SAMUEL K WATERHOUSE
STATE OF WASHINGTON
55707
REGISTERED
PROFESSIONAL ENGINEER
7/30/2018

Double-Ended Azimuth Drive Ferry

Scantling Calculations

Prepared for: North Carolina DOT • Raleigh, NC

Ref: 18026-200-061-1 Rev. - July 26, 2018

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REVISIONS

REV	DESCRIPTION	DATE	APPROVED
-	Initial Issue	07/26/18	SKW

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1 PURPOSE

This report details the structural scantling calculations performed for the design of the New River Class Ferry for the North Carolina Department of Transportation. The subject vessel is a new design for a 183 feet 7 inch length by 46 feet beam by 11 feet depth passenger and vehicle ferry vessel intended for service within the Outer Banks of North Carolina and the associated rivers. The subject vessel is designed to carry a maximum of 40 cars and 300 passengers, and will be regulated under Subchapter H of Title 46 of the U.S. Code of Federal Regulations (CFR) [1].

The structural scantlings of the vessel are generally sized according to the American Bureau of Shipping Rules for Building and Classing Steel Vessels Under 90 Meters (295 Feet) in Length [2] which gives methods for calculating requirements for structural members throughout the vessel, as well as global hull girder longitudinal strength requirements.

2 PROCEDURE

2.1 Longitudinal Strength

Scantling calculations were performed based on Reference [1]. The calculations were performed to determine if the scantlings shown in Reference [2] are suitable for general service. A summary of the calculations is presented in Appendix A. Complete ABS scantling calculations are shown in Appendix B.

2.2 Scantling Requirements

Calculations are preformed to determine the required scantlings for all general structure throughout the vessel. Measurements are taken from the structural drawings or from the vessel structural model [3]. Scantling requirements are calculated based on common groups of members. The worst-case spans, heads, and breadths from within each group are used to determine the requirements for all similar members.

2.3 Member Selection

Structural members are sized to meet the calculated section modulus requirements, as well as depth and thickness requirements for primary structural members. The effective width of attached plating is included in the section calculations based on the guidelines given in Part 3, Chapter 1, Section 2 of Reference [2].

2.4 Equivalent Sections

Where the required depth of major structural members would impact vessel arrangements or machinery, a method is used to find a shorter member with an equivalent strength. These calculations are detailed in Appendix C.

2.4.1 Equivalent Moment of Inertia

For these members, a section is first calculated which meets all of the minimum depth, thickness, and section modulus requirements. Then a new section is calculated with a total moment of inertia which matches or exceeds the moment of inertia of the previously calculated minimum section.

2.4.2 Equivalent Shear Area

For these members, a section is first calculated which meets the minimum depth and thickness. The shear area is then calculated including a maximum-depth cutout. The remaining sectional area of the proposed section is then checked against this "maximum" shear area.

3 ASSUMPTIONS

- The vessel is assumed to be constructed of ABS Grade A or ASTM A36 steel.
- The vessel is longitudinally framed. Web frames support the longitudinal stiffeners at 8ft spacings. Intermediate frames are installed between each web frame starting at Frame 14 on the A end and 18 on the B end. All web frames are sized for 8ft spacing.
- The bilge radius will be supported by cut plate brackets on ordinary frames.
- The depth of slotted members is sufficient to preclude requiring a collar or clip on the
- Ordinary frame spacing is 24 inches. The Main Deck utilizes deck beams at 12 inch centers for wheel loading.

4 LONGITUDINAL STRENGTH

Longitudinal strength was assessed following ABS methodology.

5 CONCLUSIONS

The scantling sizes shown in the Scantling Summary and Midship Section meet the ABS requirements detailed in Reference [1].

6 REFERENCES

[1] *Rules for Building and Classing Steel Vessels Under 90m,* American Bureau of Shipping, 2017.

[2] Contract Design Structural Drawings, Elliott Bay Design Group, June, 2018.

[3] General Structural Model, 18026-200-061-G-.3dm, Elliott Bay Design Group, July, 2018.

Appendix A

Scantling Calculations Summary

SCANTLING SUMMARY

ABS Rules for Building and Classing Steel Vessels Under 90 Meters (295 feet) in Length

PLATING

Member	*Member Dimensions*	*t_{req} (in)*	*t_{req} (in)*		*$t_{offered}$ (in)*	
Hull Plating						
Keel Plate	per client requirement (3/4)	0.317	0.358		**0.750**	PASS
Bottom Shell		0.321	0.365		**0.375**	PASS
Skeg Shell Plating		0.317			**0.375**	PASS
Side Shell - Amidship		0.306			**0.313**	PASS
Side Shell - At Ends		0.310			**0.313**	PASS
Guard Plate	per client requirement (3/4)	0.382			**0.750**	PASS
Deck Plating						
Main Deck CL (truck)	per client requirement (1/2)	0.238	0.302		**0.500**	PASS
Main Deck OCL (car)		0.200	0.128		**0.313**	PASS
Tank Tops (Main Deck car)		0.238			**0.313**	PASS
01 Deck		0.220	0.202		**0.250**	PASS
Bridge Deck		0.220			**0.250**	PASS
House Top		0.202			**0.188**	PASS
Superstructure Plating						
Superstructure Sides, Bulwarks		0.306			**0.313**	PASS
Mn-01 Deck Ends		0.131			**0.250**	PASS
Mn-01 Deck Side, Ends		0.131	0.306		**0.313**	PASS
Mn-01 Dk Side, Window		0.131	0.306		**0.313**	PASS
Mn-01 Deck Egen Inbd		0.131			**0.250**	PASS
Mn-01 Deck Inboard Side		0.131			**0.250**	PASS
01-Bridge Deck Ends		0.089			**0.250**	PASS
01-Bridge Deck Side		0.131			**0.250**	PASS
Pilot House Ends		0.089			**0.188**	PASS
Pilot House Side		0.131			**0.188**	PASS
Bulkhead Plating		3-2-7	3-2-7	3-2-8		
Collision Bulkhead		0.240	0.229		**0.250**	PASS
Transverse WT BHDs		0.240	0.208		**0.250**	PASS
Ballast Tank BHDs		0.240	0.208	0.281	**0.313**	PASS
Potable/FO Tank Plating		0.240	0.238		**0.250**	PASS

STIFFENERS

Member	Member Dimensions	SM_{req} (in^3)	$SM_{offered}$ (in^3)	
Hull Stiffeners				
Keel Plate Longitudinals	5 x 3.5 x 0.25 L	5.51	**6.64**	PASS
Bottom Longitudinals	5 x 3.5 x 0.25 L	5.61	**6.10**	PASS
Bottom Longitudinals - Tonnage	5x0.25 FB	1.50	**2.19**	PASS
Bottom Longitudinals - Ballast Tk	3 x 2 x 0.25 L	1.79	**2.13**	PASS
Bow End Framing (Max s, l)	4 x 3 x 0.25 L	1.10	**4.10**	PASS
Side Stiffeners				
Side Shell Long'l Stiffeners	4 x 3 x 0.25 L	3.12	**4.03**	PASS
Side Shell Stiffeners - Tonnage	4x0.25 FB	0.78	**1.41**	PASS
Deck Stiffeners	**"Failing" members are evaluated in "Alternate Wheel Loading Calc"*			
Main Deck Stiffs	140x8 Bulb Flat	5.46	**5.26**	FAIL
Main Deck Stiffs - in tanks	140x8 Bulb Flat	1.57	**4.94**	PASS
01 Deck Stiffs	3 x 2 x 0.1875 L	1.57	**1.59**	PASS
Bridge Deck Stiffs	3 x 2 x 0.1875 L	0.98	**1.59**	PASS
House Top Stiffs	3x0.1875 FB	0.12	**0.58**	PASS
Superstructure Stiffeners				
Mn-01 Deck Ends	4 x 3 x 0.25 L	3.90	**3.95**	PASS
Mn-01 Deck Side, Ends	4 x 3 x 0.25 L	3.96	**4.03**	PASS
Mn-01 Dk Side, Window	3x0.1875 FB	0.37	**0.63**	PASS
Mn-01 Dk Side, Mullions	WT6x15#	15.61	**16.05**	PASS
Mn-01 Dk Side, Headers	6 x 3 x 0.1875 Flg PL	4.83	**5.27**	PASS
Mn-01 Deck Egen Inbd	4 x 3 x 0.25 L	3.12	**3.95**	PASS
Mn-01 Deck Inboard Side	3 x 3 x 0.25 L	2.64	**2.73**	PASS
01-Bridge Deck Ends	3 x 2 x 0.1875 L	1.17	**1.59**	PASS
01-Bridge Deck Side	3 x 2 x 0.1875 L	1.34	**1.59**	PASS
Pilot House Ends	3 x 2 x 0.1875 L	0.99	**1.57**	PASS
Pilot House Side	3 x 2 x 0.1875 L	1.13	**1.57**	PASS
Pilot House Mullion	3 x 3 x 0.25 Square Tube	2.52	**2.64**	PASS
Bulkhead Stiffeners				
Watertight BHD 16/28 - CL Vertical	4 x 3 x 0.25 L	3.79	**3.95**	PASS
WT Door Mullion - CL Vertical	4 x 3 x 0.25 L	3.27	**3.95**	PASS
Watertight BHD 16/8 - OB Vertical	4 x 3 x 0.25 L	3.37	**3.95**	PASS
Watertight BHD 16/8 Sniped	4 x 3 x 0.25 L	2.77	**3.95**	PASS
Ballast Tank BHDs - Vertical	4 x 3 x 0.25 L	2.93	**4.03**	PASS
Ballast Tank BHDs - Sniped	4 x 3 x 0.25 L	3.47	**4.03**	PASS
Collision BHD 40 - Vertical	5x0.25 FB	2.07	**2.09**	PASS
Collision BHD 40 - Vertical	4 x 3 x 0.25 L	2.07	**3.95**	PASS

