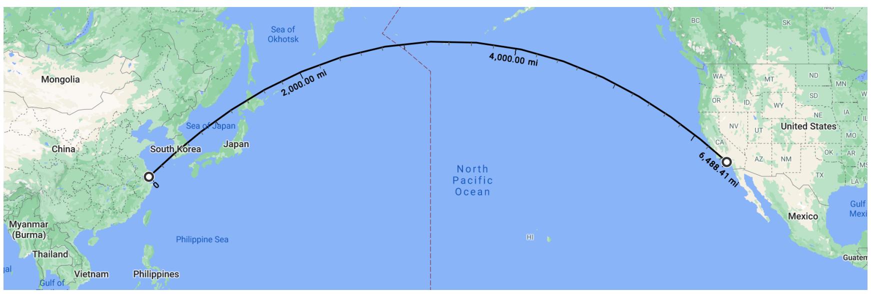


Figure 2.1: The required path of *SS Steel Ducky* .

2.2 Principal Dimensions

Determining the principal characteristics of the *SS Steel Ducky* , was a process that began by using regression on a database of ships. This process is expanded on in the Initial Point Design section. Following this, the principal dimensions were adjusted to make sure that the ship would be able to float in a stable manner in the water while meeting all the requirements. This process was made shorter by allowing the beam to be large, and then quickly being able to find a good value for length. This was tested with weight analysis. As a result three ships were iterated through before determining these final values. Table 2.1 shows these values.

Table 2.1: Summary of important information for the *SS Steel Ducky* .

Parameter	**Value**
Length Overall (LOA)	265 m
Length on Water Line (LWL)	250 m
Beam	40.5 m
Draft	11 m
Depth	20.12 m
Bloc Coefficient (C_b)	0.661
Displacement (Δ)	75502 tonnes
TEU Capacity	3500

2.3 Hull Design

The hull form was created by adjusting the parent hull given by the University of Michigan, to the desired characteristics. This was done using the *Maxsurf Modeler*. The length 250 m is quite short compared to all cargo ships and allows for great maneuverability, while the beam 40.5 m ensures transverse stability. The block coefficient 0.611 allows all the containers to be fit in without compromising efficiency. The initial hull lines from *Maxsurf Modeler* are shown in the following figures. Figure 2.2

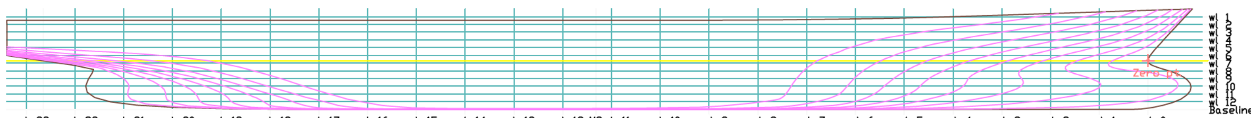


Figure 2.2: Profile Plan

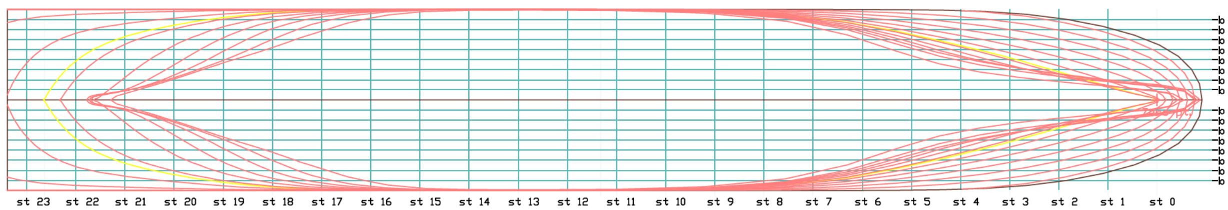


Figure 2.3: Waterlines

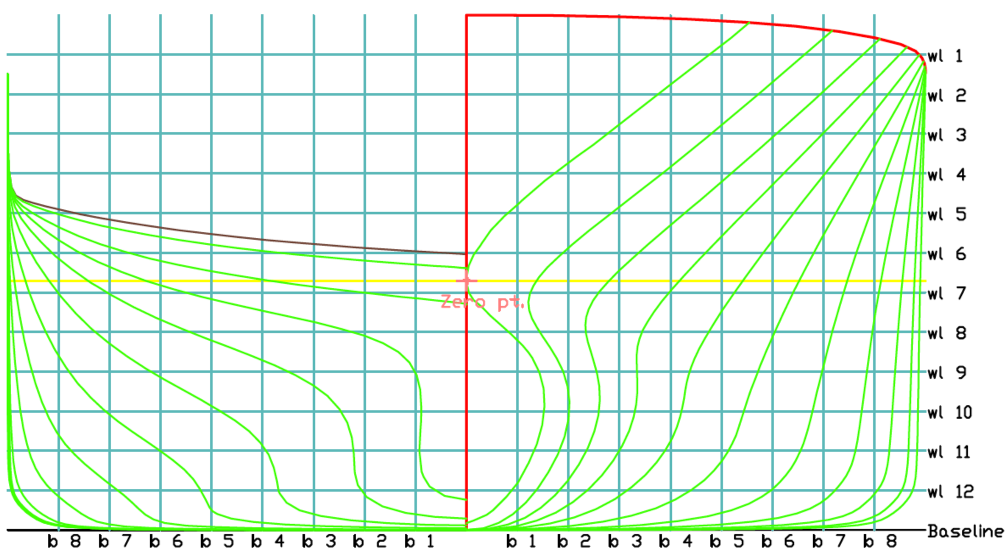


Figure 2.4: Stations

2.4 General Arrangements

The *SS Steel Ducky* 's general arrangements were designed so that all of the requirements concerning accommodations were met while still making a safe environment for workers to live and work in. Obviously, the most important aspect is the cargo that needs to transported and that the ship meets safety standards. This educated the position of the engine room, deck house, and cargo bays. Ballast tanks and cargo bays were placed with the thought of the bulkheads in mind, and keeping the ship even whilst bringing down center of gravity. The bulkheads were arranged to follow ABS standards with the forward collision bulkhead at a placing determine by ABS requirements (12.5.2). The height and placement of the deck house ensures compliance with the ABS visibility requirements. While the general arrangements are not fully completed the present designs are shown in figure 2.5. The *SS Steel Ducky* has 2 meter wide passage ways along both whole sides of the ship and containers are stacked to a maximum height of 5 containers. They are stacked 14 transversely until the fore of the ship were space is limited. The deckhouse was designed to meet living requirements of the crew and is also located directly above the machinery which allows for easy access to the cargo and the machinery. The owner required that 400 containers be refrigerated, in order to keep the design cheap and easier to manufacture this containers were grouped and put in the cargo bay adjacent to the machinery rooms.

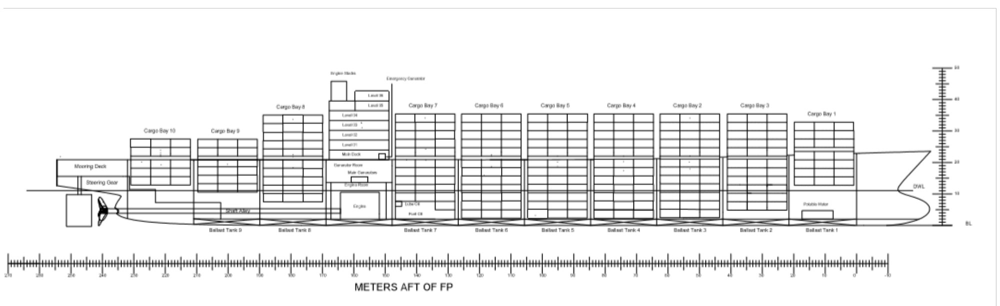


Figure 2.5: General Arrangement Drawing-Side Profile View

2.5 Propeller Selection

The POP was used to determine the design of the optimal design of the propeller and the optimal operational conditions for the propeller. The Lloyds Register was used to make sure the stern geometry and appropriate clearances were met.

The diameter was chosen to be 9.00 meters. This large diameter allows for a less power consuming optimal run conditions and meets the necessary clearances. Further, this will allow for increased torque which will increase the maneuverability of the *SS Steel Ducky* . The table below 2.2 gives a brief summary of the design aspects of the propeller settled on.

Table 2.2: Summary of POP results.

Parameter	**Value**
Propeller Type	Wageningen B-Screw
Number of Blades	5
Diameter	9 m
Pitch	8.1 m
Expanded Area Ratio	0.8291
Speed	79 RPM
Pitch to Diameter Ratio	0.9
Open Water Efficiency (η_0)	0.657
Thrust Coefficient (K_T)	0.181
Torque Coefficient (K_Q)	0.0267
Propeller Thrust	2082.9 kN
Cavitation Number	0.4516

2.6 Engine Selection

The effective power of the *SS Steel Ducky* was determined using iterations between the University of Michigan's *Propeller Optimization Program* (POP) along with the *Power Prediction Program* (PPP). This was done until the required thrust at 20 knots was converged upon by both programs. The required thrust of the engine was found by using an equation on the efficiencies of the propeller, the shafting, the gearing, and the hull. The required power was found to be 27692.7 kW with an MCR at 85 percent. This conservative MCR will make sure that the ship can meet the required speed in non-ideal conditions. There was also a 3 percent appendage drag addition on the calculation. On top of this a 10 percent margin was used to ensure any error in measurements is accounted for. These additions make certain that the engine will be able to run smoothly at the required horsepower in any sea-state conditions in the route between Shanghai and LA.

With the optimal RPM and Effective Power known, the Braking Horsepower was found and used to choose the engine. The selected engine that selected was the Win GD X72-B with 8 cylinders. The engine specifications are summarized below Table 2.3.

Table 2.3: Summary of Prime Mover Specifications.

Parameter	**Value**
Brand	Win GD
Model	X72-B
Number of Cylinders	8
Power Output Range	16960 kW - 31360 kW
RPM Range	66-84
Weight	716 tonnes
Fuel Consumption	166 g/kWh

2.7 Maneuvering and Rudder Sizing

The University of Michigan Maneuvering Prediction Program was used to find out that the *SS Steel Ducky* meets all maneuvering requirements that were defined by the IMO. After an initial rudder design was determined from this data, the propeller clearance was checked against the Lloyd's Shipping Register. As shown in the table below the ship meets all the requirements set forth by IMO for each of the load conditions.

Table 2.4: Summary of Maneuvering.

Load Case	Clarke's Turning Index	Linear Dynamic Stability Criterion	Tactical Diameter	Advance
14 Ton Departure	0.5511	0.0000062	1364.07 m	1033.93 m
14 Ton Arrival	0.5668	0.0000028	1337.54 m	1020.16 m
12 Ton Departure	0.5454	0.0000067	1398.68 m	1051.89 m
12 Ton Arrival	0.5483	0.0000060	1394.9 m	1049.93 m

2.8 Choice of Generators

To meet the required capabilities of the ship the generator must provided power for 400 containers which are to be refrigerated requiring 440V plugs and 4.75kW per container, requiring a total of 1,500 kW. The generator will have to provide 1079 kW for auxiliary loads besides refrigeration, this is based on the *Marine Diesel Power Plant Practices*. These loads will be satisfied with two Wartsila 20-9L20 generators. The generators combined provide 3960 kW which allows for a 33% margin on the estimated power. The emergency generator chosen is a Wartsila 20-4l20 Generating Set. This provides 25% of the estimated electrical load. The emergency generator is located on the main deck apart from the engine room and the other two generators. This means that if the engine room is compromised the ship will still have power. This will protect the crew. The specifications of the generators are shown in the tables below.

Table 2.5: Summary of Main Generator Specifications

Parameter	**Value**
Manufacturer	Wartsila
Model	Genset 20-9L20
Number of Cylinders	9
Output Power	1980 kW
Speed	1200 RPM
Frequency	60 Hz
Length	2.524 m
Weight	23.8 t

Table 2.6: Summary of Emergency Generator Specifications

Parameter	**Value**
Manufacturer	Wartsila
Model	Genset 20-4L20
Number of Cylinders	4
Output Power	760 kW
Speed	1000 RPM
Frequency	50 Hz
Length	2.33 m
Weight	14 t

2.9 Load Conditions

Based on the owners requirements 4 load conditions were tested in the stability analysis: 14 TEU departure, 14 TEU arrival, 12 TEU departure, and 12 TEU arrival. In an intact stability case all of these load cases passed the minimum USCG GM_T requirements, had a trim below 0.5 m and a difference in weight vs displacement percentage of -0.5% as is shown in the following tables.

Table 2.7: Load Cases GM_T and USCG requirement.

Load Case	Actual GM$_T(m)$	Required GM$_T(m)$
14 Ton Departure	0.71	0.468
14 Ton Arrival	0.49	0.468
12 Ton Departure	0.88	0.468
12 Ton Arrival	0.69	0.468

Table 2.8: Load Cases Trim and Different in Weight and Displacement.

Load Case	Trim (m) + by stern	Difference in Weight and Displacement (%)
14 Ton Departure	0.15	-0.5
14 Ton Arrival	-0.57	-0.5
12 Ton Departure	0.48	-0.5
12 Ton Arrival	0.34	-0.5

Floodable Length and Damage Stability

The *SS Steel Ducky* 's survivability was tested in a floodable length analysis and a damage stability analysis. In damage stability the ship meets SOLAS and USCG requirements in only the 12 TEU load cases.

Structure

More analysis must be done on the midship section, but currently a midship section has been developed and an initial longitudinal strength test has been performed but it has not been determined if the vessel will meet ABS structural requirements.

2.10 Cost

The initial cost analysis of the ship shows that it will cost approximately $195 Million dollars to build. This is a relatively low cost when considered against ships of similar capabilities, this cost can also be brought down with some small adjustments.

3. Hull Design

This chapter discusses the hull design in detail and how design decisions were made.

3.1 Initial Point Design

Using regression analysis and the database of ships provided, the initial point values listed in this section were found. This was not an attempt to find the best regressions by any means. As a result, the R-Values are not stellar. Furthermore, looking at the data on a scatter plot, it is evident that this is not a set of data is going to provide a substantially better estimate with a better R-Value. Initial adjustments were made to the data prior to the regressions by removing data points that were below 1000 TEU and above 6000 TEU. Lastly, a ratio between TEU uniform and TEU actual (from provided databases) was used to calculate a TEU actual of 4835 from 3600. Because of this trend, the initial values chosen were based more so on standard error than regression.

All of the regressions shown in the following figures: (LOA, Beam, Draft, DWT, and Power) are plotted against TEU on the x-axis. The standard error was relied on more heavily than the regression coefficient.

Parameter	Equation	R^2-Value	SE (Standard Error)
LOA (m)	LOA = -4E-06*TEU^2 + 0.0541*TEU + 105.68	0.8354	20.37
Beam (m)	B = -9E-18*TEU^5 + 1E-13*TEU^4 - 1E-10*TEU^3 - 3E-06TEU^2 + 0.0137*TEU + 13.395	0.7759	2.3
Draft (m)	T = 3E-11*TEU^3 - 5E-07*TEU^2 + 0.0031*TEU+ 6.256	0.7648	0.85
DWT (tonnes)	DWT = -0.0002*TEU^2 + 12.957*TEU + 4365.7	0.8414	8083
Power (kw)	Power = 9.1578*TEU - 639.43	0.8473	6300

Figure 3.1: Regression equations for the initial point design of *SS Steel Ducky* .

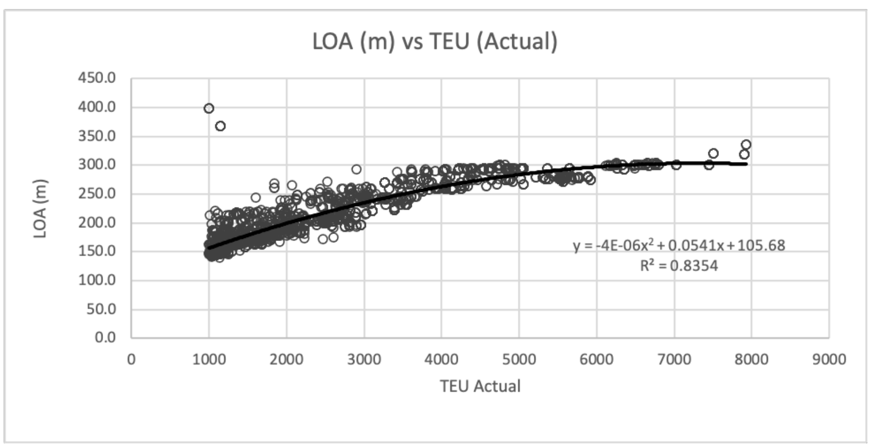


Figure 3.2: Length Overall vs TEU scatter plot with quadratic regression.

Using the graphs, regression equations, standard error, and knowledge of previous ships in general, the following values were chosen.

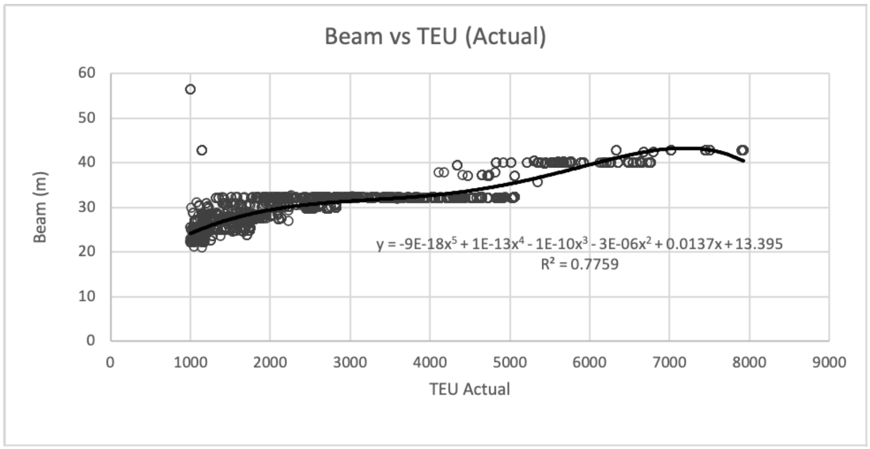


Figure 3.3: Maximum Beam vs TEU scatter plot with fourth power regression, note the lack of correlation between TEU and Beam.

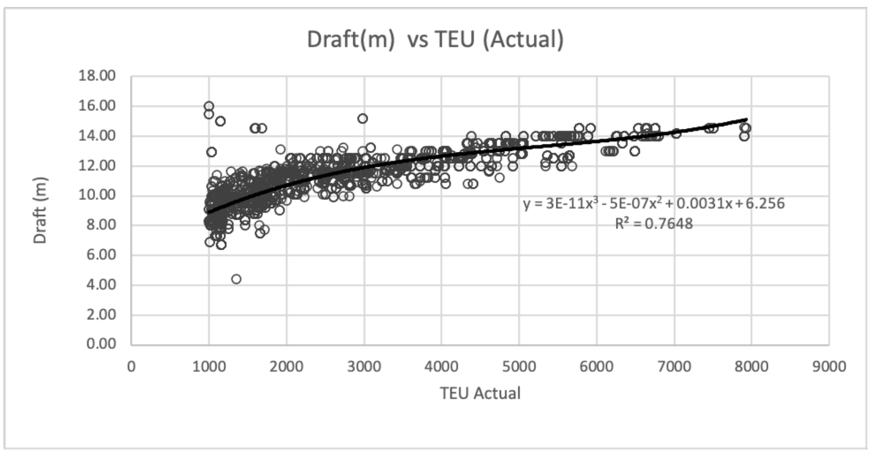


Figure 3.4: Draft vs TEU with third power regression.

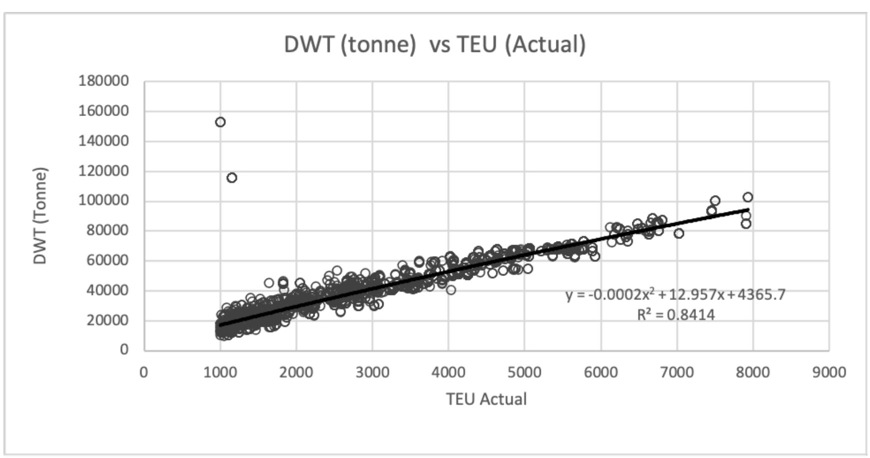


Figure 3.5: Dead Weight Tonnage vs TEU with a quadratic regression.

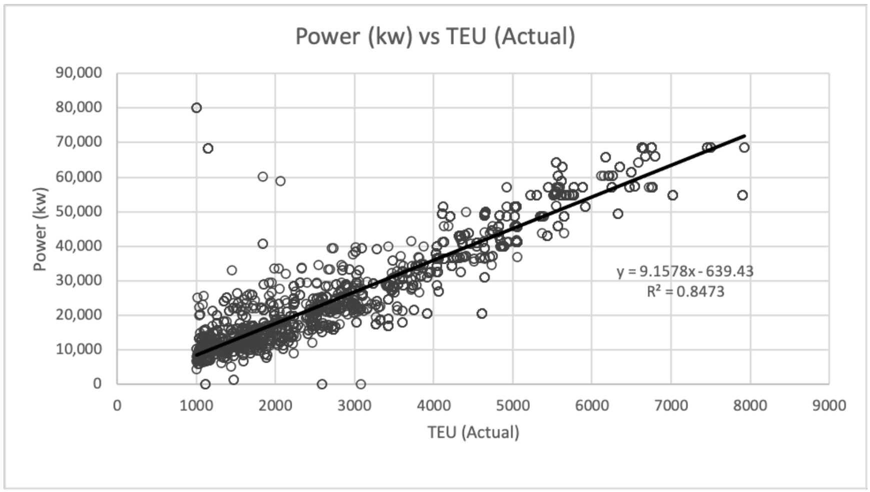


Figure 3.6: Power (kw) vs TEU with a linear regression.

Table 3.1: Initial point design values.

Parameter	**Value**
Length Overall (m)	280.73
Beam (m)	34.7
Draft (m)	13
Dead Weight Tonnage (tonnes)	62186
Power (kw)	43638

3.2 Proposed Hull Design

After using the regression analysis data, multiple iterations were performed in *Maxsurf Modeler* to find the ideal principal dimensions that would accomplish the goals for the use of the ship, while being safe and cost effective. During an initial weights analysis, the ship was set to perform well for all load cases. However, after an in depth analysis was done on the proposed design, it was found that the heavier load cases (14 Ton Departure and 14 Ton Arrival) would fail some regulations in a damage stability cases. This however, can be fixed in future work.

A parent hull provided by University of Michigan was adjusted in *Maxsurf Modeler* in order to get the hull surfaces. Following this *Rhinoceros* was used to place everything that would go on the ship: containers, tanks and machinery. The deck house was also designed in *Rhinoceros* in the 3D space while the plans were developed in *Autocad*.

The strengths of the design come from the fact that it is able to be operated with relatively low power as its beam and length are relatively low numbers compared to similar ships with similar requirements. However, in thinking about how to improve the design, the beam should be increased in order to better ensure safety in the heavier load cases. This is because the ship mainly fails in GM_t calculations for damage stability in heavier load cases. An increase in beam will allow for a higher GM_t. Despite failing some regulations in damage stability the ship passes United States Coast Guard (USCG) regulations for GM_t. Table

Table 3.2: Hydrostatic characteristics at DWL of final hull from *Maxsurf Modeler*

Parameter	**Value**
Displacement	75459 t
Volume (displaced)	73618.129 (mˆ3)
Draft Amidships	11 (m)
Immersed depth	11 (m)
WL Length	250 (m)
Beam max extents on WL	40.5 (m)
Wetted Area	11958.808 (mˆ2)
Max sect. area	441.212 (mˆ2)
Waterpl. Area	7899.45 (mˆ2)
Prismatic coeff. (Cp)	0.667
Block coeff. (Cb)	0.661
Max Sect. area coeff. (Cm)	0.99
Waterpl. area coeff. (Cwp)	0.78
LCB length	-127.329 (- aft from FP)
LCF length	-135.96 (- aft from FP)
LCB %	-50.932 %LWL
LCF %	-54.384
KB	5.819 (m)
KG fluid	14.5 (m)
BMt	11.894 (m)
BML	388.407 (m)
GMt corrected	3.213 (m)
GML	379.726 (m)
KMt	17.713 (m)
KML	394.226 (m)
Immersion (TPc)	80.969 (t/cm)
MTc	1146.933 (t.m)

3.3 Container Placement

The *SS Steel Ducky* holds exactly 3500 TEU's as was specified by the owners requirements. There are 1952 containers above deck and 1548 containers below deck.

Below deck there are 10 cargo holds spread across the ship, and above deck each cargo hold has a stack of 2 - 5 container rows on top of there 2 meter hatch covers. The containers are stacked 14 transversely except in the bow where there is less space and 3 longitudinally across the whole ship. In the cargo holds this is adjusted in various places in order to fit the containers in the ship. There are no other placements of containers on the bare deck, which differs from many similar designs which have containers placed on the mooring deck in the aft of the ship. This was avoided due to problems with the trim in further analysis as the ship was weighed heavy on the aft side. Unfortunately, over the course of the design, this lead to having to stack containers on the center compartments higher than the earlier designs, which lead to issues with transverse stability in damage cases for the heavier load cases. These problems can be mitigating by increasing the beam of the ship finding the most optimal layout of containers.

Another determining factor of how the fore containers were placed was if the ship met the *SS Steel Ducky* met the ABS visibility requirements. The ship was found to meet the ABS visibility requirements which state that the visibility cannot be impeded from the bridge for either 500 m or 2 times the length overall of the ship. The *SS Steel Ducky* meets this requirement with a visibility of 503 meters, this is shown in Figure 3.7.

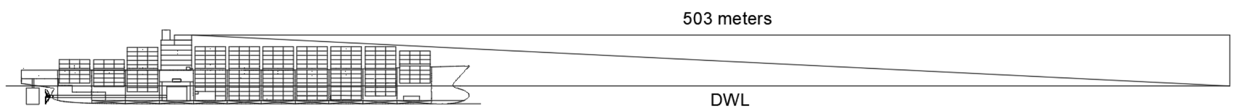


Figure 3.7: Line of sight from bridge.

Furthermore, the owner specified that 400 of the 3500 containers were to be refrigerated. This was accomplished by placing the refrigerated containers altogether into Cargo Bay 7 where it was closest to the engines and generator. This will simplify electrical wiring and outfitting, which in turn will reduce costs. Figure 5.4 shows the placement of the refrigerated containers in red. The powering of the refrigeration of these containers will be discussed in further sections.

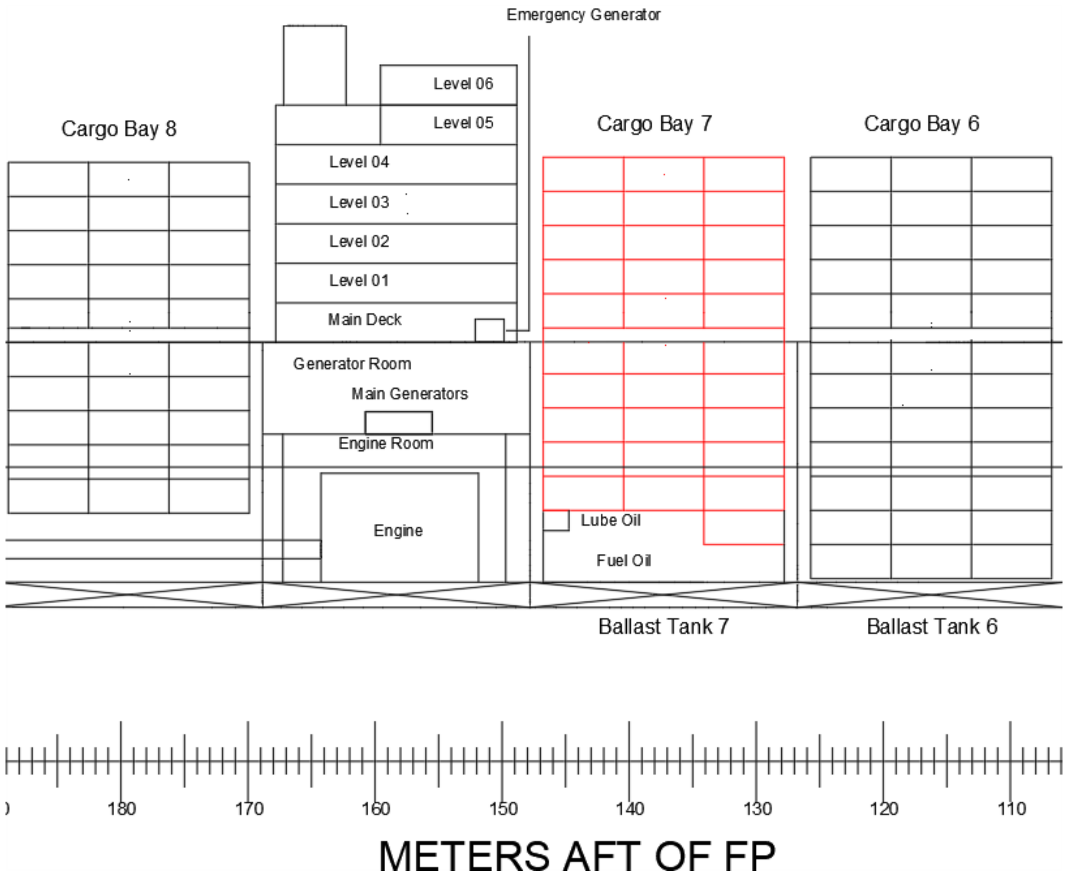


Figure 3.8: Placement of refrigerated containers.

3.4 Hull Lines

Maxsurf Modeler was used to generate the lines drawings for the *SS Steel Ducky* . This was done using 25 stations evenly spaced across the waterline, 8 buttocks lines evenly spaced transversely, and 10 waterlines evenly spaced from the baseline to the highest point of the hull. The placing of these lines are described in the Tables **??**, **??**, **??**

Table 3.3: Placement of Station Lines.

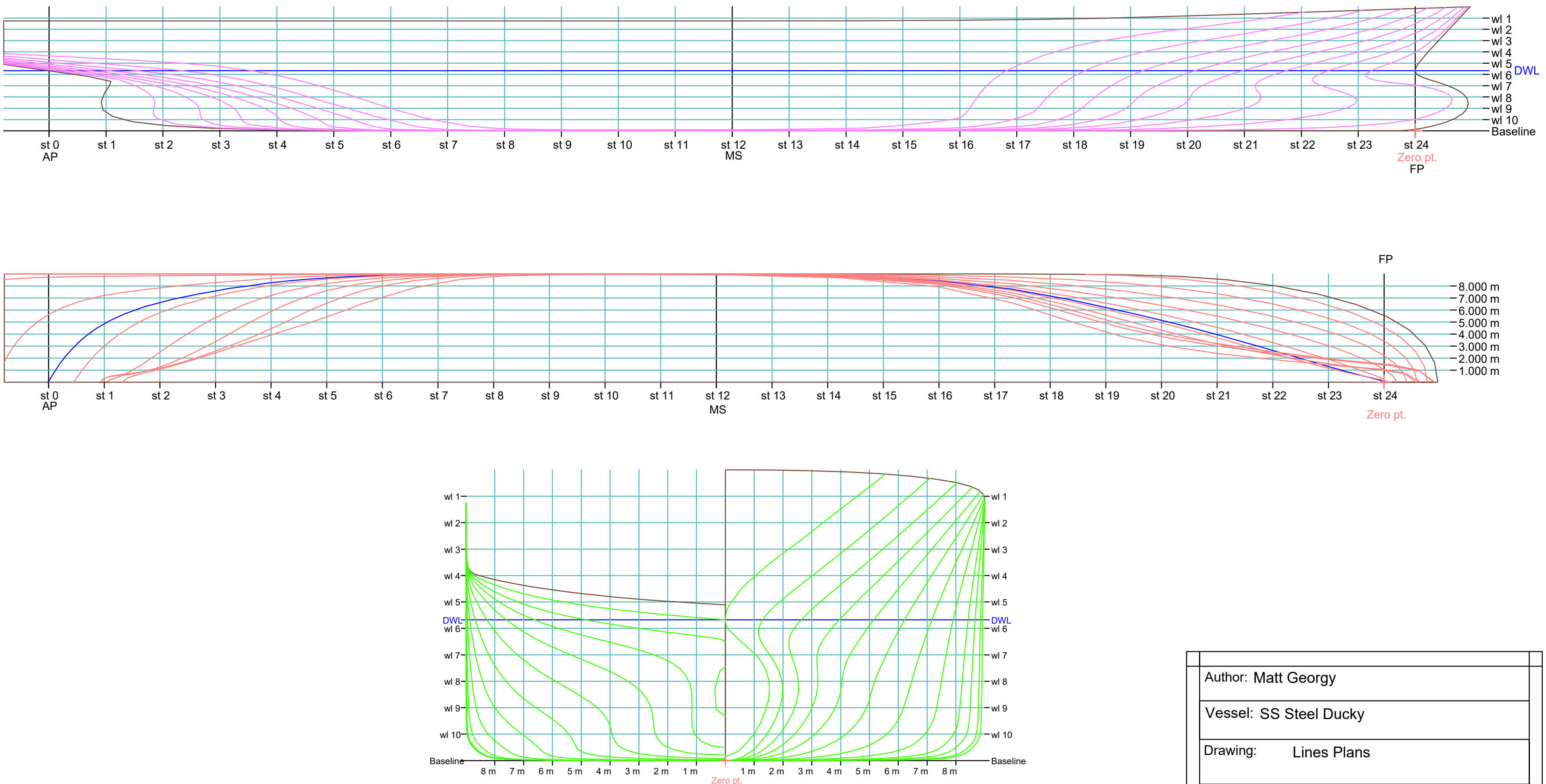
Stations	**Distance from FP (m)**
st 0	-249.828
st 1	-239.419
st 2	-229.009
st 3	-218.6
st 4	-208.19
st 5	-197.781
st 6	-187.371
st 7	-176.962
st 8	-166.552
st 9	-156.143
st 10	-145.733
st 11	-135.324
st 12	-124.914
st 13	-114.505
st 14	-104.095
st 15	-93.686
st 16	-83.276
st 17	-72.867
st 18	-62.457
st 19	-52.048
st 20	-41.638
st 21	-31.229
st 22	-20.819
st 23	-10.41
st 24	0

Table 3.4: Placement of Buttocks Lines.

Buttocks	**Distance from CL (m)**
b 1	2.25
b 2	4.5
b 3	6.75
b 4	9
b 5	11.25
b 6	13.5
b 7	15.75
b 8	18

Table 3.5: Placement of Waterlines.

Waterlines	**Distance from BL (m)**
wl 1	20.652
wl 2	18.587
wl 3	16.522
wl 4	14.457
wl 5	12.391
wl 6	10.326
wl 7	8.261
wl 8	6.196
wl 9	4.13
wl 10	2.065



Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Lines Plans	
Type Final	Date: December, 20, 2020

4. Hydrostatics

This chapter details the hydrostatic analysis done on the *SS Steel Ducky* using the 14 ton departure load. All of the analysis was done on *Maxsurf Stability*. The sign convention used is negative aft of the forward perpendicular and positive moving up from the BL. The tabulated upright hydrostatics data is shown in Table 4.1.

Table 4.1: Upright Hydrostatics for *SS Steel Ducky*

T at MS (m)	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Displacement $\Delta(t)$	52654	60026	67599	75501	83834	92615	101767
Heel deg	0	0	0	0	0	0	0
Draft at FP (m)	8	9	10	11	12	13	14
Draft at AP (m)	8	9	10	11	12	13	14
Draft at LCF (m)	8	9	10	11	12	13	14
Trim (+ve by stern) (m)	0	0	0	0	0	0	0
WL Length (m)	245.606	242.305	243.928	250	257.308	259.227	260.079
Beam max extents on WL m	40.499	40.499	40.5	40.5	40.5	40.5	40.5
Wetted Area m$\hat{2}$	9855.697	10458.025	11117.635	11861.535	12667.115	13431.543	14139.525
Waterpl. Area m$\hat{2}$	7118.706	7272.127	7524.893	7904.96	8357.831	8751.574	9066.591
Prismatic coeff. (Cp)	0.654	0.671	0.675	0.668	0.66	0.667	0.678
Block coeff. (Cb)	0.646	0.663	0.668	0.661	0.654	0.662	0.673
Max Sect. area coeff. (Cm)	0.987	0.989	0.99	0.991	0.991	0.992	0.993
Waterpl. area coeff. (Cwp)	0.716	0.741	0.762	0.781	0.802	0.834	0.861
LCB from zero pt. (+ve fwd) m	-125.356	-125.853	-126.519	-127.361	-128.366	-129.455	-130.483
LCF from zero pt. (+ve fwd) m	-128.265	-130.537	-133.111	-135.98	-138.888	-140.452	-140.809
KB m	4.211	4.738	5.272	5.819	6.384	6.965	7.553
KG m	11	11	11	11	11	11	11
BMt m	14.834	13.51	12.554	11.893	11.464	11.184	10.907
BML m	430.694	392.299	378.594	388.728	409.086	417.948	415.813
GMt m	8.046	7.248	6.826	6.712	6.848	7.149	7.46
GML m	423.906	386.037	372.866	383.547	404.471	413.913	412.366
KMt m	19.046	18.248	17.826	17.712	17.848	18.149	18.46
KML m	434.906	397.037	383.866	394.547	415.471	424.913	423.366
Immersion (TPc) tonne/cm	72.967	74.539	77.13	81.026	85.668	89.704	92.933
MTc tonne.m	893.432	927.535	1008.91	1159.124	1357.276	1534.442	1679.769
RM at 1deg = GMt.Disp.sin(1) tonne.m	7393.384	7592.968	8053.033	8844.735	10020.058	11555.092	13249.289
Max deck inclination deg	0	0	0	0	0	0	0
Trim angle (+ve by stern) deg	0	0	0	0	0	0	0