GIRDERS

Member	Member Dimensions	SM_{req} (in^3)	d_web (in)	t_web (in)	$SM_{offered}$ (in^3)	
Center Girder		(t_web	t_off	A_top	A_off)	
CVK	14.625 x 0.5 web 9 x 1 flg	0.33	0.50	8.74	**9.00**	PASS
Hull Girders	**"Failing" members are designed to meet equivalent moment of inertia*					
Bottom Girders (5' OCL)	14x3x0.3125 FP	21.43	14.00	0.26	**30.33**	PASS
Bottom Girders (12' OCL)	14x3x0.3125 FP	19.47	14.00	0.26	**30.33**	PASS
Bottom Trsv. Web (CL@Fr 0,4,8,12,24)	14.625 x 0.3125 web 6 x 0.375 flg	31.51	17.50	0.30	**52.41**	FAIL
Bottom Trsv. Web (5'-12' OCL)	14x3x0.3125 FP	15.02	12.25	0.24	**30.06**	PASS
Bottom Trsv. Web (O/B)	14x3x0.3125 FP	19.65	14.33	0.26	**30.38**	FAIL
Bottom Trsv. Half Frames (5'-12' OCL)	10.05x3x0.3125 FP	5.15	12.25	0.24	**18.14**	FAIL
Bottom Trsv. Half Frames (OB)	14x3x0.25 FP	5.88	12.25	0.24	**24.65**	PASS
Side Web Frames, Amidships	12x3x0.25 FP	7.29	10.50	0.23	**19.16**	PASS
Side Trsv. Half Frames	10.5x3x0.25 FP	3.64	10.50	0.23	**15.66**	PASS
	"Failing" members are failing the maximum cutout depth. See equivalent shear area.					
Main Deck Webs (CL)	13.5 x 0.3125 web 6 x 0.5 flg	54.65	17.50	0.30	**55.05**	FAIL
Main Deck Webs (5'-12' OCL)	14x3x0.3125 FP	11.57	12.25	0.30	**29.54**	PASS
Main Deck Webs (O/B)	14x3x0.3125 FP	21.31	16.63	0.30	**30.20**	FAIL
Main Deck Girders (5' OCL)	14x3x0.3125 FP	16.06	14.00	0.30	**31.07**	PASS
Main Deck Girders (12' OCL)	14x3x0.3125 FP	16.06	14.00	0.30	**29.85**	PASS

STANCHIONS

Member	Member Dimensions	W_{req} (LT)	$W_{offered}$ (LT)	
5' OCL Hull Stanchion	5" SCH 80	28.94	**38.08**	PASS
12' OCL Hull Stanchion	4" SCH 40	17.28	**19.10**	PASS
5' OCL BHD Girder	6 x 3.5 x 0.3125 L	28.94	**40.12**	PASS
12' OCL BHD Girder	6 x 3.5 x 0.3125 L	17.28	**40.10**	PASS
5' OCL Tonnage Fr Flg	6 x 0.375 flg w/ 1ft of 1/4" BHD	28.94	**29.35**	PASS

Appendix B

Scantling Calculations

3-1-1: Definitions

3 Length

3.1 Scantling Length (L)

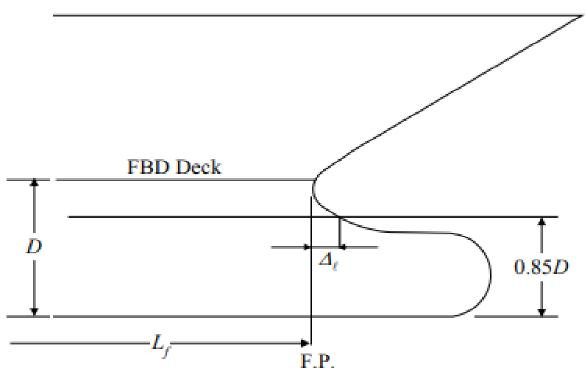
L is the distance in meters (feet) on the summer load line from the fore side of the stem to the centerline of the rudder stock. For use with the Rules, L is not to be less than 96% and need not be greater than 97% of the length on the summer load line. The forward end of L is to coincide with the fore side of the stem on the waterline on which L is measured.

$SLL =$ 178.03 ft
$L =$ 172.69 ft

3.3 Freeboard Length (Lf)

Lf is the distance in meters (feet) on a waterline at 85% of the least molded depth measured from the top of the keel from the fore side of the stem to the centerline of the rudder stock or 96% of the length on that waterline, whichever is greater. Where the stem is a fair concave curve above the waterline at 85% of the least molded depth and where the aftmost point of the stem is above the waterline, the forward end of the length, Lf, is to be taken at the aftmost point of the stem above that waterline. See 3-1-1/Figure 1.

FIGURE 1



5 Breadth

B is the greatest molded breadth in meters (feet).

$B =$ 46.00 ft

7 Depth

7.1 Molded Depth (D)

D is the molded depth at side in meters (feet) measured at the middle of L from the molded base line to the top of the freeboard-deck beams. In vessels having rounded gunwales, D is to be measured to the point of intersection of the molded lines of the deck and side shell plating. In cases where watertight bulkheads extend to a deck above the freeboard deck and are to be recorded in the Record as effective to that deck, D is to be measured to the bulkhead deck.

D = 10.50 ft

7.3 Scantling Depth (Ds)

The depth, Ds, for use with scantling requirements is measured to the strength deck, as defined in 3-1-1/13.5.

Ds = 10.50 ft

9 Draft for Scantlings (d)

d is the draft in meters (feet) measured at the middle of the length, L, from the molded keel or the rabbet line at its lowest point to the estimated summer load waterline, the design load waterline or 0.66D, whichever is greater.

Item	Formula	Value	Units
Summer Load Waterline Draft	SWL =	4.50	ft
Design Draft	DWL =	4.50	ft
Hull Depth	D =	10.50	ft
Draft for Scantlings	draft = Max(SWL, DWL, 0.66D)	6.93	ft

11 Molded Displacement and Block Coefficient

11.1 Molded Displacement

Δ is the molded displacement of the vessel in metric tons (long tons), excluding appendages, taken at the summer load line.

Δ = 522.8 LT

11.3 Block Coefficient

Cb is the block coefficient obtained from the following equation:

$Cb = 35\Delta/LBd$

Where

Δ = molded displacement, as defined in 3-1-1/11.1

L = scantling length, as defined in 3-1-1/3.1

d = draft, as defined in 3-1-1/9

Bwl = the greatest molded breadth at summer load line

Item	Formula	Value	Units
Molded Displacement	Δ =	522.80	LT
Scantling Length	L =	172.69	ft
Draft	d =	4.50	ft
Molded Breadth	Bwl =	45.00	ft
Block Coefficient	Cb =	0.52	-

3-1-2: General Requirements

5 Design

5.1 Continuity

Taper longitudinal members past the transverse member at which they stop or provide moment connection.

5.5 Brackets

Where brackets are fitted having thicknesses as required by 3-1-2/Table 5 and faces at approximately 45 degrees with the bulkhead deck or shell and the bracket is supported by a bulkhead, deck or shell and the bracket is supported by a bulkhead, deck or shell structural member, the length of each member may be measured at a point 25% of the extent of the bracket beyond the toe of the bracket, as shown in 3-1-2/Figure 2, when a reduction of the span is so permitted in each section. The minimum overlap of the bracket arm along the stiffener is not to be less than obtained from the following equation:

$x = 1.4y + 30$ mm $\qquad\qquad x = 1.4y + 1.2$ in.

where

x = length of overlap along stiffener, in mm (in.)

y = depth of stiffener, in mm (in.)

Where a bracket laps a member, the amount of overlap generally is to be 25.5 mm (1 in.).