4.1 Hydrostatic Curves

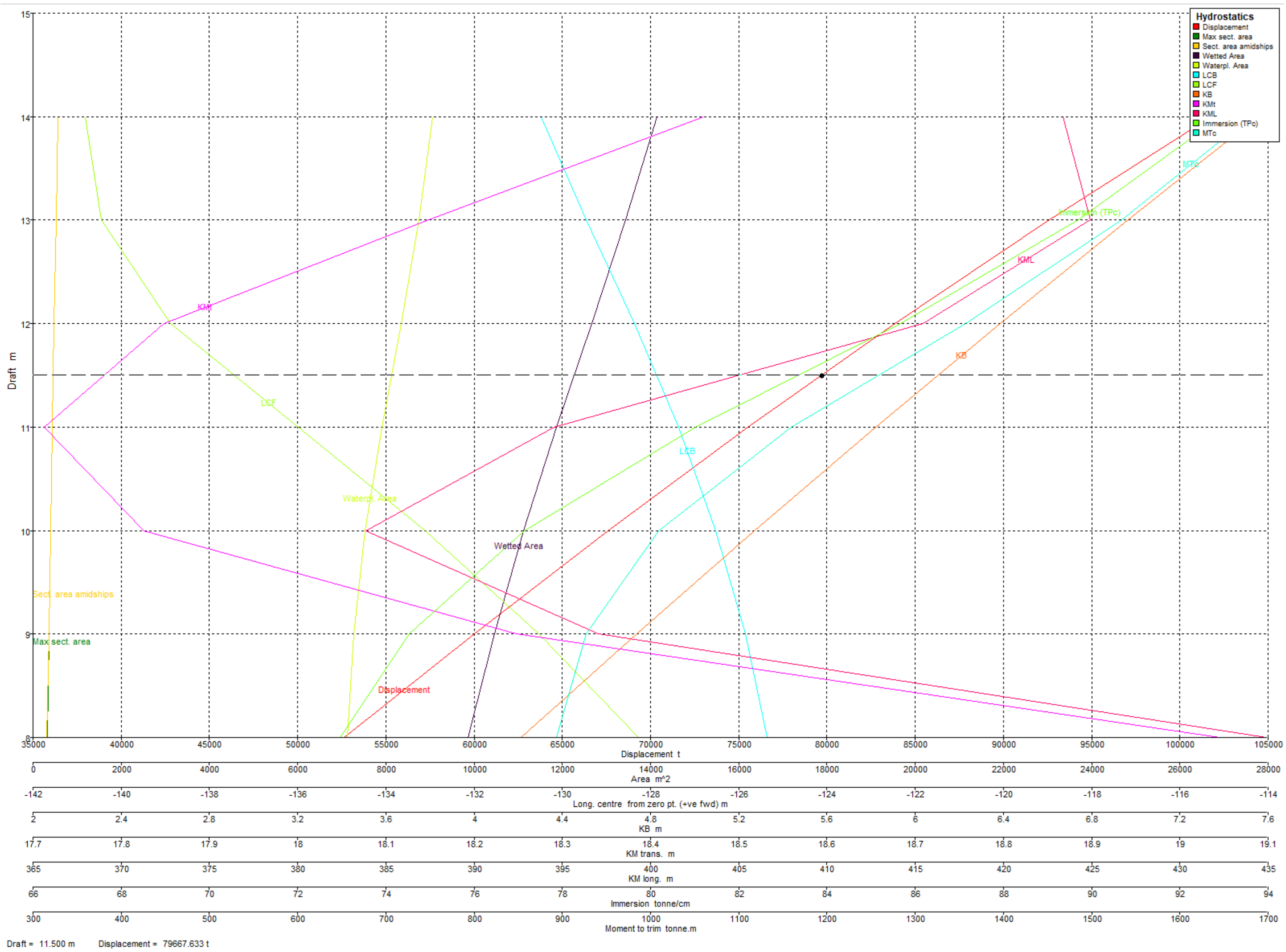


Figure 4.1: Hydrostatics Curves

4.2 Curves of Form

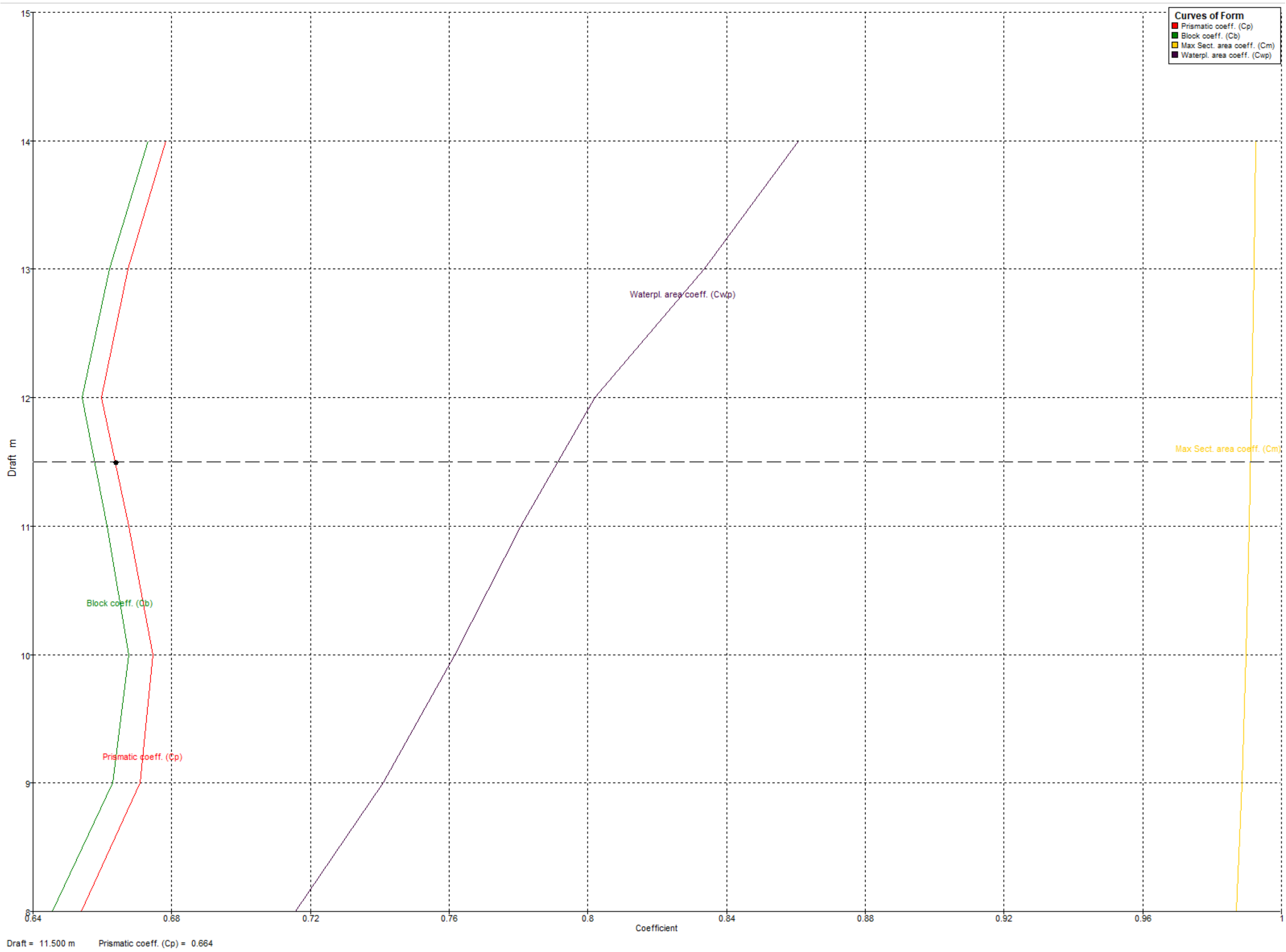


Figure 4.2: Curves of Form

4.3 Curves of Area

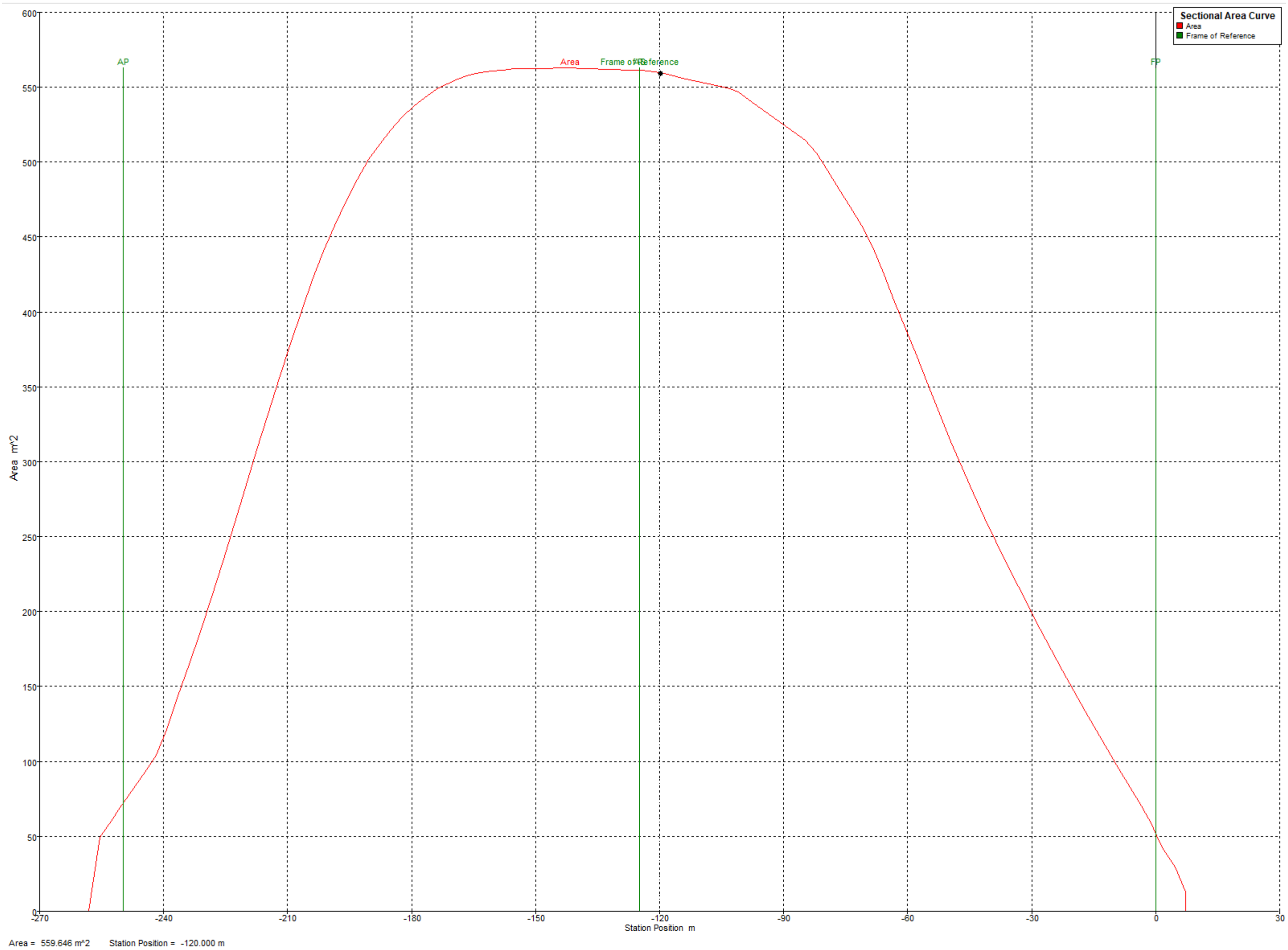


Figure 4.3: Curves of Area

4.4 Bonjean Curves

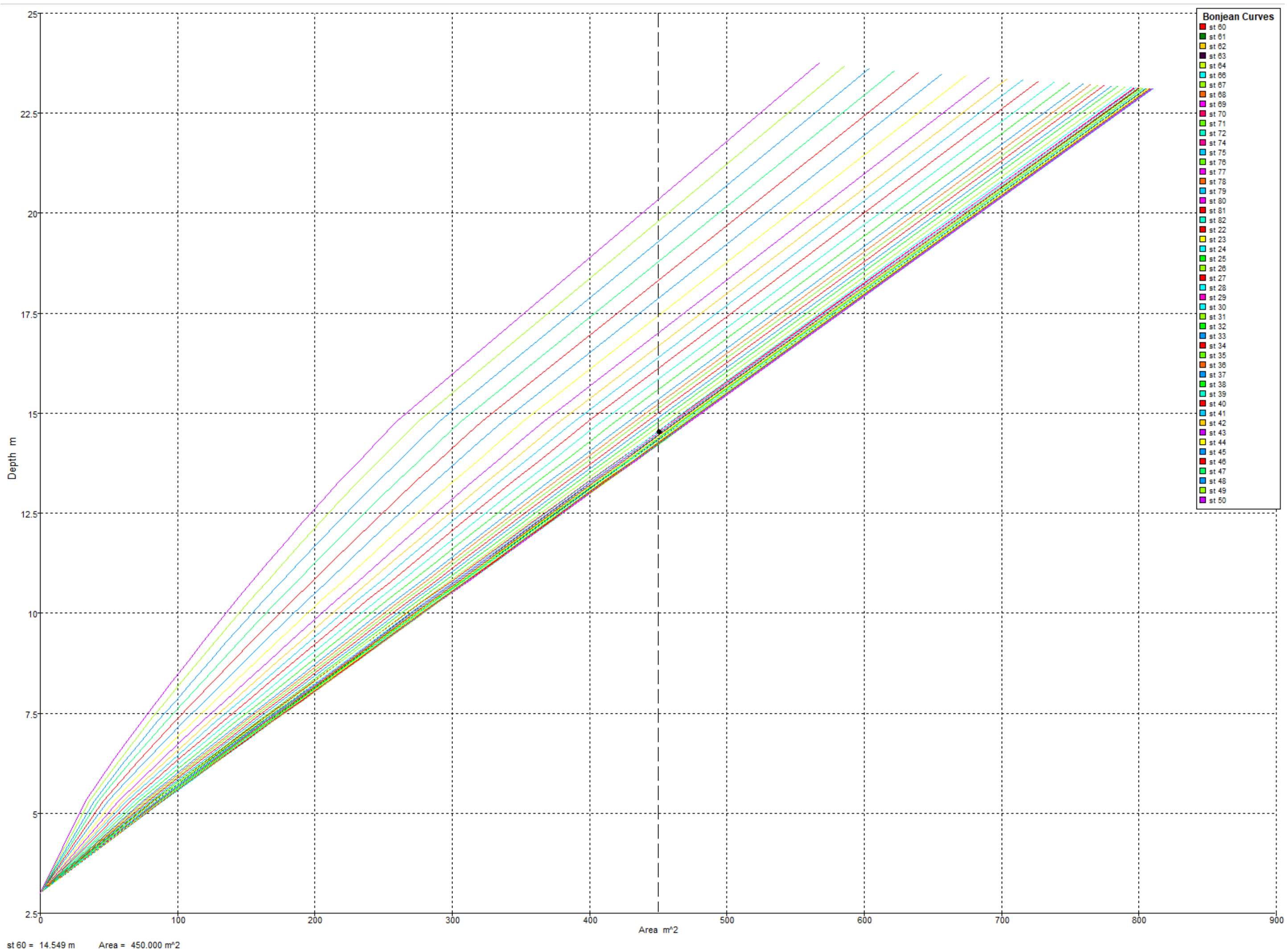


Figure 4.4: Bonjean Curves

4.5 KN Curves

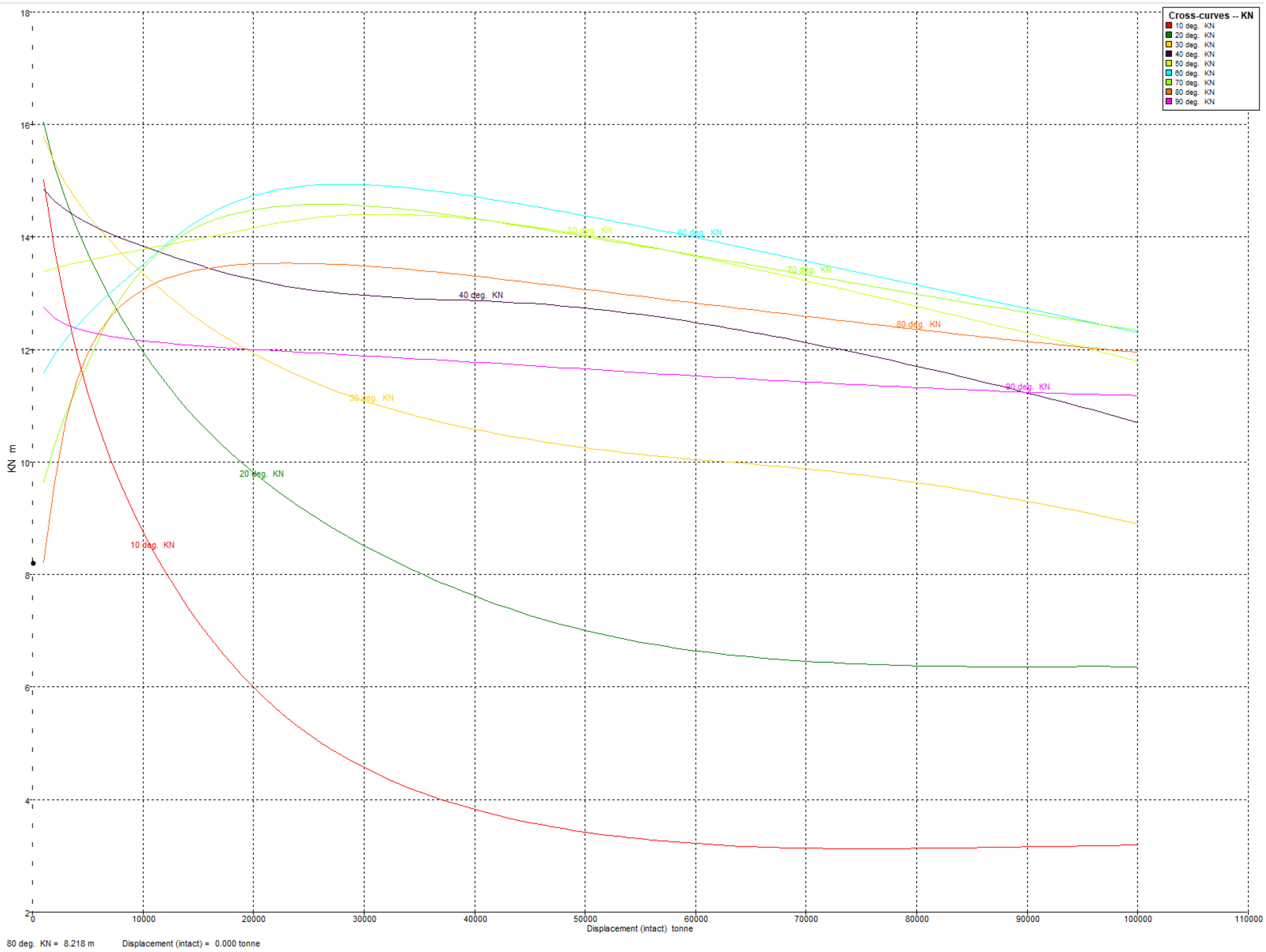


Figure 4.5: KN Curves

4.6 Intact Stability

The intact stability was also studied using *Maxsurf Stability* for the four load cases: 14 ton departure, 14 ton arrival, 12 ton departure and 12 ton arrival. The maximum GZ and heel of maximum GZ in each load case is summarized in the Table 4.2.

Table 4.2: Summary of the intact stability of the load cases.

Load Case	Max GZ [m]	Heel at Max GZ [deg]
14 ton Departure	1.09	31.8
14 ton Arrival	1.02	31.8
12 ton Departure	1.383	32.7
12 ton Arrival	1.28	32.7

4.7 Intact Stability for 14 Ton Departure

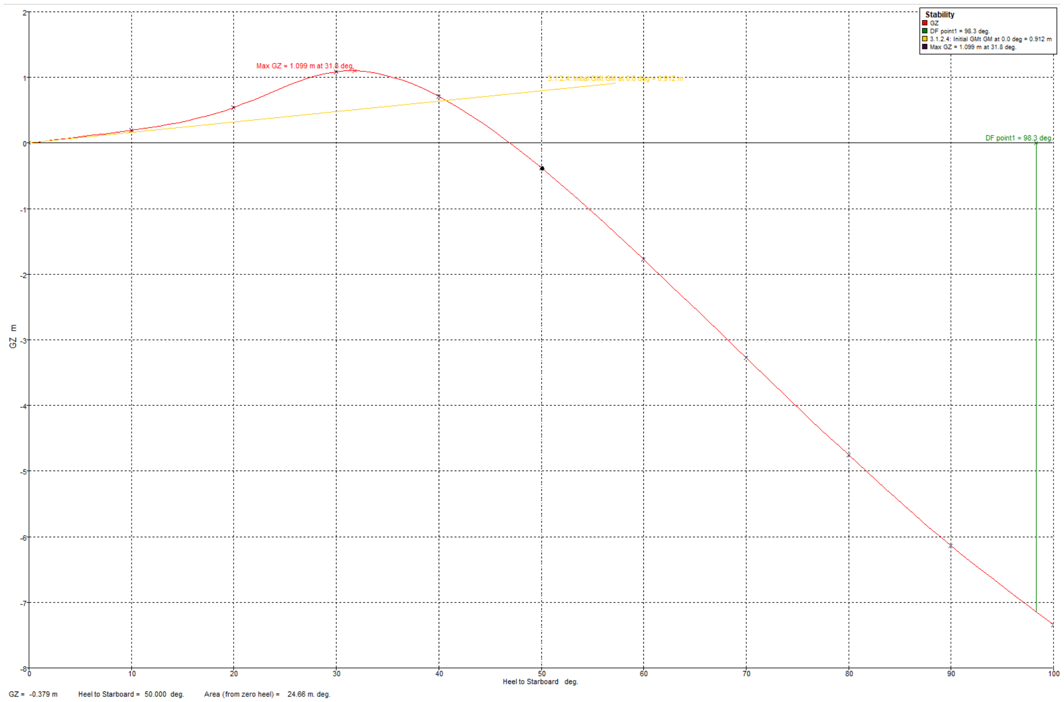


Figure 4.6: Intact Stability Righting Arm Curve for 14 Ton Departure

Heel [deg]	0	10	20	30	40	50	60	70	80	90	100
GZ (m)	0	0.196	0.542	1.086	0.709	-0.379	-1.775	-3.275	-4.757	-6.137	-7.343
Area under GZ curve from zero heel m.deg	0	0.9543	4.3587	12.8093	22.6245	24.6601	14.0474	-11.1724	-51.3799	-105.9826	-173.4813
Displacement (t)	74117	74117	74116	74117	74115	74118	74119	74122	74123	74123	74119
Draft at FP (m)	8.937	9.104	9.357	9.355	8.853	8.113	7.036	5.106	-0.368	n/a	-21.352
Draft at AP (m)	12.337	12	11.284	10.41	9.815	9.224	8.413	6.978	2.964	n/a	-18.483
WL Length (m)	262.284	261.68	260.802	261.566	263.905	265.54	266.811	267.828	267.313	267.845	268.115
Beam max extents on WL (m)	40.5	41.124	43.072	40.036	31.313	26.467	23.797	22.924	22.601	21.462	21.015
Wetted Area (m^2)	11970.118	11981.78	11996.458	12438.867	12838.259	13050.537	13140.584	13178.928	13215.382	13206.649	13188.676
Waterpl. Area (m^2)	8234.018	8298.302	8555.646	8324.492	7053.764	6226.152	5695.16	5374.443	5173.317	5036.185	5006.983
Prismatic coeff. (C_p)	0.62	0.63	0.655	0.686	0.702	0.709	0.713	0.716	0.721	0.723	0.726
Block coeff. (C_b)	0.587	0.491	0.403	0.39	0.458	0.513	0.556	0.577	0.606	0.666	0.634
LCB from zero pt. (+ fwd) (m)	-132.858	-132.847	-132.812	-132.75	-132.749	-132.748	-132.746	-132.742	-132.737	-132.733	-132.73
LCF from zero pt. (+ fwd) (m)	-142.058	-140.857	-137.046	-130.006	-125.3	-122.474	-120.939	-120.359	-119.908	-119.835	-120.451
Max deck inclination deg	0.7798	10.0211	20.0041	30.0007	40.0003	50.0002	60.0001	70.0001	80	90	100
Trim angle (+ stern) deg	0.7798	0.6641	0.4418	0.2419	0.2206	0.2549	0.3157	0.4293	0.7641	90	0.658

Table 4.3: Righting Arm Data (14 Ton Departure)

4.8 Intact Stability for 14 Ton Arrival

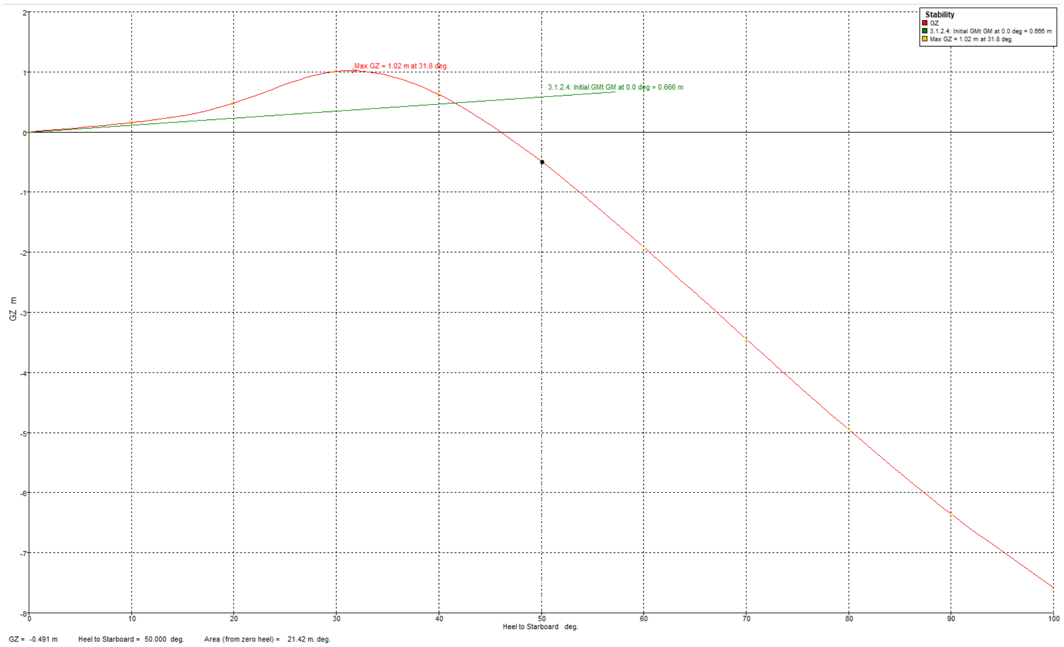


Figure 4.7: Intact Stability Righting Arm Curve for 14 Ton Arrival

Heel [deg]	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
GZ (m)	0	0.158	0.479	1.009	0.62	-0.491	-1.915	-3.442	-4.95	-6.352	-7.577
Area under GZ curve from zero heel m.deg	0	0.7565	3.6444	11.3864	20.3781	21.4158	9.5368	-17.2236	-59.2343	-115.8841	-185.6311
Displacement (t)	72804	72804	72802	72804	72801	72808	72808	72810	72804	72804	72806
Draft at FP (m)	8.792	8.964	9.236	9.257	8.741	7.971	6.84	4.798	-1.003	n/a	-21.979
Draft at AP (m)	12.172	11.83	11.093	10.159	9.454	8.72	7.696	5.866	0.661	n/a	-20.872
WL Length (m)	262.755	262.156	261.192	261.867	264.061	265.674	266.939	267.758	267.258	267.829	268.131
Beam max extents on WL (m)	40.5	41.124	43.067	40.073	31.322	26.483	23.857	22.995	22.569	21.396	20.969
Wetted Area (m^2)	11847.789	11875.96	11897.419	12295.437	12698.401	12896.902	12988.471	13033.117	13063.53	13047.696	13036.112
Waterpl. Area (m^2)	8180.786	8266.908	8525.544	8340.865	7076.392	6238.339	5712.467	5378.371	5160.06	5011.32	4985.314
Prismatic coeff. (C_p)	0.616	0.627	0.653	0.684	0.7	0.708	0.712	0.714	0.719	0.721	0.725
Block coeff. (C_b)	0.584	0.487	0.4	0.386	0.455	0.509	0.551	0.573	0.604	0.671	0.637
LCB from zero pt. (+ fwd) (m)	-132.661	-132.647	-132.614	-132.54	-132.539	-132.534	-132.531	-132.527	-132.524	-132.52	-132.518
LCF from zero pt. (+ fwd) (m)	-141.471	-140.563	-136.874	-130.201	-125.337	-122.663	-121.228	-120.486	-119.822	-119.583	-120.38
Max deck inclination deg	0.7752	10.0207	20.0038	30.0005	40.0002	50.0001	60	70	80	90	100
Trim angle (+ stern) deg	0.7752	0.6572	0.4259	0.2068	0.1636	0.1718	0.1963	0.2449	0.3816	90	0.2539

Table 4.4: Righting Arm Data (14 Ton Arrival)

4.9 Intact Stability for 12 Ton Departure

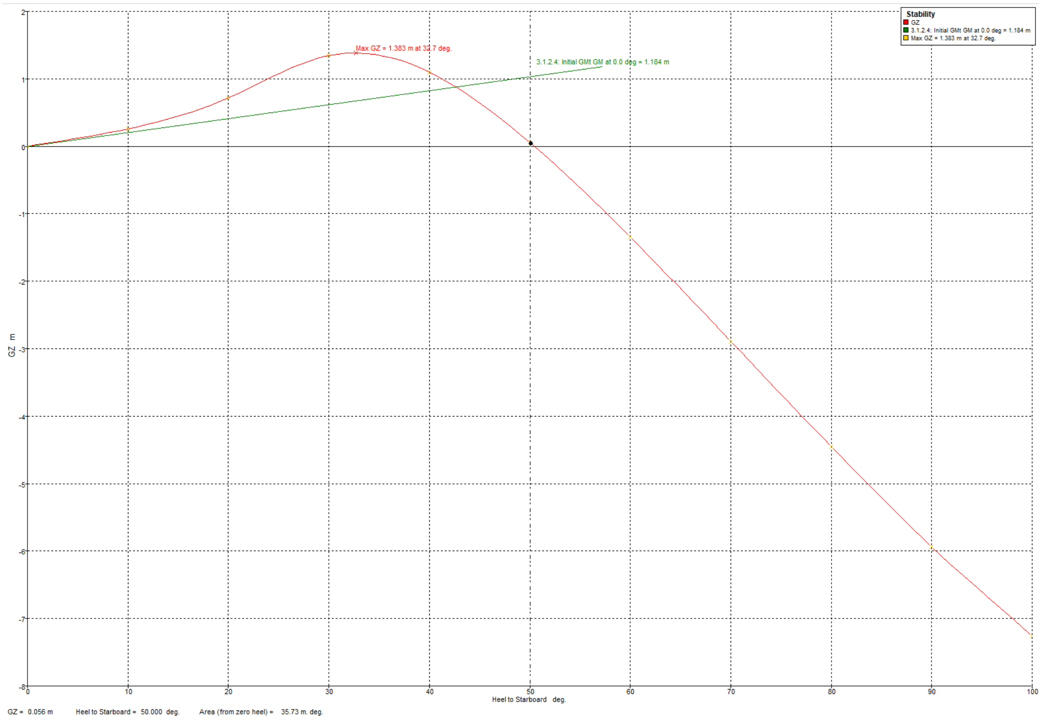


Figure 4.8: Intact Stability Righting Arm Curve for 12 Ton Departure

Heel [deg]	0	10	20	30	40	50	60	70	80	90	100
GZ (m)	0	0.259	0.717	1.346	1.098	0.056	-1.346	-2.89	-4.451	-5.934	-7.255
Area under GZ curve from zero heel m.deg	0	1.2283	5.8245	16.4356	29.5009	35.7319	29.4686	8.3465	-28.3826	-80.4251	-146.4632
Displacement (t)	67099	67098	67097	67102	67099	67099	67099	67099	67099	67099	67098
Draft at FP (m)	7.848	8.029	8.376	8.473	7.853	6.845	5.304	2.456	-5.726	n/a	-26.987
Draft at AP (m)	11.685	11.337	10.526	9.404	8.299	7.072	5.318	2.086	-7.282	n/a	-28.994
WL Length (m)	262.557	264.939	263.944	263.793	265.353	266.817	267.759	266.766	266.819	267.698	268.032
Beam max extents on WL (m)	40.5	41.124	43.024	40.15	31.382	26.584	24.297	23.428	22.242	20.985	20.775
Wetted Area (m^2)	11314.572	11407.004	11446.7	11645.459	12053.279	12226.179	12319.612	12369.127	12372.453	12362.57	12344.969
Waterpl. Area (m^2)	8006.874	8167.889	8412.055	8351.799	7127.06	6281.055	5726.47	5341.893	5062.661	4898.96	4852.274
Prismatic coeff. (C_p)	0.605	0.609	0.636	0.671	0.688	0.695	0.698	0.705	0.709	0.711	0.716
Block coeff. (C_b)	0.566	0.466	0.38	0.366	0.434	0.488	0.523	0.549	0.601	0.674	0.629
LCB from zero pt. (+ fwd) (m)	-132.888	-132.874	-132.83	-132.75	-132.719	-132.716	-132.71	-132.704	-132.697	-132.694	-132.697
LCF from zero pt. (+ fwd) (m)	-139.013	-139.335	-136.317	-131.304	-125.965	-123.559	-121.95	-120.551	-119.768	-120.309	-121.72
Max deck inclination deg	0.8798	10.0276	20.0051	30.0005	40.0001	50	60	70	80	90	100
Trim angle (+ stern) deg	0.8798	0.7586	0.493	0.2135	0.1022	0.0521	0.0033	-0.0848	-0.3569	-90	-0.4602

Table 4.5: Righting Arm Data (12 Ton Departure)

4.10 Intact Stability for 12 Ton Arrival

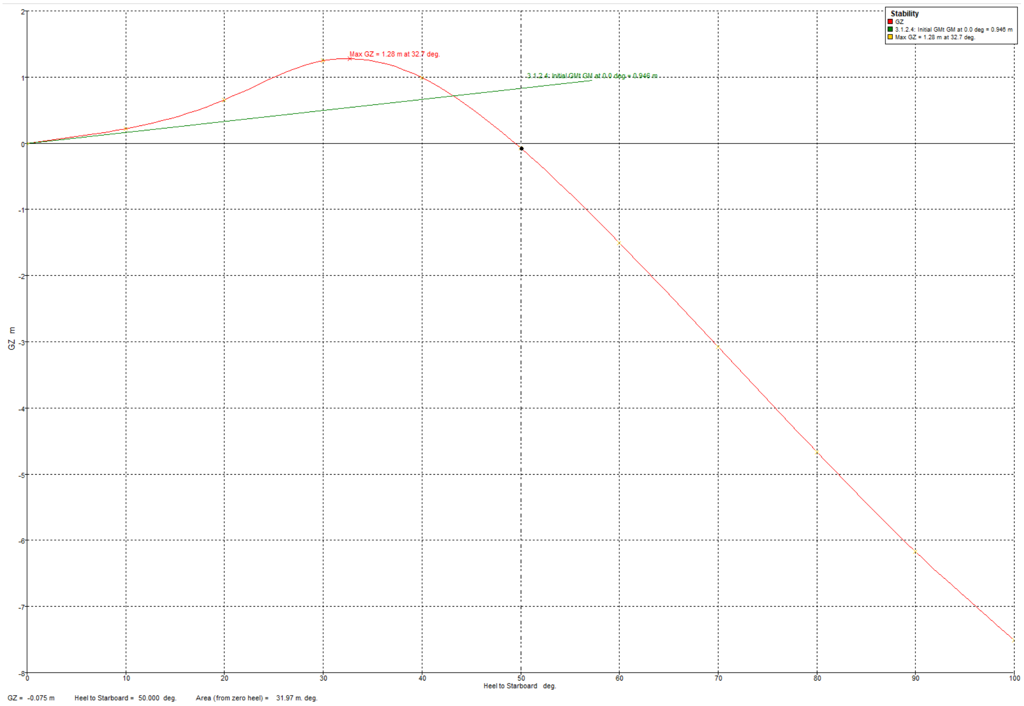


Figure 4.9: Intact Stability Righting Arm Curve for 12 Ton Arrival

Heel [deg]	0	10	20	30	40	50	60	70	80	90	100
GZ (m)	0	0.22	0.655	1.247	0.989	-0.075	-1.504	-3.078	-4.666	-6.172	-7.509
Area under GZ curve from zero heel m.deg	0	1.0168	5.1088	14.9109	26.9277	31.9698	24.2589	1.4088	-37.3335	-91.6448	-160.1466
Displacement (t)	65785	65784	65783	65788	65785	65785	65785	65785	65785	65785	65783
Draft at FP (m)	7.718	7.896	8.258	8.368	7.736	6.695	5.098	2.148	-6.336	n/a	-27.64
Draft at AP (m)	11.5	11.156	10.327	9.161	7.949	6.584	4.618	0.96	-9.668	n/a	-31.437
WL Length (m)	261.367	265.205	264.249	264.018	265.515	266.959	267.809	266.626	266.767	267.683	268.016
Beam max extents on WL (m)	40.5	41.124	43.003	40.159	31.391	26.611	24.374	23.477	22.185	20.919	20.751
Wetted Area (m^2)	11174.175	11295.502	11347.495	11500.224	11900.765	12072.414	12168.685	12212.208	12213.745	12201.552	12187.741
Waterpl. Area (m^2)	7935.285	8129.515	8377.676	8351.902	7138.496	6288.288	5724.939	5326.387	5041.342	4873.331	4828.532
Prismatic coeff. (C_p)	0.605	0.606	0.634	0.669	0.686	0.692	0.696	0.703	0.706	0.709	0.714
Block coeff. (C_b)	0.567	0.462	0.376	0.362	0.43	0.483	0.517	0.545	0.6	0.67	0.623
LCB from zero pt. (+ fwd) (m)	-132.67	-132.656	-132.61	-132.523	-132.49	-132.483	-132.475	-132.467	-132.46	-132.457	-132.462
LCF from zero pt. (+ fwd) (m)	-138.079	-138.888	-136.107	-131.589	-126.186	-123.705	-122.033	-120.46	-119.647	-120.312	-121.832
Max deck inclination deg	0.8673	10.0268	20.0048	30.0004	40	50	60	70	80	90	100
Trim angle (+ stern) deg	0.8673	0.7477	0.4746	0.1821	0.0489	-0.0254	-0.1102	-0.2724	-0.7642	-90	-0.8707

Table 4.6: Righting Arm Data (12 Ton Arrival)

5. General Arrangements

This chapter outlines the general arrangements of the *SS Steel Ducky* .

5.1 Collision and After Peak Bulkheads

The collision and and after peak bulkheads were placed with the ABS *Rules for Building and Classing Steel Vessels (2018)*. Since the hull form includes a bulbous bow the reference point is 3 m from the forward perpendicular (FP). The location of the collision bulkhead is constrained to fall between of 5% of the length or 12.65 m, whichever is less, aft of the reference point, and between 8% of the length and 5% of the length plus 3 m, whichever is greater. Therefore, the forward collision bulkhead was placed at 13 m.

The after peak bulkhead starts from the keel and encloses the shafting tubes. Equation 5.1 is based on ABA requirements (12.5.2) which determines the minimum distance of the after peak bulkhead from the AP. This was used and the bulkhead was placed 13.4 meters from the AP. Each of these bulkheads is watertight as per the regulations

$$X(\%LWL) = 9.18 - 0.026LWL + 0.0000429LWL^2 \tag{5.1}$$

Table 5.1: Position of collision and after peak bulkheads.

Bulkhead	**Measured From**	**Position[m]**	**ABS Min [m]**	**ABS Max [m]**
Forward Collision	FP	13	12.65	20
After Peak	AP	21.75	13.25	None

5.2 Watertight Bulkheads

Beginning from the aft peak bulkhead, 12 bulkheads were placed in 20.3 meter intervals until the fore of the ship where the forward collision was brought slightly closer towards the aft of the ship to match the ABS regulations for forward collision bulkheads. This design worked well to enclose each cargo hold allowing for a maximum of 3 TEU containers to be stacked longitudinally while still allowing for 0.63 meters between the containers and the bulkhead. Furthermore, it allows for the engine room to be enclosed with more than enough room. In future work it may be beneficial to decrease the size of the compartment that holds the engine room and increase the spacing of the cargo compartments. Table 5.2 summarizes the placement of the bulkheads and Figure 5.2 shows a rendering of the 12 bulkheads.

Table 5.2: Bulkhead locations.

Bulkhead	**Location Aft of FP (m)**
After Peak	236.65
1	216.35
2	196.05
3	175.75
4	155.45
5	135.15
6	114.85
7	94.55
8	74.25
9	53.95
10	33.65
Forward Collision	13

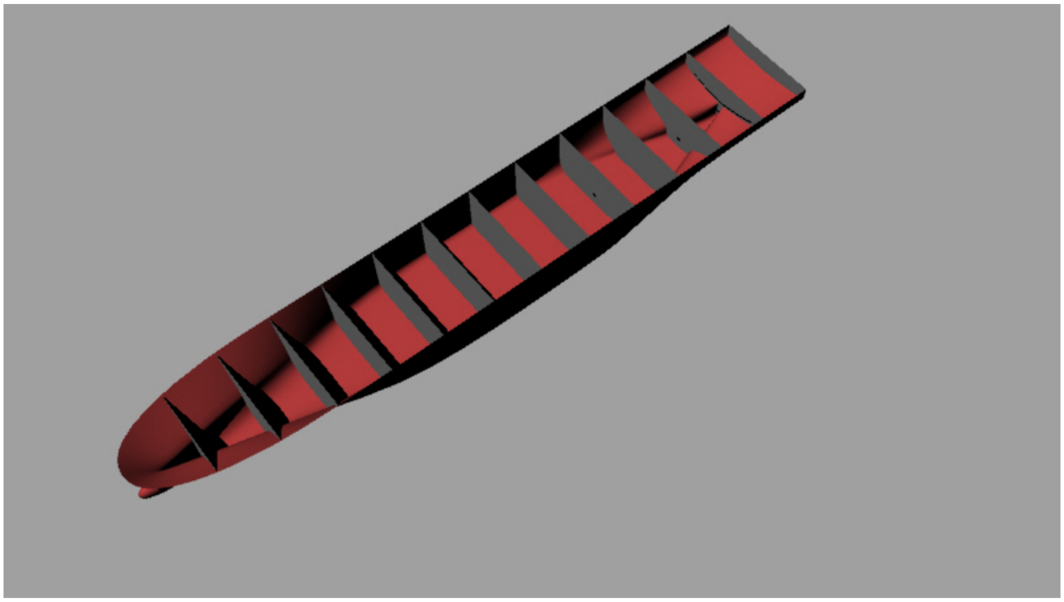


Figure 5.1: Rendering of Watertight Bulkhead placement

5.3 Double Bottom

Before making sure the containers fit, the inner bottom hull distance from the outer hull was found using 5.2 The equation specifies the minimum inner bottom hull height as per regulation from ABS *Rules For Building and Classing Steel Vessels* (2018). The double bottom starts at the forward collision bulkhead and ends at the aft peak bulkhead as specified in the regulation.

$$X(mm) = 32B + 190\sqrt{T} \tag{5.2}$$

Table 5.3: Double Bottom Height.

Feature	Height (m)	ABS Minimum (m)
Double Bottom	1.92 m	1.92 m

This resulted in an inner double bottom height of 1.92 m. The minimum double height was chosen in order to maximize space for containers and still meet safety regulations. In the aft of the ship the inner hull was opened the least possible amount to allow for the propeller shaft to reach the propeller.

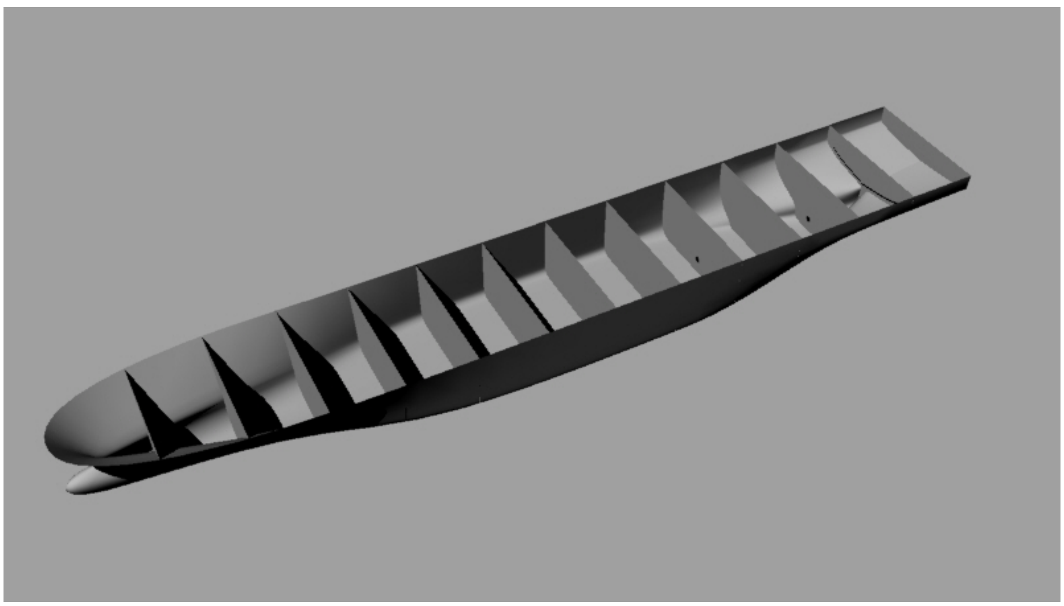


Figure 5.2: Rendering of Inner Double Bottom Height

5.4 Container Arrangement and Deck Arrangements

The *SS Steel Ducky* holds 3500 TEU containers, there are 1952 containers above deck and 1548 containers below deck. Using *Rhinocerous* modeling software a 3D layout of the container placement was created and is shown in Figure

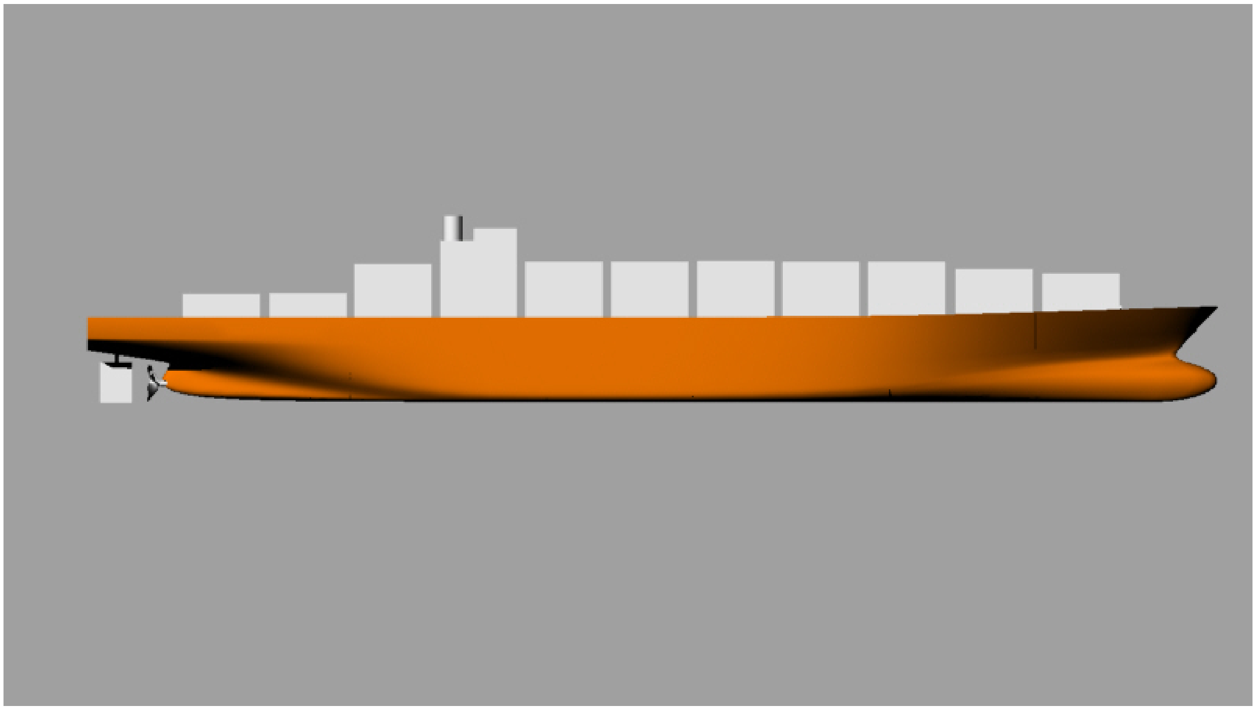


Figure 5.3: Container placement above deck.

Below the deck the containers have 6 in a stack in the center compartments while 2 in the more aft and fore compartments due to a lack of space. Transversely, the containers are arranged 14 in a row, this is bounded by the sides of the ship and allows for a 2 meter passageway on each side of the ship in order to be able to work on the ship. The main driving factors of how the containers were placed were the trim of the ship, transverse stability, proximity to a power source, and ABS line of sight requirements.

In order to address longitudinal stability and trim there was more container mass towards the fore of the ship. This allowed the ship to have a low trim for all test cases. This resulted in having only 10 container stacks on the ship as opposed to having an 11 where one is on the mooring deck. However, this also led to having stacks of 5 containers above deck in Cargo Bays 3 through 8. This led to problems with transverse stability in damage stability test cases in the heavier load cases (14 ton arrival and 14 ton departure). In this stage of the design however, intact stability meets all the requirements set forth by the USCG and SOLAS as confirmed in *Maxsurf Stability* and the University of Michigan Weights II spreadsheet. Attempts to mitigate the failing test cases in damage stability along with find the optimum container placement for both trim and transverse stability were made, however it was finally decided that because every load case was showing to have a large trim while only the heavier load cases were failing some damage stability regulations that it was more pertinent in this stage of the design to have a safer trim then it was to pass the damage stability cases. However, future work should include finding a more optimal container set up while also increasing the beam of the hull.

The owner specified that there must be 400 refrigerated containers, in order to address this while minimizing costs, these containers were grouped and put near the generators and engines. The refrigerated containers were grouped and placed in Cargo Bay 7 as is shown in Figure 5.4. Lastly, the ship was found to meet the ABS visibility requirements which state that the visibility cannot be impeded from the bridge for either 500 m or 2 times the length overall of the ship. The *SS Steel Ducky* meets this requirement with a visibility of 503 meters to the design water line, this is shown in Figure 5.5.