Stiffener Depth	Overlap		f	t(w/o flg)	t(w/flg)
3	5.4		7.614	0.1875	0.1875
4	6.8		9.588	0.1875	0.1875
5	8.2		11.562	0.1875	0.1875
6	9.6		13.536	0.25	0.1875
8	12.4		17.484	0.25	0.1875
10	15.2		21.432	0.3125	0.25
12	18		25.38	0.3125	0.25
14	20.8		29.328	0.375	0.3125

FIGURE 2
Bracket

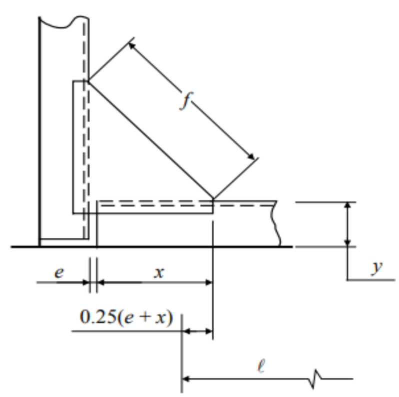


TABLE 5
Brackets

Metric

Length of Face f, mm	*Thickness, mm*		*Width of Flange, mm*
	Plain	*Flanged*	
Not exceeding 305	5.0	—	—
Over 305 to 455	6.5	5.0	38
Over 455 to 660	8.0	6.5	50
Over 660 to 915	9.5	8.0	63
Over 915 to 1370	11.0	9.5	75

Inch

Length of Face f, in.	*Thickness, in.*		*Width of Flange, in.*
	Plain	*Flanged*	
Not exceeding 12	3/16	—	—
Over 12 to 18	1/4	3/16	1 1/2
Over 18 to 26	5/16	1/4	2
Over 26 to 36	3/8	5/16	2 1/2
Over 36 to 54	7/16	3/8	3

3-2-1: Longitudinal Strength

3 Longitudinal Hull Girder Strength

3.1 Minimum Section Modulus

The minimum required hull girder section modulus, SM, at amidships, is to be determined in accordance with the following equation:

$SM = C1 \cdot C2 \cdot L^2 \cdot B \cdot (Cb + 0.7)$ ft-in²

where

$C1$ =	30.67 – 0.299L	40 ≤ L < 59 ft
=	22.40 – 0.158L	59 ≤ L < 79 ft
=	15.20 – 0.067L	79 ≤ L < 115 ft
=	11.35 – 0.033L	115 ≤ L < 150 ft
=	6.4	150 ≤ L < 200 ft
=	0.0137L + 3.65	200 ≤ L < 295 ft
$C2$ =	0.000144	
L =	length of vessel, as defined in 3-1-1/3, in m (ft)	
B =	breadth of vessel, as defined in 3-1-1/5, in m (ft)	
Cb =	block coefficient at design draft, based on the length, L, measured on the design load waterline. Cb is not to be taken as less than 0.60.	

L *(ft)*	B *(ft)*	Cb *(-)*	C1 *(-)*	C2 *(-)*	SM_{req} *(ft-in2)*	$SM_{offered}$ *(ft-in2)*
172.69	46.00	0.60	6.40	0.000144	1644	2442

3-2-5: Section Modulus Calculation (Hull to Main Deck)

LEGEND

n = Number of members		I =	Member moment of inertia about it's own axis (in^4)
t = Thickness of member (in)		A =	Member cross sectional area (in^2)
L = Length of member (in)		Y_{NA} =	$\sum(AY)/\sum(A)$ (in)
Y = Distance from reference axis to member area centroid (in		M =	$\sum(I)+\sum(AY^2)-\sum(A*Y_{NA}{}^2)$
θ = Angle of member relative to reference axis (deg)		SM =	M / Dist from NA to ref axis

Member	n	t	L	Y	θ	Ix	Iy	A	I	AY	AY^2
Plating											
Flat of Keel	1	0.500	121.00	-0.25	0	1.26	73,815	60.50	1	-15	4
Bottom Plate	2	0.375	176.44	5.81	3	0.78	171,649	132.33	942	769	4,471
Bilge Radius	2	0.375	51.13	28.00	-	0.22	4,177	38.35	4,147	1,074	30,064
Side Plate	2	0.313	64.19	83.81	85.00	0.16	6,887	40.12	13,669	3,362	281,805
Guard Plate	2	0.750	18.00	117.00	90	0.63	365	27.00	729	3,159	369,603
CL Car Deck Plate	1	0.500	118.00	132.00	0	1.23	68,460	59.00	1	7,788	1,028,016
Car Deck Plate	2	0.313	217.31	129.00	2	0.55	267,253	135.82	652	17,521	2,260,186
Girders & Webs						0.00	0				
CVK Web	1	0.500	14.63	7.56	90	0.15	130	7.31	130	55	418
CVK Flange	1	1.000	9.00	19.38	0	0.75	61	9.00	1	174	3,379
5' OCL Girder Web	2	0.375	15.00	7.00	90	0.07	105	11.25	211	79	551
5' OCL Girder Flg	2	0.375	3.00	14.19	0	0.01	1	2.25	0	32	453
12' OCL Keelson Web	2	0.313	15.00	13.00	90	0.04	88	9.38	176	122	1,584.38
12' OCL Keelson Flg	2	0.313	3.00	20.19	0	0.01	1	1.88	0	38	764.13
5' OCL Deck Girder Web	2	0.313	15.000	124.50	90	0.04	88	9.38	176	1,167	145,314.84
5' OCL Deck Girder Flg	2	0.313	3.00	115.50	0	0.01	1	1.88	0	217	25,012.97
12' OCL Deck Girder Web	2	0.313	15.00	123.50	90	0.04	88	9.38	176	1,158	142,989.84
12' OCL Deck Girder Flg	2	0.313	3.00	114.50	0	0.01	1	1.88	0	215	24,581.72
Stiffeners						0.00	0				
Keel Stiffeners (5"x3-1/2"x1/4")	4			3.36	0	5.39	2	2.06	22	7	23
Bottom Stiffs (5"x3-1/2"x1/4")	14			9.17	0	5.39	2	2.06	75	19	174
Side Stiffs (4"x3"x1/4")	8			83.81	5.00	2.77	1	1.69	22	141	11,854
Car Deck Stiffs (HP140x8)	41	-	-	126.38	90			87.70	262	11,083	1,400,712
Total								**650.2**	**21,392**	**48,165**	**5,731,960**

Distance from neutral axis (NA) to reference axis (Y_{NA}) = 74.1 in

Moment of inertia about NA (M) = 2185379 in^4 15176 in^2-ft^2

	Distance	*Section Modulus (in^3)*	*Section Modulus (in^2-ft)*
Minimum Fiber	132.25	29303	2441.9
Maximum Fiber	-0.5	37568	3130.6

3-2-2: Shell Plating

1 General

Shell plating is to be of not less thickness than is required by the equations for thickness of side and bottom plating as required by this section, nor less than required by Section 3-2-1 for longitudinal strength and Section 3-2-8 for deep tank plating with h not less than the vertical distance to the freeboard deck at side.

3 Bottom Shell Plating

3.1 Extent of Bottom Plating

The term "bottom plating" refers to the plating from the keel to the upper turn of the bilge or upper chine.

3.3 Bottom Shell Plating

The thickness of the bottom shell plating throughout is not to be less than that obtained from the following equations:

3.3.1

$t = s\sqrt{(h)} / 460 + 0.1$ in

where

t = thickness of bottom shell plating, in mm (in)
s = frame spacing, in mm (in)
h = depth, D, in m (ft), as defined in 3-1-1/7.1, but not less than 0.1L or 1.18d, whichever is greater
d = draft for scantlings, as defined in 3-1-1/9, or 0.066L, whichever is greater
L = length of vessel, in m (ft), as defined in 3-1-1/3

Member	s *(in)*	d *(ft)*	h *(ft)*	treq *(in)*
Keel Plate	24.00	11.40	17.27	0.317
Bottom Shell	24.44	11.40	17.27	0.321
Skeg Shell Plating	24.00	11.40	17.27	0.317

3.3.2

$$t = \frac{s}{R}\sqrt{\frac{SM_R}{SM_A}} \cdot \frac{1}{\sqrt{Q}} \quad \text{mm (in.)}$$

where

t = thickness of bottom shell plating, in mm (in)
s = frame spacing, in mm (in)
R = 45 with transverse framing
= 55 with longitudinal framing
SMR = hull girder section modulus required by 3-2-1/3, in cm2-m (in2-ft)
SMA = bottom hull girder section modulus, in cm2-m (in2-ft)
Q = as defined in 3-2-1/7.5

From 3-2-1/7.5
Q = 0.78 for Grade H32
Q = 0.72 for Grade H36

H32, H36 are as specified in Section 2-1-3 of the ABS Rules for Materials and Welding (Part 2). Q factor for steels having other yield point or yield strength will be specially considered.

Member	s *(in)*	R *(-)*	SMR *(ft-in2)*	SMA *(ft-in2)*	Q *(-)*	treq *(in)*
Keel Plate	24.00	55.00	1643.54	2441.93	1.00	0.36
Bottom Shell	24.44	55.00	1643.54	2441.93	1.00	0.36

3.5 Bottom Forward

For vessels of 61 m (200 ft) in length and above, where the heavy weather ballast draft or operating draft forward is less than 0.04L, the plating on the flat of bottom forward, forward of the location given in 3-2-4/Table 1 is to be not less than required by the following equation:

$$t = 0.0046s\sqrt{(0.005L^2 - 1.3d_f^2)/d_f} \quad \text{mm}$$

$$t = 0.0026s\sqrt{(0.005L^2 - 1.3d_f^2)/d_f} \quad \text{in.}$$

s = frame spacing, in mm (in.)
L = length of vessel, as defined in 3-1-1/3
df = heavy weather ballast draft at the forward perpendicular, in m (ft)

Member	s *(in)*	L *(ft)*	df *(ft)*	treq *(in)*	toffered *(in)*
N/A					

5 Side Shell Plating

5.1 General

The side shell plating is not to be less in thickness than that obtained from the following equation:

$$t = s\sqrt{(h)} / 485 + 0.1 \quad \text{in}$$

where

- t = thickness, in mm (in)
- s = spacing of transverse frames or longitudinals, in mm (in)
- h = depth, in m (ft), as defined in 3-1-1/7, but not less than 0.1L or 1.18d, whichever is greater
- d = draft for scantlings, as defined in 3-1-1/9, or 0.066L, whichever is greater
- L = length of the vessel, as defined in 3-1-1/3

Member	s *(in)*	L *(ft)*	d *(ft)*	h *(ft)*	treq *(in)*
Side Shell - Amidship	24.00	172.69	11.40	17.27	0.31

5.3 Side Shell Plating for Impact Loadings (2014)

The side shell is to be 25% greater in thickness than that obtained from 3-2-2/5.1.

Member	s *(in)*	L *(ft)*	d *(ft)*	h *(ft)*	treq *(in)*
Guard Plate	24.00	172.69	11.40	17.27	0.38

5.5 Side Shell Plating at Ends

The minimum side shell plating thickness, t, at ends is to be obtained from the following equations and is not to extend for more than 0.1L from the ends. Between the midship 0.4L and the end 0.1L, the thickness of the plating may be gradually tapered.

$$t = 0.000545L + 0.009s \quad \text{in}$$

where

- s = frame spacing, in mm (in)
- L = length of vessel, as defined in 3-1-1/3, in m (ft)

Member	s *(in)*	L *(ft)*	treq *(in)*
Side Shell - At Ends	24.00	172.69	0.31

3-2-3: Deck Plating

1 General

The thickness of the deck plating is not to be less than that required to obtain the hull-girder section modulus given in Section 3-2-1, nor less than required by this section.

3 Deck Plating

The thickness of plating on each deck is to be not less than the greater of those obtained from the following equations. The required thickness is not to be less than 5.0 mm (0.20 in), except for platform decks in enclosed passenger spaces where the thickness is not to be less than 4.5 mm (0.18 in). Thickness of strength deck inside line of openings may be reduced by 1.0 mm (0.04 in) from t obtained by 3-2-3/3.3 below.

Member	treq *(in)*	
Main Deck	0.20	
01 Deck	0.20	*0.18" for interior areas
Bridge Deck	0.20	*0.18" for interior areas
House Top	0.20	

3.1 All Decks

$t = s\sqrt{h} / 460 + 0.1$ in

where

t = thickness, in mm (in)

s = beam or longitudinal spacing, in mm (in)

h = height, in m (ft), as follows:

= for a deck or portion of deck forming a tank top, the greater of the following distances:
- two-thirds of the distance from the tank top to the top of the overflow, or
- two-thirds of the distance from the tank top to the bulkhead deck or freeboard deck.

= for a lower deck on which cargo or stores are carried, the tween-deck height at side; where the cargo weights are greater than normal [7010 N/m3 (715 kgf/m3, 45 lbf/ft3)], h is to be suitably adjusted.

= for an exposed deck on which cargo is carried, 3.66 m (12 ft). Where it is intended to carry deck cargoes in excess of 25850 N/m2 (2636 kgf/m2, 540 lbf/ft2), this head is to be increased in proportion to the added loads which will be imposed on the structure.

Member	s *(in)*	h *(ft)*	treq *(in)*
Potable/FO Tank Tops	24.00	7.00	0.24
Main Deck OCL (car)	12.00	12.00	0.19

3.1.3 Freeboard Deck within Superstructure, Any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward and 0.20L Aft of Amidships

$h = 0.014*L + 2.86$ ft

Member	s *(in)*	L *(ft)*	h *(ft)*	treq *(in)*
01 Deck	24.00	172.69	5.28	0.22
Bridge Deck	24.00	172.69	5.28	0.22

3.1.4 All Other Locations

$h = 0.014*L + 1.43$ ft

Member	s *(in)*	L *(ft)*	h *(ft)*	treq *(in)*
01 Deck	24.00	172.69	3.85	0.20
House Top	24.00	172.69	3.85	0.20

7 Wheel Loading

Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of deck plating is not to be less than that obtained from the following equation:

$t =$ k*K*n*√(C*W) in

where

$k =$ 1

$K =$ $[21.99+0.316*(a/s)^2 - 5.382*(a/s) + 2.6*(a/s)(b/s) - 0.895*(b/s)^2 - 7.624*(b/s)]10^{-2}$

as derived from curved in 3-2-3/Figure1

$n =$ 1 where l/s > 2.0

$n =$ 0.85 where l/s = 1.0

Interpolate for intermediate values

$C =$ 1.5 for vehicles stowed at sea

$W =$ static wheel load in kN (tf, Ltf)

$a =$ wheel imprint dimension, in mm (in.), parallel to the longer edge, l, of the plate panel

$b =$ wheel imprint dimension, in mm (in.), perpendicular to the longer edge, l, of the plate panel

$s =$ spacing of deck beams or deck longitudinals, in mm (in.)

$l =$ length of the plate panel, in mm (in.)

The strength deck plating thickness is to be not less than 110% of that required by the above equation. Platform deck plating thickness is to be not less than 90% of that required by the above equation. Where the wheels are close together, consideration will be given to the use of the

The equation below relates the radius of tire contact to tire inflation pressure and the total tire load:

$$a = \sqrt{\frac{P}{p\pi}}$$

Where:

$a =$ radius of tire contact

$P =$ total load on tire

$p =$ tire inflation pressure

Member	P_{axel} *(lbf)*	P_{tire} *(lbf)*	p *(psi)*	a *(in)*	b *(in)*	s *(in)*	l *(in)*
Main Deck CL (truck)	20000	10000	110	10.76	11.00	12.00	96.00
Main Deck OCL (car)	5000	1250	34	6.84	11.00	12.00	96.00

Member	k *(-)*	K *(-)*	n *(-)*	C *(-)*	W *(Ltf)*	treq *(in)*
Main Deck CL (truck)	1.00	0.12	1.00	1.50	3.57	0.30
Main Deck OCL (car)	1.00	0.13	1.00	1.50	0.56	0.13

Alternate Wheel Loading Calculation

The design loading for vehicle decks was taken as follows:

Member	P_{total} (lbf)	P (lbf)	p (psi)	a (DIA) (in)
Garbage Truck Steerer Axle	23,500	11,750	120	11.17
Trailer Single Axle Dual Tire	20,000	10,000	100	11.28
Trailer Tandem Axle Dual Tire	38,000	9,500	100	11.00
Concrete Truck Tandem Axle	46,000	11,500	100	12.10
Commodites Truck Single Axle Dual Tire	26,000	13,000	100	12.87

Member	K (-)	l/s (-)	n (-)	W (Ltf)	a (in)
Garbage Truck Steerer Axle	0.117	8.00	1.00	5.2	11.17
Trailer Single Axle Dual Tire	0.048	8.00	1.00	4.5	11.28
Trailer Tandem Axle Dual Tire	0.048	8.00	1.00	4.2	11.00
Concrete Truck Tandem Axle	0.048	8.00	1.00	5.1	12.10
Commodites Truck Single Axle Dual Tire	0.048	8.00	1.00	5.8	12.87

Member	C	b (in)	s (in)	l (in)	t_{req} (in)
Garbage Truck Steerer Axle	1.5	11.17	12.0	96.0	0.328
Trailer Single Axle Dual Tire	1.5	22.00	12.0	96.0	0.123
Trailer Tandem Axle Dual Tire	1.5	22.00	12.0	96.0	0.120
Concrete Truck Tandem Axle	1.5	22.00	12.0	96.0	0.132
Commodites Truck Single Axle Dual Tire	1.5	22.00	12.0	96.0	0.141

For wheel loading, the strength deck plating thickness is to be not less than 110% of that required by the above equation, and platform deck plating thickness is to be not less than 90% of that required by the above equation.