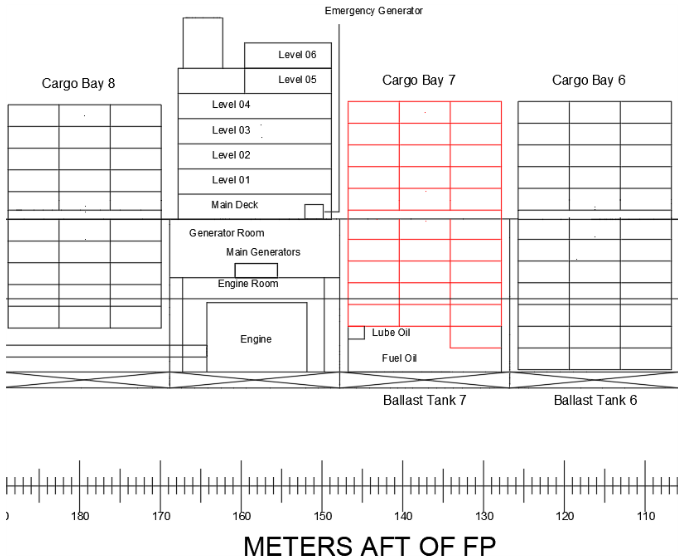


Figure 5.4: Placement of refrigerated containers.

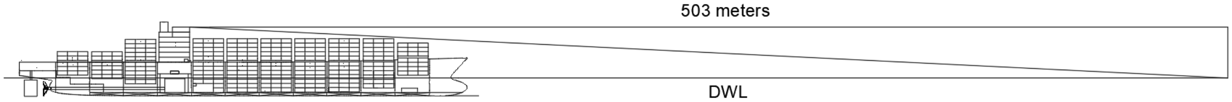


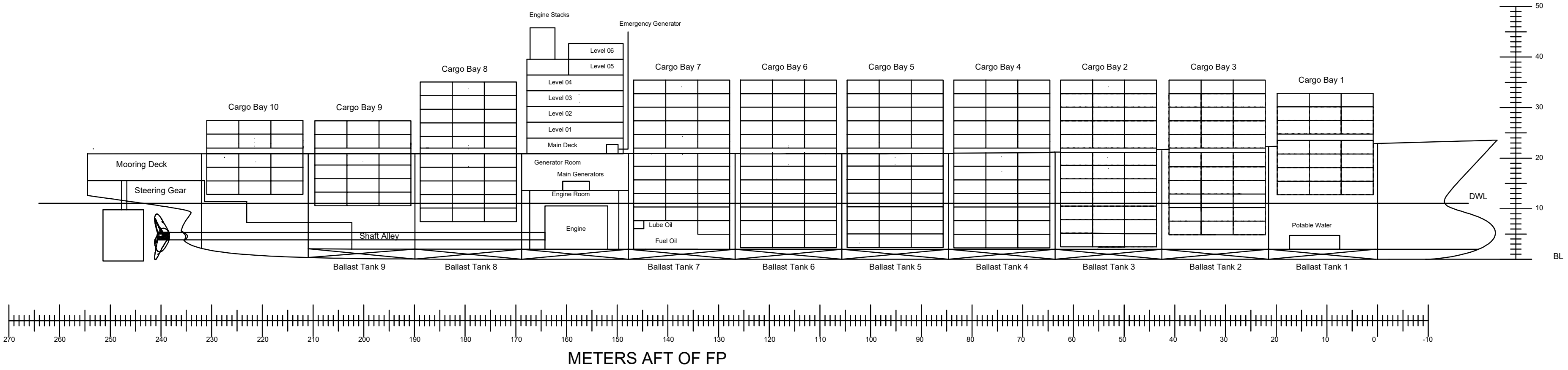
Figure 5.5: Line of sight from bridge to the DWL.

The above deck containers are placed on the hatch coverings and lashed down to the lower containers, because of the height of the containers future work has to be done to figure out of the containers above deck will require a frame.

The decks begin at 1.92 meters above the baseline where the double bottom hull begins, and are then spaced out evenly by 2.275 meters up to the main deck at 20.12 meters above the baseline. The deck placements are described in Table

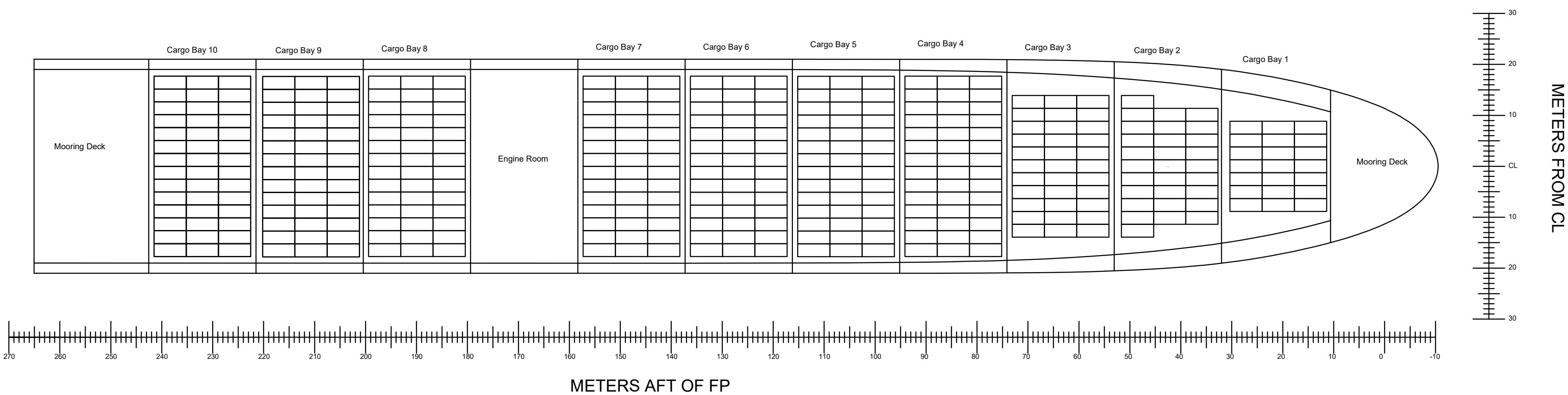
Table 5.4: Deck Heights for Deck arrangements.

Deck	Height from BL (m)
Deck 9 (Double Bottom)	1.92
Deck 8	4.195
Deck 7	6.47
Deck 6	8.745
Deck 5	11.02
Deck 4	13.295
Deck 3	15.57
Deck 2	17.845
Deck 1 (Main Deck)	20.12



Scale 1:20

Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Inboard Profile	
Type Final	Date: December, 20, 2020



Scale 1:20

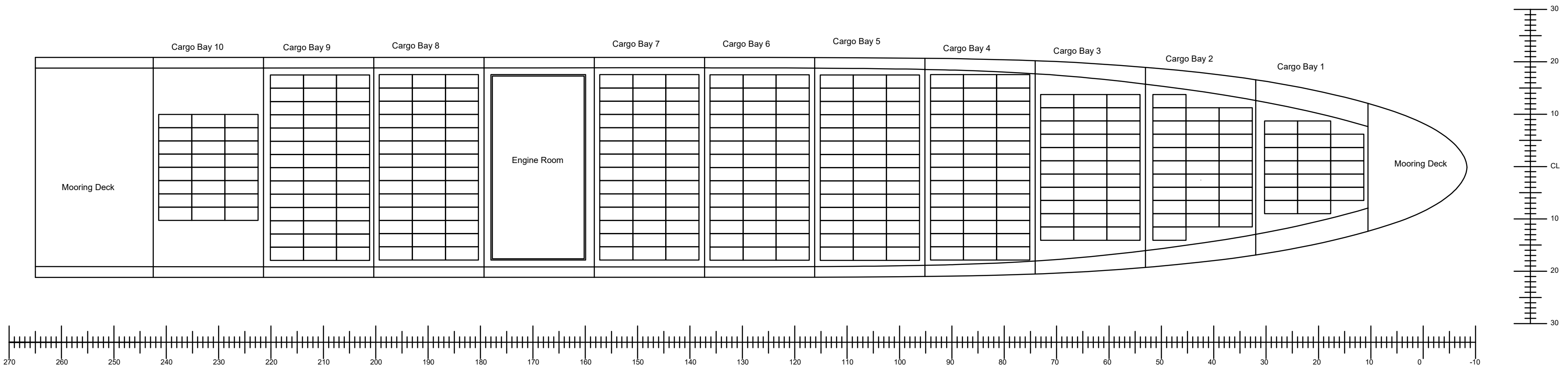
Author: Matt Georgy

Vessel: SS Steel Ducky

Drawing: Deck Plan 1st Deck

Type Final

Date: December, 20, 2020



Scale 1:20

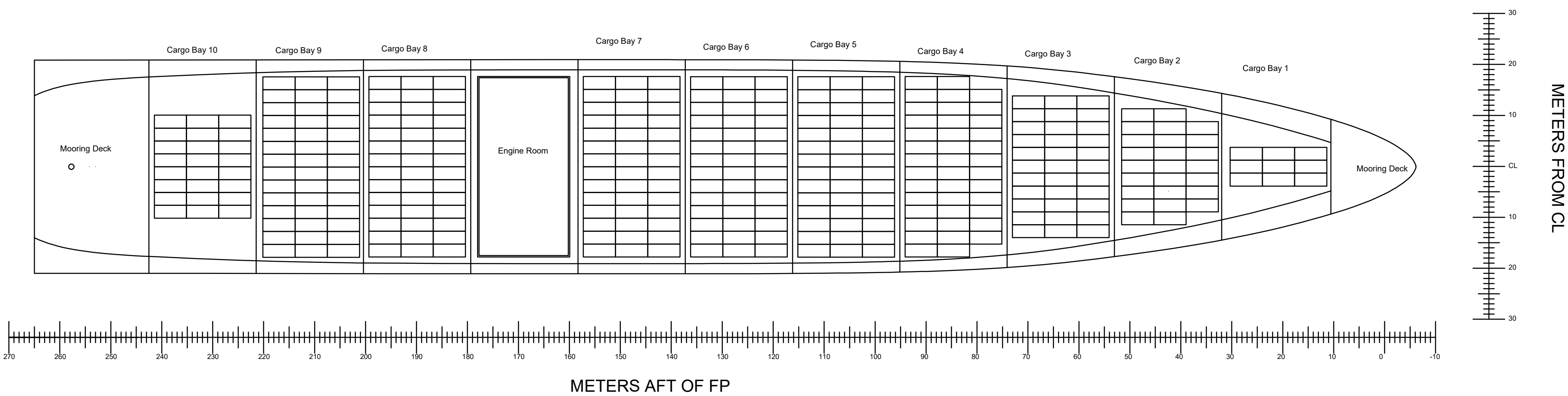
Author: Matt Georgy

Vessel: SS Steel Ducky

Drawing: Deck Plan 2nd Deck

Type Final

Date: December, 20, 2020



Scale 1:20

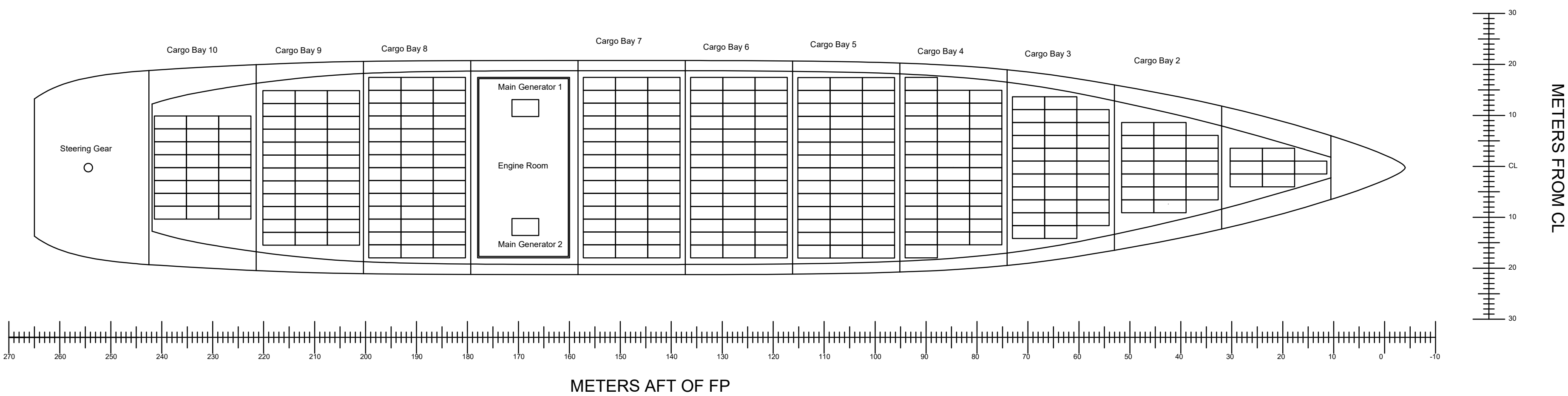
Author: Matt Georgy

Vessel: SS Steel Ducky

Drawing: Deck Plan 3rd Deck

Type Final

Date: December, 20, 2020



Scale 1:20

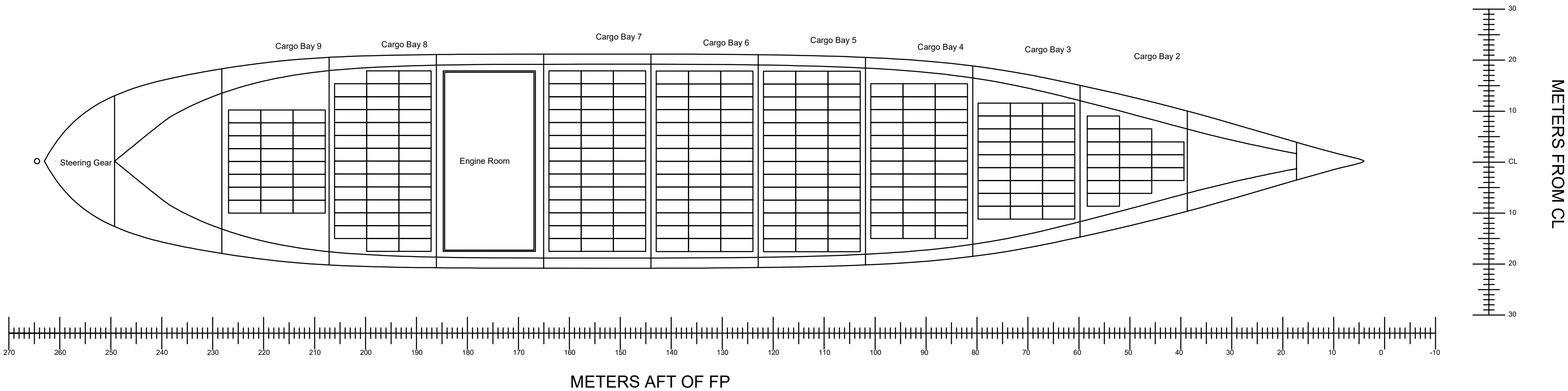
Author: Matt Georgy

Vessel: SS Steel Ducky

Drawing: Deck Plan 4th Deck

Type Final

Date: December, 20, 2020



Scale 1:20

Author: Matt Georgy

Vessel: SS Steel Ducky

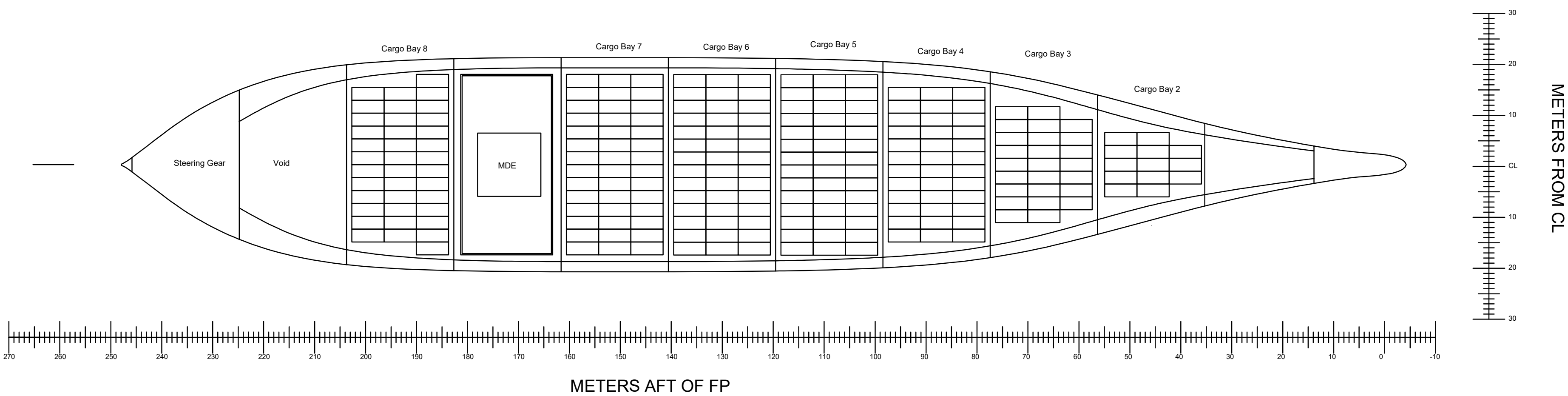
Drawing: Deck Plan 5th Deck

Type Final

Date: December, 20, 2020

A B C D E F G H I J K L M N O P

10 9 8 7 6 5 4 3 2 1

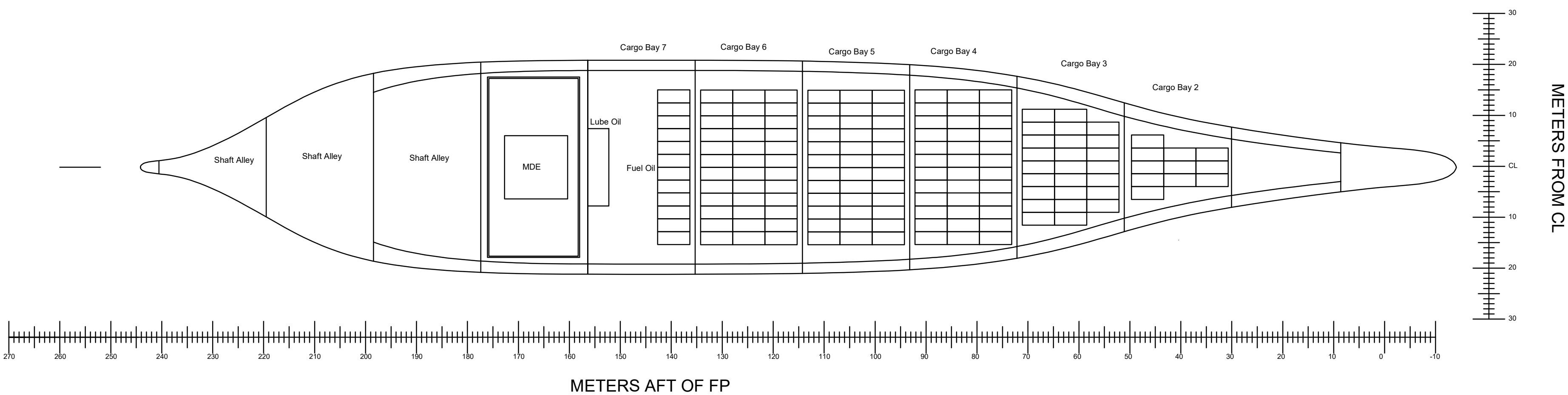


Scale 1:20

Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Deck Plan 6th Deck	
Type Final	Date: December, 20, 2020

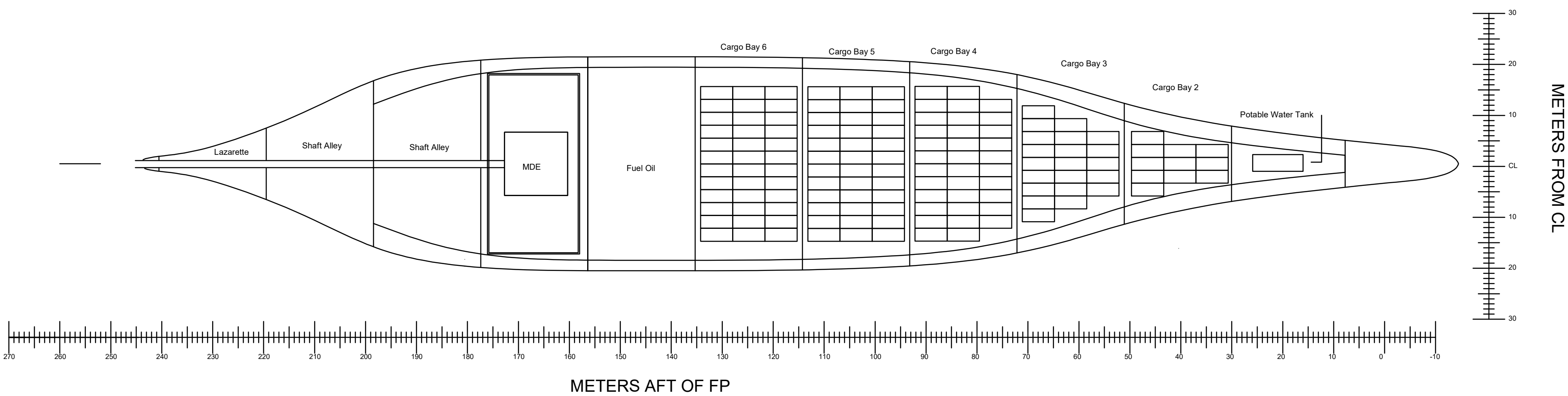
A B C D E F G H I J K L M N O P

10 9 8 7 6 5 4 3 2 1



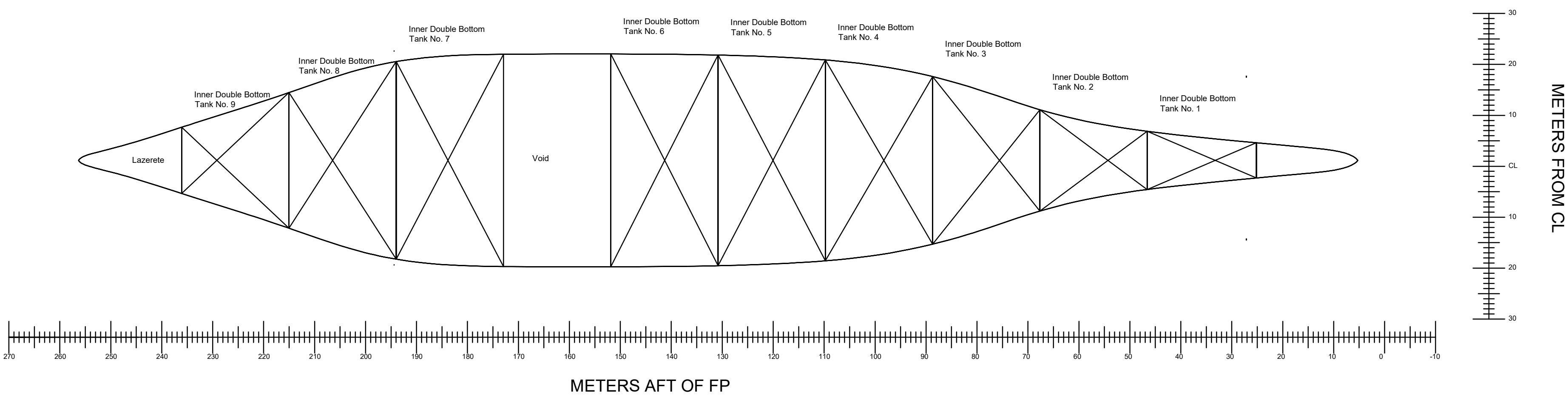
Scale 1:20

Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Deck Plan 7th Deck	
Type Final	Date: December, 20, 2020



Scale 1:20

Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Deck Plan 8th Deck	
Type Final	Date: December, 20, 2020



Scale 1:20

Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Deck Plan 9th Deck	
Type Final	Date: December, 20, 2020

5.5 Deckhouse

The deckhouse is located above the engine room over the 8th watertight compartment. The deckhouse lower decks span 15.3 meters from the centerline in each direction. This placing allows the crew to have easy access to the engine and machinery. The wheel house is above the deckhouse and is expanded 2 meters past the outer hull of the ship to allow for good visibility and better maunevering. The deckhouse is split into 7 3 meter high decks. Behind the wheel house are the engine exhaust stacks. Both the deckhouse and wheel house provide excess space then what is recommended by the *Ship Manning Trends in Northern Europe: Implications for American Ship Owners and Naval Architects* for a crew of 24 and 12 days. Therefore, in the next iteration there is room to allow for a smaller design. Figure 5.6 shows a rendering of the deckhouse.

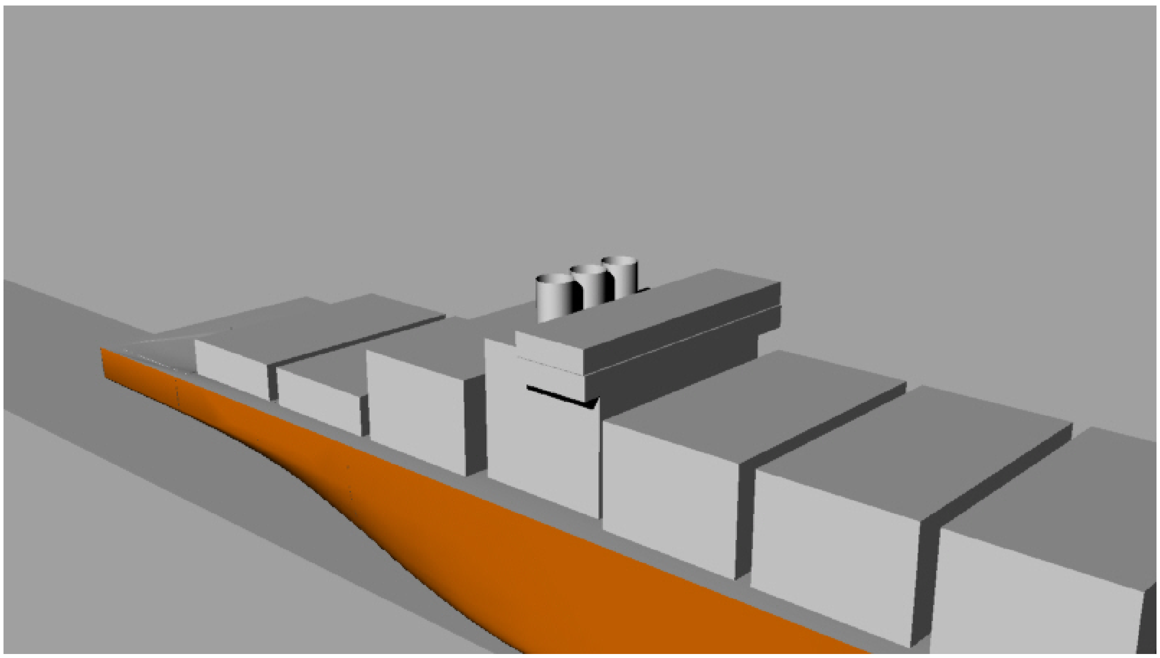


Figure 5.6: Rendering of the deckhouse

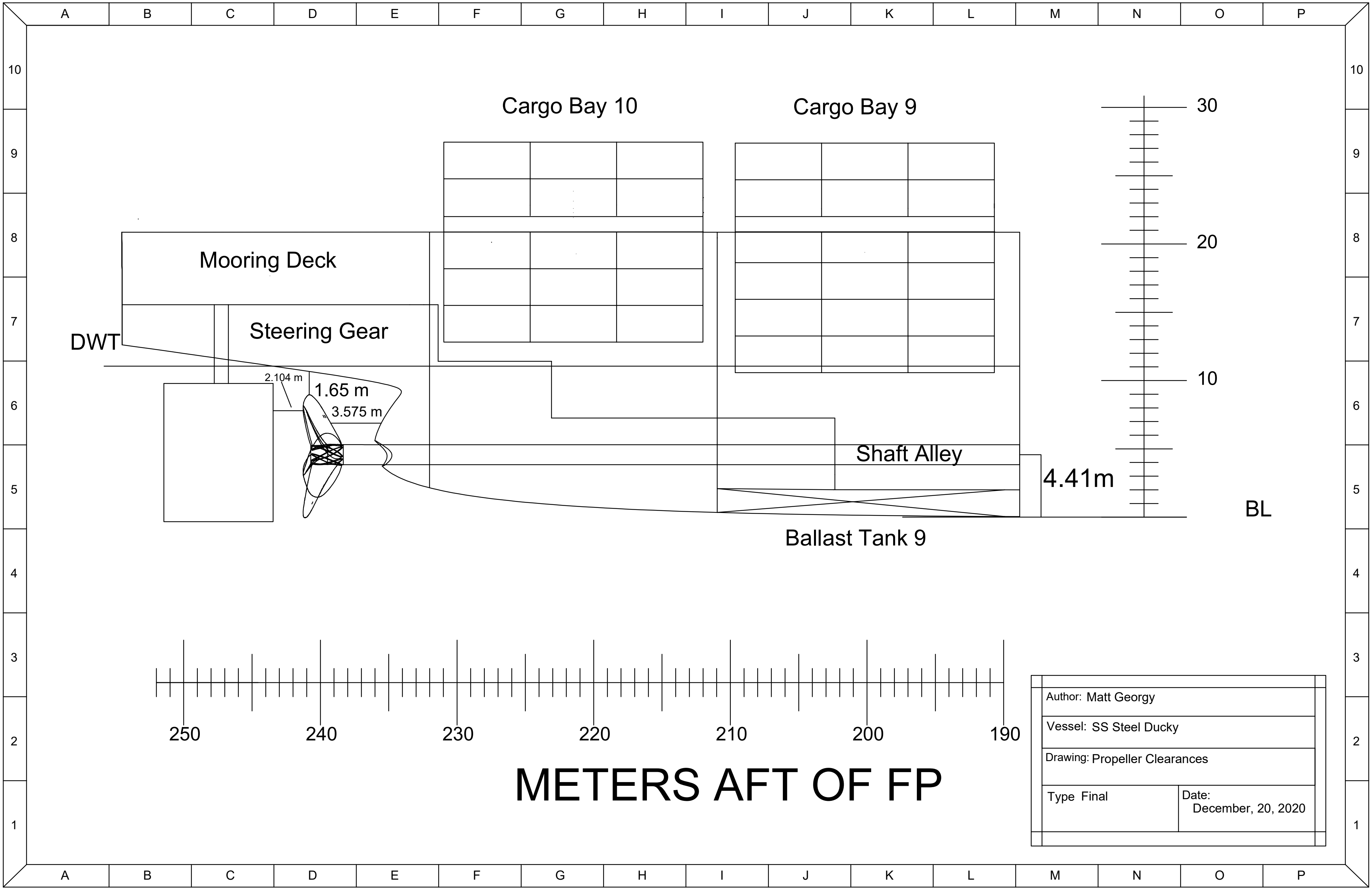
5.6 Machinery

The main engine and generators are located aft on the ship to minimize the length of the propeller shaft. The two main service generators are located on a platform above the engine room at deck 4. The emergency generator is located on the main deck and prevents from a "dark ship" scenario in the case of an engine failure.

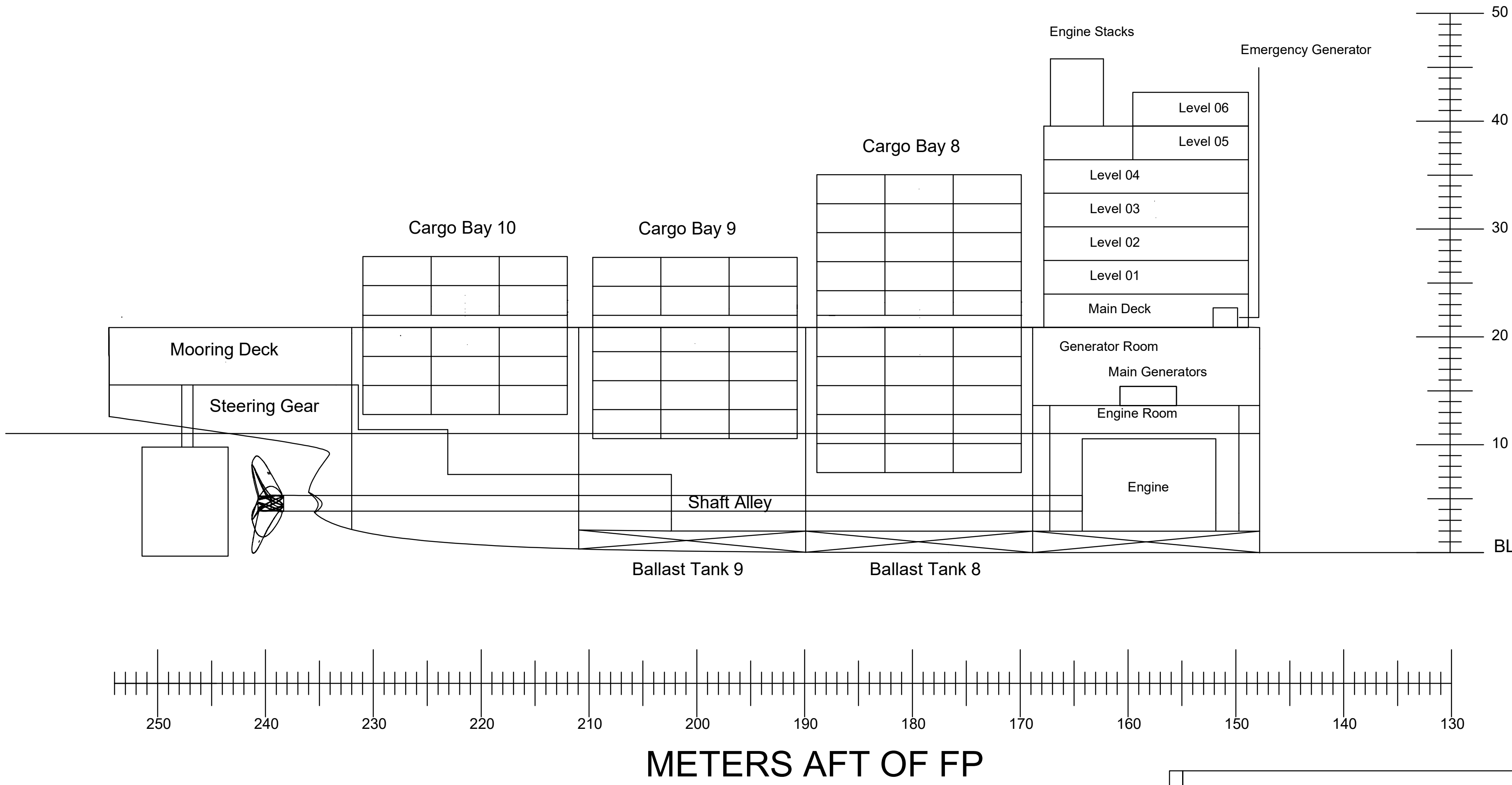
The shaft alley extends from the engine deck to the aft of the ship and is 2x2 containers width in area. It is completely clear of containers. The spacing of the propeller, hull and rudder, were checked against *Lloyd's Register of Shipping* regulations. The regulations and the actual spacing are detailed in Table 5.5. In order to meet the clearance the geometry of the aft of the ship had to be modified form the parent hull, slightly. This did not present a problem because there were no containers in this part of the ship. This allowed for a propeller diameter of 9 m which is large especially for a ship this size compared to operating designs today. However, because the diameter was large, the efficiency was very good which allowed for a smaller engine.

Table 5.5: Propeller

Dimension	Clearance (m)	Min Required (m)
a	1.426	1.008
b	3.575	1.597
c	2.104	1.065



Cargo Bay 10
Cargo Bay 9
Mooring Deck
Steering Gear
DWT
2.104 m
1.65 m
3.575 m
Shaft Alley
4.41m
BL
Ballast Tank 9
30
20
10
250
240
230
220
210
200
190
METERS AFT OF FP
Author: Matt Georgy
Vessel: SS Steel Ducky
Drawing: Propeller Clearances
Type Final
Date: December, 20, 2020



Author: Matt Georgy	
Vessel: SS Steel Ducky	
Drawing: Principal Machinery	
Type Final	Date: December, 20, 2020

6. Powering and Propulsion

The following chapter describes the design decisions behind the powering and propulsion of the *SS Steel Ducky* .

6.1 Powering Prediction

The amount of power needed to move the ship was determined by the *Powering Prediction Program* (PPP), while the propeller characteristics where determined by the *Propeller Optimization Program* (POP). Both of these software's were provided by the University of Michigan. First, values were inputted into the PPP in order to determine the necessary thrust the ship will need based on the dimensions of the ship. This analysis was also done with a 3% allowance for appendages was used, as well as a 10% design margin. These were included for unknown extra resistance and area in the calculation. A 15% service margin was also added to ensure the engine and propeller system can operate as necessary under heavy sea states. These values were then inputted into the POP to determine properties of the propeller, which spits out values that were put back into the PPP. This cycle (which is expanded on in the next section) was repeated until both programs produced the same outputs. The results from this cycle influenced the choice of propeller, ideal propeller RPM and necessary power. These results were centered around the required speed 20 knots. 79 RPM was found to be the *SS Steel Ducky* . The PPP was used to determine (P_E), the hull efficiency (η_H),and the relative rotative efficiency (η_R). The POP determined the open water efficiency (η_0) and the open water diagram for the chosen propeller. A maximum continuous rating (MCR) of 0.85 was used. The shaft efficiency (η_S) and gear efficiency (η_G) were assumed. The following equation 6.1 shows how these values were used to find the brake horsepower.

$$P_B * MCR = \frac{P_E}{\eta_0 * \eta_H * \eta_R * \eta_S * \eta_G} \tag{6.1}$$

The following table 6.1 details the summary of this analysis, from both PPP and POP.

Table 6.1: Summary of PPP results.

Parameter	**Value**
P_E	17,390.63 kW
Appendage Allowance	0.03
Design Margin	0.1
η_0	0.657
η_H	1.1657
η_R	0.9943
η_S	0.98
η_G	0.99
MCR	0.85
P_B	27692.7 kW

The following pages show inputs and results of the final PPP iteration.

```
           Shipbuilding Progress, Vol.31, No.363, Nov., 1984.

Run Identification: 4

Input Verification:

     Length of Waterline LWL (m)              =    250.00
     Maximum Beam on LWL (m)                  =     40.50
     Depth at the Bow (m)                     =     22.00

     Mean Draft (m)                           =     11.00
     Draft Forward (m)                        =     11.00
     Draft Aft (m)                            =     11.00

     Block Coefficient on LWL CB              =    0.6610
     Prismatic Coefficient on LWL CP          =    0.6677
     Midship Coefficient to LWL CM=CX         =    0.9900
     Waterplane Coefficient on LWL CWP        =    0.7800

     Center of Buoyancy LCB (% LWL; + Fwd)    =   -0.9320
     Center of Buoyancy LCB (m from FP)       =    127.33
     Molded Volume (m^3)                      =   73618.9
     Deck House/Cargo Frontal Area (m^2)      =    500.00

     Water Type                               =  Salt@15C
     Water Density (kg/m^3)                   =   1025.87
     Kinematic Viscosity (m^2/s)              =   0.118831E-05

     Appen. Drag (% Bare Hull Resistance)     =      3.00

     Bulb Section Area at Station 0 (m^2)     =     48.72
     Vertical Center of Bulb Area (m)         =      5.25

     Transom Immersed Area (m^2)              =      0.00
     Stern Type                               = Normally Shaped
     Design Margin on RT,PE,REQ.THR (%)       =     10.00
     Propulsion Type                          =  SS, Conv.

     Propeller Diameter (m)                   =      9.00
     Propeller Expanded Area Ratio Ae/Ao      =    0.8291

     Wetted Surface (m^2)                     =  11643.86
     Half Angle of Entrance (deg)             =     19.63
```

Figure 6.1: PPP Inputs

Shipbuilding Progress, Vol.31, No.363, Nov., 1984.

Run Identification: 4

Speed, Resistance Coefficients and Frictional Resistance RF(N):

V(kts)	V(m/s)	FN	SLRATIO	CF	CR	CA	RF
18.00	9.26	0.1870	0.6285	0.001411	0.000501	0.000300	722812.3
20.00	10.29	0.2078	0.6983	0.001394	0.000616	0.000300	881262.6
22.00	11.32	0.2286	0.7682	0.001378	0.000785	0.000300	1054394.6
24.00	12.35	0.2494	0.8380	0.001364	0.000980	0.000300	1242058.6
26.00	13.38	0.2701	0.9078	0.001352	0.001271	0.000300	1444121.0
28.00	14.40	0.2909	0.9777	0.001340	0.001669	0.000300	1660459.6
30.00	15.43	0.3117	1.0475	0.001329	0.001911	0.000300	1890963.1
32.00	16.46	0.3325	1.1173	0.001319	0.001970	0.000300	2135528.8

Remaining Resistance Components (N):

	Form	Appendage	Wave	Bulb	Transom	Correlation	Air Drag
V(kts)	RF*K1	RAPP	RW	RB	RTR	RA	RAIR
18.00	138707.6	29386.8	73929.0	44109.8	0.0	153726.8	30490.7
20.00	169114.2	38130.9	170274.9	50378.1	0.0	189786.2	37642.9
22.00	202338.2	49654.0	342207.8	56191.9	0.0	229641.3	45547.9
24.00	238350.9	64038.0	592649.6	61540.7	0.0	273292.1	54205.7
26.00	277126.7	84057.6	1014237.4	66435.3	0.0	320738.6	63616.4
28.00	318642.0	111858.3	1678608.9	70898.5	0.0	371980.9	73780.0
30.00	362875.6	138280.4	2280547.5	74959.4	0.0	427018.9	84696.4
32.00	409807.8	159730.1	2700349.3	78649.8	0.0	485852.6	96365.7

Resistance, Effective Power, Propulsion Factors and Required Thrust

V(kts)	RT(N)	PE(kW)	w	t	REQ.THR(N)	etaH	etaRR
18.00	1312479.4	12153.45	0.3045	0.1885	1617387.4	1.1667	0.9943
20.00	1690248.8	17390.63	0.3039	0.1885	2082918.1	1.1657	0.9943

Figure 6.2: PPP Outputs

6.2 Propeller Selection

Following use of the PPP, the POP was used to find a propeller expanded area ratio (A_e A_o) and a propeller diameter. This program was used to determine the following characteristics of the propeller. The odd number of blades reduces hull vibrations, and the 9 m diameter provides the necessary power while still fitting with Lloyd's Register clearances. The propellers optimal operation speed of 79 RPM provides the needed power and works in the optimal operating range of the chosen prime mover. The propeller characteristics are summarized in 7.2. The following pages have the summary of POP inputs and outputs and the open water diagram produced by the program.

Table 6.2: Summary of POP results.

Parameter	**Value**
Propeller Type	Wageningen B-Screw
Number of Blades	5
Diameter	9 m
Pitch	8.1 m
Expanded Area Ratio	0.8291
Speed	79 RPM
Pitch to Diameter Ratio	0.9
Open Water Efficiency (η_0)	0.657
Thrust Coefficient (K_T)	0.181
Torque Coefficient (K_Q)	0.0267
Propeller Thrust	2082.9 kN
Cavitation Number	0.4516

```
Run Identification:  Final

 Input Data:

     Optimization Run

     Fixed-Pitch Propeller
     Number of Propeller Blades              =        5
     Required Propeller Thrust (kN)          =    2082.9
     Ship Speed Vk (knots)                   =     20.00
     Wake Fraction w                         =     0.307
     Depth of Shaft below Waterline (m)      =      6.50
     Water Type                              =  salt@15C
     Water Density Rho (kg/m^3)              =   1025.87
     Kinematic Viscosity Nu (m^2/sec)        =   0.118831E-05
     Burrill Back Cavitation Constraint      =        5%

     Initial Expanded Area Ratio Ae/Ao       =     0.829
     Initial Pitch Diameter Ratio P/Dp       =     0.900
     Initial Propeller Diameter Dp (m)       =      9.00
     Minimum Diameter Constraint Dpmin (m)   =      7.00
     Maximum Diameter Constraint Dpmax (m)   =      9.00


 Optimal Design Results:

     Propeller Diameter Dp (m)                 =      9.00
     Propeller Pitch P (m)                     =      8.10
     Expanded Area Ratio Ae/Ao                 =    0.8291
     Pitch Diameter Ratio P/Dp                 =    0.9000
     Propeller Revolutions per Minute (rpm)    =     78.36
     Advance Coefficient J                     =    0.6071
     Thrust Coefficient KT                     =    0.1816
     Torque Coefficient KQ                     =   0.02670
     Propeller Open Water Efficiency Eta 0     =     0.657
     Propeller Thrust (kN)                     =    2082.9
     Reynolds Number RN                        = 0.796E+08
     Cavitation Number Sigma                   =    0.4516
     Optimization Search Evaluation Count      =       104
```

Figure 6.3: POPall

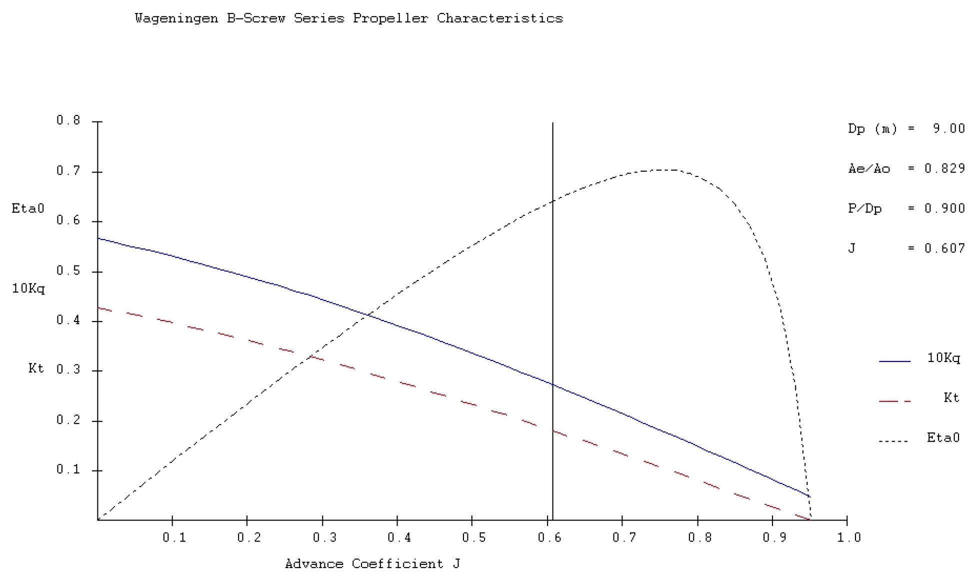


Figure 6.4: POPall

6.3 Main Engine Selection

A low speed WinGD-Diesel engine was selected as the prime mover. The 8 cylinder WinGD X72-B allows the engine to operate in an optimal capacity while still spinning the propeller at the optimal 78 RPM. The power needed to be generated by the engine is 27692.7 kW, the engine chosen can go up to 28,8851 kW while still performing at an optimal level. This is useful because it will allow the customer to make up for any unexpected delays during certain aspects of the trip such as offloading. This is demonstrated in Figure 7.1. The engine will be running at the R1 mode in order to perform optimally with the propeller and the engine. A summary of the engines parameters is shown in the table below.

Table 6.3: Summary of Prime Mover Specifications.

Parameter	**Value**
Brand	WinGD
Model	x72-B
Number of Cylinders	8
Power Output Range	22880 kW - 31360 kW
RPM Range	66-84
Weight	716 tonnes
Fuel Consumption	166 g/kWh

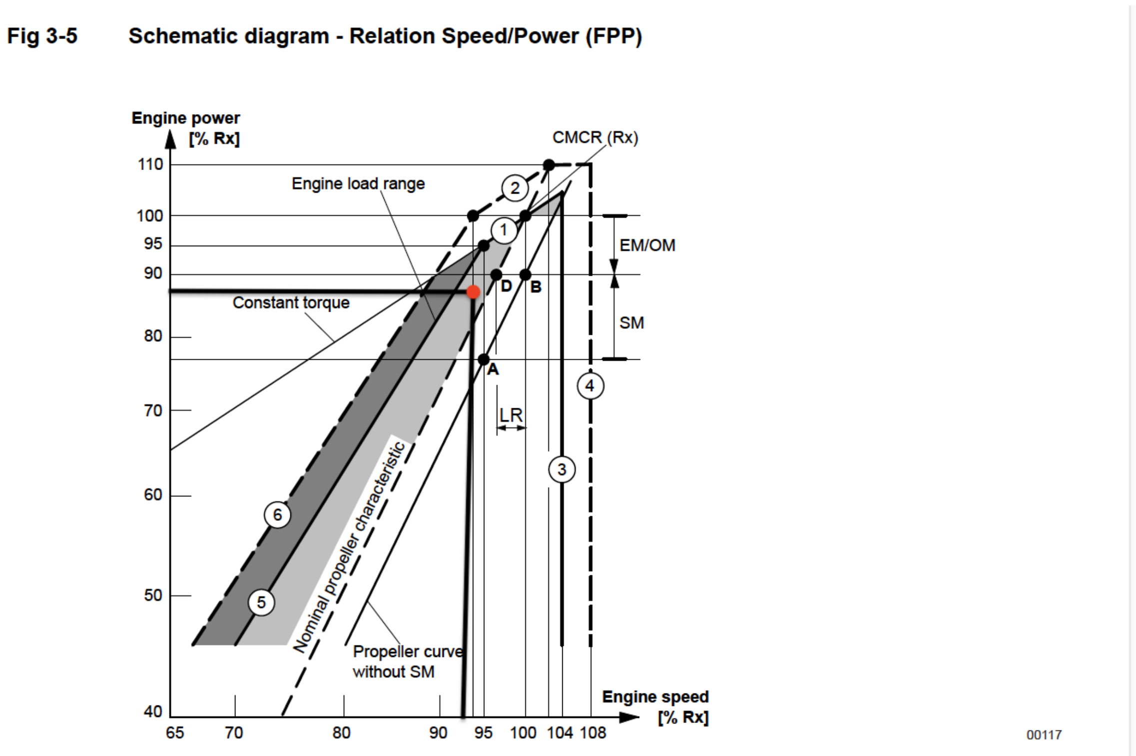


Figure 6.5: Optimal running plot for chosen prime-mover where the red-dot marks the necessary power and the optimal RPM for the propeller.

WinGD X72-B

IMO Tier II/Tier III (SCR)

Cylinder bore: 720mm	**Stroke/bore:** 4.29
Piston stroke: 3086mm	**Mean effective pressure at R1:** 21.0 bar
Speed: 66-89rpm	

RATED POWER, PRINCIPAL DIMENSIONS AND WEIGHTS

	Output in kw at					
	84rpm		66rpm			
Cyl.	R1	R2	R3	R4	Length A (mm)	Weight (tonnes)
5	19600	14300	14550	10600	8085	481
6	23520	17160	17460	12720	9375	561
7	27440	20020	20370	14840	10665	642
8	31360	22880	23280	16960	11960	716

Figure 6.6: Specifications of *SS Steel Ducky* Prime Mover, operation will mostly take place at R1

7. Generator Selection

The main generators chosen were the 2 Wartsila 20-9L20 these will provide a sufficient amount of electrical power for the refrigerated containers and the deck house. The owner requires that 400 containers be refrigerated each required 4.75 kW of power. The following equation from *Marine Diesel Power Plant Practices* was used to calculate the ship service loads.

$$kW_e \mathrm{kW}_e kW_e \mathrm{kW}_e = 100 + 0.55 MCR^{0}.7 \quad (7.1)$$

The ship service load was calculated to be 1079 kW. The refrigeration electrical load was calculated to be 1900 for a total of 2,979 kW required. These loads will be satisfied with two Wartsila 20-9L20 generators. The generators combined provide 3960 kW which allows for a 33% margin on the estimated power. The emergency generator chosen is a Wartsila 20-4l20 Generating Set. This provides 25% of the estimated electrical load. The emergency generator is located on the main deck apart from the engine room and the other two generators. This means that if the engine room is compromised the ship will still have power. This will protect the crew. The specifications of the generators are shown in the tables below.

Table 7.1: Summary of Main Generator Specifications

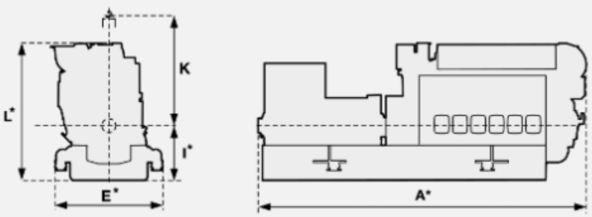
Parameter	**Value**
Manufacturer	Wartsila
Model	Genset 20-9L20
Number of Cylinders	9
Output Power	1980 kW
Speed	1200 RPM
Frequency	60 Hz
Length	2.524 m
Weight	23.8 t

Table 7.2: Summary of Emergency Generator Specifications

Parameter	**Value**
Manufacturer	Wartsila
Model	Genset 20-4L20
Number of Cylinders	4
Output Power	760 kW
Speed	1000 RPM
Frequency	50 Hz
Length	2.33 m
Weight	14 t

Wärtsilä 20DF generating set		IMO Tier III	
Cylinder bore	200 mm	Generator voltage	0.4 - 13.8 kV
Piston stroke	280 mm	Generator efficiency	0.95 - 0.96
Cylinder output	160, 185 kW/cyl	Fuel specification:	Fuel oil
Speed	1000, 1200 rpm	700 cSt/50°C	7200 sR1/100°C
Mean effective pressure	22.0, 21.0 bar	ISO 8217, category ISO-F-DMX, DMA & DMB	
Piston speed	9.3, 11.2 m/s	BSEC 8390 kJ/kWh at ISO cond. BSGC 8220 kJ/kWh at ISO cond.	

20DF, Rated power				
	60 Hz		50 Hz	
Engine type	185 kW/cyl, 1200 rpm		160 kW/cyl, 1000 rpm	
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
6L20DF	1110	1065	960	920
8L20DF	1480	1420	1280	1230
9L20DF	1665	1600	1440	1380



Dimensions (mm) and weights (tonnes)						
Engine type	A*	E*	I*	K	L*	Weight*
6L20DF	5325	2070	895 975 1025	1800	2731	16.7
8L20DF	6030	2070	1025 1075	1800	2791	20.8
9L20DF	6535	2300	1075 1125	1800	2831	23.7

* Dependent on generator type and size.

Figure 7.1: Main Generator Specifications

8. Weights and Stability

This chapter summarizes how weights and stability effect the design of the *SS Steel Ducky* .

Four load cases were used for this analysis: 14 ton departure, 14 ton arrival, 12 ton departure, and 12 ton arrival. The University of Michigan Weights II spreadsheet was used to perform the weight analysis. It was used to determine the weight, displacement, trim, forward and aft draft, VCG, GM_T and GM_L. The spreadsheets are shown in the following pages. The arrival cases were different in that the fuel oil, lube oil, and potable water weights were decreased by 10 of there original values.

The 14 ton departure was used to educate the design of the ship. The *SS Steel Ducky* was equipped with ballast tanks but after this analysis was done it was found that none of these cases need to use ballast in an intact form. This is not recommended in operation in case of damage, where the ballast tanks should be full for the arrival loads in order to ensure the GM_T is high and the ship will be transversely stable. In each load case the percent difference between the displacement and weight are within 1%, the GM_t passes the USCG requirements, and the trim is less than 0,5 m. The calculation of the USCG requirements for Wind Heel is shown after the Weights analysis spreadsheet.

Table 8.1: Load Cases GM_T and USCG requirement.

Load Case	Actual $GM_T(m)$	Required $GM_T(m)$
14 Ton Departure	0.71	0.468
14 Ton Arrival	0.49	0.468
12 Ton Departure	0.88	0.468
12 Ton Arrival	0.69	0.468

Table 8.2: Load Cases Trim and Different in Weight and Displacement.

Load Case	Trim (m) + by stern	Difference in Weight and Displacement (%)
14 Ton Departure	0.15	-0.5
14 Ton Arrival	-0.57	-0.5
12 Ton Departure	0.48	-0.5
12 Ton Arrival	0.34	-0.5

WEIGHTS AND CENTERS ESTIMATION FOR WEIGHTS II (R21)

Condition: All Cases

Models from: Watson, D. G. M. and A. W. Gilfillan, "Some Ship Design Methods," *Transactions* RINA, 1977.
Kupras, L. K., "Optimization Method and Parametric Study in Precontract Ship Design," *International Shipbuilding Progress*, May, 1971.
Watson, D. G. M.. *Practical Ship Design*, Elsevier Science Ltd, Oxford, UK, 1998.
Parsons, M. G., "Parametric Design," Ch. 11 in *Ship Design and Construction*, SNAME, 2003 (corrected).

Additional Parameters	*input data in yellow*	
depth D	20.12	m
design LWL for weight models	250.00	m
design B for weight models	40.50	m
design draft T for weight models	11.00	m
design block coeff. Cb for weight models	0.661	
superstructures sum(li*hi)	0	m^2
deckhouses sum(li*hi)	391	m^2
structural K	0.0336	Watson & Gilfillan or Watson Table
distance from amidships to hull LCG	0.553	% LWL positive aft
outfit Co	0.40	Watson & Gilfillan or Watson Figure
fraction of Wo at machinery	0.250	|
fraction of Wo at amidships	0.375	| fractions need to total one = 1.00
fraction of Wo at deckhouse	0.375	| check sum
total propulsion MCR	27692	kW
number of main engines	1	
propulsion engine Ne	79	rpm
ship type Km for mach'y Wrem	0.69	Km = [0.69 cargo; 0.72 tankers; 0.83 passenger; 0.19 frigates]
fuel capacity margin	5	per cent on total
endurance range	5700	nautical miles
endurance speed	20	knots
specific fuel rate	0.000182	t/kW*hr [use vendor's data + 10%]
engineroom overhead	13.0	meters above baseline
innerbottom height	1.92	meters above baseline
complement (crew+extras)	24	people
endurance days	12	days

Structural weight estimate details		
Cb'	0.713	
Ehull	14813.0	
Esuperstructure	0.0	
Edeckhouse	293.25	
Ws hull+ss+dh	16326.1	tonnes
Ws hull+ss	15896.6	tonnes
Ws hull only	15896.6	tonnes
Ws superstructure	0.0	tonnes
Ws deckhouse	429.5	tonnes
Outfit weight		
Wo	4050	tonnes
1.000		
LCB from Weights II		
LCB	126.44	m
Machinery weight estimate details		
Wme **	716.0	tonnes
Wrem	888.2	tonnes
Total Wm	1604.2	tonnes
Wfuel	1508.2	tonnes

** enter actual vendor's weight when known

Units in meters and tonnes

Figure 8.1: Weights II inputs for all cases

WEIGHTS II - WEIGHT SUMMARY (R21)

Condition: 14 Ton Departure

enter data in yellow

LWL for Hydrostatic Condition	250.00	meters
B for Hydrostatic Condition	40.50	meters
Weight Margin	3.00	per cent Light Ship at CG of Light Ship Weight
(1 + s)	1.005	shell/appendage allowance
KG Margin	0.30	meters
Free Surface Margin	3.00	per cent of KG
Water Weight Density	1.025	tonnes/m^3 (SW 1.025; FW 1.000)

Note: weights and centers in *italics* are linked to models from Input Data These may be overwritten if not applicable

HYDROSTATIC DATA input from HECSALV **(Input data @ 3 drafts spanning expected T ± 0.5 meter; @ expected trim)**

resulting interpolated properties

	T1	<	T2	<	T3				
						Cb	0.657		corresponding Cb
T	10.50		11.00		11.50	T	10.68	m	interpolated T
molded displacement	71408		75410		79504	**molded** Δ	72859	t	required displacement
BMT	12.21		11.91		11.66	BMT	12.10	m	
KB=VCB	5.54		5.82		6.10	KB=VCB	5.64	m	
BML	383.73		384.60		393.22	BML	383.18	m	from amidship, + fwd
LCB	127.02		127.46		127.91	LCB	127.18	m aft FP	-0.87%
LCF	134.70		135.66		137.05	LCF	134.98	m aft FP	-3.99%
Cx	0.990		0.990		0.991	Cx	0.990		for referencce LWL
Cwp	0.771		0.777		0.787	Cwp	0.767		

Note: Interpolated draft T must be T1 < T < T3

WEIGHT CATEGORY

LIGHT SHIP	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
*Hull Structure	*15896.6*	*15.30*	243217.3	-9.5	259.9	*132.25*	2102319.5
*Superstructures	*0.0*	0.00	0.0	0.0	0.0	0.00	0.0
*Deckhouses	*429.5*	31.48	13521.5	156.6	174.9	165.00	70867.3
Total Structure	16326.1	15.73				133.11	
* Outfit @ deckhouse	*1518.8*	*31.48*	47811.8	*156.6*	*174.9*	*165.00*	250586.2
* Outfit @ machinery	*1012.5*	*5.80*	5870.5	*159.0*	*208.0*	*183.50*	185793.8
* Outfit @ amidships	*1518.8*	*22.62*	34354.1	*-9.5*	*259.9*	*125.00*	189843.8
* Special outfit	0.0	0.00	0.0	0.0	0.0	0.00	0.0
Total Outfit	4050.0	21.74				154.62	
*Machinery	*1604.2*	*5.80*	9301.0	159.0	208.0	183.50	294365.6
*Permanent Ballast	0.00	0.00	0.0	0.0	0.0	0.00	0.0
*Light Ship Margin	659.4	16.11	10622.3			140.75	92813.3
Light Ship Weight	22639.6	16.11				140.75	

continued: **Condition:** 14 Ton Departure

WEIGHT CATEGORY DEADWEIGHT	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
* Cargo #1	2128.0	22.845	48614.2	13.91	32.19	23.05	49039.76
* Cargo #2	3416.0	20.25	69174.0	34.45	52.73	43.94	150095.62
* Cargo #3	4900.0	19.421	95162.9	55.11	73.39	64.39	315520.80
* Cargo #4	6118.0	19.545	119576.3	75.41	93.69	84.61	517631.74
* Cargo #5	6888.0	18	123984.0	95.71	113.99	100.85	694668.58
* Cargo #6	6888.0	18.054	124356.0	116.01	134.29	119.15	820718.98
* Cargo #7	6048.0	19.93	120536.6	136.31	154.59	139.05	840974.40
* Cargo #8	5810.0	19.892	115572.5	176.91	195.19	179.99	1045759.33
* Cargo #9	3780.0	18.693	70659.5	196.95	215.23	206.09	779035.32

Units in meters and tonnes

Figure 8.2: Weights II input first page 14 Ton Departure

WEIGHTS II - WEIGHT SUMMARY (R21)

* Cargo #10	3024.0	19.764	59766.3	217.51	235.79	226.65	685395.65
Cargo Deadweight	49000.0	19.33				120.38	
*Fuel Oil	*1508.2*	4.78	7212.2	141.00	153.00	158.09	238436.4
*Lube Oil	20.0	6.52	130.5	151.29	153.19	163.33	3266.5
*Water	*49.0*	4.66	228.0	19.88	29.41	24.64	1206.6
*Crew and Effects	*4.1*	15.50	63.2	120.00	130.00	125.00	510.0
*Provisions	*2.9*	13.00	37.4	125.00	130.00	127.50	367.2
* Ballast #1	0.0	1.13	0.0	13.00	33.80	23.40	0.0
* Ballast #2	0.0	1.02	0.0	33.80	54.10	43.95	0.0
* Ballast #3	0.0	1.06	0.0	54.10	74.40	64.25	0.0
* Ballast #4	0.0	1.01	0.0	74.40	94.71	84.55	0.0
* Ballast #5	0.0	0.99	0.0	94.71	115.00	104.85	0.0
* Ballast #6	0.0	1.03	0.0	115.00	135.30	125.15	0.0
* Ballast #7	0.0	1.07	0.0	135.30	155.60	145.45	0.0
* Ballast #8	0.0	0.96	0.0	0.00	0.00	0.00	0.0
Total Temp. Ballast	0.0	0.00				0.00	
Total Deadweight	50584.1	16.30				121.43	
Total Weight	73223.8	16.24	total VCG			127.41	total LCG

GM AND TRIM RESULTS

resulting hydrostatic conditions

Design KG	17.03	m, including design and free surface margins		
GM_t	0.71	m	**GM_L**	371.79 m
Trim	0.15	m; + by the stern		
T forward	10.60	m	**T aft**	10.75 m
%Diff Weight and Displacemer	-0.50			

Figure 8.3: Weights II input second page 14 Ton Departure

WEIGHTS II - WEIGHT SUMMARY (R21)

Condition: 14 Ton Arrival

	enter data in yellow	
LWL for Hydrostatic Condition	250.00	meters
B for Hydrostatic Condition	40.50	meters
Weight Margin	3.00	per cent Light Ship at CG of Light Ship Weight
(1 + s)	1.005	shell/appendage allowance
KG Margin	0.30	meters
Free Surface Margin	3.00	per cent of KG
Water Weight Density	1.025	tonnes/m^3 (SW 1.025; FW 1.000)

Note: weights and centers in *italics* are linked to models from Input Data. These may be overwritten if not applicable

HYDROSTATIC DATA
input from HECSALV

(Input data @ 3 drafts spanning expected T ± 0.5 meter; @ expected trim)

	T1	<	T2	<	T3	resulting interpolated properties			
						Cb	0.655		corresponding Cb
T	10.50		11.00		11.50	T	10.51	m	interpolated T
molded displacement	71408		75410		79504	molded Δ	71456	t	required displacement
BMT	12.21		11.91		11.66	BMT	12.21	m	
KB=VCB	5.54		5.82		6.10	KB=VCB	5.55	m	
BML	383.73		384.60		393.22	BML	383.69	m	from amidship, + fwd
LCB	127.02		127.46		127.91	LCB	127.03	m aft FP	-0.81%
LCF	134.70		135.66		137.05	LCF	134.71	m aft FP	-3.88%
Cx	0.990		0.990		0.991	Cx	0.990		for referencce LWL
Cwp	0.771		0.777		0.787	Cwp	0.771		

Note: Interpolated draft T must be T1 < T < T3

WEIGHT CATEGORY

LIGHT SHIP	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
*Hull Structure	*15896.6*	*15.30*	243217.3	-9.5	259.9	*129.25*	2054629.8
*Superstructures	*0.0*	0.00	0.0	0.0	0.0	0.00	0.0
*Deckhouses	*429.5*	31.48	13521.5	156.6	174.9	165.00	70867.3
Total Structure	16326.1	15.73				130.19	
* Outfit @ deckhouse	*1518.8*	*31.48*	47811.8	*156.6*	*174.9*	*165.00*	250586.2
* Outfit @ machinery	*1012.5*	*5.80*	5870.5	*159.0*	*208.0*	*183.50*	185793.8
* Outfit @ amidships	*1518.8*	*22.62*	34354.1	*-9.5*	*259.9*	*125.00*	189843.8
* Special outfit	0.0	0.00	0.0	0.0	0.0	0.00	0.0
Total Outfit	4050.0	21.74				154.62	
*Machinery	*1604.2*	*5.80*	9301.0	159.0	208.0	183.50	294365.6
*Permanent Ballast	0.00	0.00	0.0	0.0	0.0	0.00	0.0
*Light Ship Margin	659.4	16.11	10622.3			138.58	91382.6
Light Ship Weight	22639.6	16.11				138.58	

continued: Condition: 14 Ton Arrival

WEIGHT CATEGORY **DEADWEIGHT**	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
* Cargo #1	2128.0	22.845	48614.2	13.91	32.19	23.05	49039.76
* Cargo #2	3416.0	20.25	69174.0	34.45	52.73	43.94	150095.62
* Cargo #3	4900.0	19.421	95162.9	55.11	73.39	64.39	315520.80
* Cargo #4	6118.0	19.545	119576.3	75.41	93.69	84.61	517631.74
* Cargo #5	6888.0	18	123984.0	95.71	113.99	100.85	694668.58
* Cargo #6	6888.0	18.054	124356.0	116.01	134.29	119.15	820718.98
* Cargo #7	6048.0	19.93	120536.6	136.31	154.59	139.05	840974.40
* Cargo #8	5810.0	19.892	115572.5	176.91	195.19	179.99	1045759.33
* Cargo #9	3780.0	18.693	70659.5	196.95	215.23	206.09	779035.32

Units in meters and tonnes

Figure 8.4: Weights II input second page 14 Ton Arrival first page

WEIGHTS II - WEIGHT SUMMARY (R21)

* Cargo #10	3024.0	19.764	59766.3	217.51	235.79	226.65	685395.65
Cargo Deadweight	49000.0	19.33				120.38	
*Fuel Oil	158.9	4.78	759.9	141.00	153.00	148.09	23532.0
*Lube Oil	4.1	6.52	26.7	151.29	153.19	153.33	628.6
*Water	4.1	4.66	19.1	19.88	29.41	24.64	101.0
*Crew and Effects	4.1	15.50	63.2	120.00	130.00	125.00	510.0
*Provisions	2.9	13.00	37.4	125.00	130.00	127.50	367.2
* Ballast #1	0.0	1.13	0.0	13.00	33.80	23.40	0.0
* Ballast #2	0.0	1.02	0.0	33.80	54.10	43.95	0.0
* Ballast #3	0.0	1.06	0.0	54.10	74.40	64.25	0.0
* Ballast #4	0.0	1.01	0.0	74.40	94.71	84.55	0.0
* Ballast #5	0.0	0.99	0.0	94.71	115.00	104.85	0.0
* Ballast #6	0.0	1.03	0.0	115.00	135.30	125.15	0.0
* Ballast #7	0.0	1.07	0.0	135.30	155.60	145.45	0.0
* Ballast #8	0.0	0.96	0.0	0.00	0.00	0.00	0.0
Total Temp. Ballast	0.0	0.00				0.00	
Total Deadweight	49174.1	16.63				120.47	
Total Weight	71813.7	16.47	total VCG			126.18	total LCG

GM AND TRIM RESULTS

resulting hydrostatic conditions

Design KG	17.26	m, including design and free surface margins		
GM_t	0.49	m	GM_L	371.98 m
Trim	-0.57	m; + by the stern		
T forward	10.81	m	T aft	10.24 m
%Diff Weight and Diplacement	-0.50			

Figure 8.5: Weights II input second page 14 Ton Arrival second page

WEIGHTS II - WEIGHT SUMMARY (R21)

Condition: 12 Ton Departure

enter data in yellow

LWL for Hydrostatic Condition	250.00	meters
B for Hydrostatic Condition	40.50	meters
Weight Margin	3.00	per cent Light Ship at CG of Light Ship Weight
(1 + s)	1.005	shell/appendage allowance
KG Margin	0.30	meters
Free Surface Margin	3.00	per cent of KG
Water Weight Density	1.025	tonnes/m^3 (SW 1.025; FW 1.000)

Note: weights and centers in *italics* are linked to models from Input Data. These may be overwritten if not applicable

HYDROSTATIC DATA
input from HECSALV

(Input data @ 3 drafts spanning expected T ± 0.5 meter; @ expected trim)

resulting interpolated properties

	T1	<	T2	<	T3				
						Cb	0.648		corresponding Cb
T	10.50		11.00		11.50	T	9.79	m	interpolated T
molded displacement	71408		75410		79504	**molded Δ**	65894	t	required displacement
BMT	12.21		11.91		11.66	BMT	12.70	m	
KB=VCB	5.54		5.82		6.10	KB=VCB	5.16	m	
BML	383.73		384.60		393.22	BML	394.77	m	from amidship, + fwd
LCB	127.02		127.46		127.91	LCB	126.44	m aft FP	-0.58%
LCF	134.70		135.66		137.05	LCF	134.74	m aft FP	-3.90%
Cx	0.990		0.990		0.991	Cx	0.992		for referencce LWL
Cwp	0.771		0.777		0.787	Cwp	0.779		

Note: Interpolated draft T must be T1 < T < T3

WEIGHT CATEGORY

LIGHT SHIP	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
*Hull Structure	*15896.6*	*15.30*	243217.3	-9.5	265.0	*129.25*	2054629.8
*Superstructures	*0.0*	0.00	0.0	0.0	0.0	0.00	0.0
*Deckhouses	*429.5*	31.48	13521.5	156.6	174.9	165.00	70867.3
Total Structure	16326.1	15.73				130.19	
* Outfit @ deckhouse	*1518.8*	*31.48*	47811.8	*156.6*	*174.9*	*165.00*	250586.2
* Outfit @ machinery	*1012.5*	*5.80*	5870.5	*159.0*	*208.0*	*183.50*	185793.8
* Outfit @ amidships	*1518.8*	*22.62*	34354.1	*-9.5*	*265.0*	*125.00*	189843.8
* Special outfit	0.0	0.00	0.0	0.0	0.0	0.00	0.0
Total Outfit	4050.0	21.74				154.62	
*Machinery	*1604.2*	*5.80*	9301.0	159.0	208.0	183.50	294365.6
*Permanent Ballast	0.00	0.00	0.0	0.0	0.0	0.00	0.0
*Light Ship Margin	659.4	16.11	10622.3			138.58	91382.6
Light Ship Weight	22639.6	16.11				138.58	

continued: **Condition:** 12 Ton Departure

WEIGHT CATEGORY DEADWEIGHT	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
* Cargo #1	1824.0	22.845	41669.3	13.91	32.19	23.05	42034.08
* Cargo #2	2928.0	20.25	59292.0	34.45	52.73	43.94	128653.39
* Cargo #3	4200.0	19.421	81568.2	55.11	73.39	64.39	270446.40
* Cargo #4	5244.0	19.545	102494.0	75.41	93.69	84.61	443684.35
* Cargo #5	5904.0	18	106272.0	95.71	113.99	100.85	595430.21
* Cargo #6	5904.0	18.054	106590.8	116.01	134.29	119.15	703473.41
* Cargo #7	5184.0	19.93	103317.1	136.31	154.59	139.05	720835.20
* Cargo #8	4980.0	19.892	99062.2	176.91	195.19	179.99	896365.14
* Cargo #9	3240.0	18.693	60565.3	196.95	215.23	206.09	667744.56

Units in meters and tonnes

Figure 8.6: Weights II input second page 12 Ton Departure first page

WEIGHTS II - WEIGHT SUMMARY (R21)

* Cargo #10	2592.0	19.764	51228.3	217.51	235.79	226.65	587481.98
Cargo Deadweight	42000.0	19.33				120.38	
*Fuel Oil	*1508.2*	4.78	7212.2	141.00	153.00	148.09	223354.3
*Lube Oil	20.0	6.52	130.5	151.29	153.19	153.33	3066.5
*Water	*49.0*	4.66	228.0	19.88	29.41	24.64	1206.6
*Crew and Effects	*4.1*	15.50	63.2	120.00	130.00	125.00	510.0
*Provisions	*2.9*	13.00	37.4	125.00	130.00	127.50	367.2
* Ballast #1	0.0	1.13	0.0	13.00	33.80	23.40	0.0
* Ballast #2	0.0	1.02	0.0	33.80	54.10	43.95	0.0
* Ballast #3	0.0	1.06	0.0	54.10	74.40	64.25	0.0
* Ballast #4	0.0	1.01	0.0	74.40	94.71	84.55	0.0
* Ballast #5	0.0	0.99	0.0	94.71	115.00	104.85	0.0
* Ballast #6	0.0	1.03	0.0	115.00	135.30	125.15	0.0
* Ballast #7	0.0	1.07	0.0	135.30	155.60	145.45	0.0
* Ballast #8	0.0	0.96	0.0	0.00	0.00	0.00	0.0
Total Temp. Ballast	0.0	0.00				0.00	
Total Deadweight	43584.1	16.24				121.25	
Total Weight	66223.8	16.20	total VCG			127.18	total LCG

GM AND TRIM RESULTS

resulting hydrostatic conditions

Design KG	16.98	m, including design and free surface margins		
GM_t	0.88	m	**GM_L**	382.95 m
Trim	0.48	m; + by the stern		
T forward	9.53	m	**T aft**	10.01 m
%Diff Weight and Displacement	-0.50			

Figure 8.7: Weights II input second page 12 Ton Departure second page

WEIGHTS II - WEIGHT SUMMARY (R21)

Condition: 12 Ton Arrival

enter data in yellow

LWL for Hydrostatic Condition	250.00	meters	
B for Hydrostatic Condition	40.50	meters	
Weight Margin	3.00	per cent Light Ship at CG of Light Ship Weight	
(1 + s)	1.005	shell/appendage allowance	
KG Margin	0.30	meters	
Free Surface Margin	3.00	per cent of KG	
Water Weight Density	1.025	tonnes/m^3	(SW 1.025; FW 1.000)

Note: weights and centers in *italics* are linked to models from Input Data. These may be overwritten if not applicable

HYDROSTATIC DATA
input from HECSALV

(Input data @ 3 drafts spanning expected T ± 0.5 meter; @ expected trim)

resulting interpolated properties

	T1	<	T2	<	T3				
						Cb	0.647		corresponding Cb
T	10.50		11.00		11.50	T	9.62	m	interpolated T
molded displacement	71408		75410		79504	molded Δ	64585	t	required displacement
BMT	12.21		11.91		11.66	BMT	12.83	m	
KB=VCB	5.54		5.82		6.10	KB=VCB	5.07	m	
BML	383.73		384.60		393.22	BML	399.47	m	from amidship, + fwd
LCB	127.02		127.46		127.91	LCB	126.30	m aft FP	-0.52%
LCF	134.70		135.66		137.05	LCF	135.10	m aft FP	-4.04%
Cx	0.990		0.990		0.991	Cx	0.992		for reference LWL
Cwp	0.771		0.777		0.787	Cwp	0.738		

Note: Interpolated draft T must be T1 < T < T3

WEIGHT CATEGORY LIGHT SHIP	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
*Hull Structure	*15896.6*	*15.30*	243217.3	-9.5	259.9	*129.25*	2054629.8
*Superstructures	*0.0*	0.00	0.0	0.0	0.0	0.00	0.0
*Deckhouses	*429.5*	31.48	13521.5	156.6	174.9	165.00	70867.3
Total Structure	16326.1	15.73				130.19	
* Outfit @ deckhouse	*1518.8*	*31.48*	47811.8	*156.6*	*174.9*	*165.00*	250586.2
* Outfit @ machinery	*1012.5*	*5.80*	5870.5	*159.0*	*208.0*	*183.50*	185793.8
* Outfit @ amidships	*1518.8*	*22.62*	34354.1	*-9.5*	*259.9*	*125.00*	189843.8
* Special outfit	0.0	0.00	0.0	0.0	0.0	0.00	0.0
Total Outfit	4050.0	21.74				154.62	
*Machinery	*1604.2*	*5.80*	9301.0	159.0	208.0	183.50	294365.6
*Permanent Ballast	0.00	0.00	0.0	0.0	0.0	0.00	0.0
*Light Ship Margin	659.4	16.11	10622.3			138.58	91382.6
Light Ship Weight	22639.6	16.11				138.58	

continued: Condition: 12 Ton Arrival

WEIGHT CATEGORY DEADWEIGHT	WT [t]	VCG [m abv. BL]	product	start point [m aft FP]	end point [m aft FP]	LCG [m from FP]	product
* Cargo #1	1824.0	22.845	41669.3	13.91	32.19	23.05	42034.08
* Cargo #2	2928.0	20.25	59292.0	34.45	52.73	43.94	128653.39
* Cargo #3	4200.0	19.421	81568.2	55.11	73.39	64.39	270446.40
* Cargo #4	5244.0	19.545	102494.0	75.41	93.69	84.61	443684.35
* Cargo #5	5904.0	18	106272.0	95.71	113.99	100.85	595430.21
* Cargo #6	5904.0	18.054	106590.8	116.01	134.29	119.15	703473.41
* Cargo #7	5184.0	19.93	103317.1	136.31	154.59	139.05	720835.20
* Cargo #8	4980.0	19.892	99062.2	176.91	195.19	179.99	896365.14
* Cargo #9	3240.0	18.693	60565.3	196.95	215.23	206.09	667744.56

Units in meters and tonnes

Figure 8.8: Weights II input second page 12 Ton Arrival first page

WEIGHTS II - WEIGHT SUMMARY (R21)

* Cargo #10	2592.0	19.764	51228.3	217.51	235.79	226.65	587481.98
Cargo Deadweight	42000.0	19.33				120.38	
*Fuel Oil	255.0	4.78	1219.4	141.00	153.00	148.09	37763.7
*Lube Oil	2.1	6.52	13.7	151.29	153.19	153.33	322.0
*Water	4.1	4.66	19.1	19.88	29.41	24.64	101.0
*Crew and Effects	4.1	15.50	63.2	120.00	130.00	125.00	510.0
*Provisions	2.9	13.00	37.4	125.00	130.00	127.50	367.2
* Ballast #1	0.0	1.13	0.0	13.00	33.80	23.40	0.0
* Ballast #2	0.0	1.02	0.0	33.80	54.10	43.95	0.0
* Ballast #3	0.0	1.06	0.0	54.10	74.40	64.25	0.0
* Ballast #4	0.0	1.01	0.0	74.40	94.71	84.55	0.0
* Ballast #5	0.0	0.99	0.0	94.71	115.00	104.85	0.0
* Ballast #6	0.0	1.03	0.0	115.00	135.30	125.15	0.0
* Ballast #7	0.0	1.07	0.0	135.30	155.60	145.45	0.0
* Ballast #8	0.0	0.96	0.0	0.00	0.00	0.00	0.0
Total Temp. Ballast	0.0	0.00				0.00	
Total Deadweight	42268.2	16.60				120.54	
Total Weight	64907.8	16.43	total VCG			126.84	total LCG

GM AND TRIM RESULTS

resulting hydrostatic conditions

Design KG	17.22	m, including design and free surface margins			
GM_t	0.69	m	**GM_L**	387.32	m
Trim	0.34	m; + by the stern			
T forward	9.44	m	**T aft**	9.78	m
%Diff Weight and Diplacement	-0.50				

Figure 8.9: Weights II input second page 12 Ton Arrival second page

U.S. Coast Guard Wind Heel GMt (R2) [46CFR170.170]

Draft T	11.00	m		input
Depth D	20.12	m		
Length LOA	265	m		output
Beam BOA	40.5	m		
Displacement	75502	t		
Freeboard F	9.12	m		

	number	length	height	#ℓh	abv DWL	Az
Lateral Areas	#	ℓ [m]	h [m]	A [m^2]	z [m]	moment
Hull above DWL	1	265	9.120	2416.8	4.560	11020.61
First level	1	210.4	4.790	1007.82	11.515	11605.00
Second level	1	210.4	2.600	547.04	15.210	8320.48
Third level	1	105.16	2.600	273.42	17.810	4869.54
Fourth level	2	120.00	2.600	624.00	20.410	12735.84
Fifth level	2	15.72	7.700	242.09	25.560	6187.77
				0.00	29.410	0.00
Summation				5111.16	10.710	54739.24
				total area	net z	

h			net z + T/2 =	16.210	m
P	0.09598	t/m^2			
min(14,atan(F/B))	0.2215	radians	14 deg. =	0.2443	radians
GMt reqd	0.468	m			

Note: these are the same deckhouse and superstructure profile view ℓ x h areas used in the Watson and Gilfillan structural weight modeling.

Figure 8.10: USCG minimum GM$_T$*required*.

9. Floodable Length

Maxsurf Stability was used to verify the *SS Steel Ducky* 's floodable lengths curves were suitable for the customer and were safe in case of flooding. Curves for compartment permeabilities of 100%, 98%, 95%, 85%, and 75% were generated for each of the test cases. This was done while also considering the one and two compartment flooding criteria. None of the load cases at any of the permeabilities reach the marigin line. The graphs for each load case and permeability are shown below.

9.1 Floodable Length for 14 Ton Departure

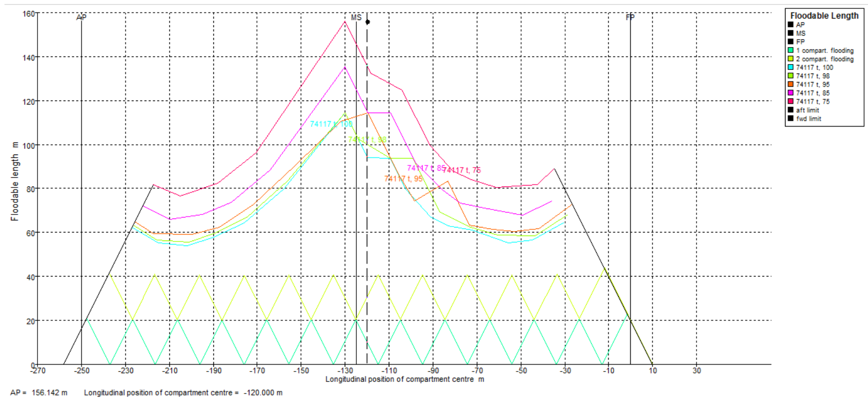


Figure 9.1: Floodable Length Curves for 14 Ton Arrival

Table 9.1: Floodable Length Data for 14 Ton Arrival

Dist from FP (m)	100%	98%	95%	85%	75%
0	20.07	20.07	20.07	20.07	20.07
10.41	40.89	40.89	40.89	40.89	40.89
20.819	61.71	61.71	61.71	61.71	61.71
31.229	63.99	66.32	69.51	82.52	82.52
41.638	58.23	59.83	62.06	71.53	82.49
52.047	55.64	58.69	60.50	68.31	81.17
62.457	57.63	59.31	61.47	70.24	80.98
72.866	61.29	62.53	63.35	72.42	84.04
83.276	63.00	67.59	83.28	77.63	90.60
93.685	69.76	83.28	76.97	87.45	104.10
104.095	83.28	93.69	83.61	104.09	124.91
114.504	93.82	96.74	104.09	114.54	130.45
124.914	104.09	104.09	112.89	124.91	145.73
135.323	108.01	108.27	107.44	128.12	148.42
145.733	95.02	95.80	97.21	113.71	132.97
156.142	82.02	83.35	87.20	99.30	117.52
166.552	72.46	74.16	77.61	86.35	102.08
176.961	63.91	65.81	69.36	77.70	91.09
187.371	58.94	60.47	62.47	71.34	82.78
197.78	55.39	56.83	59.53	67.70	79.10
208.19	54.72	56.21	59.33	66.21	78.05
218.599	57.43	58.47	60.52	70.34	79.06
229.009	58.24	58.24	58.24	58.24	58.24
239.418	37.42	37.42	37.42	37.42	37.42
249.828	16.60	16.60	16.60	16.60	16.60

9.2 Floodable Length for 14 Ton Arrival

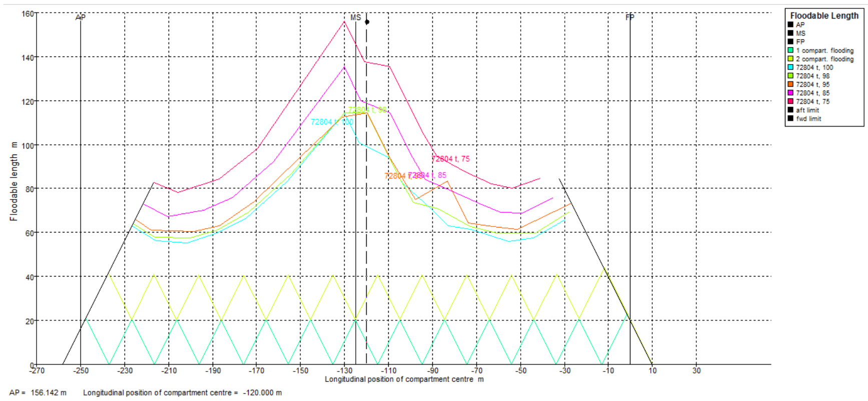


Figure 9.2: Floodable Length Curves for 14 Ton Arrival

Table 9.2: Floodable Length Data for 14 Ton Arrival

Dist from FP (m)	100%	98%	95%	85%	75%
0	20.07	20.07	20.07	20.07	20.07
10.41	40.89	40.89	40.89	40.89	40.89
20.819	61.71	61.71	61.71	61.71	61.71
31.229	70.99	71.09	73.18	82.52	82.52
41.638	66.18	63.98	65.96	77.46	91.74
52.047	61.62	62.90	64.13	74.14	86.21
62.457	62.68	63.10	65.65	74.40	87.21
72.866	63.60	64.75	70.31	79.15	93.31
83.276	70.62	73.59	73.76	87.07	104.09
93.685	83.28	83.28	83.56	104.10	124.91
104.095	93.83	104.09	104.09	114.72	135.56
114.504	104.09	111.03	109.75	124.91	145.73
124.914	124.91	124.91	124.91	145.73	166.55
135.323	114.23	116.17	124.38	134.80	155.06
145.733	103.54	106.58	111.33	123.87	143.56
156.142	92.26	94.77	97.94	111.24	130.29
166.552	80.94	82.96	85.39	98.41	116.47
176.961	72.47	74.61	76.93	87.27	102.65
187.371	66.00	67.57	70.21	80.30	94.70
197.78	64.13	63.38	66.02	76.06	89.41
208.19	62.29	63.06	64.88	74.53	87.99
218.599	63.23	64.65	69.28	79.06	79.06
229.009	58.24	58.24	58.24	58.24	58.24
239.418	37.42	37.42	37.42	37.42	37.42
249.828	16.60	16.60	16.60	16.60	16.60

9.3 Floodable Length for 12 Ton Departure

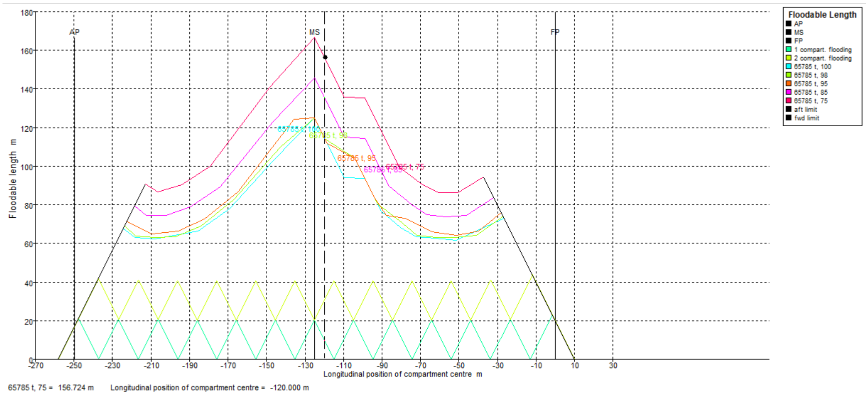


Figure 9.3: Floodable Length Curves for 12 Ton Departure

Table 9.3: Floodable Length Data for 12 Ton Departure

Dist from FP (m)	100%	98%	95%	85%	75%
0	20.07	20.07	20.07	20.07	20.07
10.41	40.89	40.89	40.89	40.89	40.89
20.819	61.71	61.71	61.71	61.71	61.71
31.229	70.99	71.09	73.18	82.52	82.52
41.638	66.18	63.98	65.96	77.46	91.74
52.047	61.62	62.90	64.13	74.14	86.21
62.457	62.68	63.10	65.65	74.40	87.21
72.866	63.60	64.75	70.31	79.15	93.31
83.276	70.62	73.59	73.76	87.07	104.09
93.685	83.28	83.28	83.56	104.10	124.91
104.095	93.83	104.09	104.09	114.72	135.56
114.504	104.09	111.03	109.75	124.91	145.73
124.914	124.91	124.91	124.91	145.73	166.55
135.323	114.23	116.17	124.38	134.80	155.06
145.733	103.54	106.58	111.33	123.87	143.56
156.142	92.26	94.77	97.94	111.24	130.29
166.552	80.94	82.96	85.39	98.41	116.47
176.961	72.47	74.61	76.93	87.27	102.65
187.371	66.00	67.57	70.21	80.30	94.70
197.78	64.13	63.38	66.02	76.06	89.41
208.19	62.29	63.06	64.88	74.53	87.99
218.599	63.23	64.65	69.28	79.06	79.06
229.009	58.24	58.24	58.24	58.24	58.24
239.418	37.42	37.42	37.42	37.42	37.42
249.828	16.60	16.60	16.60	16.60	16.60

9.4 Floodable Length for 12 Ton Arrival

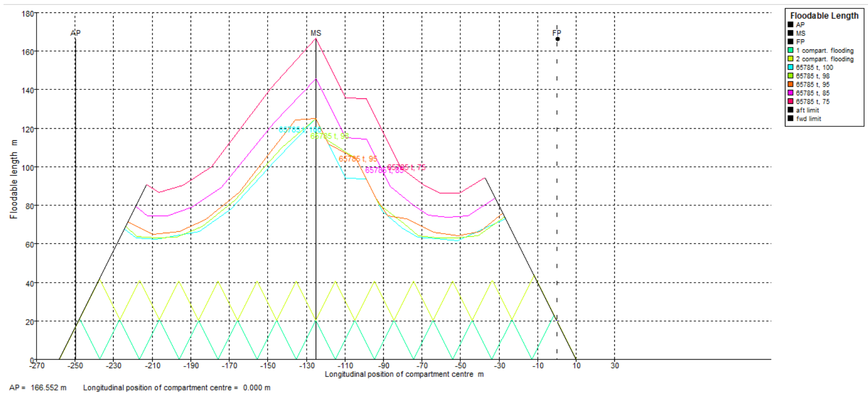


Figure 9.4: Floodable Length Curves for 12 Ton Arrival

Table 9.4: Floodable Length Data for 12 Ton Arrival

Dist from FP (m)	100%	98%	95%	85%	75%
0	20.07	20.07	20.07	20.07	20.07
10.41	40.89	40.89	40.89	40.89	40.89
20.819	61.71	61.71	61.71	61.71	61.71
31.229	70.99	71.09	73.18	82.52	82.52
41.638	66.18	63.98	65.96	77.46	91.74
52.047	61.62	62.9	64.13	74.14	86.21
62.457	62.68	63.1	65.65	74.4	87.21
72.866	63.6	64.75	70.31	79.15	93.31
83.276	70.62	73.59	73.76	87.07	104.09
93.685	83.28	83.28	83.56	104.1	124.91
104.095	93.83	104.09	104.09	114.72	135.56
114.504	104.09	111.03	109.75	124.91	145.73
124.914	124.91	124.91	124.91	145.73	166.55
135.323	114.23	116.17	124.38	134.8	155.06
145.733	103.54	106.58	111.33	123.87	143.56
156.142	92.26	94.77	97.94	111.24	130.29
166.552	80.94	82.96	85.39	98.41	116.47
176.961	72.47	74.61	76.93	87.27	102.65
187.371	66	67.57	70.21	80.3	94.7
197.78	64.13	63.38	66.02	76.06	89.41
208.19	62.29	63.06	64.88	74.53	87.99
218.599	63.23	64.65	69.28	79.06	79.06
229.009	58.24	58.24	58.24	58.24	58.24
239.418	37.42	37.42	37.42	37.42	37.42
249.828	16.6	16.6	16.6	16.6	16.6

10. Structure

In order to ensure the *SS Steel Ducky* 's structure can withstand moments placed on it by the sea, the maximum longitudinal strength characteristics for each load case were found using *Maxsurf Stability*. This included the maximum bending moment and the maximum shear stress force. Following this the *SS Steel Ducky* 's midship section was created and analyzed in *Rhinoceros 3D* and was found to meet the requirements set forth by the ABS in *Rules for Building and Classing Steel Vessels (2019)*. This chapter details this analysis.