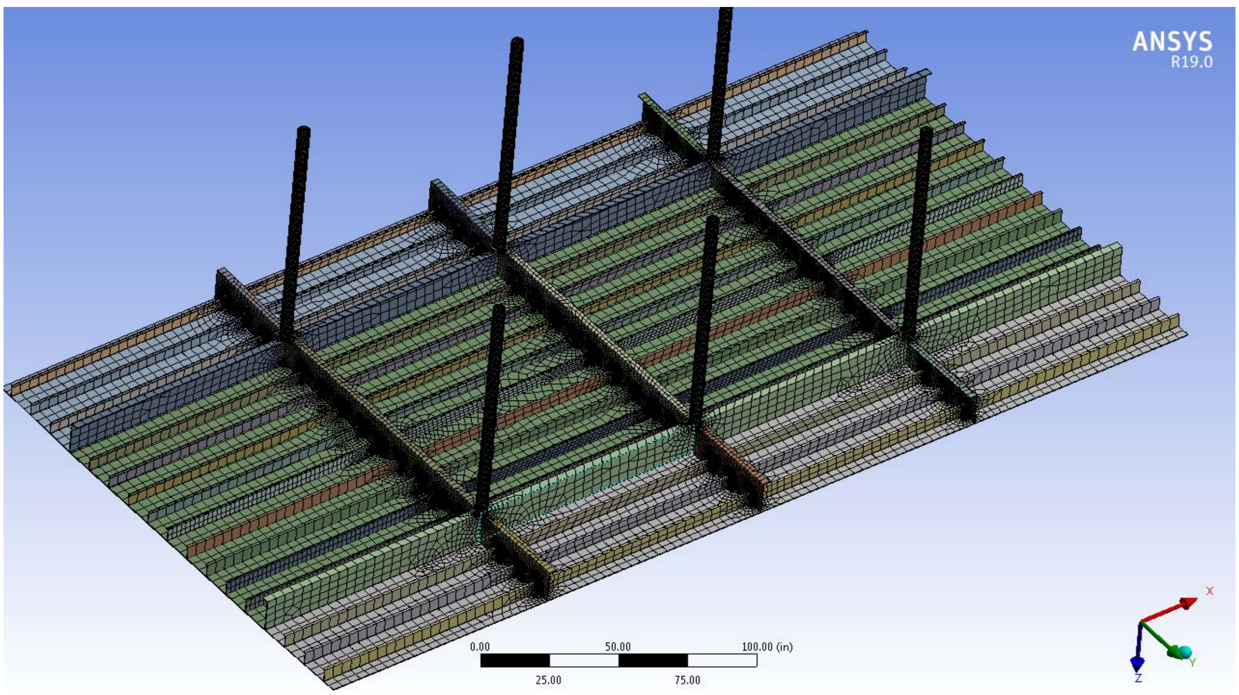
Member	C	t_{base} (in)	Change (%)	t_{add} (in)	t_{req} (in)
Garbage Truck Steerer Axle	1.5	0.328	10.0%	0.033	0.361
Trailer Single Axle Dual Tire	1.5	0.123	10.0%	0.012	0.135
Trailer Tandem Axle Dual Tire	1.5	0.120	10.0%	0.012	0.132
Concrete Truck Tandem Axle	1.5	0.132	10.0%	0.013	0.145
Commodites Truck Single	1.5	0.141	10.0%	0.014	0.155

Main Deck FEA Eng: MJW (Calculations), SKW (Writeup)

Purpose
While the alternative wheel loading indicates sufficient deck thickness, an FEA of the deck structure was performed to verify its structural suitability.

Procedure
The structure was modeled in Rhino and evaluated in ANSYS.

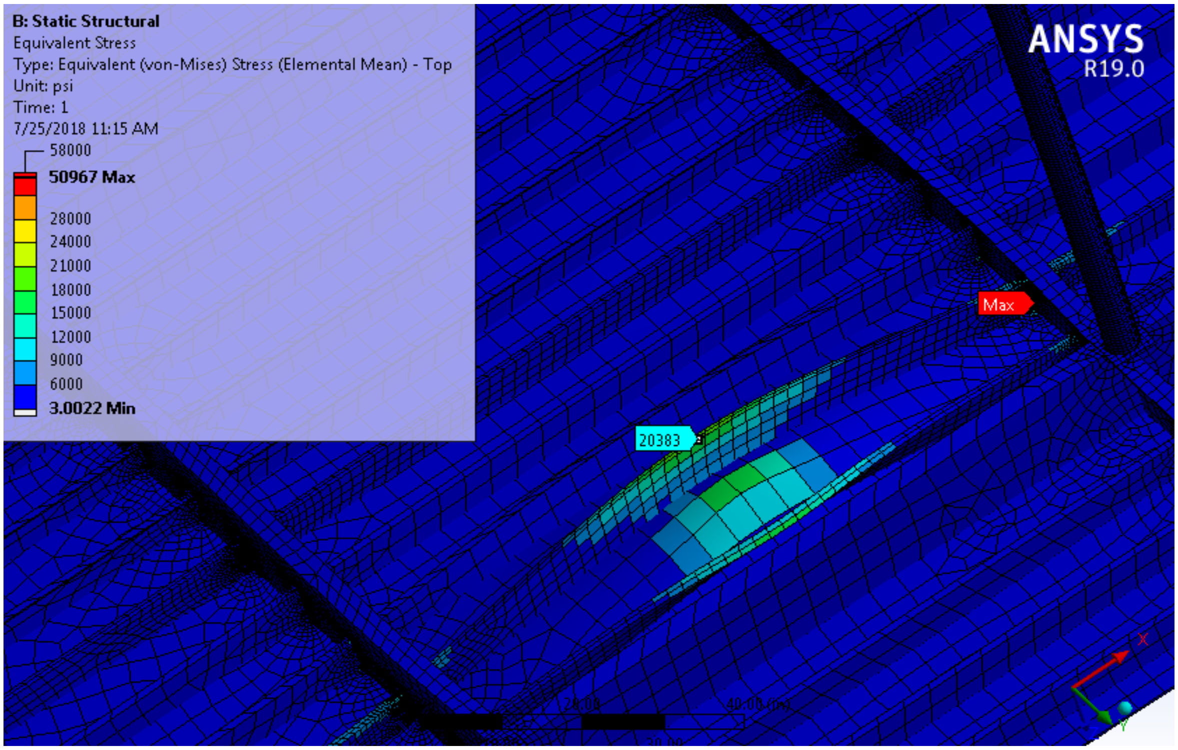
Given and Assumed Parameters
Representative structure was modeled for 32ft of deck 9ft to each side of CL, see figure below. The 140x8mm BF stiffeners were modeled as representative 5.512"x1"x0.25" L's which have a lesser section modulus but the same maximum fiber. This is considered to be a conservative

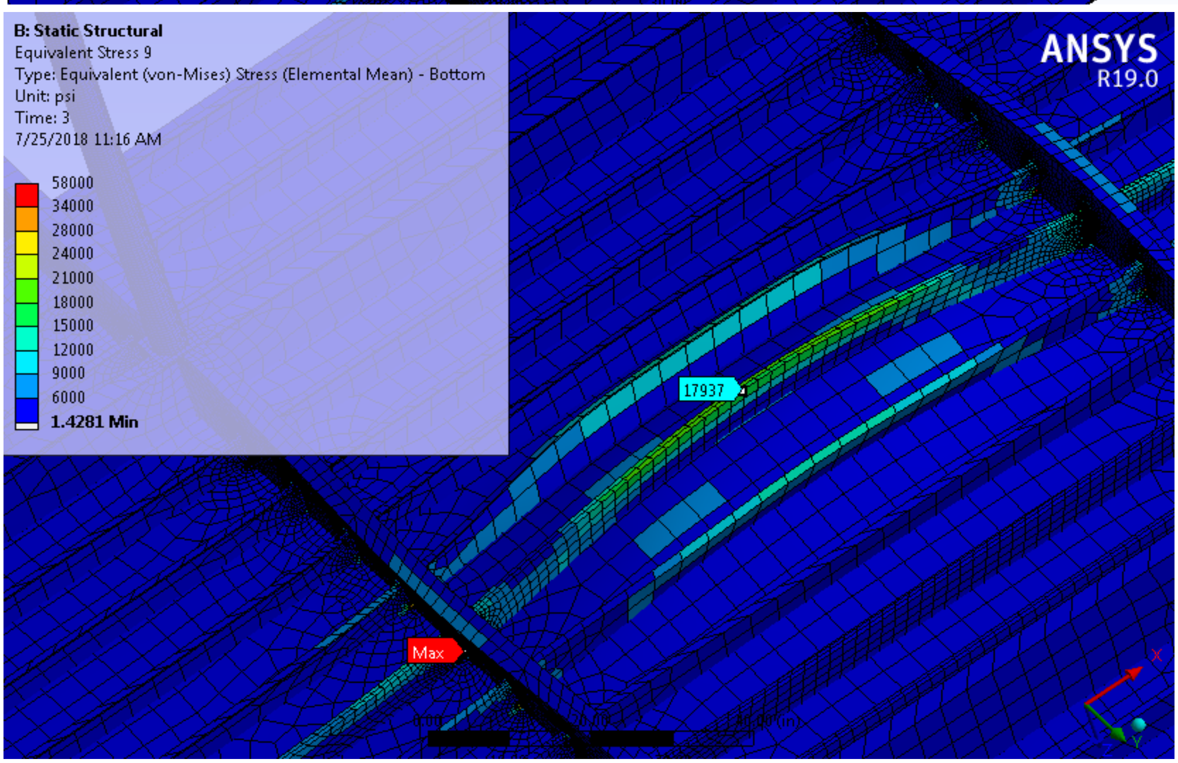


The model was given zero displacements in the x and y along the deck plate edges and fixed supports on the bottom of the stanchions. Gravity was applied to all structure. Loads were applied over a pinball area. The maximum axle weight was assumed to be 23,500 lb. A variety of loading patters was analyzed.