10.1 Still Water Bending Moments

Using *Maxsurf Stability* the values of the still water bending moments and shear force stress were found for each load case. These values are summarized in Table 10.1. The actual analysis is shown in the following pages.

Table 10.1: Summary of Longitudinal Strength Charactereststics.

Strength Characteristic	14 Ton Departure	14 Ton Arrival	12 Ton Departure	12 Ton Arrival
Max Bending Moment (t-m)	227,338	252,092	227,538	252,148
Max Shear Force (t)	4,397	4,678	4,374	4,641

10.1.1 Longitudinal Strength Analysis for 14 Ton Departure

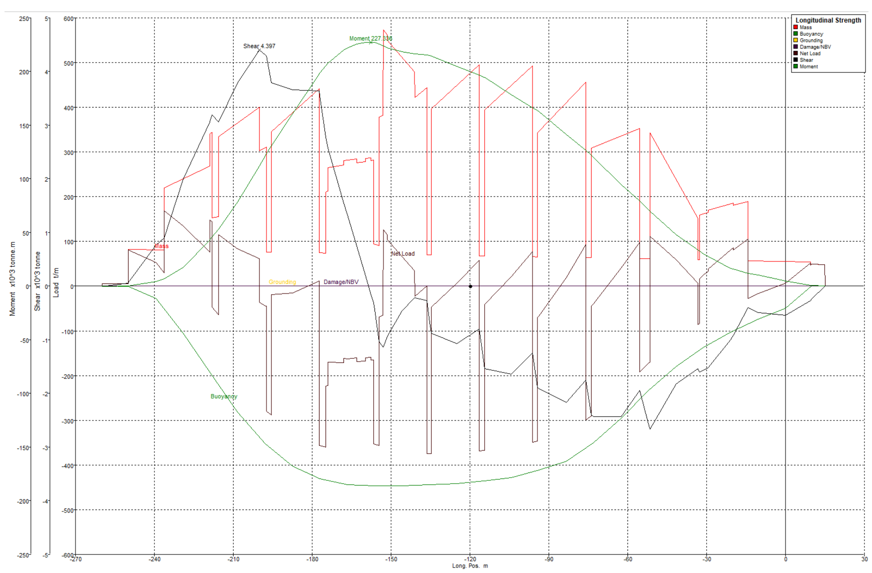


Figure 10.1: Longitudinal Strength Data for 14 Ton Departure

Table 10.2: Floodable Length Data for 14 Ton Arrival

Station	Long Pos (m)	**Mass (t/m)**	**Bouyancy (t/m)**	**Net Load (t/m)**	**Shear (10ˆ3 t)**	Moment **(10ˆ3 tm)**
st 0	0	55.614	-49.01	6.604	-0.545	4.742
st 1	-10.41	56.721	-73.585	-16.864	-0.491	10.24
st 2	-20.819	184.128	-102.66	81.468	-0.999	16.683
st 3	-31.229	161.716	-137.068	24.648	-1.569	30.394
st 4	-41.638	239.085	-179.66	59.426	-1.818	47.782
st 5	-52.047	61.151	-233.506	-172.355	-2.576	71.384
st 6	-62.457	335.812	-294.859	40.953	-2.427	94.517
st 7	-72.866	310.958	-349.912	-38.953	-2.436	119.936
st 8	-83.276	410.914	-391.453	19.461	-2.159	141.104
st 9	-93.685	346.317	-411.581	-65.264	-1.919	162.444
st 10	-104.095	449.883	-428.131	21.753	-1.633	178.044
st 11	-114.504	67.795	-435.588	-367.793	-1.497	194.649
st 12	-124.914	449.26	-441.636	7.624	-1.069	204.868
st 13	-135.323	70.01	-444.142	-374.132	-0.643	214.973
st 14	-145.733	511.825	-446.034	65.791	-0.46	218.325
st 15	-156.142	93.118	-446.828	-353.711	-0.476	226.885
st 16	-166.552	281.746	-443.817	-162.07	1.313	222.188
st 17	-176.961	74.44	-431.085	-356.645	3.51	198.98
st 18	-187.371	388.548	-402.959	-14.41	3.657	161.174
st 19	-197.78	309.523	-353.632	-44.109	4.309	121.711
st 20	-208.19	365.974	-282.098	83.876	3.801	78.602
st 21	-218.599	342.167	-195.055	147.112	3.106	43.854
st 22	-229.009	240.01	-105.501	134.509	1.998	17.469
st 23	-239.418	81.084	-27.921	53.163	0.768	4.417
st 24	-249.828	82.192	-0.706	81.486	0.067	0.175

10.1.2 Longitudinal Strength Analysis for 14 Ton Arrival

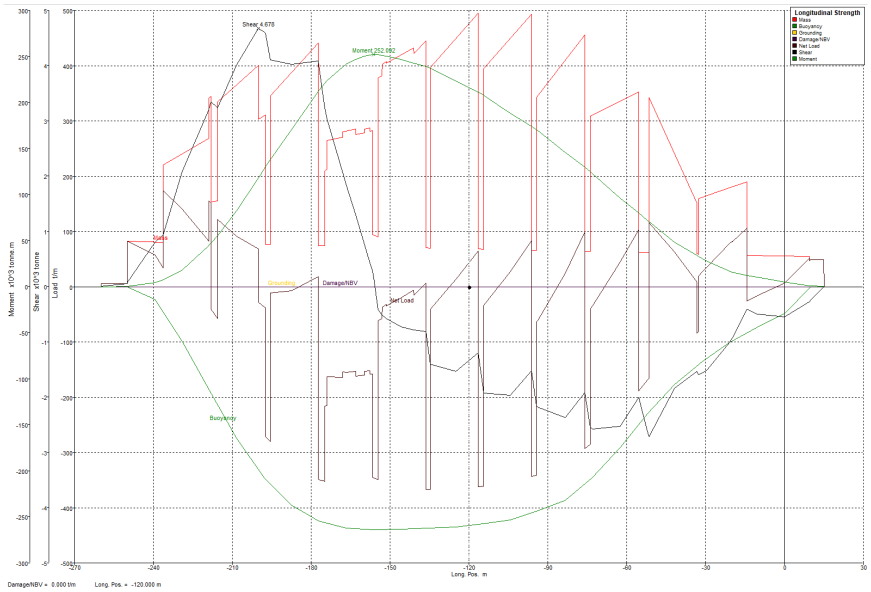


Figure 10.2: Longitudinal Strength Data for 12 Ton Departure

Table 10.3: Longitudinal Strength Data for 12 Ton Departure

Station	Long Pos (m)	**Mass (t/m)**	**Bouyancy (t/m)**	**Net Load (t/m)**	**Shear (10ˆ3 t)**	Moment **(10ˆ3 tm)**
st 0	0	55.614	-46.76	8.854	-0.556	4.775
st 1	-10.41	56.721	-66.547	-9.825	-0.551	10.628
st 2	-20.819	166.835	-89.534	77.301	-1.046	17.795
st 3	-31.229	147.033	-117.312	29.721	-1.62	31.969
st 4	-41.638	213.508	-153.559	59.949	-1.925	50.219
st 5	-52.047	61.151	-201.937	-140.786	-2.659	74.71
st 6	-62.457	296.733	-258.866	37.867	-2.581	99.516
st 7	-72.866	275.588	-310.942	-35.354	-2.593	126.542
st 8	-83.276	361.422	-350.94	10.482	-2.314	149.748
st 9	-93.685	306.212	-371.13	-64.918	-2.029	172.445
st 10	-104.095	395.141	-388.084	7.057	-1.677	189.266
st 11	-114.504	67.795	-396.561	-328.766	-1.429	205.705
st 12	-124.914	394.923	-403.741	-8.817	-0.912	215.204
st 13	-135.323	70.01	-407.589	-337.579	-0.379	222.958
st 14	-145.733	464.747	-410.855	53.893	-0.096	223.23
st 15	-156.142	93.118	-413.054	-319.936	-0.081	227.505
st 16	-166.552	281.746	-411.487	-129.74	1.364	220.481
st 17	-176.961	74.44	-400.299	-325.859	3.233	198.44
st 18	-187.371	343.834	-373.878	-30.044	3.556	162.664
st 19	-197.78	276.256	-326.599	-50.342	4.272	123.615
st 20	-208.19	337.157	-257.714	79.443	3.82	80.573
st 21	-218.599	315.001	-173.957	141.044	3.107	45.504
st 22	-229.009	217.148	-88.275	128.874	2.06	18.772
st 23	-239.418	81.084	-16.271	64.814	0.835	4.822
st 24	-249.828	82.192	0	82.192	0.07	0.201

10.1.3 Longitudinal Strength Analysis for 12 Ton Departure

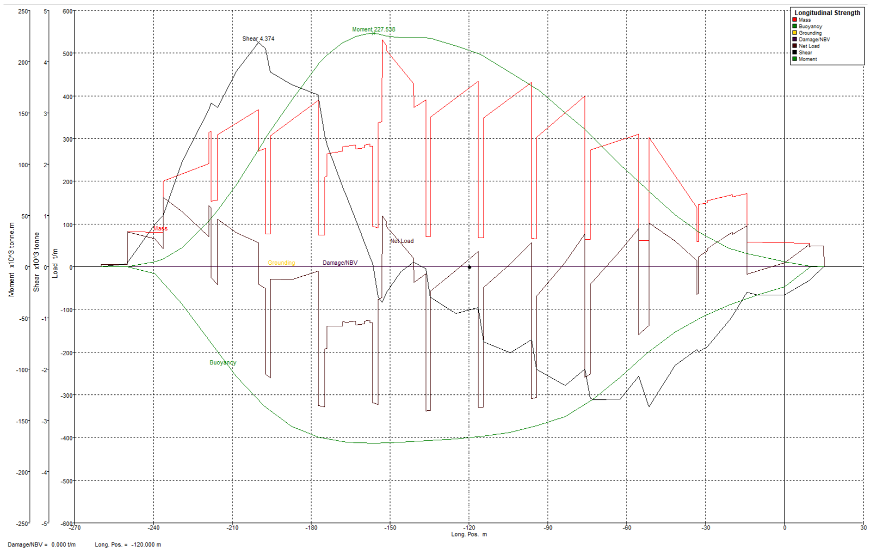


Figure 10.3: Longitudinal Strength Data for 12 Ton Arrival

Table 10.4: Longitudinal Strength Data for 12 Ton Arrival

Station	Long Pos (m)	**Mass (t/m)**	**Bouyancy (t/m)**	**Net Load (t/m)**	**Shear (10ˆ3 t)**	Moment **(10ˆ3 tm)**
st 0	0	55.614	-48.941	6.673	-0.545	4.757
st 1	-10.41	56.721	-72.935	-16.214	-0.495	10.287
st 2	-20.819	179.316	-101.284	78.032	-1.009	16.829
st 3	-31.229	161.716	-134.876	26.84	-1.556	30.496
st 4	-41.638	239.085	-176.642	62.443	-1.832	47.901
st 5	-52.047	61.151	-229.681	-168.53	-2.626	71.843
st 6	-62.457	335.812	-290.269	45.543	-2.52	95.735
st 7	-72.866	310.958	-344.692	-33.734	-2.58	122.403
st 8	-83.276	410.914	-385.76	25.154	-2.36	145.383
st 9	-93.685	346.317	-405.626	-59.309	-2.18	169.138
st 10	-104.095	449.883	-421.9	27.983	-1.958	187.807
st 11	-114.504	67.795	-429.18	-361.385	-1.888	208.145
st 12	-124.914	449.26	-435.041	14.219	-1.527	222.8
st 13	-135.323	70.01	-437.399	-367.389	-1.171	238.043
st 14	-145.733	419.458	-439.139	-19.681	-0.726	246.468
st 15	-156.142	93.118	-439.788	-346.671	0.12	252.074
st 16	-166.552	281.746	-436.647	-154.901	1.836	241.561
st 17	-176.961	74.44	-423.822	-349.382	3.957	213.308
st 18	-187.371	388.548	-395.654	-7.106	4.029	171.257
st 19	-197.78	309.523	-346.38	-36.857	4.605	128.319
st 20	-208.19	365.974	-275.061	90.913	4.023	82.527
st 21	-218.599	342.167	-188.435	153.732	3.257	45.837
st 22	-229.009	240.01	-99.526	140.484	2.084	18.231
st 23	-239.418	81.084	-23.278	57.806	0.798	4.585
st 24	-249.828	82.192	-0.019	82.173	0.07	0.178

10.1.4 Longitudinal Strength Analysis for 12 Ton Arrival

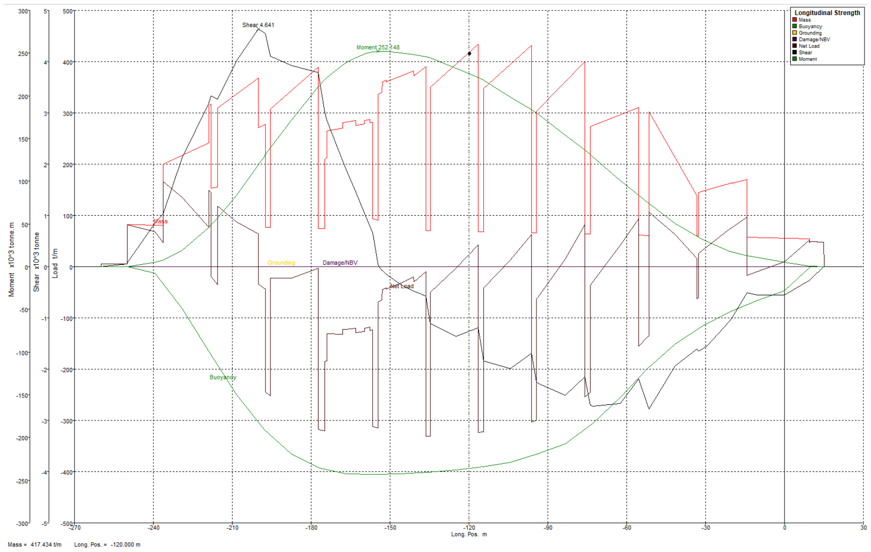


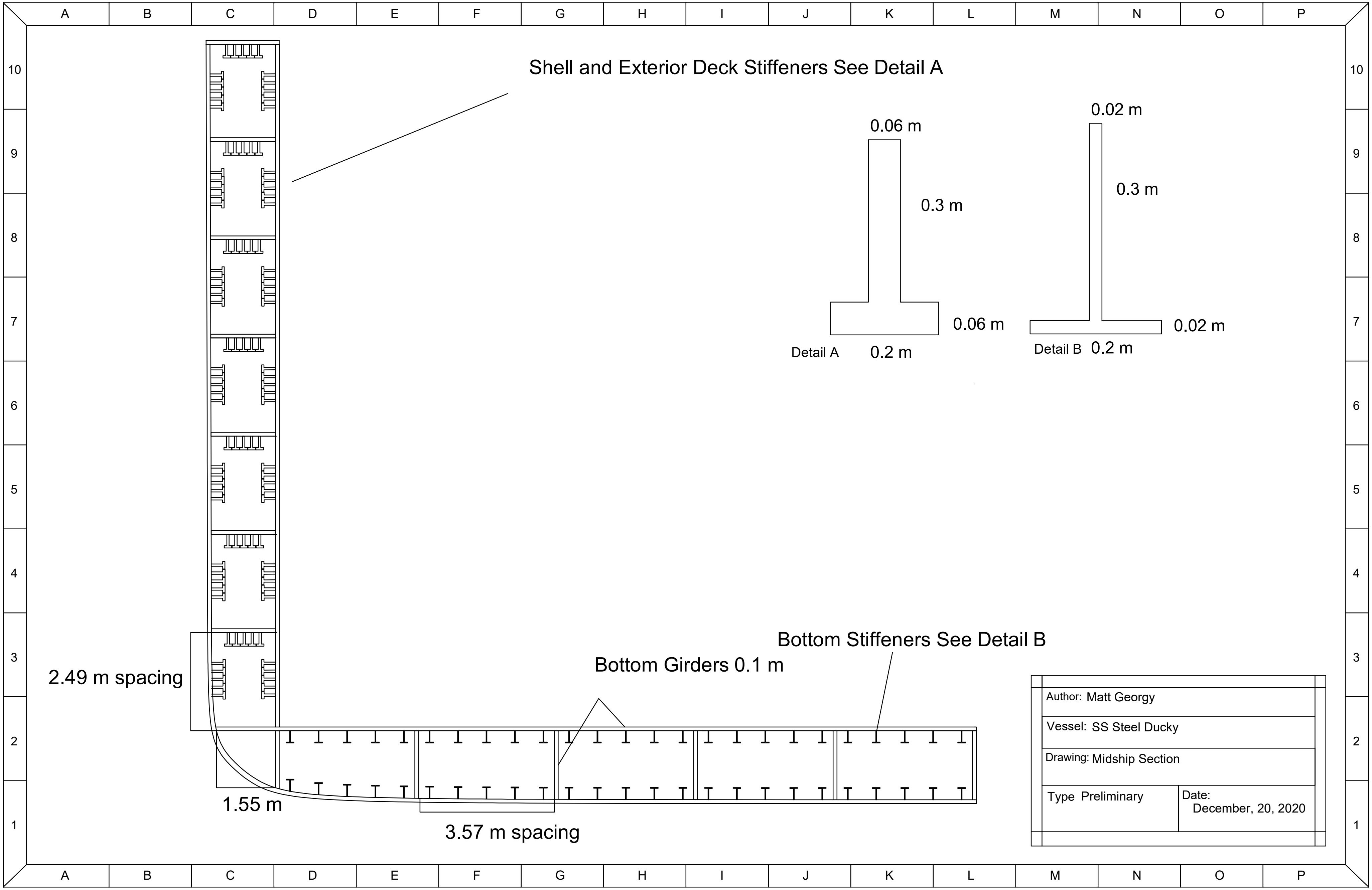
Figure 10.4: Longitudinal Strength Data for 14 Ton Arrival

Table 10.5: Longitudinal Strength Data for 12 Ton Arrival

Station	Long Pos (m)	**Mass (t/m)**	**Bouyancy (t/m)**	**Net Load (t/m)**	**Shear (10ˆ3 t)**	Moment **(10ˆ3 tm)**
st 0	0	55.614	-46.396	9.218	-0.558	4.797
st 1	-10.41	56.721	-65.863	-9.142	-0.558	10.706
st 2	-20.819	162.022	-88.335	73.687	-1.058	18.003
st 3	-31.229	147.033	-115.434	31.599	-1.608	32.144
st 4	-41.638	213.508	-150.868	62.64	-1.936	50.393
st 5	-52.047	61.151	-198.394	-137.243	-2.702	75.172
st 6	-62.457	296.733	-254.497	42.236	-2.666	100.652
st 7	-72.866	275.588	-305.87	-30.282	-2.726	128.823
st 8	-83.276	361.422	-345.317	16.106	-2.503	153.717
st 9	-93.685	306.212	-365.169	-58.957	-2.278	178.704
st 10	-104.095	395.141	-381.792	13.35	-1.989	198.464
st 11	-114.504	67.795	-390.036	-322.24	-1.809	218.517
st 12	-124.914	394.923	-396.981	-2.058	-1.361	232.341
st 13	-135.323	70.01	-400.635	-330.625	-0.9	245.146
st 14	-145.733	372.381	-403.707	-31.326	-0.356	250.422
st 15	-156.142	93.118	-405.72	-312.603	0.518	251.707
st 16	-166.552	281.746	-403.982	-122.236	1.886	238.859
st 17	-176.961	74.44	-392.664	-318.224	3.676	211.802
st 18	-187.371	343.834	-366.177	-22.343	3.919	171.844
st 19	-197.78	276.256	-318.956	-42.7	4.556	129.435
st 20	-208.19	337.157	-250.363	86.794	4.025	83.862
st 21	-218.599	315.001	-167.203	147.798	3.239	47.041
st 22	-229.009	217.148	-82.537	134.611	2.128	19.281
st 23	-239.418	81.084	-12.671	68.413	0.854	4.902
st 24	-249.828	82.192	0	82.192	0.07	0.192

10.2 Midship Section Design

Due to a lack of time an analysis on the midship section design was not done. In order for the design to be complete the midship section must be tested against the ABS requirements in *Rules for Building and Classing Steel Vessels*. A detail description of the current preliminary midship section design is shown in the following page.


Shell and Exterior Deck Stiffeners See Detail A
0.06 m
0.3 m
0.06 m
0.2 m
Detail A
0.02 m
0.3 m
0.02 m
0.2 m
Detail B
Bottom Stiffeners See Detail B
Bottom Girders 0.1 m
2.49 m spacing
1.55 m
3.57 m spacing
Author: Matt Georgy
Vessel: SS Steel Ducky
Drawing: Midship Section
Type Preliminary
Date: December, 20, 2020

11. Maneuverability

The maneuverability of the ship was calculated using University of Michigan Maneuvering Prediction Program (MPP). The inputs are the vessels characterstics and the output are values that can be compared to IMO maunevering requirements. This process helped determine the size of the rudder, and was also constrained by the propeller clearances. The table below summarizes the outputs of the program and the IMO regulations for each output. The Clarke's Turning Index had to be less than 40, the Linear Dynamic Stability had to be greater than 0, the Tactical Diameter had to be less than 1250 meters which is equal to five times the LWL, and the Advance had to be less than 1125 meters which is equal to 4.5 times the length of the LWL.

Table 11.1: Summary of Maneuvering.

Load Case	Clarke's Turning Index	Linear Dynamic Stability Criterion	Tactical Diameter	Advance
14 Ton Departure	0.5511	0.0000062	1364.07 m	1033.93 m
14 Ton Arrival	0.5668	0.0000028	1337.54 m	1020.16 m
12 Ton Departure	0.5454	0.0000067	1398.68 m	1051.89 m
12 Ton Arrival	0.5483	0.0000060	1394.9 m	1049.93 m

```
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 Department of Naval Architecture and Marine Engineering


Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons

  References:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983
               Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circles,"
                Trans. NECIES, 1978-1979


 Run Identification: 14 Ton Departure


 Input Verification:

      Length of Waterline LWL (m)              =    250.00

      Maximum Beam on LWL (m)                  =     40.50

      Mean Draft (m)                           =     10.68

      Draft Forward (m)                        =     10.60

      Draft Aft (m)                            =     10.75

      Block Coefficient on LWL CB              =    0.6570

      Molded Volume (m^3)                      =  71011.44

      Center of Gravity LCG (%LWL; + Fwd)      =   -0.9100
      Center of Gravity LCG (m from FP)        =    127.28

      Midships to Rudder CE XR (%LWL; + Aft)   =   49.0000
      Rudder Center of Effort XR (m from FP)   =    247.50

      Initial Ship Speed (knots)               =     20.00
      Initial Ship Speed (m/s)                 =   10.2888

      Water Type                               =  Salt@15C
      Water Density (kg/m^3)                   =   1025.87
      Kinematic Viscosity (m^2/s)              =   0.118831E-05

      Yaw Radius of Gyration K33/LWL           =    0.2500

      Water Depth to Ship Draft Ratio H/T      =   1000.00

      Steering Gear Time Constant (s)          =      2.50

      Total Rudder Area - Fraction of LWL*T    =    0.0248

      Number of Propellers                     =         1

      Type of Single Screw Stern               =    Closed

      Submerged Bow Area - Fraction of LWL*T   =    0.0050
```

Figure 11.1: MPP Inputs for 14 Ton Departure

```
                University of Michigan
 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Linear Maneuvering Criteria Option ***

  Reference:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983


 Run Identification: 14 Ton Departure


    Linear Maneuvering Derivatives

 Nondimensional Mass               M prime     =  0.009089
 Nondimensional Mass Moment        I sub zz    =  0.000568

 Sway Velocity Derivative          Y sub v     = -0.012508
 Sway Acceleration Derivative      Y sub v dot = -0.007246

 Yaw Velocity Derivative           N sub v     = -0.002937
 Yaw Acceleration Derivative       N sub v dot = -0.000130

 Sway Velocity Derivative          Y sub r     =  0.003062
 Sway Acceleration Derivative      Y sub r dot = -0.000350

 Yaw Velocity Derivative           N sub r     = -0.001997
 Yaw Acceleration Derivative       N sub r dot = -0.000414

 Sway Rudder Derivative            Y sub delta =  0.003177
 Yaw Rudder Derivative             N sub delta = -0.001557


    Time Constants and Gains for Nomoto"s Equation

 Dominant Ship Time Constant    T1 prime      =    6.4043
 Ship Time Constant             T2 prime      =    0.4008
 Numerator Time Constant        T3 prime      =    0.8881
 Numerator Time Constant        T4 prime      =    0.2286

 1st Order Eqn. Time Constant   T prime       =    5.9170
 Rudder Gain Factor             K prime       =   -4.6132
 Rudder Gain Factor             K sub v prime =    2.4769

 Steering Gear Time Constant    TE prime      =    0.1029


    Evaluation of Turning Ability and Stability

 Inverse Time Constant          1/|T prime|   =    0.1690
 Inverse Gain Factor            1/|K prime|   =    0.2168

 Clarke"s Turning Index                     P =    0.5511
 Linear Dynamic Stability Criterion         C = 0.0000062

 Vessel is hydrodynamically open loop course stable

 Closed Loop Phase Margin with Steering Engine  =   23.1944 degrees
```

Figure 11.2: MPP Outputs page 1 for 14 Ton Departure

```
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 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Turning Prediction Option ***


  Reference:  Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circle",
                Trans. NECIES, 1978-1979


 Run Identification: 14 Ton Departure


 Approach Speed                       =      20.00 knots

 Rudder Angle                         =      20.00 degrees

 Steady Turning Diameter              =    1236.63 meters
 Tactical Diameter                    =    1364.07 meters
 Advance                              =    1033.93 meters
 Transfer                             =     662.01 meters
 Steady Speed in Turn                 =      11.22 knots
```

Figure 11.3: MPP Outputs page 2 for 14 Ton Departure

```
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 Department of Naval Architecture and Marine Engineering


Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons

  References:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983
               Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships" Turning Circles,"
                Trans. NECIES, 1978-1979


 Run Identification: 14 Ton Arrival


 Input Verification:

      Length of Waterline LWL (m)                =    250.00

      Maximum Beam on LWL (m)                    =     40.50

      Mean Draft (m)                             =     10.52

      Draft Forward (m)                          =     10.81

      Draft Aft (m)                              =     10.24

      Block Coefficient on LWL CB                =    0.6550

      Molded Volume (m^3)                        =  69800.48

      Center of Gravity LCG (%LWL; + Fwd)        =   -0.9100
      Center of Gravity LCG (m from FP)          =    127.28

      Midships to Rudder CE XR (%LWL; + Aft)     =   49.0000
      Rudder Center of Effort XR (m from FP)     =    247.50

      Initial Ship Speed (knots)                 =     20.00
      Initial Ship Speed (m/s)                   =   10.2888

      Water Type                                 =  Salt@15C
      Water Density (kg/m^3)                     =   1025.87
      Kinematic Viscosity (m^2/s)                =   0.118831E-05

      Yaw Radius of Gyration K33/LWL             =    0.2500

      Water Depth to Ship Draft Ratio H/T        =   1000.00

      Steering Gear Time Constant (s)            =      2.50

      Total Rudder Area - Fraction of LWL*T      =    0.0248

      Number of Propellers                       =         1

      Type of Single Screw Stern                 =    Closed

      Submerged Bow Area - Fraction of LWL*T     =    0.0050
```

Figure 11.4: MPP Inputs for 14 Ton Arrival

```
                University of Michigan
 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Linear Maneuvering Criteria Option ***

  Reference:  Clarke,D., Gedling,P., and Hine,G.,
              "The Application of Manoeuvring Criteria in Hull
               Design using Linear Theory," Trans. RINA, 1983


 Run Identification: 14 Ton Arrival


    Linear Maneuvering Derivatives

 Nondimensional Mass                M prime     =  0.008934
 Nondimensional Mass Moment         I sub zz    =  0.000558

 Sway Velocity Derivative           Y sub v     = -0.011684
 Sway Acceleration Derivative       Y sub v dot = -0.007068

 Yaw Velocity Derivative            N sub v     = -0.003064
 Yaw Acceleration Derivative        N sub v dot = -0.000114

 Sway Velocity Derivative           Y sub r     =  0.002845
 Sway Acceleration Derivative       Y sub r dot = -0.000332

 Yaw Velocity Derivative            N sub r     = -0.001916
 Yaw Acceleration Derivative        N sub r dot = -0.000405

 Sway Rudder Derivative             Y sub delta =  0.003132
 Yaw Rudder Derivative              N sub delta = -0.001535


    Time Constants and Gains for Nomoto"s Equation

 Dominant Ship Time Constant      T1 prime      =   13.8251
 Ship Time Constant               T2 prime      =    0.3998
 Numerator Time Constant          T3 prime      =    0.8959
 Numerator Time Constant          T4 prime      =    0.2254

 1st Order Eqn. Time Constant     T prime       =   13.3289
 Rudder Gain Factor               K prime       =   -9.8742
 Rudder Gain Factor               K sub v prime =    5.4141

 Steering Gear Time Constant      TE prime      =    0.1029


    Evaluation of Turning Ability and Stability

 Inverse Time Constant            1/|T prime|   =    0.0750
 Inverse Gain Factor              1/|K prime|   =    0.1013

 Clarke"s Turning Index                      P =    0.5668
 Linear Dynamic Stability Criterion          C = 0.0000028

 Vessel is hydrodynamically open loop course stable

 Closed Loop Phase Margin with Steering Engine  =   18.3888 degrees
```

Figure 11.5: MPP Outputs page 1 for 14 Ton Arrival

```
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 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Turning Prediction Option ***


  Reference:  Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circle",
                Trans. NECIES, 1978-1979


 Run Identification: 14 Ton Arrival


 Approach Speed                        =     20.00 knots

 Rudder Angle                          =     20.00 degrees

 Steady Turning Diameter               =   1207.47 meters
 Tactical Diameter                     =   1337.54 meters
 Advance                               =   1020.16 meters
 Transfer                              =    648.83 meters
 Steady Speed in Turn                  =     11.06 knots
```

Figure 11.6: MPP Outputs page 2 for 14 Ton Arrival

```
                University of Michigan
 Department of Naval Architecture and Marine Engineering


Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons

  References:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983
               Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circles,"
                Trans. NECIES, 1978-1979


 Run Identification: 12 Ton Departure


 Input Verification:

      Length of Waterline LWL (m)                =    250.00

      Maximum Beam on LWL (m)                    =     40.50

      Mean Draft (m)                             =      9.77

      Draft Forward (m)                          =      9.53

      Draft Aft (m)                              =     10.01

      Block Coefficient on LWL CB                =    0.6480

      Molded Volume (m^3)                        =  64100.97

      Center of Gravity LCG (%LWL; + Fwd)        =   -0.9100
      Center of Gravity LCG (m from FP)          =    127.28

      Midships to Rudder CE XR (%LWL; + Aft)     =   49.0000
      Rudder Center of Effort XR (m from FP)     =    247.50

      Initial Ship Speed (knots)                 =     20.00
      Initial Ship Speed (m/s)                   =   10.2888

      Water Type                                 =  Salt@15C
      Water Density (kg/m^3)                     =   1025.87
      Kinematic Viscosity (m^2/s)                =   0.118831E-05

      Yaw Radius of Gyration K33/LWL             =    0.2500

      Water Depth to Ship Draft Ratio H/T        =   1000.00

      Steering Gear Time Constant (s)            =      2.50

      Total Rudder Area - Fraction of LWL*T      =    0.0248

      Number of Propellers                       =         1

      Type of Single Screw Stern                 =    Closed

      Submerged Bow Area - Fraction of LWL*T     =    0.0050
```

Figure 11.7: MPP Inputs for 12 Ton Departure

```
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 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Linear Maneuvering Criteria Option ***

  Reference:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983


 Run Identification: 12 Ton Departure


    Linear Maneuvering Derivatives

 Nondimensional Mass               M prime     =  0.008205
 Nondimensional Mass Moment        I sub zz    =  0.000513

 Sway Velocity Derivative          Y sub v     = -0.011180
 Sway Acceleration Derivative      Y sub v dot = -0.006218

 Yaw Velocity Derivative           N sub v     = -0.002278
 Yaw Acceleration Derivative       N sub v dot = -0.000040

 Sway Velocity Derivative          Y sub r     =  0.002814
 Sway Acceleration Derivative      Y sub r dot = -0.000249

 Yaw Velocity Derivative           N sub r     = -0.001775
 Yaw Acceleration Derivative       N sub r dot = -0.000362

 Sway Rudder Derivative            Y sub delta =  0.002908
 Yaw Rudder Derivative             N sub delta = -0.001425


    Time Constants and Gains for Nomoto"s Equation

 Dominant Ship Time Constant     T1 prime      =    4.6646
 Ship Time Constant              T2 prime      =    0.4023
 Numerator Time Constant         T3 prime      =    0.9066
 Numerator Time Constant         T4 prime      =    0.2212

 1st Order Eqn. Time Constant    T prime       =    4.1602
 Rudder Gain Factor              K prime       =   -3.3506
 Rudder Gain Factor              K sub v prime =    1.8757

 Steering Gear Time Constant     TE prime      =    0.1029


    Evaluation of Turning Ability and Stability

 Inverse Time Constant           1/|T prime|   =    0.2404
 Inverse Gain Factor             1/|K prime|   =    0.2985

 Clarke"s Turning Index                      P =    0.5454
 Linear Dynamic Stability Criterion          C = 0.0000067

 Vessel is hydrodynamically open loop course stable

 Closed Loop Phase Margin with Steering Engine  =   27.2079 degrees
```

Figure 11.8: MPP Outputs page 1 for 12 Ton Departure

```
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 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Turning Prediction Option ***


  Reference:  Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships" Turning Circle",
                Trans. NECIES, 1978-1979


 Run Identification: 12 Ton Departure


 Approach Speed                      =     20.00 knots

 Rudder Angle                        =     20.00 degrees

 Steady Turning Diameter             =   1274.66 meters
 Tactical Diameter                   =   1398.68 meters
 Advance                             =   1051.89 meters
 Transfer                            =    679.21 meters
 Steady Speed in Turn                =     11.43 knots
```

Figure 11.9: MPP Outputs page 2 for 14 Ton Departure

```
                University of Michigan
 Department of Naval Architecture and Marine Engineering


Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons

  References:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983
               Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circles,"
                Trans. NECIES, 1978-1979


 Run Identification: 12 Ton Arrival


 Input Verification:

      Length of Waterline LWL (m)                =    250.00

      Maximum Beam on LWL (m)                    =     40.50

      Mean Draft (m)                             =      9.61

      Draft Forward (m)                          =      9.44

      Draft Aft (m)                              =      9.78

      Block Coefficient on LWL CB                =    0.6470

      Molded Volume (m^3)                        =  62953.91

      Center of Gravity LCG (%LWL; + Fwd)        =   -0.9100
      Center of Gravity LCG (m from FP)          =    127.28

      Midships to Rudder CE XR (%LWL; + Aft)     =   49.0000
      Rudder Center of Effort XR (m from FP)     =    247.50

      Initial Ship Speed (knots)                 =     20.00
      Initial Ship Speed (m/s)                   =   10.2888

      Water Type                                 =  Salt@15C
      Water Density (kg/m^3)                     =   1025.87
      Kinematic Viscosity (m^2/s)                =   0.118831E-05

      Yaw Radius of Gyration K33/LWL             =    0.2500

      Water Depth to Ship Draft Ratio H/T        =   1000.00

      Steering Gear Time Constant (s)            =      2.50

      Total Rudder Area - Fraction of LWL*T      =    0.0248

      Number of Propellers                       =         1

      Type of Single Screw Stern                 =    Closed

      Submerged Bow Area - Fraction of LWL*T     =    0.0050
```

Figure 11.10: MPP Inputs for 12 Ton Arrival

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              University of Michigan
 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Linear Maneuvering Criteria Option ***

  Reference:  Clarke,D., Gedling,P., and Hine,G.,
               "The Application of Manoeuvring Criteria in Hull
                Design using Linear Theory," Trans. RINA, 1983


 Run Identification: 12 Ton Arrival


    Linear Maneuvering Derivatives

 Nondimensional Mass               M prime     =  0.008058
 Nondimensional Mass Moment        I sub zz    =  0.000504

 Sway Velocity Derivative          Y sub v     = -0.010812
 Sway Acceleration Derivative      Y sub v dot = -0.006046

 Yaw Velocity Derivative           N sub v     = -0.002228
 Yaw Acceleration Derivative       N sub v dot = -0.000025

 Sway Velocity Derivative          Y sub r     =  0.002727
 Sway Acceleration Derivative      Y sub r dot = -0.000232

 Yaw Velocity Derivative           N sub r     = -0.001727
 Yaw Acceleration Derivative       N sub r dot = -0.000354

 Sway Rudder Derivative            Y sub delta =  0.002860
 Yaw Rudder Derivative             N sub delta = -0.001401


    Time Constants and Gains for Nomoto"s Equation

 Dominant Ship Time Constant     T1 prime      =    5.0154
 Ship Time Constant              T2 prime      =    0.4023
 Numerator Time Constant         T3 prime      =    0.9119
 Numerator Time Constant         T4 prime      =    0.2192

 1st Order Eqn. Time Constant    T prime       =    4.5059
 Rudder Gain Factor              K prime       =   -3.5889
 Rudder Gain Factor              K sub v prime =    2.0340

 Steering Gear Time Constant     TE prime      =    0.1029


    Evaluation of Turning Ability and Stability

 Inverse Time Constant           1/|T prime|   =    0.2219
 Inverse Gain Factor             1/|K prime|   =    0.2786

 Clarke"s Turning Index                      P =    0.5483
 Linear Dynamic Stability Criterion          C = 0.0000060

 Vessel is hydrodynamically open loop course stable

 Closed Loop Phase Margin with Steering Engine  =   26.4739 degrees
```

Figure 11.11: MPP Outputs page 1 for 12 Ton Arrival

```
                University of Michigan
 Department of Naval Architecture and Marine Engineering

Maneuvering Prediction Program (MPP-1.3) by M.G. Parsons


 *** Turning Prediction Option ***


  Reference:  Lyster, C., and Knights, H. L.,
               "Prediction Equations for Ships' Turning Circle",
                Trans. NECIES, 1978-1979


 Run Identification: 12 Ton Arrival


 Approach Speed                     =     20.00 knots

 Rudder Angle                       =     20.00 degrees

 Steady Turning Diameter            =   1270.51 meters
 Tactical Diameter                  =   1394.90 meters
 Advance                            =   1049.93 meters
 Transfer                           =    677.33 meters
 Steady Speed in Turn               =     11.40 knots
```

Figure 11.12: MPP Outputs page 2 for 12 Ton Arrival

12. Damage Stability

Using *Maxsurf Stability*, a large angle stability test was run on the *SS Steel Ducky* for a total of 25 damage cases. The first 13 are single compartment flooding test cases while the second 12 are every combination of double compartment flooding. Each of these test cases was shown to meet regulations put forth by SOLAS and the USCG.

Table 12.1: Summary Single Compartment Damage Cases.

Compartment	1	2	3	4	5	6	7	8	9	10	11	12	13
Forepeak													X
Cargo Bay 1												X	
Cargo Bay 2											X		
Cargo Bay 3										X			
Engine Room									X				
Cargo Bay 4								X					
Cargo Bay 5							X						
Cargo Bay 6						X							
Cargo Bay 7					X								
Cargo Bay 8				X									
Cargo Bay 9			X										
Cargo Bay 10		X											
Afterpeak	X												

Table 12.2: Summary Double Compartment Damage Cases.

Compartment	14	15	16	17	18	19	20	21	22	23	24	25
Forepeak												X
Cargo Bay 1											X	X
Cargo Bay 2										X	X	
Cargo Bay 3									X	X		
Engine Room								X	X			
Cargo Bay 4							X	X				
Cargo Bay 5						X	X					
Cargo Bay 6					X	X						
Cargo Bay 7				X	X							
Cargo Bay 8			X	X								
Cargo Bay 9		X	X									
Cargo Bay 10	X	X										
Afterpeak	X											

The permeability of the compartments changes based on contents of each compartment. The compartments with containers had a permeability of 75%, the engine room 85%, and the aft and forepeak which contain next to nothing have permiabilities of 95%. These are an overestimate but will help ensure the safety of the ship in a damage scenario. The permiabilities of each compartment are summarized below.

Table 12.3: Summary Couble Compartment Damage Cases.

Compartment	Permeability %
Forepeak	95
Cargo Bay 1	75
Cargo Bay 2	75
Cargo Bay 3	75
Engine Room	85
Cargo Bay 4	75
Cargo Bay 5	75
Cargo Bay 6	75
Cargo Bay 7	75
Cargo Bay 8	75
Cargo Bay 9	75
Cargo Bay 10	75
Afterpeak	95

Despite multiple iterations of cargo placement the *SS Steel Ducky* did not meet damage stability criteria in any of the 14 Ton load cases. This will need to be improved upon in future designs. The following analysis was done on the 12 Ton Departure case.

12.0.1 Damage Case 1

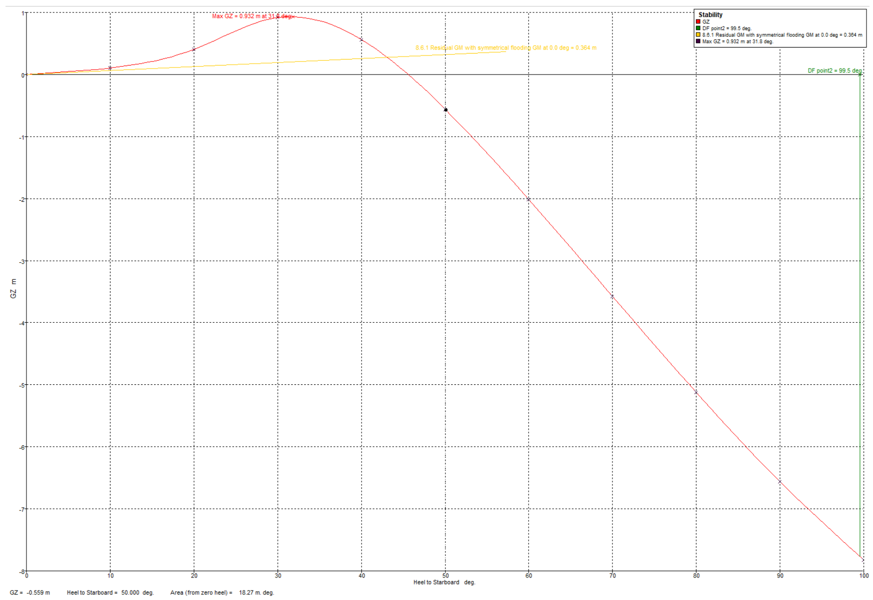

Figure 12.1: Righting Arm Curve (Damage Case 1)

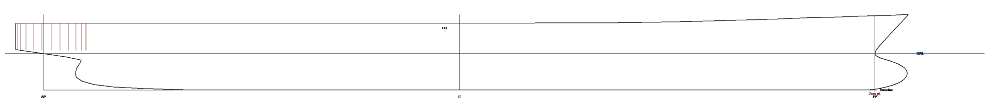

Figure 12.2: Flooding Rendering (Damage Case 1)

Table 12.4: Righting Arm Curve Data (Damage Case 1).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.104	0.407	0.918	0.561	-0.559	-2.01	-3.573	-5.12	-6.564	-7.823
Area under GZ curve	0	0.461	2.7106	9.6074	17.8328	18.273	5.5916	-22.2886	-65.8013	-124.363	-196.402
Displacement (t)	66991	66991	66991	66986	66985	66991	66991	66991	66991	66991	66991
Draft at FP (m)	9.021	9.127	9.254	9.044	8.27	7.158	5.515	2.415	-6.477	0	-29.331
Draft at AP (m)	10.724	10.469	9.927	9.226	8.559	7.867	6.891	5.197	0.365	0	-18.611
WL Length (m)	251.74	256.63	261.077	262.44	264.735	266.512	267.718	266.693	266.723	267.651	267.959
Beam max on WL (m)	40.498	41.121	43.019	40.135	31.36	26.546	24.193	23.327	22.166	20.96	20.781
Wetted Area (m^2)	11187.13	11275.8	11483	11755	12119.95	12370.146	12490.27	12562.48	12594.26	12611.08	12599.67
Waterpl. Area (m^2)	7702.763	7766.64	8070.04	8020.9	6743.966	5961.582	5460.713	5126.874	4883.075	4737.269	4668.61
Prismatic coeff. (Cp)	0.644	0.639	0.647	0.667	0.674	0.675	0.674	0.678	0.678	0.676	0.677
Block coeff. (Cb)	0.623	0.486	0.385	0.365	0.429	0.479	0.511	0.534	0.58	0.624	0.579
LCB (m)	-129.311	-129.28	-129.252	-129.2	-129.236	-129.246	-129.257	-129.269	-129.276	-129.283	-129.295
LCF (m)	-135.735	-134.34	-131.33	-125.4	-121.691	-118.7	-117.576	-116.81	-115.861	-117.081	-118.513
Max Deck Incl (°)	0.3904	10.0045	20.0005	30	40	50.0001	60.0001	70.0002	80.0001	90	99.9997
Trim (°)	0.3904	0.3078	0.1545	0.0418	0.0662	0.1625	0.3156	0.6381	1.5687	90	2.457

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	99.5	deg			
	angle of vanishing stability	45.6	deg	45.6		
	shall not be less than (>=)	**15.0**	**deg**	**45.6**	Pass	+203.80
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	99.5	deg			
	angle of vanishing stability	45.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.6358**	Pass	+323.06
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.5	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.932**	Pass	+832.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.364**	Pass	+628.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.6**	Pass	+30.20
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**99.5**	Pass	+397.58
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.5	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.2931**	Pass	+146.36

Figure 12.3: Regulations (Damage Case 1)

12.0.2 Damage Case 2

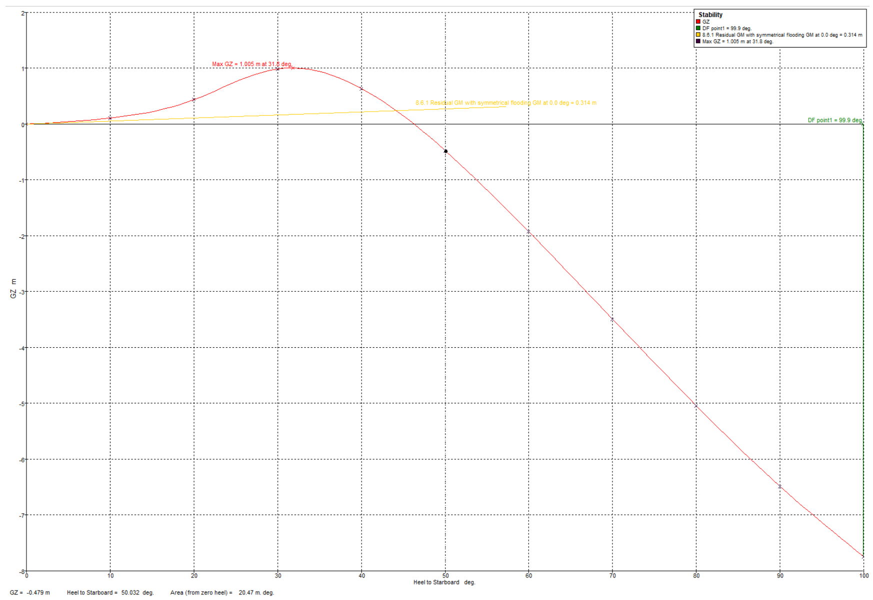

Figure 12.4: Righting Arm Curve (Damage Case 2)

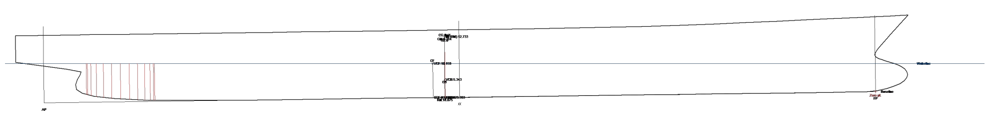

Figure 12.5: Flooding Rendering (Damage Case 2)

Table 12.5: Righting Arm Curve Data (Damage Case 2).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.104	0.407	0.918	0.561	-0.559	-2.01	-3.573	-5.12	-6.564	-7.823
Area under GZ curve	0	0.461	2.7106	9.6074	17.8328	18.273	5.5916	-22.2886	-65.8013	-124.363	-196.402
Displacement (t)	66991	66991	66991	66986	66985	66991	66991	66991	66991	66991	66991
Draft at FP (m)	9.021	9.127	9.254	9.044	8.27	7.158	5.515	2.415	-6.477	n/a	-29.331
Draft at AP (m)	10.724	10.469	9.927	9.226	8.559	7.867	6.891	5.197	0.365	n/a	-18.611
WL Length (m)	251.74	256.63	261.077	262.44	264.735	266.512	267.718	266.693	266.723	267.651	267.959
Beam max on WL (m)	40.498	41.121	43.019	40.135	31.36	26.546	24.193	23.327	22.166	20.96	20.781
Wetted Area (m^2)	11187.13	11275.8	11483	11755	12119.95	12370.146	12490.27	12562.48	12594.26	12611.08	12599.67
Waterpl. Area (m^2)	7702.763	7766.64	8070.04	8020.9	6743.966	5961.582	5460.713	5126.874	4883.075	4737.269	4668.61
Prismatic coeff. (Cp)	0.644	0.639	0.647	0.667	0.674	0.675	0.674	0.678	0.678	0.676	0.677
Block coeff. (Cb)	0.623	0.486	0.385	0.365	0.429	0.479	0.511	0.534	0.58	0.624	0.579
LCB (m)	-129.311	-129.28	-129.252	-129.2	-129.236	-129.246	-129.257	-129.269	-129.276	-129.283	-129.295
LCF (m)	-135.735	-134.34	-131.33	-125.4	-121.691	-118.7	-117.576	-116.81	-115.861	-117.081	-118.513
Max Deck Incl (°)	0.3904	10.0045	20.0005	30	40	50.0001	60.0001	70.0002	80.0001	90	99.9997
Trim (°)	0.3904	0.3078	0.1545	0.0418	0.0662	0.1625	0.3156	0.6381	1.5687	90	2.457

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	99.9	deg			
	angle of vanishing stability	46.2	deg	46.2		
	shall not be less than (>=)	**15.0**	**deg**	**46.2**	Pass	+208.31
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	99.9	deg			
	angle of vanishing stability	46.2	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.8613**	Pass	+349.30
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.9	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.005**	Pass	+905.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.314**	Pass	+528.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**46.2**	Pass	+32.13
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**99.9**	Pass	+399.71
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.9	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**12.1055**	Pass	+164.08

Figure 12.6: Regulations (Damage Case 2)

12.0.3 Damage Case 3

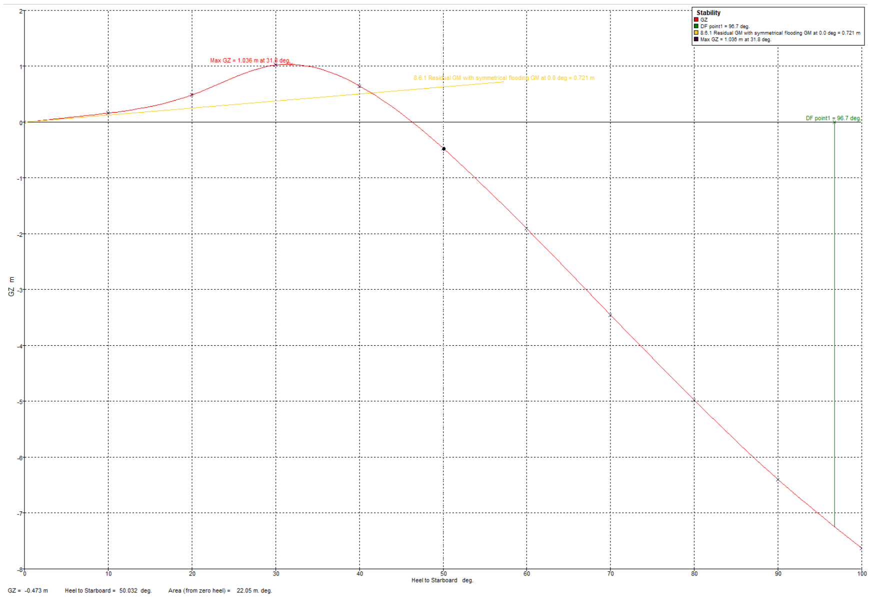

Figure 12.7: Righting Arm Curve (Damage Case 3)

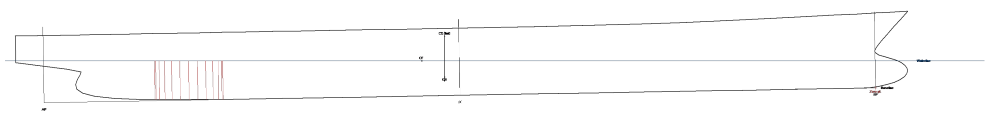

Figure 12.8: Flooding Rendering (Damage Case 3)

Table 12.6: Righting Arm Curve Data (Damage Case 3).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.162	0.486	1.023	0.647	-0.468	-1.906	-3.451	-4.975	-6.396	-7.634
Area under GZ curve	0	0.7766	3.7203	11.563	20.7646	22.0661	10.3514	-16.4055	-58.5855	-115.582	-185.837
Displacement (t)	66991	66991	66991	66991	66991	66986	66988	66990	66991	66991	66991
Draft at FP (m)	8.094	8.27	8.544	8.522	7.861	6.868	5.356	2.493	-5.805	n/a	-27.574
Draft at AP (m)	12.562	12.211	11.501	10.671	10.126	9.568	8.826	7.567	4.189	n/a	-16.786
WL Length (m)	264.867	264.354	263.534	263.75	265.426	266.888	267.787	266.698	266.78	267.685	268.008
Beam max on WL (m)	40.498	41.122	43.059	40.076	31.344	26.529	24.188	23.306	22.221	21.029	20.831
Wetted Area (m^2)	11721.43	11725.1	11730	12107	12462.94	12670.153	12779.74	12822.04	12846.71	12820.78	12783.35
Waterpl. Area (m^2)	7598.251	7683.94	7927.72	7744.2	6522.007	5748.226	5252.363	4966.525	4779.019	4623.597	4569.107
Prismatic coeff. (Cp)	0.562	0.572	0.594	0.622	0.638	0.645	0.65	0.657	0.661	0.662	0.665
Block coeff. (Cb)	0.523	0.445	0.365	0.352	0.415	0.465	0.498	0.522	0.565	0.606	0.569
LCB (m)	-129.428	-129.43	-129.356	-129.3	-129.305	-129.301	-129.322	-129.313	-129.292	-129.267	-129.29
LCF (m)	-136.243	-135.42	-131.764	-124.9	-120.267	-117.111	-115.489	-115.22	-115.133	-115.235	-117.151
Max Deck Incl (°)	1.0246	10.0391	20.0097	30.003	40.0016	50.0012	60.0008	70.0005	80.0002	90	99.9997
Trim (°)	1.0246	0.9039	0.6782	0.4929	0.5195	0.6192	0.796	1.1635	2.2908	90	2.4727

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	96.7	deg			
	angle of vanishing stability	46.3	deg	46.3		
	shall not be less than (>=)	**15.0**	**deg**	**46.3**	**Pass**	+208.64
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	96.7	deg			
	angle of vanishing stability	46.3	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.8103**	**Pass**	+459.73
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.7	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.036**	**Pass**	+936.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.721**	**Pass**	+1342.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**46.3**	**Pass**	+32.27
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**96.7**	**Pass**	+383.66
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.7	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**13.4400**	**Pass**	+193.19

Figure 12.9: Regulations (Damage Case 3)

12.0.4 Damage Case 4

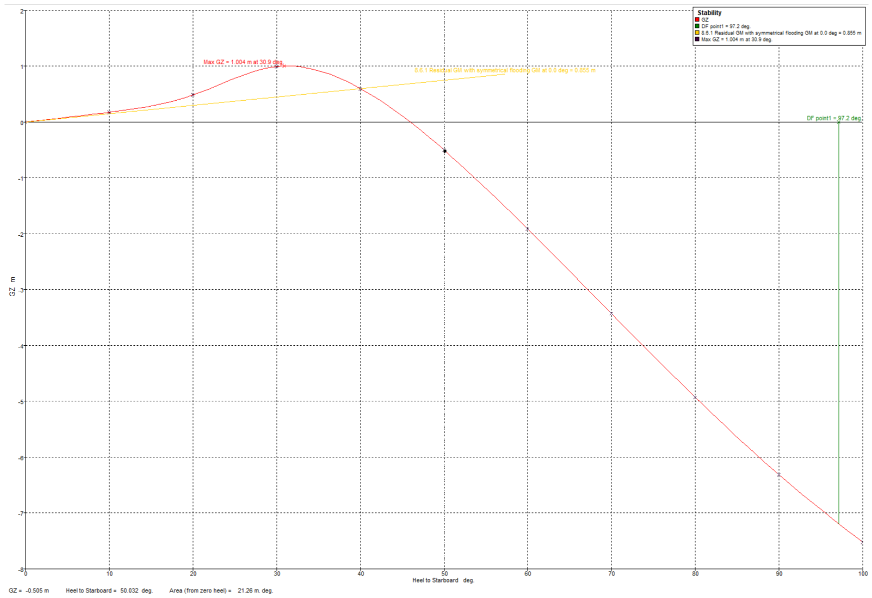

Figure 12.10: Righting Arm Curve (Damage Case 4)

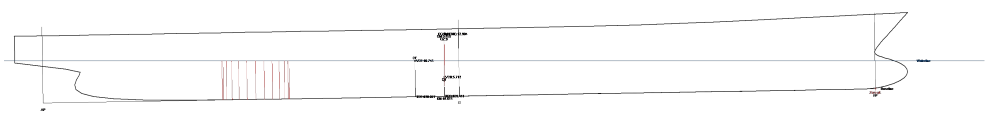

Figure 12.11: Flooding Rendering (Damage Case 4)

Table 12.7: Righting Arm Curve Data (Damage Case 4).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.177	0.485	0.995	0.599	-0.501	-1.912	-3.428	-4.923	-6.315	-7.525
Area under GZ curve	0	0.8717	3.904	11.601	20.3982	21.2726	9.3667	-17.3075	-59.1153	-115.445	-184.748
Displacement (t)	66991	66991	66991	66991	66991	66994	66987	66990	66991	66991	66991
Draft at FP (m)	8.407	8.582	8.84	8.832	8.26	7.364	6.005	3.464	-3.861	n/a	-25.365
Draft at AP (m)	12.64	12.278	11.544	10.658	10.038	9.453	8.69	7.389	3.87	n/a	-17.3
WL Length (m)	264.005	263.456	262.575	263.04	264.812	266.349	267.599	267.197	266.969	267.74	268.071
Beam max on WL (m)	40.498	41.122	43.065	40.059	31.33	26.501	24.002	23.193	22.318	21.187	20.867
Wetted Area (m^2)	11846.7	11844	11837	12235	12553.01	12771.341	12891.18	12924.69	12949.29	12933.02	12872.7
Waterpl. Area (m^2)	7605.979	7673.06	7886.85	7686.7	6473.438	5755.919	5274.767	4988.148	4804.514	4661.681	4607.372
Prismatic coeff. (Cp)	0.556	0.566	0.589	0.618	0.635	0.643	0.647	0.653	0.657	0.658	0.662
Block coeff. (Cb)	0.52	0.441	0.363	0.351	0.415	0.465	0.5	0.521	0.56	0.603	0.571
LCB (m)	-129.411	-129.39	-129.343	-129.3	-129.287	-129.286	-129.31	-129.299	-129.29	-129.294	-129.269
LCF (m)	-138.027	-136.94	-132.728	-125.4	-121.404	-118.216	-116.43	-116.22	-115.948	-115.793	-117.571
Max Deck Incl (°)	0.9709	10.0344	20.0081	30.002	40.001	50.0007	60.0005	70.0003	80.0001	90	99.9998
Trim (°)	0.9709	0.8475	0.6203	0.4189	0.4077	0.479	0.6157	0.9001	1.7724	90	1.8491

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	97.2	deg			
	angle of vanishing stability	45.9	deg	45.9		
	shall not be less than (>=)	**15.0**	**deg**	**45.9**	**Pass**	+206.26
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	97.2	deg			
	angle of vanishing stability	45.9	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.9859**	**Pass**	+480.16
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	97.2	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.004**	**Pass**	+904.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.9		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.855**	**Pass**	+1610.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.9**	**Pass**	+31.25
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**97.2**	**Pass**	+385.82
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	97.2	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**12.5094**	**Pass**	+172.89

Figure 12.12: Regulations (Damage Case 4)

12.0.5 Damage Case 5

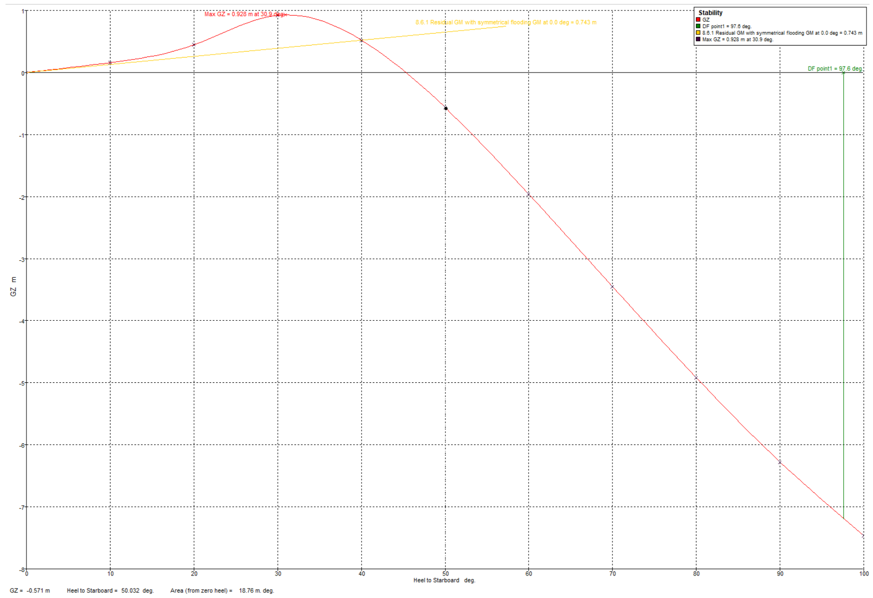

Figure 12.13: Righting Arm Curve (Damage Case 4)

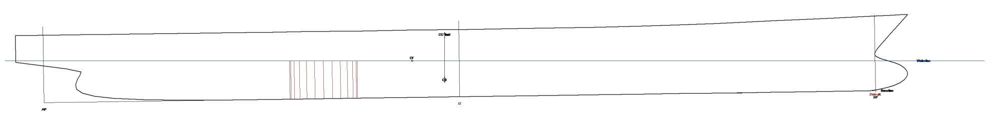

Figure 12.14: Flooding Rendering (Damage Case 5)

Table 12.8: Righting Arm Curve Data (Damage Case 5).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.159	0.444	0.92	0.519	-0.566	-1.957	-3.448	-4.915	-6.276	-7.46
Area under GZ curve	0	0.7787	3.526	10.637	18.6372	18.7768	6.312	-20.6913	-62.5586	-118.647	-187.427
Displacement (t)	66991	66991	66991	66991	66991	66991	66995	66990	66991	66995	66991
Draft at FP (m)	8.986	9.142	9.363	9.328	8.819	8.038	6.927	4.838	-1.116	n/a	-22.314
Draft at AP (m)	12.506	12.154	11.42	10.518	9.904	9.33	8.535	7.189	3.516	n/a	-17.808
WL Length (m)	262.123	261.556	260.789	261.68	263.959	265.623	266.897	267.756	267.238	267.819	268.145
Beam max on WL (m)	40.499	41.122	43.07	40.025	31.313	26.461	23.811	22.973	22.368	21.377	20.981
Wetted Area (m^2)	11958.8	11965.1	11970.2	12394	12832.36	12921.75	13027.01	13058.56	13089.03	13087.45	13021.35
Waterpl. Area (m^2)	7491.844	7561.87	7777.19	7584.2	6549.609	5709.06	5223.063	4948.417	4779.929	4656.662	4628.593
Prismatic coeff. (Cp)	0.555	0.565	0.588	0.617	0.633	0.64	0.644	0.647	0.651	0.653	0.656
Block coeff. (Cb)	0.524	0.441	0.363	0.352	0.414	0.463	0.501	0.521	0.553	0.6	0.57
LCB (m)	-129.377	-129.36	-129.312	-129.2	-129.255	-129.281	-129.258	-129.253	-129.252	-129.251	-129.254
LCF (m)	-139.032	-137.95	-133.594	-125.9	-119.859	-118.908	-117.295	-116.929	-116.24	-115.674	-116.765
Max Deck Incl (°)	0.8072	10.0229	20.0047	30.001	40.0004	50.0003	60.0002	70.0001	80.0001	90	100
Trim (°)	0.8072	0.6906	0.4717	0.273	0.2486	0.2963	0.3689	0.5393	1.0621	90	1.0331

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	97.6	deg			
	angle of vanishing stability	45.3	deg	45.3		
	shall not be less than (>=)	**15.0**	**deg**	**45.3**	Pass	+201.98
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	97.6	deg			
	angle of vanishing stability	45.3	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.5195**	Pass	+425.89
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	97.6	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.928**	Pass	+828.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.9		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.743**	Pass	+1386.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.3**	Pass	+29.42
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**97.6**	Pass	+388.13
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	97.6	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.4773**	Pass	+150.38

Figure 12.15: Regulations (Damage Case 5)

12.0.6 Damage Case 6

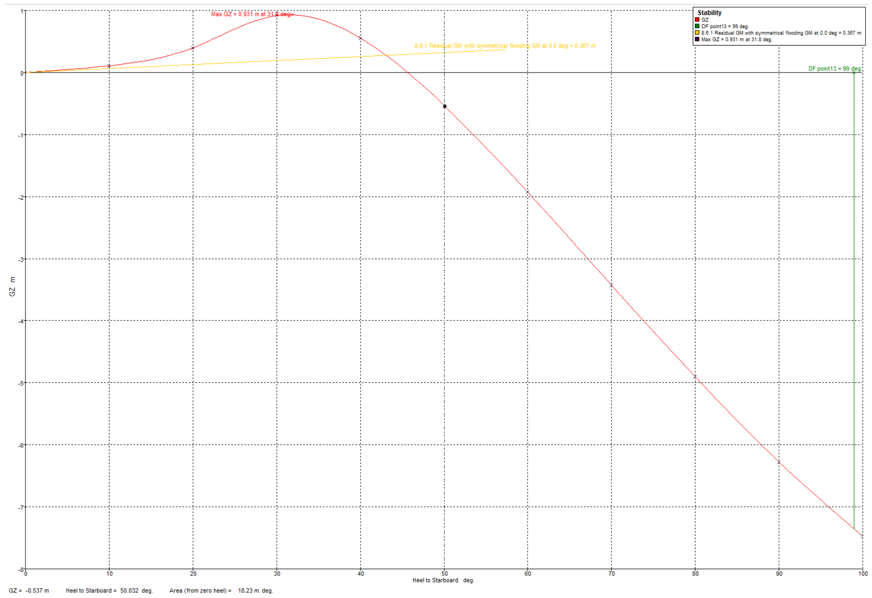

Figure 12.16: Righting Arm Curve (Damage Case 6)

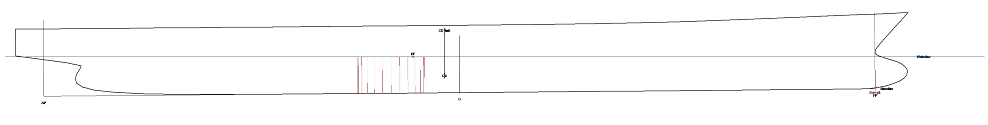

Figure 12.17: Flooding Rendering (Damage Case 6)

Table 12.9: Righting Arm Curve Data (Damage Case 6).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.108	0.398	0.918	0.553	-0.532	-1.927	-3.426	-4.904	-6.276	-7.475
Area under GZ curve	0	0.4933	2.7095	9.5666	17.7482	18.2437	6.0991	-20.6348	-62.3343	-118.37	-187.223
Displacement (t)	66991	66991	66995	66991	66991	66991	66991	66994	66991	66991	66991
Draft at FP (m)	9.589	9.73	9.942	9.896	9.445	8.848	7.973	6.369	1.944	n/a	-18.992
Draft at AP (m)	11.795	11.461	10.705	9.735	8.933	8.038	6.79	4.582	-1.833	n/a	-23.441
WL Length (m)	257.825	259.664	259.155	259.29	262.704	264.728	266.07	267.358	267.559	267.916	268.041
Beam max on WL (m)	40.498	41.122	43.064	40.066	31.312	26.438	23.705	22.694	22.353	21.651	21.099
Wetted Area (m^2)	11816.16	11877.2	11943.3	12345	12723.14	12842.623	12920.46	12963.54	12988.83	13031.35	12920.79
Waterpl. Area (m^2)	7405.132	7533.07	7805.55	7705.3	6609.373	5777.484	5307.101	5005.172	4807.402	4727.856	4694.925
Prismatic coeff. (Cp)	0.577	0.581	0.605	0.636	0.648	0.654	0.658	0.659	0.662	0.664	0.668
Block coeff. (Cb)	0.556	0.451	0.37	0.358	0.421	0.471	0.512	0.535	0.562	0.608	0.578
LCB (m)	-129.34	-129.3	-129.28	-129.2	-129.198	-129.192	-129.19	-129.191	-129.192	-129.192	-129.195
LCF (m)	-138.749	-138.37	-134.743	-128.2	-122.588	-121.082	-119.862	-118.609	-116.598	-116.26	-116.163
Max Deck Incl (°)	0.5059	10.0076	20.0006	30	40.0001	50.0001	60.0001	70.0001	80	90	100
Trim (°)	0.5059	0.3968	0.175	-0.037	-0.1174	-0.1856	-0.2712	-0.4098	-0.8662	-90	-1.0203

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	99.0	deg			
	angle of vanishing stability	45.6	deg	45.6		
	shall not be less than (>=)	**15.0**	**deg**	**45.6**	Pass	+204.14
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	99.0	deg			
	angle of vanishing stability	45.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.6182**	Pass	+321.01
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.931**	Pass	+831.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.367**	Pass	+634.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.6**	Pass	+30.35
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**99.0**	Pass	+394.81
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	99.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.2522**	Pass	+145.47

Figure 12.18: Regulations (Damage Case 6)

12.0.7 Damage Case 7

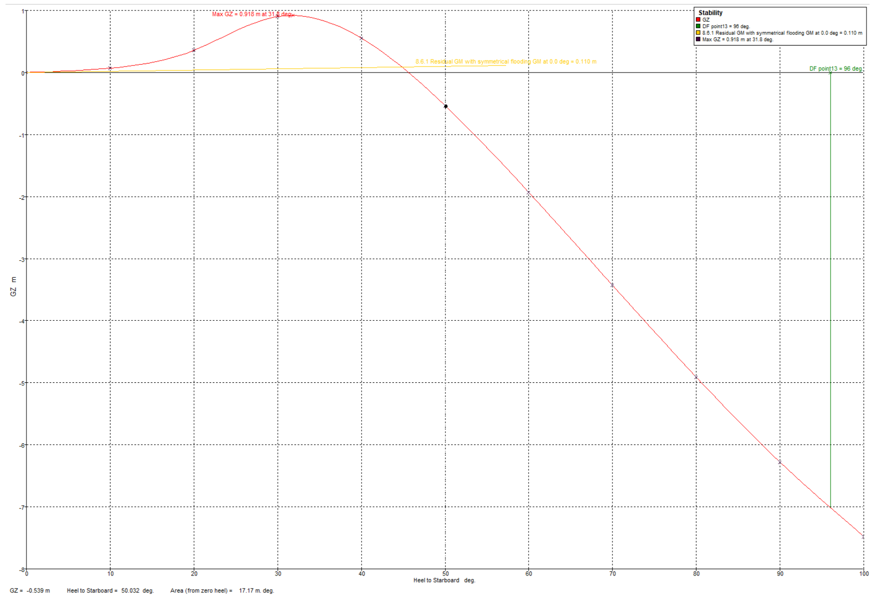

Figure 12.19: Righting Arm Curve (Damage Case 7)

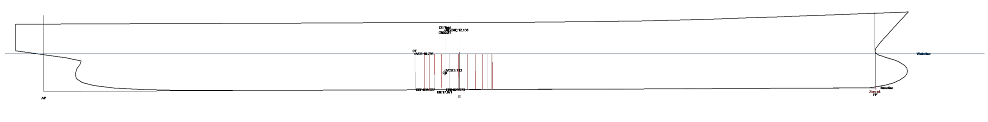

Figure 12.20: Flooding Rendering (Damage Case 7)

Table 12.10: Righting Arm Curve Data (Damage Case 7).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.068	0.357	0.901	0.55	-0.535	-1.928	-3.428	-4.908	-6.278	-7.478
Area under GZ curve	0	0.2714	2.0474	8.6107	16.7098	17.1864	5.0224	-21.7303	-63.4616	-119.524	-188.396
Displacement (t)	66991	66985	66986	66991	66994	66991	66991	66997	66991	66991	66991
Draft at FP (m)	10.219	10.33	10.526	10.439	10.054	9.614	8.971	7.85	4.884	n/a	-15.874
Draft at AP (m)	11.26	10.957	10.197	9.229	8.318	7.238	5.723	2.962	-5.159	n/a	-26.936
WL Length (m)	252.367	258.503	258.309	258.37	259.906	263.771	265.322	266.649	267.782	268.011	267.953
Beam max on WL (m)	40.498	41.122	43.062	40.076	31.306	26.424	23.649	22.508	22.296	21.853	21.266
Wetted Area (m^2)	11745.55	11864.7	11978	12405	12717.35	12858.193	12924.45	12970.55	13013.03	13032.77	12924.69
Waterpl. Area (m^2)	7276.34	7468.6	7786.92	7738.4	6586.416	5793.264	5316.582	5003.437	4822.365	4727.359	4733.221
Prismatic coeff. (Cp)	0.595	0.589	0.61	0.638	0.656	0.657	0.66	0.662	0.663	0.665	0.669
Block coeff. (Cb)	0.582	0.456	0.372	0.36	0.426	0.474	0.516	0.542	0.564	0.594	0.566
LCB (m)	-129.273	-129.25	-129.205	-129.2	-129.153	-129.142	-129.139	-129.141	-129.143	-129.149	-129.157
LCF (m)	-138.227	-138.67	-135.516	-129.9	-124.826	-122.817	-121.427	-119.509	-117.411	-115.66	-116.109
Max Deck Incl (°)	0.2387	10.001	20.0001	30.001	40.001	50.0009	60.0007	70.0005	80.0002	90	99.9997
Trim (°)	0.2387	0.1438	-0.0755	-0.278	-0.3983	-0.5448	-0.745	-1.1208	-2.3022	-90	-2.5352

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	96.0	deg			
	angle of vanishing stability	45.6	deg	45.6		
	shall not be less than (>=)	**15.0**	**deg**	**45.6**	**Pass**	+204.05
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	96.0	deg			
	angle of vanishing stability	45.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**2.8778**	**Pass**	+234.86
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.918**	**Pass**	+818.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.110**	**Pass**	+120.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.6**	**Pass**	+30.31
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**96.0**	**Pass**	+380.04
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**10.2695**	**Pass**	+124.03

Figure 12.21: Regulations (Damage Case 7)

12.0.8 Damage Case 8

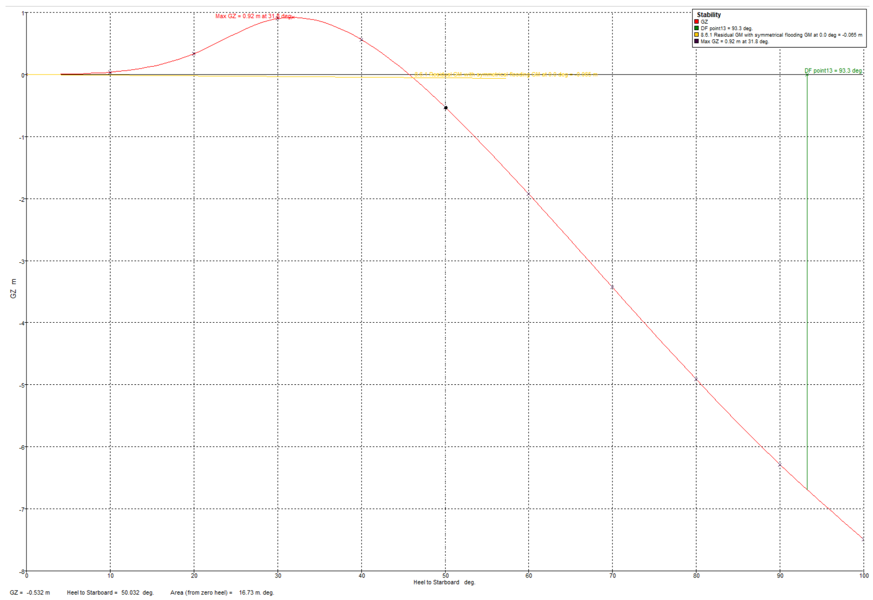

Figure 12.22: Righting Arm Curve (Damage Case 8)

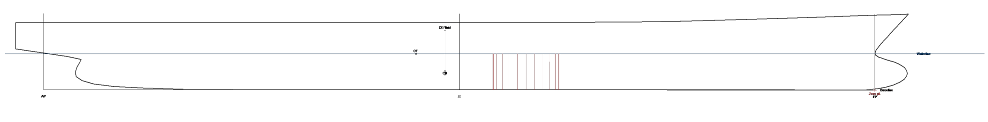

Figure 12.23: Flooding Rendering (Damage Case 8)

Table 12.11: Righting Arm Curve Data (Damage Case 8).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.038	0.335	0.9	0.559	-0.527	-1.924	-3.429	-4.913	-6.286	-7.489
Area under GZ curve	0	0.1009	1.5923	8.0395	16.1856	16.7457	4.6377	-22.0998	-63.8634	-119.996	-188.97
Displacement (t)	66991	66991	66991	66991	66991	66995	66991	66991	66991	66991	66991
Draft at FP (m)	10.839	10.924	11.101	10.976	10.675	10.364	9.947	9.291	7.713	n/a	-12.875
Draft at AP (m)	10.708	10.441	9.687	8.727	7.695	6.45	4.66	1.319	-8.472	n/a	-30.425
WL Length (m)	247.98	252.699	258.152	258.14	258.23	262.171	265.437	266.959	267.761	268.107	267.873
Beam max on WL (m)	40.498	41.122	43.059	40.083	31.3	26.411	23.595	22.314	22.141	21.981	21.508
Wetted Area (m^2)	11732.52	11812.8	12013.6	12440	12748.61	12869.884	12932.47	12970.28	13038.39	13054.8	12922.79
Waterpl. Area (m^2)	7204.649	7389.47	7822	7763.8	6538.961	5813.468	5319.558	4988.62	4837.965	4750.656	4764.766
Prismatic coeff. (Cp)	0.611	0.605	0.609	0.637	0.66	0.662	0.661	0.662	0.664	0.667	0.671
Block coeff. (Cb)	0.601	0.468	0.372	0.36	0.429	0.478	0.517	0.547	0.569	0.583	0.552
LCB (m)	-129.215	-129.2	-129.154	-129.1	-129.114	-129.092	-129.089	-129.091	-129.096	-129.104	-129.121
LCF (m)	-137.938	-138.15	-136.484	-131.4	-127.592	-124.636	-122.811	-120.16	-118.134	-115.599	-116.298
Max Deck Incl (°)	0.0301	10.0006	20.0022	30.003	40.0028	50.0024	60.0019	70.0012	80.0006	90	99.9992
Trim (°)	-0.0301	-0.1106	-0.3243	-0.516	-0.6832	-0.8975	-1.2124	-1.8277	-3.7067	-90	-4.0185

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	93.3	deg			
	angle of vanishing stability	45.7	deg	45.7		
	shall not be less than (>=)	**15.0**	**deg**	**45.7**	**Pass**	+204.54
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	93.3	deg			
	angle of vanishing stability	45.7	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**2.3827**	**Pass**	+177.25
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	93.3	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.920**	**Pass**	+820.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Fail	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**-0.065**	Fail	-230.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**45.7**	**Pass**	+30.52
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**93.3**	**Pass**	+366.31
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	93.3	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**9.6982**	**Pass**	+111.57

Figure 12.24: Regulations (Damage Case 8)

12.0.9 Damage Case 9

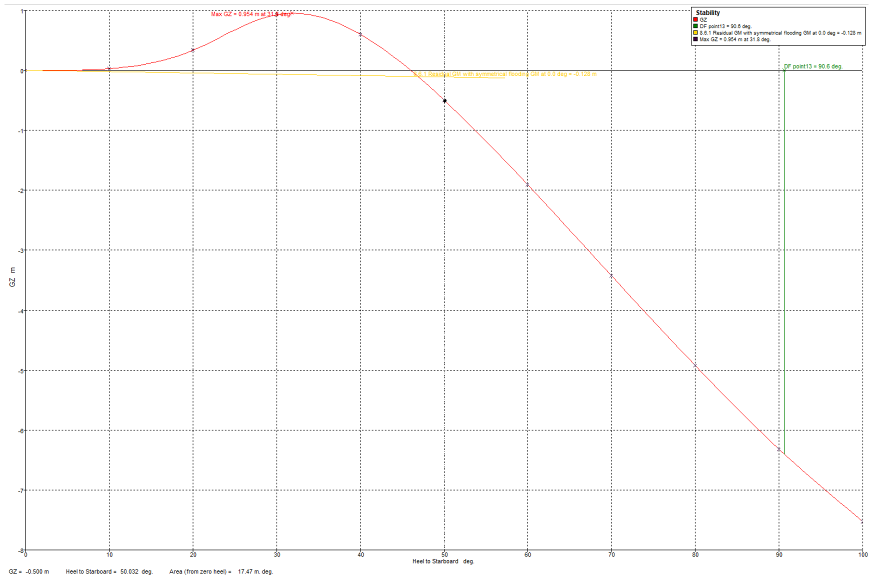

Figure 12.25: Righting Arm Curve (Damage Case 9)

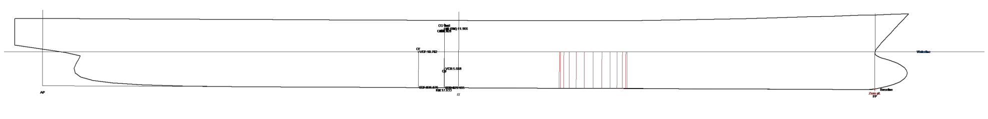

Figure 12.26: Flooding Rendering (Damage Case 9)

Table 12.12: Righting Arm Curve Data (Damage Case 9).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.029	0.334	0.93	0.597	-0.496	-1.906	-3.425	-4.922	-6.318	-7.523
Area under GZ curve	0	0.0461	1.4612	8.0564	16.57	17.4884	5.6348	-20.9908	-62.7707	-119.108	-188.424
Displacement (t)	66991	66990	66991	66991	66991	66991	66996	66991	66991	66991	66991
Draft at FP (m)	11.334	11.402	11.561	11.446	11.241	11.017	10.784	10.519	10.084	n/a	-10.327
Draft at AP (m)	10.18	9.938	9.219	8.24	7.078	5.677	3.615	-0.306	-11.741	n/a	-33.888
WL Length (m)	244.515	247.822	258.275	258.26	258.161	263.021	265.914	267.235	267.848	268.16	267.811
Beam max on WL (m)	40.498	41.122	43.057	40.096	31.298	26.401	23.554	22.204	21.974	22.086	21.755
Wetted Area (m^2)	11603.69	11817.3	12005.9	12445	12720.11	12914.76	12936.56	12978.4	13033.91	12892.31	12919.82
Waterpl. Area (m^2)	7124.359	7385.19	7821.9	7805.1	6526.017	5775.374	5308.856	5001.082	4841.633	4808.039	4768.845
Prismatic coeff. (Cp)	0.621	0.618	0.609	0.634	0.658	0.659	0.661	0.663	0.666	0.668	0.673
Block coeff. (Cb)	0.585	0.478	0.372	0.36	0.429	0.477	0.519	0.551	0.576	0.572	0.54
LCB (m)	-129.165	-129.16	-129.112	-129.1	-129.08	-129.048	-129.042	-129.043	-129.052	-129.062	-129.079
LCF (m)	-136.976	-138.26	-136.506	-132.7	-129.98	-127.251	-124.16	-121.091	-118.458	-115.043	-117.108
Max Deck Incl (°)	0.2646	10.0054	20.0061	30.006	40.0056	50.0045	60.0034	70.0023	80.0012	90	99.9986
Trim (°)	-0.2646	-0.3357	-0.537	-0.735	-0.9547	-1.2246	-1.6437	-2.4809	-4.9927	-90	-5.3875

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	5.1	deg	5.1		
	to the lesser of					
	first downflooding angle	90.6	deg			
	angle of vanishing stability	46.0	deg	46.0		
	shall not be less than (>=)	**15.0**	**deg**	**40.9**	**Pass**	+172.51
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	5.1	deg	5.1		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	90.6	deg			