Conclusions
The evaluated stiffeners are sufficient for supporting the maximum load of 23,500 lb. The selected stiffeners are stronger than those evaluated, so the structure is sufficient as designed.

Results





Bending stresses in all scenarios stayed well below yield. Some higher hotspot stresses were witnessed at the intersection of the girders and stiffeners, but the model has insufficient detail for these stresses to be realistic.

3-2-4: Bottom Structure

3 Single Bottoms with Floors and Keelsons

3.1 General
Where double bottom construction is not required by 3-2-4/1.1 or is not applied, single bottom construction is to be in accordance with 3-2-4/3 or 3-2-4/5, as may be applicable.

3.3 Center Keelsons
Single-bottom vessels are to have center keelsons formed of continuous or intercostal center girder plates with horizontal top plates. The thickness of the keelson and the area of the horizontal top plate are to be not less than that obtained from the following equations. Vessels less than 30.5 m (100 ft) in length will be subject to special consideration. Tapering of the horizontal top plate area at the ends is not normally considered for vessels less than 30.5 m (100 ft) in length. The keelsons are to extend as far forward and aft as practicable.

3.3.1 Center-girder Plate Thickness Amidships
t = 0.00075L + 0.2 in
3.3.2 Center-girder Plate Thickness at Ends
t = 85% of center keelson thickness amidships
3.3.3 Horizontal Top-plate Area Amidships
A = 0.0044L^(3/2) - 1.25 in²
3.3.4 Horizontal Top-plate Area Amidships
A = 0.0033L^(3/2) - 0.15 in²
where
t = thickness of center-girder plate, in.
L = Length of the vessel
A = area of horizontal top plate, in ²

Member	t_{mid} *(in)*	t_{end} *(in)*	A_{mid} *(in²)*	A_{end} *(in²)*
CVK	0.33	0.28	8.74	7.34

5 Single Bottoms with Longitudinal or Transverse Frames

5.1 General
Where longitudinal frames supported by bottom transverses or transverse frames supported by longitudinal girders and bottom transverses are proposed in lieu of keelsons referred to in 3-2-4/3, the construction is to be in accordance with this subsection. Frames are not to have less strength than is required for watertight bulkhead stiffeners or girders in the same location in association with head to the bulkhead deck. In way of deep tanks, frames are not to have less strength than is required for stiffeners or girders on deep tank bulkheads. See 3-2-4/Figure 2, 3-2-4/Figure 3 and 3-2-4/Figure 4.

5.3 Bottom Girders and Transverses

The section modulus, SM, of each bottom girder and transverse, where intended as a primary supporting member, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = 0.0041chsl^2 \quad in^3$$

where

c = 0.915

h = vertical distance, in m (ft), from the center of area supported to the deck at side

s = member spacing in m (ft)

l = unsupported span of the member, in m (ft). Where brackets of the thicknesses given in 3-2-1/Table 1 are fitted, l may be measured to a point 25% of the extent of the bracket beyond its toe.

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and stiffeners are to be fitted as may be required.

Member	c *(-)*	h *(ft)*	s *(ft)*	l *(ft)*	SMreq *(in3)*
CVK	0.915	10.50	23.00	48.00	2087.39
Bottom Girders (5' OCL)	0.915	10.50	8.50	8.00	21.43
Bottom Girders (12' OCL)	0.915	10.50	7.72	8.00	19.47
Bottom Trsv. Web (CL@Fr 0,4,8,12,24	0.915	10.50	8.00	10.00	31.51
Bottom Trsv. Web (5'-12' OCL)	0.915	10.21	8.00	7.00	15.02
Bottom Trsv. Web (O/B)	0.915	9.77	8.00	8.19	19.65
Bottom Trsv. Half Frames (5'-12' OCL)	0.915	7.00	4.00	7.00	5.15
Bottom Trsv. Half Frames (OB)	0.915	8.00	4.00	7.00	5.88

Note: This equation is not meant for the CVK

<u>5.3.2 Depth</u>

The minimum depth of the girder or transverse is to be not less than 2.5 times the depth of the cutouts for bottom frames, unless effective compensation for cutouts is provided, nor less than that obtained from the following equation:

$hw = 1.75l$ in.

where

hw = girder or transverse depth, in mm (in)

l = unsupported span of the member, in m (ft). Where brackets of the thicknesses given in 3-2-1/Table 1 are fitted, l may be measured to a point 25% of the extent of the bracket beyond its toe.

Member	l *(ft)*	hcutout *(ft)*	hw req *(in)*
Bottom Girders (5' OCL)	8.000	0.00	14.00
Bottom Girders (12' OCL)	8.000	0.00	14.00
Bottom Trsv. Web (CL@Fr 0,4,8,12,24	10.000	6.00	17.50
Bottom Trsv. Web (5'-12' OCL)	7.000	0.00	12.25
Bottom Trsv. Web (O/B)	8.188	0.00	14.33
Bottom Trsv. Half Frames (5'-12' OCL)	7.000	0.00	12.25
Bottom Trsv. Half Frames (OB)	7.000	0.00	12.25

<u>5.3.3 Thickness</u>

The minimum thickness of the web is to be not less than that obtained from the following equation:

$$t = 0.01h_w + 3 \quad \text{mm}$$

$$t = 0.01h_w + 0.12 \quad \text{in.}$$

$t = 0.01 * hw + 0.12$

where

t = floor thickness, in mm (in)

hw = web depth, in mm (in), as given in 3-2-4/5.3.2

Floors under engine girders are to be not less in thickness than the thickness required for keelsons.

Member	h_w *(in)*	treq *(in)*
Bottom Girders (5' OCL)	14.0	0.260
Bottom Girders (12' OCL)	14.0	0.260
Bottom Trsv. Web (CL@Fr 0,4,8,12,24	17.5	0.295
Bottom Trsv. Web (5'-12' OCL)	12.3	0.243
Bottom Trsv. Web (O/B)	14.3	0.263
Bottom Trsv. Half Frames (5'-12' OCL)	12.3	0.243
Bottom Trsv. Half Frames (OB)	12.3	0.243

5.7 Frames

The section modulus, SM, of each bottom frame to the chine or upper turn of bilge, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$SM = 0.0041chsl^2$ in^3

Where

c = 0.80 for transverse frames clear of tanks
= 1.00 for longitudinal frames clear of tanks, and in way of tanks
= 1.00 for transverse frames in way of tanks

h = vertical distance, in m (ft), from the middle of l to the deck at side. In way of a deep tank, h is the greatest of the distances, in m (ft), from the middle of l to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, a point located above the top of the tank not less than 0.01L + 0.15 m (0.01L + 0.5 ft) or 0.46 m (1.5 ft), whichever is greatest.

s = member spacing in m (ft)

l = unsupported span of the member, in m (ft). Where brackets of the thicknesses given in 3-2-1/Table 1 are fitted, l may be measured to a point 25% of the extent of the bracket beyond its toe.

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and stiffeners are to be fitted as may be required.

Member	c *(-)*	h *(ft)*	s *(ft)*	l *(ft)*	SMreq *(in3)*
Keel Plate Longitudinals	1.000	10.50	2.00	8.00	5.51
Bottom Longitudinals	1.000	10.50	2.04	8.00	5.61
Bottom Longitudinals - Tonnage	1.000	10.50	2.04	4.14	1.50
Bottom Longitudinals - Ballast Tk	1.000	12.50	2.04	4.14	1.79
Bow End Framing (Max s, l)	0.800	10.50	2.00	4.00	1.10

3-2-5: Side Frames, Webs, and Stringers

3 Longitudinal Side Frames

3.1 Section Modulus
The section modulus, SM, of each longitudinal side frame above the chine or upper turn of bilge is to be not less than that obtained from the following equation:

$SM = 0.0041chsl^2$ in³

where

s = frame spacing, in m (ft)

l = straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, the length, l, may be measured as permitted

h = vertical distance, in m (ft), from the frame to the freeboard deck at side, but not less than 0.02L + 0.46 m (0.02L + 1.5 ft)

c = 0.915

Member	c (-)	h (ft)	s (ft)	l (ft)	SMreq (in3)
Side Shell Long'l Stiffeners	0.915	6.50	2.00	8.00	3.12
Side Shell Stiffeners - Tonnage	0.915	6.50	2.00	4.00	0.78

7 Side Web Frames

7.1 Section Modulus

The section modulus, SM, of each side web frame supporting longitudinal framing or shell stringers above the chine or upper turn of bilge, in association with the plating to which the web frame is attached, is not to be less than that obtained from the following equation:

$SM =$ $0.0041chsl^2$ in^3

where

$c =$ 0.915 aft of the forepeak

$=$ 1.13 in the forepeak of vessel 61 m (200 ft) or greater in length.