	angle of vanishing stability	46.0	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**2.2618**	**Pass**	+163.19
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	5.1	deg	5.1		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	90.6	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.954**	**Pass**	+854.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Fail	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**-0.128**	Fail	-356.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**5.1**	**Pass**	+48.88
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**46.0**	**Pass**	+31.40
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**90.6**	**Pass**	+353.16
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	90.6	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**9.7739**	**Pass**	+113.22

Figure 12.27: Regulations (Damage Case 9)

12.0.10 Damage Case 10

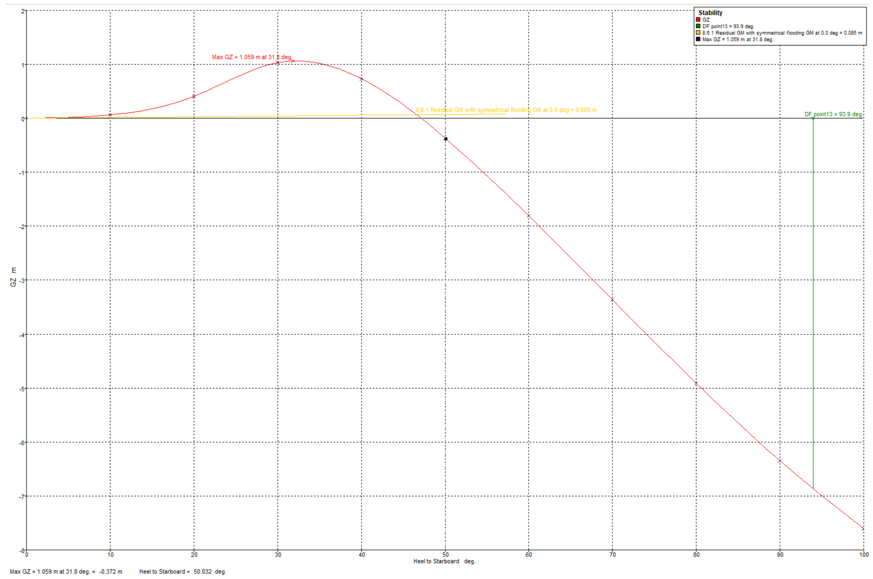

Figure 12.28: Righting Arm Curve (Damage Case 10)

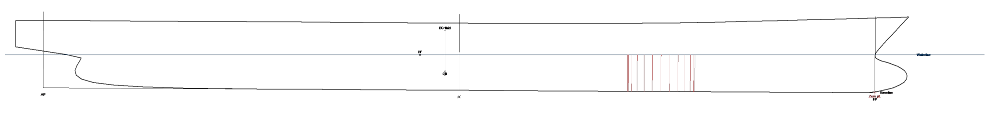

Figure 12.29: Flooding Rendering (Damage Case 10)

Table 12.13: Righting Arm Curve Data (Damage Case 10).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.044	0.37	0.996	0.682	-0.425	-1.861	-3.41	-4.939	-6.366	-7.6
Area under GZ curve	0	0.1249	1.7905	8.8919	18.1832	19.9003	8.6261	-17.7036	-59.4984	-116.168	-186.11
Displacement (t)	66991	66990	66991	66991	66991	66991	66992	66991	66991	66991	66991
Draft at FP (m)	11.349	11.428	11.639	11.605	11.479	11.295	11.122	10.999	11.018	n/a	-9.298
Draft at AP (m)	9.859	9.625	8.898	7.869	6.585	5.037	2.73	-1.68	-14.604	n/a	-36.842
WL Length (m)	242.607	245.04	258.305	258.32	258.256	263.284	266.042	267.354	267.891	268.141	267.791
Beam max on WL (m)	40.498	41.122	43.051	40.113	31.3	26.401	23.553	22.166	21.894	22.043	21.844
Wetted Area (m^2)	11462.92	11698.1	11916.1	12367	12631.4	12859.626	12870.52	12933.28	12945.36	12819.44	12837.47
Waterpl. Area (m^2)	7112.374	7391.14	7838.47	7864.8	6552.393	5778.714	5292.227	4997.155	4806.384	4762.586	4747.689
Prismatic coeff. (Cp)	0.635	0.634	0.615	0.637	0.66	0.662	0.664	0.667	0.67	0.672	0.677
Block coeff. (Cb)	0.589	0.488	0.375	0.361	0.431	0.48	0.522	0.556	0.583	0.572	0.536
LCB (m)	-129.148	-129.14	-129.093	-129.1	-129.057	-129.017	-129.009	-129.01	-129.019	-129.054	-129.052
LCF (m)	-136.716	-138.26	-136.707	-133.5	-131.753	-128.96	-125.366	-122.411	-118.437	-117.199	-118.466
Max Deck Incl (°)	0.3418	10.0082	20.0084	30.008	40.0077	50.0062	60.0047	70.0031	80.0016	90	99.9981
Trim (°)	-0.3418	-0.4137	-0.6285	-0.857	-1.1222	-1.4349	-1.924	-2.9053	-5.8558	-90	-6.2916

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	93.9	deg			
	angle of vanishing stability	47.1	deg	47.1		
	shall not be less than (>=)	**15.0**	**deg**	**47.1**	**Pass**	+214.16
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	93.9	deg			
	angle of vanishing stability	47.1	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.1424**	**Pass**	+265.65
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	93.9	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.059**	**Pass**	+959.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.085**	**Pass**	+70.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**47.1**	**Pass**	+34.64
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**93.9**	**Pass**	+369.74
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	93.9	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.5442**	**Pass**	+151.84

Figure 12.30: Regulations (Damage Case 10)

12.0.11 Damage Case 11

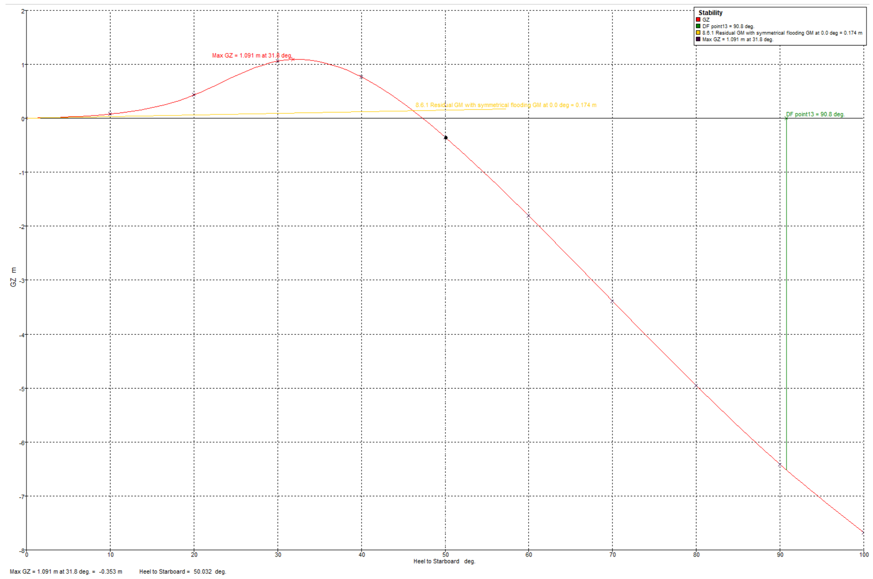

Figure 12.31: Righting Arm Curve (Damage Case 11)

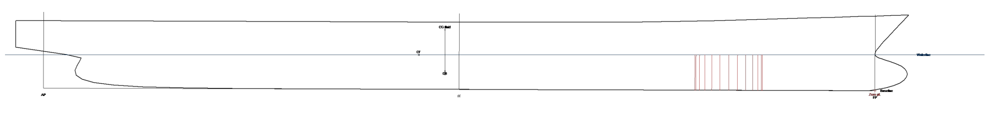

Figure 12.32: Flooding Rendering (Damage Case 11)

Table 12.14: Righting Arm Curve Data (Damage Case 11).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.079	0.431	1.059	0.765	-0.348	-1.806	-3.386	-4.951	-6.412	-7.681
Area under GZ curve	0	0.2968	2.4637	10.19	20.2108	22.7534	12.1519	-13.7727	-55.5047	-112.463	-183.039
Displacement (t)	66991	66990	66991	66991	66991	66991	66988	66998	66991	66991	66997
Draft at FP (m)	10.769	10.876	11.182	11.283	11.176	10.992	10.763	10.484	10.027	n/a	-10.332
Draft at AP (m)	9.923	9.672	8.891	7.771	6.396	4.734	2.261	-2.43	-16.251	n/a	-38.464
WL Length (m)	242.803	245.282	258.154	258.2	258.165	263.025	265.931	267.255	267.866	268.171	267.821
Beam max on WL (m)	40.498	41.122	43.035	40.132	31.307	26.413	23.58	22.249	21.999	22.083	21.735
Wetted Area (m^2)	11313.83	11547	11764.5	12195	12482.86	12686.943	12706.01	12773.84	12781.16	12677.89	12702.38
Waterpl. Area (m^2)	7208.321	7479.85	7901.86	7943.8	6639.251	5827.949	5305.878	5002.102	4792.031	4788.205	4747.331
Prismatic coeff. (Cp)	0.651	0.649	0.631	0.651	0.671	0.672	0.673	0.675	0.679	0.681	0.685
Block coeff. (Cb)	0.619	0.497	0.381	0.365	0.436	0.485	0.527	0.561	0.587	0.577	0.544
LCB (m)	-129.178	-129.17	-129.112	-129.1	-129.058	-129.014	-129.002	-129.001	-129.01	-129.042	-129.045
LCF (m)	-137.062	-138.63	-137.296	-134.1	-132.158	-129.651	-126.193	-123.595	-119.931	-117.671	-119.265
Max Deck Incl (°)	0.194	10.0037	20.0058	30.007	40.0073	50.0062	60.0048	70.0033	80.0017	90	99.9981
Trim (°)	-0.194	-0.2763	-0.5253	-0.805	-1.0963	-1.4351	-1.949	-2.9591	-6.0047	-90	-6.4249

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	90.8	deg			
	angle of vanishing stability	47.3	deg	47.3		
	shall not be less than (>=)	**15.0**	**deg**	**47.3**	**Pass**	+215.49
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	90.8	deg			
	angle of vanishing stability	47.3	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.4593**	**Pass**	+302.53
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	90.8	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.091**	**Pass**	+991.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.174**	**Pass**	+248.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**47.3**	**Pass**	+35.21
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**90.8**	**Pass**	+354.01
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	90.8	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**12.1494**	**Pass**	+165.04

Figure 12.33: Regulations (Damage Case 11)

12.0.12 Damage Case 12

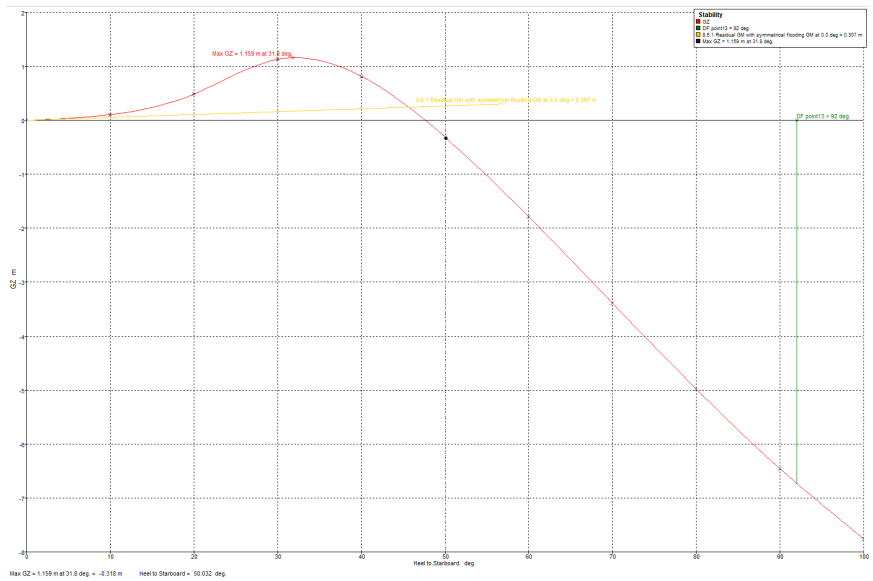

Figure 12.34: Righting Arm Curve (Damage Case 12)

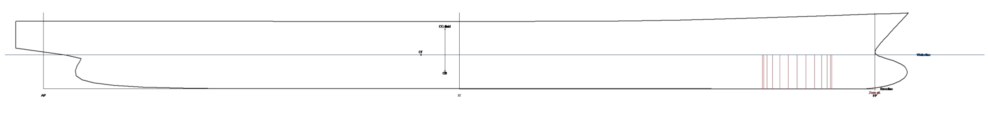

Figure 12.35: Flooding Rendering (Damage Case 12)

Table 12.15: Righting Arm Curve Data (Damage Case 12).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.104	0.486	1.13	0.814	-0.313	-1.787	-3.388	-4.979	-6.457	-7.759
Area under GZ curve	0	0.4205	2.9909	11.372	22.0012	24.9522	14.6201	-11.2149	-53.1013	-110.419	-181.593
Displacement (t)	66991	66990	66991	66986	66991	66991	66991	66991	66991	66991	66991
Draft at FP (m)	10.198	10.3	10.601	10.699	10.647	10.523	10.291	9.907	9.084	n/a	-11.024
Draft at AP (m)	10.115	9.859	9.067	7.919	6.454	4.682	2.095	-2.773	-17.085	n/a	-39.42
WL Length (m)	244.383	247.298	258.269	258.24	258.254	262.451	265.713	267.138	267.838	268.19	267.841
Beam max on WL (m)	40.498	41.122	43.024	40.145	31.319	26.428	23.621	22.311	22.083	22.004	21.658
Wetted Area (m^2)	11228.3	11447.2	11636.5	11997	12349.43	12504.294	12579.59	12657.62	12679.19	12754.54	12608.1
Waterpl. Area (m^2)	7386.893	7646.95	8046.44	8010.1	6690.511	5881.105	5307.47	4969.037	4756.51	4728.533	4723.841
Prismatic coeff. (Cp)	0.657	0.656	0.644	0.667	0.683	0.682	0.681	0.682	0.685	0.688	0.691
Block coeff. (Cb)	0.648	0.5	0.385	0.369	0.44	0.49	0.531	0.564	0.59	0.586	0.549
LCB (m)	-129.206	-129.21	-129.147	-129.1	-129.077	-129.018	-129.003	-129.002	-129.007	-129.021	-129.051
LCF (m)	-136.356	-137.89	-136.871	-134.7	-132.579	-129.899	-127.488	-125.328	-121.969	-120.303	-120.732
Max Deck Incl (°)	0.019	10.0005	20.0026	30.005	40.0056	50.0054	60.0044	70.0031	80.0017	90	99.998
Trim (°)	-0.019	-0.1011	-0.3518	-0.638	-0.9614	-1.3394	-1.8789	-2.9056	-5.9798	-90	-6.4846

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	92.0	deg			
	angle of vanishing stability	47.6	deg	47.6		
	shall not be less than (>=)	**15.0**	**deg**	**47.6**	Pass	+217.45
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	92.0	deg			
	angle of vanishing stability	47.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.1022**	Pass	+377.33
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	92.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.159**	Pass	+1059.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.307**	Pass	+514.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**47.6**	Pass	+36.05
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**92.0**	Pass	+359.94
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	92.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**13.4575**	Pass	+193.57

Figure 12.36: Regulations (Damage Case 12)

12.0.13 Damage Case 13

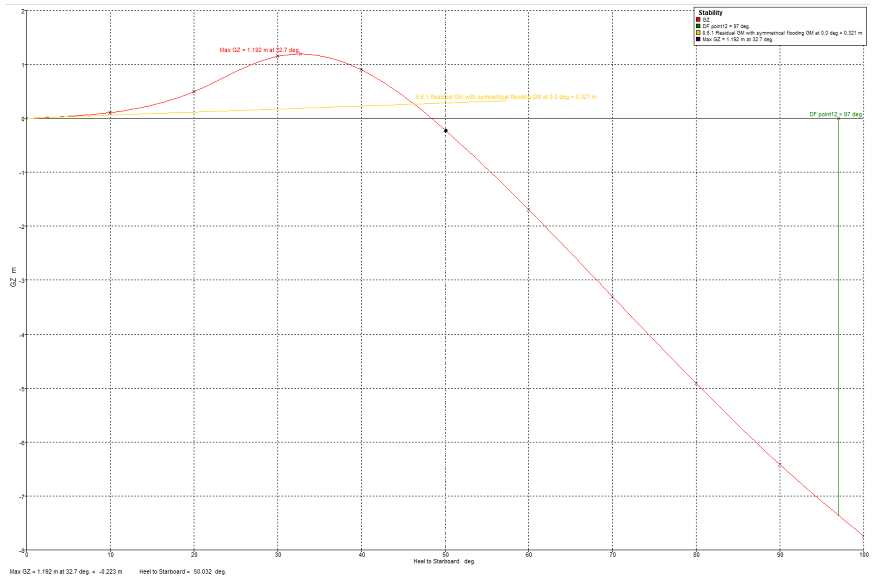

Figure 12.37: Righting Arm Curve (Damage Case 13)

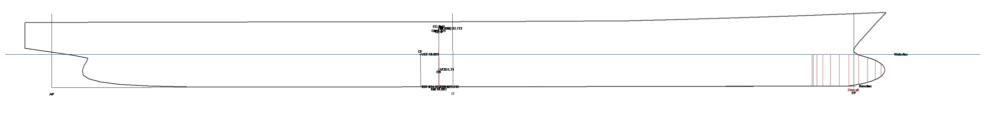

Figure 12.38: Flooding Rendering (Damage Case 13)

Table 12.16: Righting Arm Curve Data (Damage Case 13).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.108	0.495	1.149	0.895	-0.218	-1.692	-3.304	-4.914	-6.42	-7.745
Area under GZ curve	0	0.4322	3.0679	11.554	22.6812	26.5536	17.1796	-7.7515	-48.8855	-105.691	-176.617
Displacement (t)	66992	66990	66985	66992	66991	66991	66991	66991	66994	66997	66992
Draft at FP (m)	9.826	9.932	10.196	10.191	9.813	9.43	8.875	7.884	5.185	n/a	-14.908
Draft at AP (m)	10.276	10.01	9.23	8.127	6.792	5.106	2.62	-2.06	-15.724	n/a	-38.084
WL Length (m)	246.147	249.362	258.668	258.69	261.189	263.966	265.344	266.703	267.706	268.062	267.939
Beam max on WL (m)	40.498	41.121	43.018	40.15	31.333	26.462	23.717	22.564	22.305	21.856	21.262
Wetted Area (m^2)	11191.34	11394.5	11561.1	11838	12178.88	12310.786	12397.85	12481.38	12492.46	12561.02	12456.16
Waterpl. Area (m^2)	7550.207	7813.2	8247.47	8327	6953.289	5986.965	5359.647	4980.441	4716.117	4663.029	4688.395
Prismatic coeff. (Cp)	0.657	0.656	0.651	0.677	0.69	0.692	0.694	0.695	0.696	0.699	0.703
Block coeff. (Cb)	0.646	0.499	0.388	0.371	0.439	0.492	0.535	0.565	0.591	0.605	0.574
LCB (m)	-129.246	-129.22	-129.174	-129.1	-129.107	-129.07	-129.054	-129.047	-129.048	-129.056	-129.079
LCF (m)	-134.952	-136.27	-134.822	-131	-128.56	-128.767	-127.736	-126.793	-124.529	-123.491	-123.238
Max Deck Incl (°)	0.1033	10	20.001	30.003	40.0029	50.003	60.0026	70.0019	80.0011	90	99.9987
Trim (°)	0.1033	0.0179	-0.2217	-0.473	-0.6927	-0.9917	-1.4342	-2.2794	-4.7842	-90	-5.2999

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	97.0	deg			
	angle of vanishing stability	48.4	deg	48.4		
	shall not be less than (>=)	**15.0**	**deg**	**48.4**	**Pass**	+222.41
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	97.0	deg			
	angle of vanishing stability	48.4	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.1967**	**Pass**	+388.33
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	32.7	deg	32.7		
	first downflooding angle	97.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.192**	**Pass**	+1092.00
	Intermediate values					
	angle at which this GZ occurs		deg	32.7		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.321**	**Pass**	+542.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**48.4**	**Pass**	+38.17
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**97.0**	**Pass**	+385.18
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	32.7	deg	32.7		
	first downflooding angle	97.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**14.7646**	**Pass**	+222.09

Figure 12.39: Regulations (Damage Case 13)

12.0.14 Damage Case 14

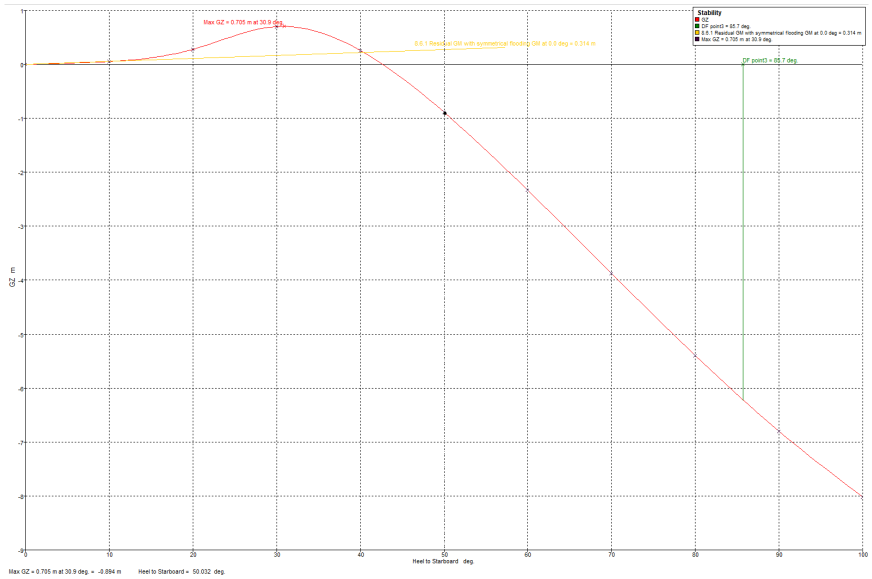

Figure 12.40: Righting Arm Curve (Damage Case 14)

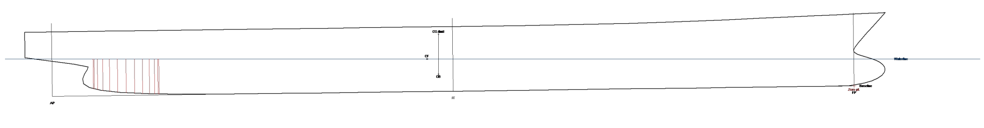

Figure 12.41: Flooding Rendering (Damage Case 14)

Table 12.17: Righting Arm Curve Data (Damage Case 14).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.054	0.277	0.702	0.253	-0.889	-2.331	-3.872	-5.393	-6.801	-8.018
Area under GZ curve	0	0.2242	1.5876	6.7715	12.3525	9.5507	-6.4035	-37.3915	-83.7714	-144.891	-219.092
Displacement (t)	66991	66991	66988	66991	66991	66991	66991	66991	66991	66985	66991
Draft at FP (m)	8.405	8.388	8.317	7.927	6.813	5.223	2.81	-1.746	-15.181	n/a	-39.197
Draft at AP (m)	11.702	11.639	11.443	11.211	11.456	12.004	12.921	14.721	20.136	n/a	2.467
WL Length (m)	261.187	263.979	264.176	265.14	267.032	267.849	266.352	263.729	265.884	266.927	267.752
Beam max on WL (m)	40.498	41.122	43.055	40.078	31.36	26.604	24.942	23.416	21.595	20.695	20.716
Wetted Area (m^2)	11418.99	11539.1	11641.9	12068	12549.21	12787.689	12922.69	13029.22	13029.19	13070.06	13157.69
Waterpl. Area (m^2)	7464.813	7311.9	7612.04	7461.1	6380.779	5588.321	5059.479	4709.942	4450.662	4307.98	4323.899
Prismatic coeff. (Cp)	0.596	0.592	0.6	0.61	0.614	0.614	0.619	0.625	0.62	0.616	0.614
Block coeff. (Cb)	0.563	0.457	0.367	0.348	0.405	0.449	0.467	0.501	0.551	0.527	0.489
LCB (m)	-129.393	-129.38	-129.364	-129.4	-129.403	-129.444	-129.473	-129.489	-129.484	-129.489	-129.469
LCF (m)	-132.903	-128.08	-125.495	-120.1	-114.881	-112.51	-111.239	-110.51	-112.519	-113.838	-114.306
Max Deck Incl (°)	0.756	10.0266	20.0109	30.006	40.0069	50.0073	60.0068	70.0053	80.003	90	99.9958
Trim (°)	0.756	0.7455	0.7169	0.7532	1.0647	1.5549	2.3176	3.7711	8.0465	90	9.4681

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	85.7	deg			
	angle of vanishing stability	42.6	deg	42.6		
	shall not be less than (>=)	**15.0**	**deg**	**42.6**	Pass	+184.19
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	85.7	deg			
	angle of vanishing stability	42.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**2.2377**	Pass	+160.38
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	85.7	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.705**	Pass	+605.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.9		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.314**	Pass	+528.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**42.6**	Pass	+21.80
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**85.7**	Pass	+328.65
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	85.7	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**7.4109**	Pass	+61.67

Figure 12.42: Regulations (Damage Case 14)

12.0.15 Damage Case 15

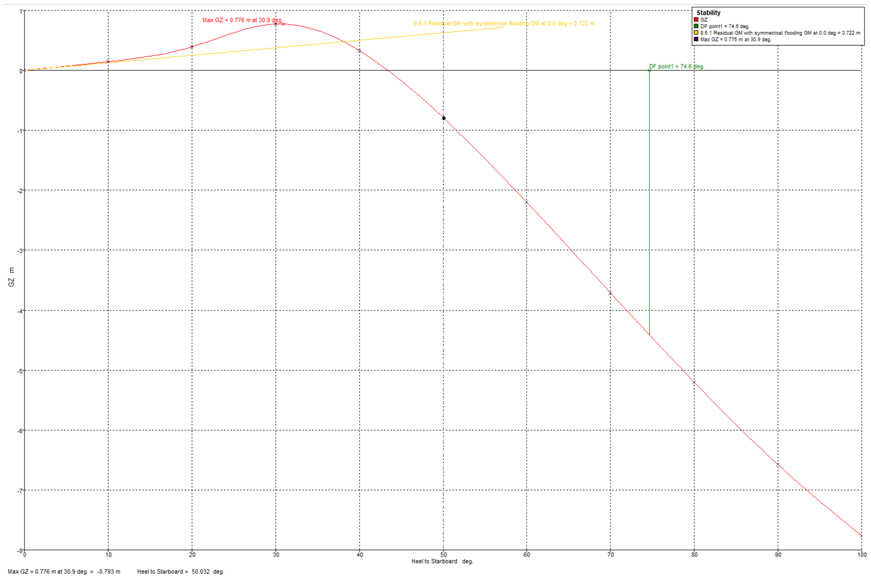

Figure 12.43: Righting Arm Curve (Damage Case 15)

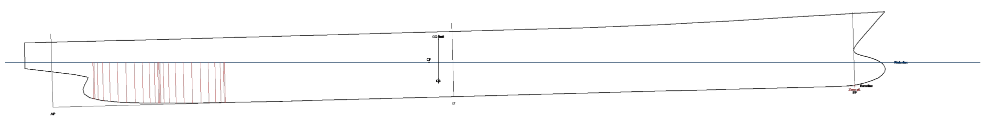

Figure 12.44: Flooding Rendering (Damage Case 15)

Table 12.18: Righting Arm Curve Data (Damage Case 15).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.143	0.393	0.776	0.326	-0.789	-2.199	-3.71	-5.2	-6.578	-7.767
Area under GZ curve	0	0.6986	3.1583	9.2994	15.5682	13.6232	-1.1685	-30.6871	-75.2885	-134.326	-206.159
Displacement (t)	66996	66991	66991	66991	66991	66991	66991	66991	66991	66991	66991
Draft at FP (m)	7.299	7.501	7.56	7.296	6.298	4.797	2.499	-1.858	-14.708	n/a	-37.19
Draft at AP (m)	13.91	13.538	13.192	12.954	13.398	14.219	15.532	18.066	25.593	n/a	5.086
WL Length (m)	266.53	266.215	266.069	266.45	267.557	267.755	266.08	263.651	265.944	267.053	267.811
Beam max on WL (m)	40.499	41.122	43.077	39.976	31.342	26.59	25.001	23.417	21.669	20.758	20.745
Wetted Area (m^2)	12055.19	12021.2	11950.6	12486	12959.06	13148.944	13256.67	13332.68	13330.96	13337.64	13382.31
Waterpl. Area (m^2)	7270.389	7371.73	7529.55	7197.3	6196.183	5398.03	4879.538	4554.158	4288.043	4209.119	4202.078
Prismatic coeff. (Cp)	0.528	0.537	0.547	0.562	0.574	0.581	0.591	0.601	0.599	0.6	0.601
Block coeff. (Cb)	0.479	0.422	0.347	0.334	0.389	0.433	0.45	0.485	0.525	0.509	0.479
LCB (m)	-129.545	-129.52	-129.469	-129.5	-129.491	-129.522	-129.538	-129.537	-129.521	-129.5	-129.47
LCF (m)	-132.363	-131.91	-127.201	-119.8	-113.666	-111.116	-109.531	-108.847	-110.131	-111.841	-112.367
Max Deck Incl (°)	1.5159	10.0915	20.0353	30.019	40.0162	50.0141	60.0112	70.0078	80.004	90	99.9956
Trim (°)	1.5159	1.3842	1.2915	1.2974	1.6279	2.1599	2.9864	4.5597	9.1635	90	9.6047

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	74.6	deg			
	angle of vanishing stability	43.4	deg	43.4		
	shall not be less than (>=)	**15.0**	**deg**	**43.4**	Pass	+189.25
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	74.6	deg			
	angle of vanishing stability	43.4	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.0343**	Pass	+369.43
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	74.6	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.776**	Pass	+676.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.9		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.722**	Pass	+1344.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**43.4**	Pass	+23.97
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**74.6**	Pass	+273.14
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.9	deg	30.9		
	first downflooding angle	74.6	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**10.0047**	Pass	+118.25

Figure 12.45: Regulations (Damage Case 15)

12.0.16 Damage Case 16

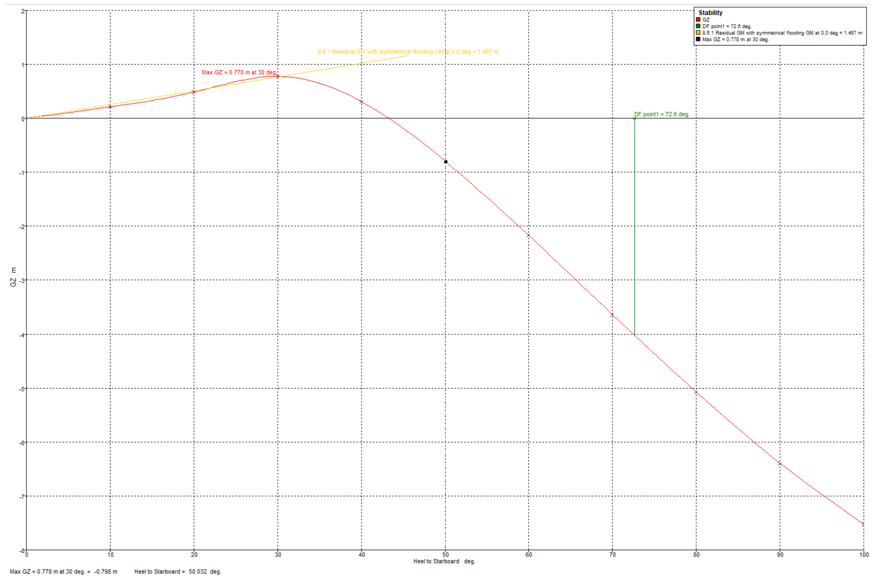

Figure 12.46: Righting Arm Curve (Damage Case 16)

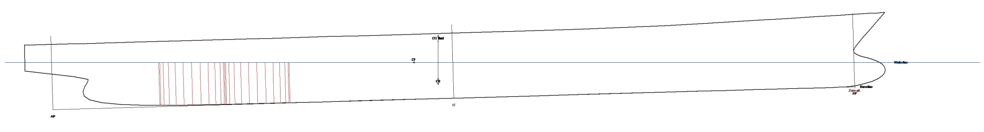

Figure 12.47: Flooding Rendering (Damage Case 16)

Table 12.19: Righting Arm Curve Data (Damage Case 16).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.212	0.485	0.778	0.309	-0.793	-2.171	-3.636	-5.071	-6.392	-7.522
Area under GZ curve	0	1.0546	4.4158	11.051	17.1844	15.119	0.4276	-28.5891	-72.1801	-129.642	-199.318
Displacement (t)	66991	66991	66991	66991	66985	66991	66991	66991	66991	66991	66991
Draft at FP (m)	7.559	7.618	7.761	7.493	6.624	5.342	3.374	-0.362	-11.297	n/a	-33.181
Draft at AP (m)	14.591	14.418	13.905	13.737	14.229	15.074	16.437	19.101	27.039	n/a	5.574
WL Length (m)	266.196	266.079	265.7	266.21	267.317	267.894	266.741	265.177	266.26	267.404	267.909
Beam max on WL (m)	40.499	41.123	43.085	39.829	31.311	26.51	24.729	23.443	21.865	20.928	20.837
Wetted Area (m^2)	12393.9	12223	12266.2	12864	13286.95	13463.191	13550.4	13610.37	13636.89	13577.62	13610.72
Waterpl. Area (m^2)	7358.631	7282.6	7401.73	6996.7	5997.463	5255.289	4774.543	4491.204	4299.015	4207.646	4217.718
Prismatic coeff. (Cp)	0.505	0.509	0.522	0.538	0.553	0.564	0.575	0.585	0.588	0.59	0.592
Block coeff. (Cb)	0.456	0.405	0.337	0.326	0.38	0.424	0.445	0.473	0.514	0.502	0.476
LCB (m)	-129.543	-129.53	-129.475	-129.5	-129.502	-129.521	-129.527	-129.517	-129.484	-129.447	-129.441
LCF (m)	-136.947	-133.66	-128.416	-119.5	-113.592	-110.742	-109.196	-108.595	-109.2	-112.495	-114.02
Max Deck Incl (°)	1.6122	10.116	20.042	30.023	40.0186	50.0151	60.0113	70.0074	80.0036	90	99.9963
Trim (°)	1.6122	1.5591	1.4089	1.4317	1.7436	2.231	2.9932	4.4547	8.7238	90	8.8178

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	72.6	deg			
	angle of vanishing stability	43.3	deg	43.3		
	shall not be less than (>=)	**15.0**	**deg**	**43.3**	**Pass**	+188.34
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	72.6	deg			
	angle of vanishing stability	43.3	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**5.4641**	**Pass**	+535.81
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	72.6	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.778**	**Pass**	+678.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.0		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**1.467**	**Pass**	+2834.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**43.3**	**Pass**	+23.57
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**72.6**	**Pass**	+263.19
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	72.6	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.0509**	**Pass**	+141.08

Figure 12.48: Regulations (Damage Case 16)

12.0.17 Damage Case 17

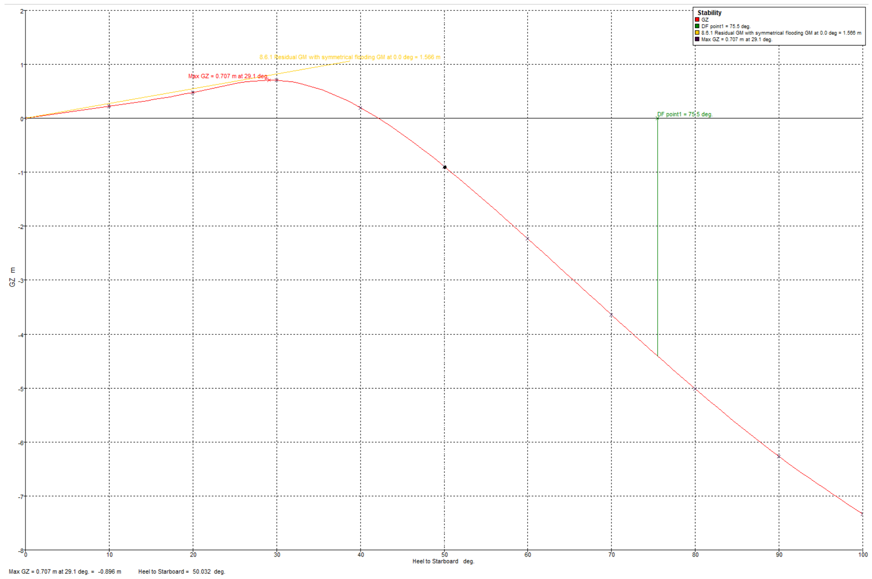

Figure 12.49: Righting Arm Curve (Damage Case 17)

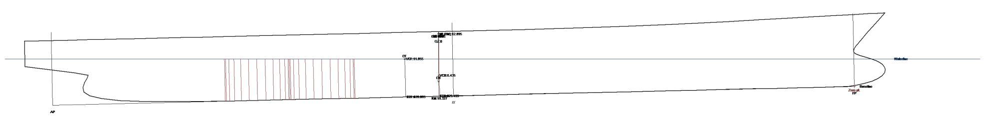

Figure 12.50: Flooding Rendering (Damage Case 17)

Table 12.20: Righting Arm Curve Data (Damage Case 17).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.225	0.48	0.704	0.196	-0.892	-2.229	-3.64	-5.012	-6.267	-7.334
Area under GZ curve	0	1.1254	4.5632	10.812	15.9599	12.8038	-2.6835	-32.0205	-75.3395	-131.885	-199.998
Displacement (t)	66991	66991	66992	66991	66991	66991	66991	66991	66991	66991	66991
Draft at FP (m)	8.579	8.64	8.748	8.492	7.829	6.858	5.402	2.65	-5.271	n/a	-26.64
Draft at AP (m)	14.43	14.228	13.677	13.415	13.723	14.363	15.48	17.739	24.448	n/a	2.746
WL Length (m)	263.659	263.444	263.012	264	265.671	267.102	267.876	266.657	266.816	267.734	268.062
Beam max on WL (m)	40.499	41.123	43.088	39.64	31.281	26.43	23.998	23.235	22.308	21.228	20.972
Wetted Area (m^2)	12627.06	12464.2	12494.4	13148	13482.29	13682.34	13792.45	13854.38	13893.31	13866.09	13816
Waterpl. Area (m^2)	7260.689	7174.91	7287.29	6836.8	5810.906	5179.82	4761.24	4508.339	4347.684	4293.881	4268.834
Prismatic coeff. (Cp)	0.5	0.505	0.519	0.538	0.555	0.565	0.572	0.581	0.585	0.587	0.59
Block coeff. (Cb)	0.461	0.403	0.337	0.328	0.381	0.425	0.455	0.472	0.505	0.505	0.483
LCB (m)	-129.499	-129.47	-129.415	-129.4	-129.432	-129.446	-129.449	-129.444	-129.437	-129.405	-129.369
LCF (m)	-139.865	-136.39	-130.516	-119.9	-115.585	-112.34	-110.599	-109.758	-109.698	-112.004	-114.456
Max Deck Incl (°)	1.3418	10.0785	20.027	30.014	40.0111	50.009	60.0067	70.0044	80.0022	90	99.9979
Trim (°)	1.3418	1.2812	1.1302	1.129	1.3513	1.7208	2.3101	3.4563	6.7839	90	6.7088

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	75.5	deg			
	angle of vanishing stability	42.1	deg	42.1		
	shall not be less than (>=)	**15.0**	**deg**	**42.1**	Pass	+180.81
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	75.5	deg			
	angle of vanishing stability	42.1	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**5.5893**	Pass	+550.37
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	29.1	deg	29.1		
	first downflooding angle	75.5	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.707**	Pass	+607.00
	Intermediate values					
	angle at which this GZ occurs		deg	29.1		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**1.566**	Pass	+3032.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**42.1**	Pass	+20.35
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**75.5**	Pass	+277.49
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	29.1	deg	29.1		
	first downflooding angle	75.5	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**10.1708**	Pass	+121.88

Figure 12.51: Regulations (Damage Case 17)

12.0.18 Damage Case 18

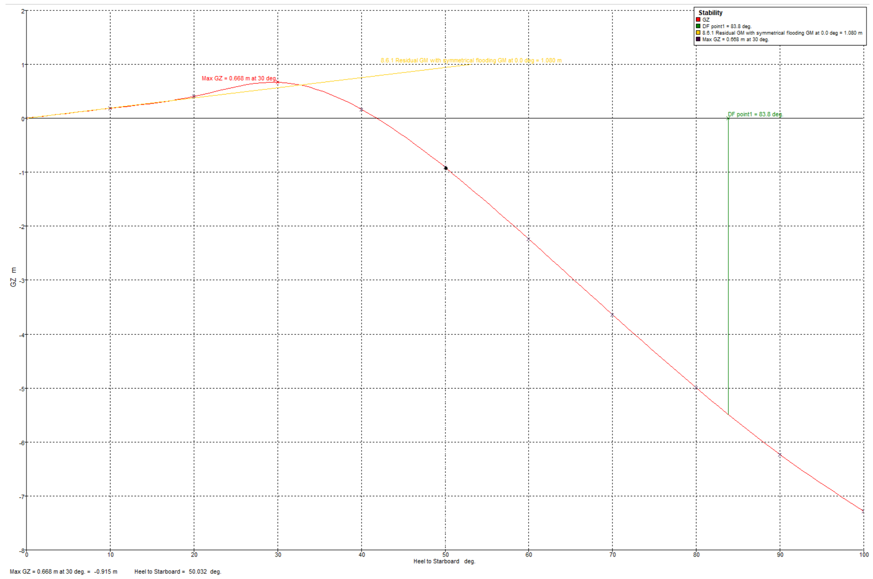

Figure 12.52: Righting Arm Curve (Damage Case 18)

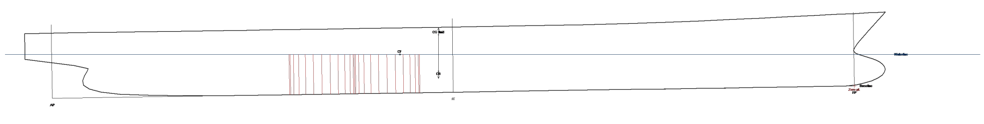

Figure 12.53: Flooding Rendering (Damage Case 18)

Table 12.21: Righting Arm Curve Data (Damage Case 18).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.185	0.406	0.668	0.166	-0.911	-2.237	-3.637	-4.995	-6.232	-7.285
Area under GZ curve	0	0.9362	3.7632	9.4469	14.2901	10.8766	-4.7461	-34.1117	-77.3371	-133.617	-201.303
Displacement (t)	66991	66991	66991	66991	66991	66991	66991	66991	66991	66991	66997
Draft at FP (m)	9.786	9.921	9.959	9.735	9.247	8.613	7.7	6.05	1.448	n/a	-19.594
Draft at AP (m)	13.58	13.232	12.683	12.175	12.167	12.377	12.824	13.779	16.671	n/a	-4.817
WL Length (m)	259.568	259.234	259.133	260.07	263.288	265.111	266.431	267.653	267.458	267.896	268.093
Beam max on WL (m)	40.499	41.123	43.087	39.627	31.277	26.391	23.602	22.674	22.36	21.689	21.235
Wetted Area (m^2)	12644.89	12620.9	12558.4	13204	13600.05	13704.354	13805.38	13864.28	13895.33	13932.01	13818.37
Waterpl. Area (m^2)	7134.712	7168.41	7288.22	6839.6	5946.624	5221.032	4800.128	4545.244	4440.726	4387.062	4438.349
Prismatic coeff. (Cp)	0.515	0.523	0.539	0.563	0.578	0.586	0.591	0.594	0.599	0.601	0.604
Block coeff. (Cb)	0.487	0.416	0.345	0.338	0.391	0.437	0.473	0.491	0.512	0.527	0.506
LCB (m)	-129.398	-129.36	-129.33	-129.3	-129.324	-129.334	-129.337	-129.335	-129.327	-129.314	-129.3
LCF (m)	-141.337	-139.73	-133.697	-123.1	-117.185	-115.783	-114.026	-112.849	-112.58	-112.774	-115.006
Max Deck Incl (°)	0.8701	10.0276	20.0083	30.004	40.0027	50.0023	60.0017	70.0012	80.0006	90	99.9995
Trim (°)	0.8701	0.7594	0.6247	0.5596	0.6696	0.8631	1.1749	1.772	3.4869	90	3.3851

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	83.8	deg			
	angle of vanishing stability	41.8	deg	41.8		
	shall not be less than (>=)	**15.0**	**deg**	**41.8**	**Pass**	+178.83
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	83.8	deg			
	angle of vanishing stability	41.8	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.6459**	**Pass**	+440.60
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	83.8	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.668**	**Pass**	+568.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.0		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**1.080**	**Pass**	+2060.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**41.8**	**Pass**	+19.50
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**83.8**	**Pass**	+319.22
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	83.8	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**9.4469**	**Pass**	+106.08

Figure 12.54: Regulations (Damage Case 18)

12.0.19 Damage Case 19

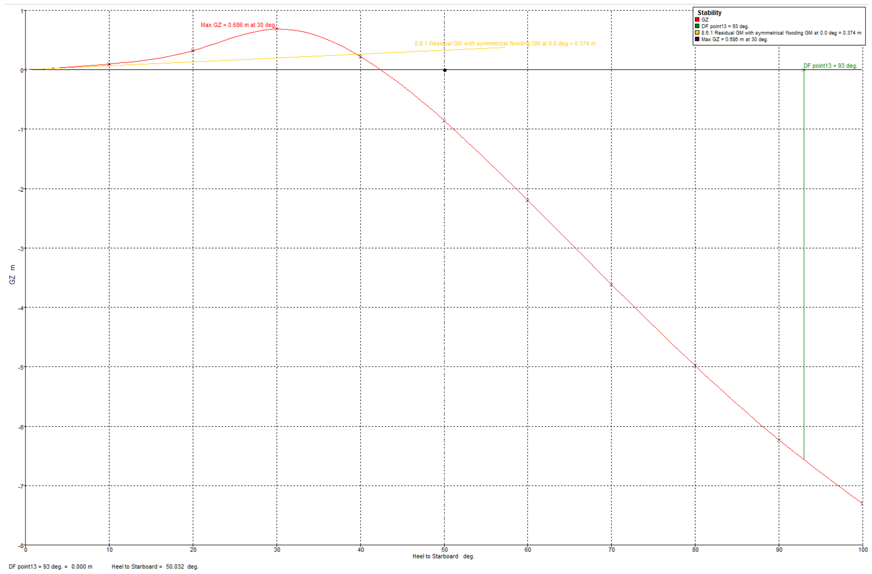

Figure 12.55: Righting Arm Curve (Damage Case 19)

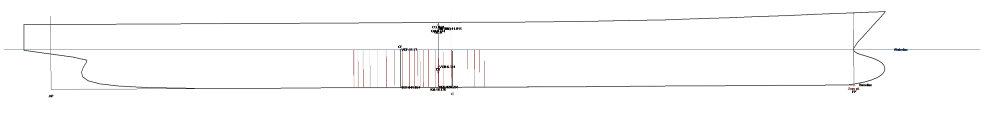

Figure 12.56: Flooding Rendering (Damage Case 19)

Table 12.22: Righting Arm Curve Data (Damage Case 19).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.096	0.323	0.686	0.222	-0.857	-2.196	-3.611	-4.983	-6.231	-7.306