$s =$ frame spacing, in m (ft)

$l =$ straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by decks or inner bottoms, the length, l, may be measured as permitted therein.

$h =$ on frames having no tween decks above, the vertical distance, in m (ft), from the mid length of the frame to the freeboard deck at side, but not less than 0.02L + 0.46 m (0.02L + 1.5 ft).

$=$ on frames having tween decks above, the vertical distance, in m (ft), from the middle of l to the load line or 0.5l, whichever is greater, plus bh1/45K (bh1/150K).

$b =$ horizontal distance, in m (ft), from the outside of the frames to the first row of deck beam supports.

$h1 =$ vertical distance, in m (ft), from the deck at the top of the web frame to the bulkhead or freeboard deck plus the height of all cargo tween deck spaces above the bulkhead or freeboard deck plus one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plus 2.44 m (8 ft), if that is greater. Where the cargo load differs from 715 kgf/m3 (45 lbf/ft3), h1 is to be adjusted accordingly.

$K =$ 1.0 where the deck is longitudinally framed and a deck transverse is fitted in way of each web frame.

$=$ the number of transverse frame spaces between web frames where the deck is transversely framed.

Member	c *(-)*	h *(ft)*	s *(ft)*	l *(ft)*	SMreq *(in3)*
Side Web Frames, Amidships	0.915	4.95	8.00	7.00	7.29
Side Trsv. Half Frames	0.915	4.95	4.00	7.00	3.64

7.5 Proportions

The depth of each web frame is to be not less than 125l mm (1.5l in) or, unless effective compensation is provided for cutouts, 2.5 times the cutout for frame or longitudinal if greater. The thickness of the web of web frame or stringer is to be not less than 0.01 times the depth plus 3 mm (0.12 in), l is as defined in 3-2-5/7.1.

Member	l *(ft)*	hcutout *(ft)*	h_web *(in)*
Side Web Frames, Amidships	7.00	4.00	10.50
Side Trsv. Half Frames	7.00	0.00	10.50

Member	hw *(in)*	treq *(in)*
Side Web Frames, Amidships	10.50	0.23
Side Trsv. Half Frames	10.50	0.23

7.7 Tripping Brackets and Stiffeners

Where the shell is longitudinally framed, stiffeners attached to the longitudinal frames and extending the full depth of the web frame are to be fitted at least at alternate longiduinal frames.

3-2-6: Beams, Deck Girders, Deck Transverses, and Pillars

1 Beams

1.3 Section Modulus

The section modulus, SM, of each transverse or longitudinal beam, in association with the plating to which it is attached, is not to be less than that obtained from the following equations:

$SM =$ $0.0041chsl^2$ in^3

where

$c =$	1	for transverse or longitudinal beams at the tops of tank, with deep tank h
$=$	1/(1.709 – 0.651k)	for longitudinal beams of strength decks and effective lower decks
$=$	0.6	for all other transverse beams
$=$	0.7	for all other longitudinal beams
$k =$	$SM_R Y/I_A$	

SM_R = required hull-girder section modulus amidships from 3-2-1/3, in cm2-m (in2-ft)

Y = distance, in m (ft), from the neutral axis to the deck being considered, always taken as positive

I_A = hull girder moment of inertia of the vessel amidships, in cm2-m2 (in2-ft2)

The values of IA and Y are to be those obtained using the area of the longitudinal beams given by the above equation.

s = frame spacing, in m (ft)

l = straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, the length, l, may be measured as permitted

h = height, in m (ft), as follows:

= for a deep tank top, is the greatest of the following: two-thirds of the distance from the top of the tank to the top of the overflow, or
• two-thirds of the distance from the top of the tank to the bulkhead deck or freeboard deck, or
• the height to the load line, or
• 0.01L + 0.15 m (0.01L + 0.5 ft)

= for a lower deck on which cargo or stores are carried, the tween-deck height at side. Where the cargo weights differ from 7010 N/m3 (715 kgf/m3, 45 lbf/ft3), h is to be proportionately adjusted.

= for an exposed deck on which cargo is carried, 3.66 m (12 ft). Where it is intended to carry deck cargoes in excess of 25850 N/m2 (2636 kgf/m2, 540 lbf/ft2), this head is to be increased in proportion to the added loads which will be imposed on the structure.

Member	Beam Type	SMR (in2-ft)	Y (-)	IA (-)	k (-)	c (-)
Main Deck Stiffs	Longl	1643.54	5.33	15176.24	0.58	0.75
Main Deck Stiffs - in tanks	Longl					1.00
01 Deck Stiffs	Longl					0.70
Bridge Deck Stiffs	Transv					0.60
House Top Stiffs	Transv					0.60

Elsewhere, the value of h is obtained from the appropriate equation below, where L = length of the vessel, in m (ft), as defined in 3-1-1/3.

Member	c (-)	Rule 1.3.[ ]	h (ft)	s (ft)	l (ft)	SMreq (in^3)
Main Deck Stiffs*	0.75	1.3.1	27.77	1.00	8.00	5.46
Main Deck Stiffs - in tanks	1.00	1.3.1	2.23	1.00	8.00	0.58
01 Deck Stiffs	0.70	1.3.4	2.73	2.00	10.00	1.57
Bridge Deck Stiffs	0.60	1.3.5	2.00	2.00	10.00	0.98
House Top Stiffs	0.60	1.3.6	1.50	2.00	4.00	0.12

**h has been overwritten with the maximum wheel loading psf.*

1.3.1 Exposed Freeboard Deck Having No Deck Below

$h = 0.02*L + 2.5$ ft

1.3.2 Exposed Freeboard Deck Having a Deck Below, Forecastle Deck, Superstructure Deck Forward of Amidships 0.5L

$h = 0.02*L + 1.5$ ft

1.3.3 Freeboard Deck within Superstructure, any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward of 0.30L Aft of Amidships

$h = 0.01*L + 2.0$ ft

1.3.4 All Other First Tier Above Freeboard Deck Locations

$h = 0.01*L + 1.0$ ft

1.3.5 Second Tier Above Freeboard Deck; Deckhouse Top or Short Superstructure*

* Where used only as weather covering, may be used as 3-2-6/1.3.6, but L need not be taken greater than 45.70 m (150 ft).

$h = 0.01*L + 0.5$ ft

1.3.6 Third Tier Above Freeboard Deck Deckhouse Top or Short Superstructure*

* Where used only as weather covering, may be used as 3-2-6/1.3.6, but L need not be taken greater than 45.70 m (150 ft).

$h = 0.01*L$ ft

3 Deck Girders and Deck Transverses

3.3 Deck Girders and Transverses Clear of Tanks

Section modulus, SM, of each longitudinal deck girder and deck transverse clear of tanks is not to be less than that obtained from the following equation:

SM = $0.0041chbl^2$ in^3

where

b = mean breadth of area of deck supported (for girders), or spacing of deck transverses (for transverses), in m (ft)

l = unsupported span, in m (ft). Where brackets are fitted at bulkhead supports, in accordance with 3-1-2/5.5, the length, l, may be measured as permitted therein.

h = height, in m (ft), as required by 3-2-6/1.3 for the beams supported

c = 0.60

Member	c *(-)*	Rule *1.3.[ ]*	h *(ft)*	b *(ft)*	l *(ft)*	SMreq *(in3)*
Main Deck Webs (CL)	0.60		27.77	8.00	10.00	54.65
Main Deck Webs (5'-12' OCL)	0.60		12.00	8.00	7.00	11.57
Main Deck Webs (O/B)	0.60		12.00	8.00	9.50	21.31
Main Deck Girders (5' OCL)	0.60		12.00	8.50	8.00	16.06
Main Deck Girders (12' OCL)	0.60		12.00	8.50	8.00	16.06

11.3 Proportions

The minimum depth of a deck girder or transverse supporting member is to be 58.3*l* mm (0.7*l* in), where *l* is as defined in 3-2-6/3.3; the depth is also not to be less than 2.5 times the cutout for the beam or longitudinal unless effective compensation is provided for the cutouts. The minimum thickness is to be 1 mm per 100 millimeters (0.01 in per inch) of depth plus 4 mm (0.16 in).