Area under GZ curve	0	0.4515	2.3125	7.6551	12.9312	10.0872	-5.0495	-34.0749	-77.1106	-133.323	-201.105
Displacement (t)	66991	66991	66995	66991	66992	66987	66991	66985	66986	66992	66991
Draft at FP (m)	10.99	11.093	11.149	10.949	10.63	10.33	9.93	9.302	7.722	n/a	-13.117
Draft at AP (m)	12.372	12.048	11.385	10.655	10.266	9.896	9.472	8.742	6.789	n/a	-14.65
WL Length (m)	258.14	258.143	258.157	258.14	258.243	262.037	265.329	266.894	267.728	268.07	267.878
Beam max on WL (m)	40.499	41.123	43.084	39.775	31.279	26.37	23.521	22.194	22.102	21.992	21.586
Wetted Area (m^2)	12495.22	12515.7	12554.2	13177	13489.61	13628.332	13709.65	13760.54	13784.26	13819.85	13662.86
Waterpl. Area (m^2)	7041.831	7118.46	7338.9	6990.6	5958.63	5315.838	4888.51	4649.369	4569.14	4533.74	4527.815
Prismatic coeff. (Cp)	0.533	0.541	0.559	0.589	0.611	0.615	0.615	0.616	0.618	0.62	0.623
Block coeff. (Cb)	0.52	0.427	0.353	0.346	0.407	0.453	0.489	0.517	0.533	0.563	0.535
LCB (m)	-129.293	-129.26	-129.252	-129.2	-129.208	-129.185	-129.211	-129.214	-129.216	-129.201	-129.217
LCF (m)	-141.024	-139.82	-135.241	-127.6	-123.69	-120.219	-118.425	-116.936	-116.137	-114.603	-114.7
Max Deck Incl (°)	0.3169	10.0023	20.0001	30	40	50	60	70	80	90	100
Trim (°)	0.3169	0.2189	0.0542	-0.068	-0.0834	-0.0994	-0.105	-0.1284	-0.2138	-90	-0.3516

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	93.0	deg			
	angle of vanishing stability	42.4	deg	42.4		
	shall not be less than (>=)	**15.0**	**deg**	**42.4**	**Pass**	+182.78
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	93.0	deg			
	angle of vanishing stability	42.4	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.0441**	**Pass**	+254.21
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	93.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.686**	**Pass**	+586.00
	Intermediate values					
	angle at which this GZ occurs		deg	30.0		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.374**	**Pass**	+648.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**42.4**	**Pass**	+21.19
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**93.0**	**Pass**	+364.81
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	30.0	deg	30.0		
	first downflooding angle	93.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**7.6551**	**Pass**	+67.00

Figure 12.57: Regulations (Damage Case 19)

12.0.20 Damage Case 20

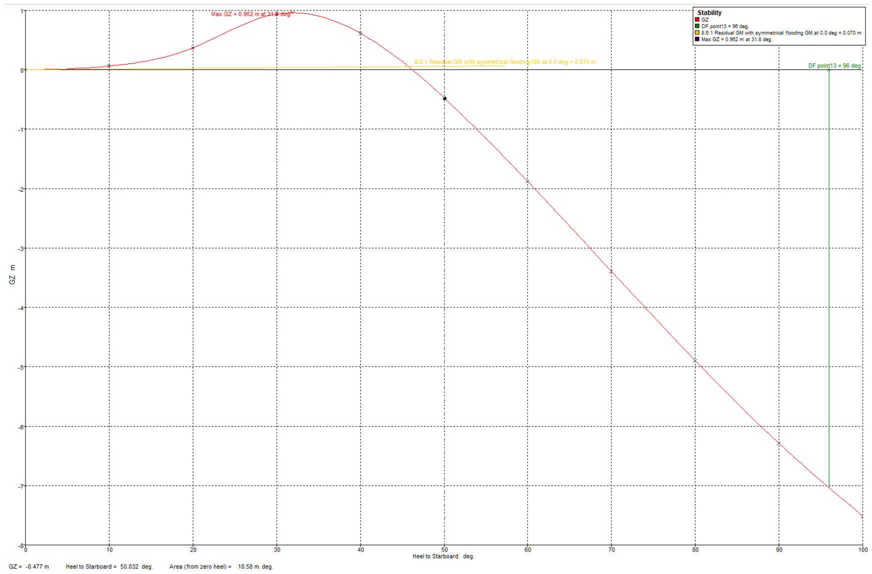

Figure 12.58: Righting Arm Curve (Damage Case 20)

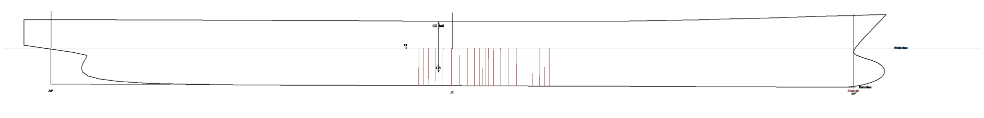

Figure 12.59: Flooding Rendering (Damage Case 20)

Table 12.23: Righting Arm Curve Data (Damage Case 20).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.062	0.372	0.94	0.613	-0.473	-1.877	-3.395	-4.896	-6.291	-7.514
Area under GZ curve	0	0.2227	2.0296	8.8624	17.4799	18.5943	6.9994	-19.3277	-60.8338	-116.906	-186.026
Displacement (t)	66991	66991	66991	66991	66988	66991	66991	66991	66991	66991	66991
Draft at FP (m)	10.201	10.306	10.533	10.447	10.065	9.624	8.976	7.861	4.92	n/a	-15.781
Draft at AP (m)	10.931	10.647	9.862	8.876	7.843	6.603	4.838	1.555	-8.06	n/a	-29.947
WL Length (m)	250.037	255.449	258.304	258.37	259.818	263.741	265.305	266.659	267.753	268.021	267.952
Beam max on WL (m)	40.498	41.122	43.055	40.096	31.313	26.431	23.667	22.524	22.301	21.85	21.25
Wetted Area (m^2)	11654.06	11719	11888.4	12263	12580.37	12709.272	12781.23	12818.26	12882.91	12892.36	12791.74
Waterpl. Area (m^2)	7343.013	7513.42	7922.22	7883.4	6699.606	5896.886	5393.409	5049.236	4881.772	4773.969	4788.08
Prismatic coeff. (Cp)	0.613	0.607	0.621	0.648	0.666	0.667	0.67	0.671	0.672	0.675	0.679
Block coeff. (Cb)	0.602	0.468	0.376	0.363	0.43	0.479	0.521	0.548	0.571	0.598	0.569
LCB (m)	-129.257	-129.24	-129.188	-129.1	-129.134	-129.12	-129.116	-129.117	-129.119	-129.125	-129.137
LCF (m)	-138.062	-138.13	-136.259	-130.5	-125.562	-123.746	-122.065	-119.6	-117.932	-115.901	-116.559
Max Deck Incl (°)	0.1674	10.0003	20.0005	30.002	40.0016	50.0015	60.0011	70.0008	80.0004	90	99.9995
Trim (°)	0.1674	0.0782	-0.1539	-0.36	-0.5097	-0.6926	-0.9491	-1.4459	-2.9742	-90	-3.2454

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	96.0	deg			
	angle of vanishing stability	46.2	deg	46.2		
	shall not be less than (>=)	**15.0**	**deg**	**46.2**	**Pass**	+207.79
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	96.0	deg			
	angle of vanishing stability	46.2	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**2.8951**	**Pass**	+236.87
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.0	deg			
	shall not be less than (>=)	**0.100**	**m**	**0.962**	**Pass**	+862.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.070**	**Pass**	+40.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**46.2**	**Pass**	+31.91
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**96.0**	**Pass**	+380.01
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.0	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**10.5965**	**Pass**	+131.16

Figure 12.60: Regulations (Damage Case 20)

12.0.21 Damage Case 21

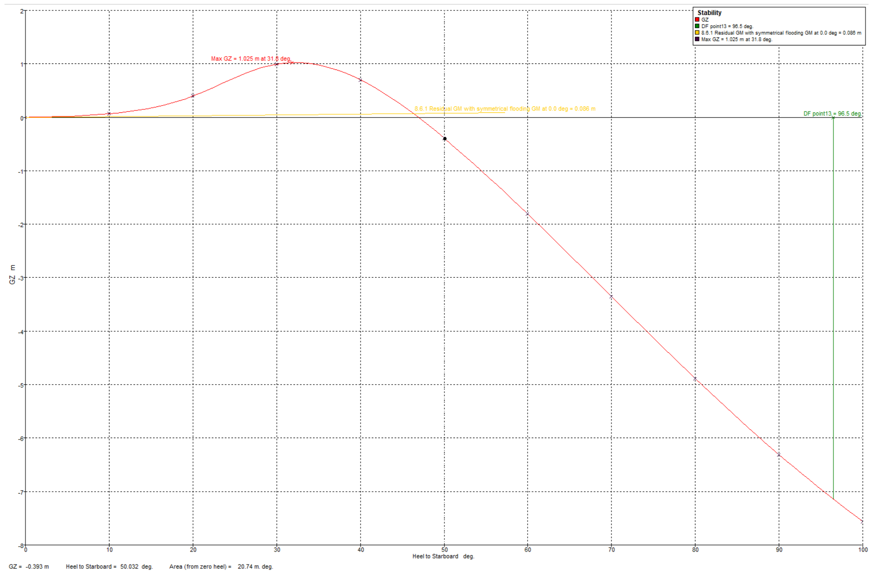

Figure 12.61: Righting Arm Curve (Damage Case 21)

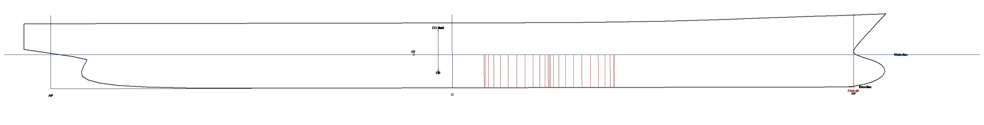

Figure 12.62: Flooding Rendering (Damage Case 21)

Table 12.24: Righting Arm Curve Data (Damage Case 21).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.066	0.398	0.997	0.698	-0.389	-1.809	-3.352	-4.882	-6.311	-7.565
Area under GZ curve	0	0.233	2.1782	9.4223	18.7706	20.7558	9.9333	-15.8294	-57.048	-113.15	-182.629
Displacement (t)	66985	66991	66991	66992	66991	66997	66991	66991	66991	66991	66991
Draft at FP (m)	10.071	10.168	10.415	10.368	9.98	9.509	8.818	7.639	4.488	n/a	-16.163
Draft at AP (m)	10.577	10.314	9.534	8.493	7.32	5.899	3.837	-0.05	-11.378	n/a	-33.389
WL Length (m)	247.764	251.958	258.413	258.46	260.324	263.879	265.401	266.709	267.831	268.02	267.965
Beam max on WL (m)	40.498	41.122	43.04	40.122	31.323	26.443	23.7	22.572	22.315	21.818	21.192
Wetted Area (m^2)	11430.04	11523	11738.5	12071	12399.67	12515.21	12591.95	12641.12	12688.55	12709.37	12613.59
Waterpl. Area (m^2)	7385.373	7585.11	8036.59	8074.9	6853.811	6021.352	5487.343	5135.14	4941.01	4840.944	4853.978
Prismatic coeff. (Cp)	0.635	0.631	0.634	0.661	0.677	0.679	0.682	0.683	0.684	0.688	0.692
Block coeff. (Cb)	0.624	0.484	0.382	0.367	0.434	0.485	0.528	0.556	0.581	0.604	0.575
LCB (m)	-129.224	-129.23	-129.178	-129.1	-129.116	-129.098	-129.093	-129.091	-129.095	-129.1	-129.115
LCF (m)	-136.904	-137.37	-136.094	-131.2	-126.169	-124.493	-122.536	-120.201	-118.154	-116.496	-117.153
Max Deck Incl (°)	0.116	10.0001	20.0009	30.002	40.0023	50.0021	60.0016	70.0012	80.0006	90	99.9993
Trim (°)	0.116	0.0334	-0.2021	-0.43	-0.6101	-0.8278	-1.1422	-1.7629	-3.6338	-90	-3.9443

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	96.5	deg			
	angle of vanishing stability	46.9	deg	46.9		
	shall not be less than (>=)	**15.0**	**deg**	**46.9**	**Pass**	+212.71
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	96.5	deg			
	angle of vanishing stability	46.9	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.1015**	**Pass**	+260.90
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.5	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.025**	**Pass**	+925.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.086**	**Pass**	+72.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**46.9**	**Pass**	+34.02
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**96.5**	**Pass**	+382.33
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	96.5	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.2659**	**Pass**	+145.77

Figure 12.63: Regulations (Damage Case 21)

12.0.22 Damage Case 22

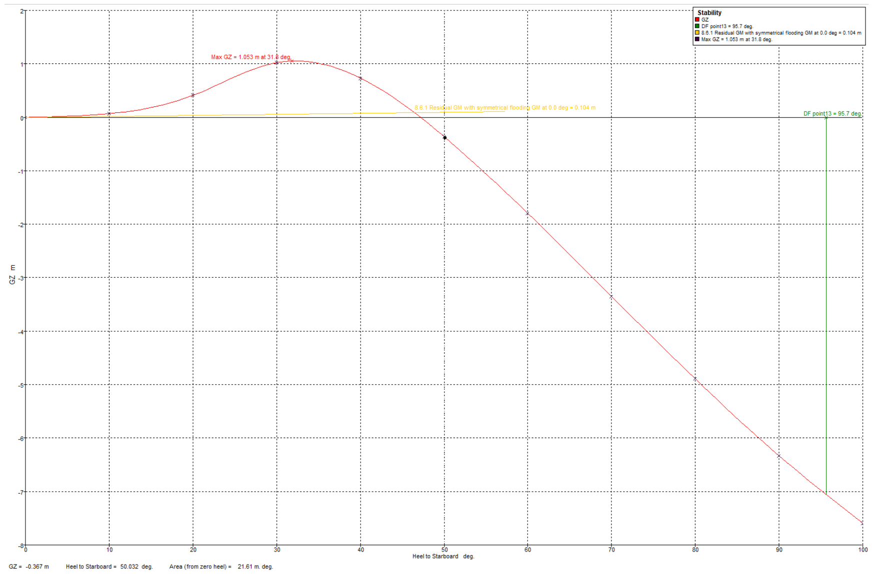

Figure 12.64: Righting Arm Curve (Damage Case 22)

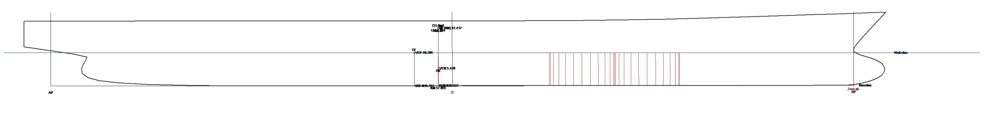

Figure 12.65: Flooding Rendering (Damage Case 22)

Table 12.25: Righting Arm Curve Data (Damage Case 22).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.069	0.41	1.023	0.731	-0.363	-1.793	-3.348	-4.89	-6.33	-7.594
Area under GZ curve	0	0.2453	2.2575	9.689	19.3369	21.6204	11.0097	-14.6517	-55.8883	-112.123	-181.841
Displacement (t)	66991	66990	66991	66992	66991	66991	66991	66991	66991	66991	66991
Draft at FP (m)	10.177	10.28	10.538	10.518	10.158	9.727	9.104	8.063	5.33	n/a	-15.265
Draft at AP (m)	10.376	10.113	9.339	8.277	7.044	5.54	3.342	-0.825	-12.985	n/a	-35.051
WL Length (m)	246.188	249.809	258.301	258.33	259.248	263.535	265.194	266.726	267.701	268.052	267.943
Beam max on WL (m)	40.498	41.122	43.035	40.129	31.322	26.441	23.688	22.526	22.29	21.865	21.254
Wetted Area (m^2)	11354.64	11542.8	11714.5	12054	12362.45	12488.438	12562.22	12619.4	12643.28	12690.07	12583.92
Waterpl. Area (m^2)	7361.559	7614.81	8042.07	8103.8	6861.99	6027.296	5483.357	5137.008	4921.525	4850.149	4860.968
Prismatic coeff. (Cp)	0.643	0.641	0.637	0.663	0.682	0.682	0.684	0.686	0.687	0.69	0.694
Block coeff. (Cb)	0.635	0.49	0.383	0.367	0.437	0.487	0.53	0.559	0.584	0.601	0.572
LCB (m)	-129.227	-129.22	-129.163	-129.1	-129.098	-129.079	-129.072	-129.07	-129.074	-129.081	-129.099
LCF (m)	-136.717	-137.93	-136.271	-131.8	-127.286	-125.282	-123.13	-120.786	-118.112	-116.798	-117.421
Max Deck Incl (°)	0.0457	10.0001	20.0016	30.003	40.0031	50.0028	60.0022	70.0015	80.0008	90	99.999
Trim (°)	0.0457	-0.0383	-0.275	-0.514	-0.7141	-0.9601	-1.3213	-2.0375	-4.1929	-90	-4.5282

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	95.7	deg			
	angle of vanishing stability	47.1	deg	47.1		
	shall not be less than (>=)	**15.0**	**deg**	**47.1**	Pass	+214.31
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	95.7	deg			
	angle of vanishing stability	47.1	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.2068**	Pass	+273.14
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	95.7	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.053**	Pass	+953.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.104**	Pass	+108.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	Pass	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**47.1**	Pass	+34.71
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**95.7**	Pass	+378.25
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	95.7	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.5814**	Pass	+152.65

Figure 12.66: Regulations (Damage Case 22)

12.0.23 Damage Case 23

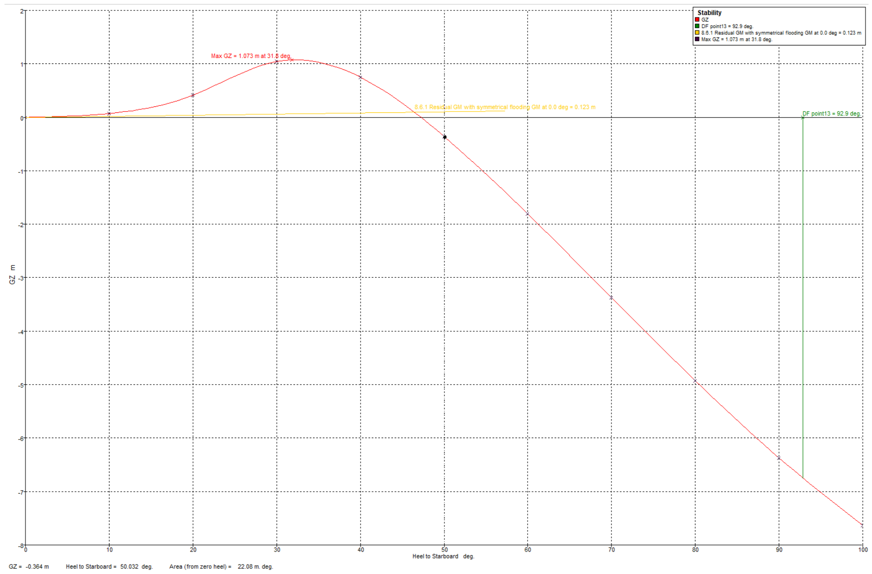

Figure 12.67: Righting Arm Curve (Damage Case 23)

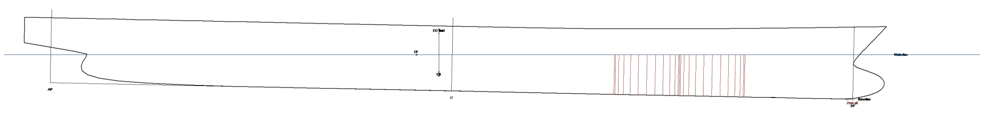

Figure 12.68: Flooding Rendering (Damage Case 23)

Table 12.26: Righting Arm Curve Data (Damage Case 23).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.071	0.417	1.042	0.747	-0.36	-1.805	-3.372	-4.925	-6.369	-7.638
Area under GZ curve	0	0.2575	2.3095	9.8734	19.7109	22.0952	11.4374	-14.4103	-55.949	-112.559	-182.695
Displacement (t)	66996	66990	66991	66991	66991	66991	66995	66991	66991	66991	66991
Draft at FP (m)	10.588	10.698	10.975	11.008	10.781	10.497	10.118	9.544	8.224	n/a	-12.244
Draft at AP (m)	10.091	9.829	9.058	7.972	6.666	5.074	2.721	-1.755	-14.872	n/a	-37.019
WL Length (m)	243.893	246.742	258.151	258.18	258.186	262.401	265.589	267.048	267.801	268.15	267.867
Beam max on WL (m)	40.498	41.122	43.036	40.13	31.313	26.424	23.621	22.33	22.127	21.985	21.51
Wetted Area (m^2)	11335.33	11556.1	11755.3	12154	12456.37	12586.53	12646.35	12714.08	12723.42	12791.78	12650.18
Waterpl. Area (m^2)	7259.401	7523.32	7951.24	8005	6714.407	5932.989	5382.383	5055.903	4839.416	4804.404	4810.814
Prismatic coeff. (Cp)	0.648	0.646	0.632	0.655	0.676	0.678	0.677	0.679	0.682	0.685	0.689
Block coeff. (Cb)	0.626	0.495	0.381	0.366	0.437	0.487	0.528	0.56	0.585	0.588	0.556
LCB (m)	-129.218	-129.19	-129.13	-129.1	-129.071	-129.038	-129.03	-129.03	-129.036	-129.047	-129.071
LCF (m)	-136.954	-138.34	-136.823	-133.1	-130.31	-127.213	-124.711	-122.391	-118.946	-117.493	-118.083
Max Deck Incl (°)	0.1139	10.0019	20.0041	30.006	40.0054	50.0047	60.0036	70.0025	80.0013	90	99.9985
Trim (°)	-0.1139	-0.1991	-0.4396	-0.696	-0.9437	-1.2436	-1.6959	-2.5895	-5.2819	-90	-5.6636

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	92.9	deg			
	angle of vanishing stability	47.2	deg	47.2		
	shall not be less than (>=)	**15.0**	**deg**	**47.2**	**Pass**	+214.71
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				**Pass**	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	92.9	deg			
	angle of vanishing stability	47.2	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.2750**	**Pass**	+281.08
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				**Pass**	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	92.9	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.073**	**Pass**	+973.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				**Pass**	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.123**	**Pass**	+146.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				**Pass**	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				**Pass**	
	shall not be less than (>=)	**35.0**	**deg**	**47.2**	**Pass**	+34.88
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				**Pass**	
	shall not be less than (>=)	**20.0**	**deg**	**92.9**	**Pass**	+364.41
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				**Pass**	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	92.9	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.8011**	**Pass**	+157.44

Figure 12.69: Regulations (Damage Case 23)

12.0.24 Damage Case 24

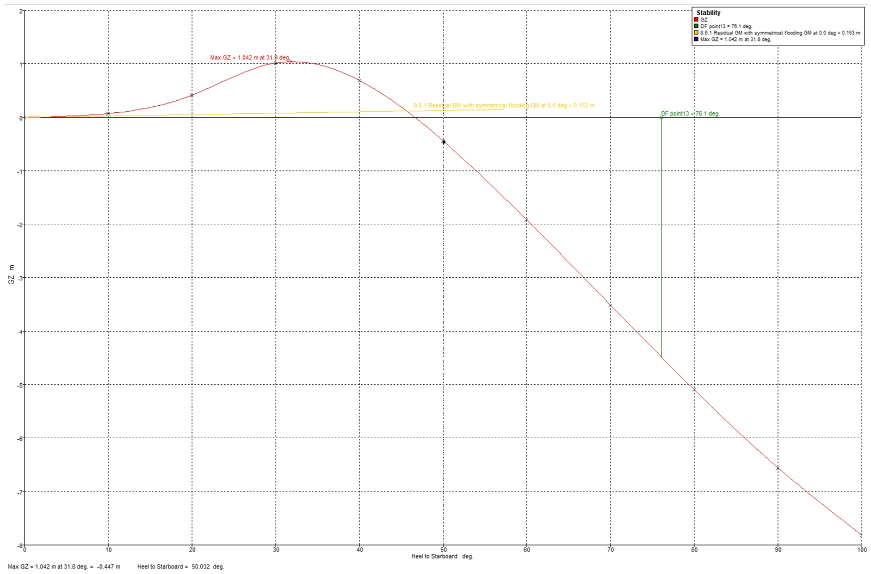

Figure 12.70: Righting Arm Curve (Damage Case 24)

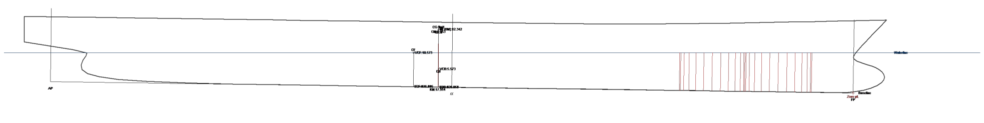

Figure 12.71: Flooding Rendering (Damage Case 24)

Table 12.27: Righting Arm Curve Data (Damage Case 24).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.07	0.415	1.018	0.684	-0.442	-1.917	-3.51	-5.095	-6.555	-7.814
Area under GZ curve	0	0.2495	2.2957	9.7508	19.1496	20.8034	9.1723	-17.9274	-61.0078	-119.42	-191.376
Displacement (t)	66991	66991	66991	66991	66991	66997	66996	66991	66991	66991	66988
Draft at FP (m)	12.491	12.573	12.853	13.211	13.806	14.492	15.609	17.697	25.232	n/a	4.394
Draft at AP (m)	8.99	8.781	8.055	6.845	5.191	3.177	0.104	-5.676	-23.259	n/a	-45.307
WL Length (m)	239.757	239.381	259.167	259.51	262.13	266.094	267.621	268.049	268.177	267.843	266.936
Beam max on WL (m)	40.498	41.122	43.051	40.117	31.292	26.338	23.422	21.805	21.137	21.429	22.341
Wetted Area (m^2)	11476.52	11575.2	12026.6	12618	13120.06	13279.841	13385.59	13409.5	13163.92	13145.5	13137.91
Waterpl. Area (m^2)	6917.19	7063.64	7619.78	7519.5	6357.872	5438.947	4835.947	4457.315	4260.31	4239.574	4286.225
Prismatic coeff. (Cp)	0.632	0.635	0.593	0.608	0.62	0.624	0.63	0.636	0.64	0.645	0.65
Block coeff. (Cb)	0.545	0.49	0.367	0.353	0.415	0.463	0.507	0.547	0.582	0.542	0.486
LCB (m)	-129.058	-129.04	-128.998	-128.9	-128.889	-128.876	-128.849	-128.839	-128.85	-128.873	-128.915
LCF (m)	-136.885	-136.9	-138.305	-138.4	-137.061	-136.88	-136.374	-134.026	-132.435	-130.555	-129.073
Max Deck Incl (°)	0.803	10.0362	20.0256	30.024	40.0238	50.0204	60.0159	70.0107	80.0057	90	99.994
Trim (°)	-0.803	-0.8696	-1.1002	-1.46	-1.975	-2.5931	-3.5514	-5.3449	-10.9845	-90	-11.2517

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	76.1	deg			
	angle of vanishing stability	46.6	deg	46.6		
	shall not be less than (>=)	**15.0**	**deg**	**46.6**	**Pass**	+210.55
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	76.1	deg			
	angle of vanishing stability	46.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**3.2553**	**Pass**	+278.79
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	angle of equilibrium	0.0	deg			
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	76.1	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.042**	**Pass**	+942.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.153**	**Pass**	+206.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**46.6**	**Pass**	+33.09
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**76.1**	**Pass**	+280.39
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	76.1	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**11.6281**	**Pass**	+153.67

Figure 12.72: Regulations (Damage Case 24)

12.0.25 Damage Case 25

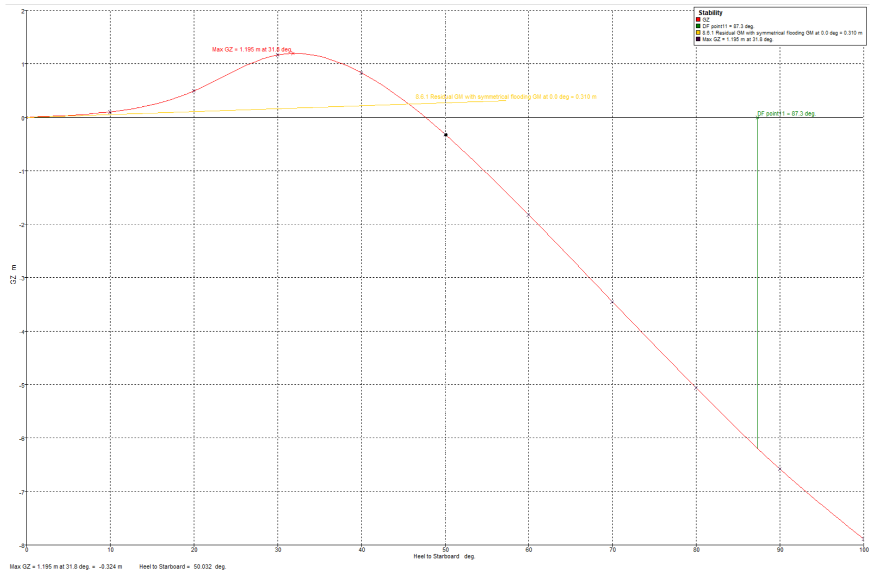

Figure 12.73: Righting Arm Curve (Damage Case 25)

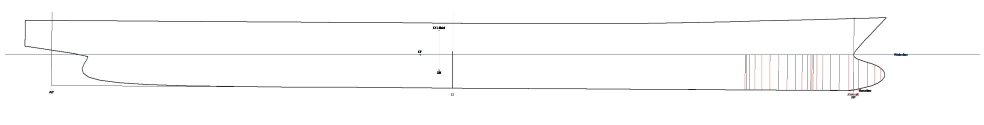

Figure 12.74: Flooding Rendering (Damage Case 25)

Table 12.28: Righting Arm Curve Data (Damage Case 25).

Heel (°)	0	10	20	30	40	50	60	70	80	90	100
GZ m	0	0.102	0.494	1.166	0.829	-0.32	-1.823	-3.448	-5.062	-6.579	-7.891
Area under GZ curve	0	0.4071	2.9794	11.597	22.5112	25.504	14.9686	-11.3533	-53.9441	-112.295	-184.764
Displacement (t)	66991	66991	66991	66990	66991	66991	66991	66991	66991	66991	66991
Draft at FP (m)	11.174	11.247	11.496	11.626	12.101	12.556	13.379	14.907	19.416	n/a	1.269
Draft at AP (m)	9.551	9.33	8.58	7.424	5.693	3.641	0.497	-5.418	-22.65	n/a	-46.18
WL Length (m)	241.198	242.397	258.254	258.33	258.682	264.459	266.848	267.845	268.219	267.93	267.222
Beam max on WL (m)	40.498	41.122	43.031	40.141	31.3	26.38	23.503	21.9	21.415	21.61	22.373
Wetted Area (m^2)	11267.76	11512.3	11758.7	12209	12595.11	12905.163	13021.43	13078.16	13154.88	12926.66	12937.47
Waterpl. Area (m^2)	7246.247	7530.03	7964.06	7865.2	6462.814	5630.504	4990.217	4585.27	4375.171	4287.103	4296.066
Prismatic coeff. (Cp)	0.654	0.656	0.629	0.647	0.66	0.654	0.654	0.656	0.659	0.659	0.663
Block coeff. (Cb)	0.602	0.502	0.38	0.365	0.433	0.478	0.52	0.559	0.591	0.551	0.495
LCB (m)	-129.143	-129.13	-129.084	-129.1	-128.972	-128.945	-128.909	-128.867	-128.875	-128.906	-128.921
LCF (m)	-134.952	-136.83	-136.375	-136	-137.325	-135.118	-135.093	-133.128	-131.775	-131.76	-131.378
Max Deck Incl (°)	0.3721	10.0093	20.0095	30.011	40.0132	50.0126	60.011	70.0081	80.0043	90	99.9945
Trim (°)	-0.3721	-0.4397	-0.6686	-0.964	-1.4694	-2.0435	-2.9517	-4.6511	-9.5579	-90	-10.7538

Code	Criteria	Value	Units	Actual	Status	Margin %
SOLAS, II-1	**8.2.3.1: Range of residual positive stability**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	87.3	deg			
	angle of vanishing stability	47.6	deg	47.6		
	shall not be less than (>=)	**15.0**	**deg**	**47.6**	**Pass**	+217.39
SOLAS, II-1	**8.2.3.2: Area under residual GZ curve**				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	22.0	deg	22.0		
	first downflooding angle	87.3	deg			
	angle of vanishing stability	47.6	deg			
	shall not be less than (>=)	**0.8594**	**m.deg**	**4.1117**	**Pass**	+378.43
SOLAS, II-1	**8.2.3.3: Maximum residual GZ (method 2)**				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	87.3	deg			
	shall not be less than (>=)	**0.100**	**m**	**1.195**	**Pass**	+1095.00
	Intermediate values					
	angle at which this GZ occurs		deg	31.8		
SOLAS, II-1	**8.6.1 Residual GM with symmetrical flooding**				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	**0.050**	**m**	**0.310**	**Pass**	+520.00
SOLAS, II-1	**8.6.2: Heel angle at equilibrium for unsymmetrical flooding - GZ ba**				Pass	
	shall be less than (<)	**10.0**	**deg**	**0.0**	**Pass**	+100.00
Part 170, St	**170.173: e1(i) - Angle of vanishing stability**				Pass	
	shall not be less than (>=)	**35.0**	**deg**	**47.6**	**Pass**	+36.03
Part 170, St	**170.173: e1(ii) - Angle of downflooding**				Pass	
	shall not be less than (>=)	**20.0**	**deg**	**87.3**	**Pass**	+336.63
Part 170, St	**170.173: e1(iii) - Area 0 to 40, df or GZmax**				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg			
	angle of max. GZ	31.8	deg	31.8		
	first downflooding angle	87.3	deg			
	shall be greater than (>)	**4.5840**	**m.deg**	**13.7490**	**Pass**	+199.93

Figure 12.75: Regulations (Damage Case 25)

13. Estimated Cost

The cost of the *SS Steel Ducky* is estimated to be \$195.68 million dollars to build. The cost analysis was performed using University of Michigan's cost analysis spread sheet. The cost of steel was assumed to be \$1,000 per ton; the overhead rate 80%; the profit rate 6%; the labor rate was what it would cost to build in America set at \$28 per hour; the appended shipyard costs are assumed to be \$ 1 Million; and lastly the owners added costs was set to \$1.2 Million.

One aspect for further work is making the oversized deck house smaller, this will decrease the cost of the outfitting and the tons of steel required but by a small margin of not even over \$1 Million. Beyond this, the ships principal particulars specifically length, could be altered, as in the final design the aft mooring deck was not used to store containers. If the ships length overall was decreased by 5 meters, which would be completely feasible given the current container positions, the cost of the ship would decrease by \$3 million. However, in future design iterations, the effects this will have on stability and trim must be considered. Overall, because of the short length and low speed which causes the machinery weight to be much lower, the ship has a very good build cost compared to ships built to similar requirements. Another principle dimension to consider is block coefficient. The block coefficient of 0.661 is low compared to similar ships, this increases construction costs but decreases operational costs.

While the ships current design is cost effective there are small adjustments that can be made in future iterations to make the cost lower without drastically effecting the performance or safetey of the ship, this will be up to the owner.

The next page shows the cost analysis spreadsheet.

SHIPBUILDING COST ESTIMATE - BASED UPON CARREYETTE (R11)

ECONOMIC PARAMETERS

	parameters	
Profit	6.0%	per cent (enter as decimal)
Direct Labor Rate (Bur. Labor Stat.)	$28.00	$ wages plus add'l compensation/hour
Overhead Rate	80.0%	per cent direct labor (enter as decimal)
Steel Cost	$1,000.00	$ per tonne
Wastage and Welding Rod	10.6%	per cent steel (calculated by algorithm)
	change if desired	

SHIP CHARACTERISTICS

	enter data in boxes			
LBP	250.00	meters		
Cb	0.661			
Structural Steel Weight	16,325.0	tonnes		
Outfit Weight	4,050.0	tonnes		
Installed Propulsion Power	27,692.0	kW		
Number of Propellers	1	[enter 1 or 2]		
Propeller RPM	79.0	RPM		
Fixed Pitch (0) or CRP (1)	0	[enter 0 or 1]		
Bow and/or Stern Thruster No.	0	with thrust	5.0	tonnes each
Vessel Displacement	71,408.0	tonnes		
Fin Stabilizers: no (0); yes (1)	0	[enter 0 or 1]		

COST CATEGORY	Material Cost	Labor hours	Labor Cost
	Million $US	hours	Million $US
Structural	18.05	1,104,113	30.92
Outfit and Hull Engineering	38.50	413,502	11.58
Machinery	30.92	368,283	10.31

	Million $US
Total Labor Cost	52.81
Total Material Cost	87.48
Overhead	42.24
Add on for CRP Propeller(s), if installed	0.00
Add on for Thruster(s), if installed	0.00
Add on for Anti-Roll Fin Stabilizers, if installed	0.00
Profit	10.95
Appended Shipyard Costs	1.00
TOTAL SHIPYARD BILL	194.48
Owner's Added Costs	1.20
TOTAL SHIP CAPITAL COST	**195.68 Million US$**

Figure 13.1: Cost Analysis Spreadsheet

14. Conclusion

The *SS Steel Ducky* was designed to in accordance to the owners requirements to transport 3500 TEU's from Shanghai, China to Los Angeles, USA at a design speed of 20 knots. The *SS Steel Ducky* was required to meet two loading conditions: 14 ton and 12 ton homogeneously loaded containers. During the design process low cost and meeting regulations were prioritized, and in terms of this preliminary design these goals were met well with the exception of the heavier load cases.

The *SS Steel Ducky* is an incredibly promising design as it is able to meet all the owners requirements while still operating at a low cost and does not have a high build cost. The container placement allows for much adjustment to be done in future work which will lower the costs even more and allow the ship to pass all of the safety requirements put forth by the vast majority of international and American ship building regulation bodies. One of the strengths of the design is the low weight engine that also allows the operating crew to travel at higher speeds in order to ameliorate the effect of delays. Furthermore, with the large propeller diameter the ship can reach its design speed in a very efficient manner.

Overall the strength of the design is mainly due to its low operational cost which is mostly because of the low power required to move the ship. Because of the container layout, with a slight adjustment to the principle dimensions, the *SS Steel Ducky* can exceed expectations in terms of operational and build costs while still being able to safely transport crew and cargo from Los Angeles to Shanghai and back.

While the *SS Steel Ducky* is a promising design, future work must be done to ensure that it will be an optimal design. The ships hull and container placement was not iterated enough times to ensure that all the safety requirements were met. Furthermore, a more detailed analysis must be done on the structural requirements of the ship and the hull vibrations of the ship to ensure that the *SS Steel Ducky* will perform to the necessary regulatory body standards. The deckhouse design needs to be completed, but it has been found that the current design of the deckhouse will exceed the standards of living at sea for the crew. Lastly, In order for the ship to be fully ready for the build phase a more in depth analysis will have to be done in order to study the lifecycle of the ship.

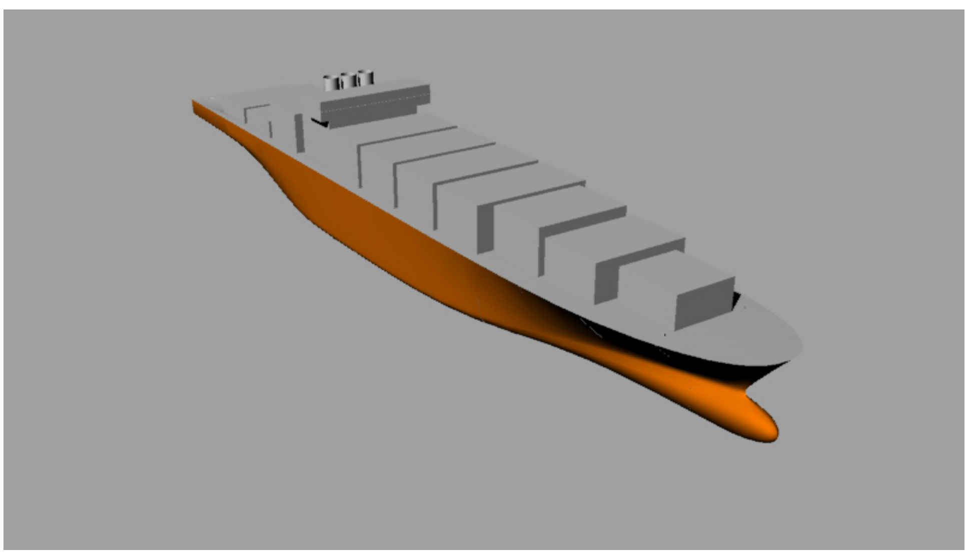

Figure 14.1: Rendering of the *SS Steel Ducky*

15. References

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