Member	l *(ft)*	hw req *(in)*	hcutout *(in)*	hw req *(in)*	hw req *(in)*	hw *(in)*
Main Deck Webs (CL)	10.00	7.00	6.50	17.50	17.50	13.50
Main Deck Webs (5'-12' OCL)	7.00	4.90	6.50	12.25	12.25	14.00
Main Deck Webs (O/B)	9.50	6.65	6.50	16.63	16.63	14.00
Main Deck Girders (5' OCL)	8.00	5.60	0.00	14.00	14.00	14.00
Main Deck Girders (12' OCL)	8.00	5.60	0.00	14.00	14.00	14.00

Member	hw *(in)*	treq *(in)*	toffered *(in)*
Main Deck Webs (CL)	13.50	0.30	0.31
Main Deck Webs (5'-12' OCL)	14.00	0.30	0.31
Main Deck Webs (O/B)	14.00	0.30	0.31
Main Deck Girders (5' OCL)	14.00	0.30	0.31
Main Deck Girders (12' OCL)	14.00	0.30	0.31

5 Stanchions and Pillars

5.1 Permissible Load

The permissible load a pillar can carry is to be equal to or greater than the pillar load, W, as determined in 3-2-6/5.5. The permissible load may be obtained from the following equation:

Wa = (k-nl/r)A

where

Wa = load, in kN (tf, LTf)
k = 12.09 (1.232, 7.83)
n = 0.0444 (0.00452, 0.345)
l = unsupported span of the stanchion, in cm (ft)
r = least radius of gyration, in cm (in)
A = cross sectional area of the stanchion, in cm2 (in2)

Member	k *(-)*	n *(-)*	l *(ft)*	r *(in)*	A *(in2)*	Wa *(LTf)*
5' OCL Hull Stanchion	7.83	0.345	8.53	1.84	6.11	38.08
12' OCL Hull Stanchion	7.83	0.345	7.93	1.51	3.17	19.10
5' OCL BHD Girder	7.83	0.345	8.55	2.51	6.03	40.12
12' OCL BHD Girder	7.83	0.345	8.58	2.51	6.03	40.10
5' OCL Tonnage Fr Flg	7.83	0.345	7.37	1.14	5.25	29.35

5.3 Calculated Load

The load on a pillar is to be obtained from the following equation:

$W = nbhs$ Ltf

where

n = 7.04 (0.715, 0.02)
b = mean breadth of the area supported, in m (ft)
h = height, in m (ft), above the deck supported, as defined below
s = mean length, in m (ft), of area supported

For a pillar below an exposed deck on which cargo is carried, h is the distance from the deck supported to a point 3.66 m (12 ft) above the exposed deck. Where it is intended to carry deck cargoes in excess of 2636 kilograms per square meter (540 pounds per square foot), this head is to be increased in proportion to the added loads which will be imposed on the structure.

For a pillar below the freeboard deck, h is to be measured to a point not less than 0.02L + 0.76 m (0.02L + 2.5 ft) above the freeboard deck.

For a pillar below the superstructure deck, h is to be measured to a point not less than 0.02L + 0.46 m (0.02L + 1.5 ft) above the superstructure deck.

The height, h, for any pillar is not to be less than the given height in 3-2-6/1.3 for the beams at the top of the pillar plus the sum of the heights given in the same paragraphs for the beams of all complete cargo decks and one-half the heights given for all partial superstructure decks above.

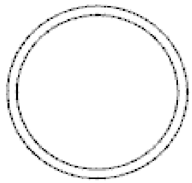
L is the length of vessel, in m (ft), as defined in 3-1-1/3.

Member	n *(-)*	b *(ft)*	h *(ft)*	s *(ft)*	W *(LTf)*	Pass / *Fail*
5' OCL Hull Stanchion	0.02	8.50	21.28	8.00	28.94	PASS
12' OCL Hull Stanchion	0.02	9.00	12.00	8.00	17.28	PASS
5' OCL BHD Girder	0.02	8.50	21.28	8.00	28.94	PASS
12' OCL BHD Girder	0.02	9.00	12.00	8.00	17.28	PASS
5' OCL Tonnage Fr Flg	0.02	8.50	21.28	8.00	28.94	PASS

5.9 Bulkheads

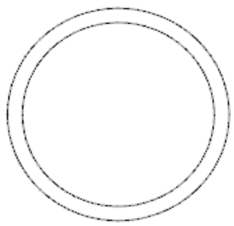
Bulkheads supporting girders or bulkheads fitted in lieu of girders are to be stiffened to provide supports not less effective than required for pillars.

4" Sch 40 pipe



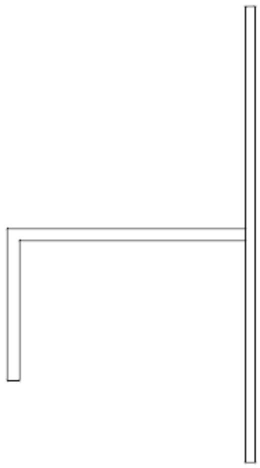
Area = 3.174048 (+/- 1.1e-05) square inches
Area Centroid = 155.523,54.59403,0 (+/- 0.0011,0.00038,0)
Area Moments:
First Moments
x: 493.6375 (+/- 0.0017)
y: 173.2841 (+/- 0.00061)
z: 0 (+/- 0)
Second Moments
xx: 76779.2 (+/- 1.3)
yy: 9467.51 (+/- 0.16)
zz: 0 (+/- 0)
Product Moments
xy: 26949.7 (+/- 0.47)
yz: 0 (+/- 0)
zx: 0 (+/- 0)
Area Moments of Inertia about World Coordinate Axes
Ix: 9467.51 (+/- 0.16)
Iy: 76779.2 (+/- 1.3)
Iz: 86246.7 (+/- 1.5)
Area Radii of Gyration about World Coordinate Axes
Rx: 54.6149 (+/- 0.00057)
Ry: 155.53 (+/- 0.0016)
Rz: 164.841 (+/- 0.0017)
Area Moments of Inertia about Centroid Coordinate Axes
Ix: 7.2326 (+/- 1.3e-05)
Iy: 7.2326 (+/- 1.3e-05)
Iz: 14.4652 (+/- 2.5e-05)
Area Principal Moments of Inertia about Centroid and Principal Axes
I1: 7.2326 , Direction (0.9555775, 0.29474 ,0)
I2: 7.2326 , Direction (-0.29474, 0.9555775 ,0)
I3: 0 , Direction (0, 0 ,1)
Area Radii of Gyration about Centroid Coordinate Axes
Rx: 1.509526 (+/- 3.9e-06)
Ry: 1.509526 (+/- 3.9e-06)
Rz: 2.134791 (+/- 5.6e-06)

5" Sch 80 pipe



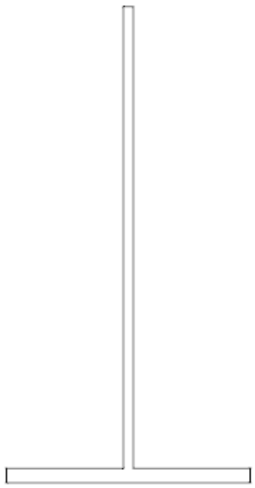
Area = 6.111969 (+/- 1.6e-05) square inches
Area Centroid = 154.7403,36.68607,0 (+/- 0.00083,0.0002,0)
Area Moments:
First Moments
x: 945.768 (+/- 0.0025)
y: 224.2241 (+/- 0.00061)
z: 0 (+/- 0)
Second Moments
xx: 146369 (+/- 2)
yy: 8246.57 (+/- 0.11)
zz: 0 (+/- 0)
Product Moments
xy: 34696.5 (+/- 0.47)
yz: 0 (+/- 0)
zx: 0 (+/- 0)
Area Moments of Inertia about World Coordinate Axes
Ix: 8246.57 (+/- 0.11)
Iy: 146369 (+/- 2)
Iz: 154616 (+/- 2.1)
Area Radii of Gyration about World Coordinate Axes
Rx: 36.73213 (+/- 0.0003)
Ry: 154.7512 (+/- 0.0012)
Rz: 159.0509 (+/- 0.0013)
Area Moments of Inertia about Centroid Coordinate Axes
Ix: 20.67065 (+/- 2.8e-05)
Iy: 20.67065 (+/- 2.8e-05)
Iz: 41.34131 (+/- 5.6e-05)
Area Principal Moments of Inertia about Centroid and Principal Axes
I1: 20.67065 , Direction (-0.994851, 0.1013483 ,0)
I2: 20.67065 , Direction (-0.1013483, -0.994851 ,-0)
I3: 0 , Direction (0, 0 ,1)
Area Radii of Gyration about Centroid Coordinate Axes
Rx: 1.83902 (+/- 3.7e-06)
Ry: 1.83902 (+/- 3.7e-06)
Rz: 2.600768 (+/- 5.3e-06)

6x3.5x0.3125 L Eff. Stanchion



```
Cumulative Area = 6.02734375 (+/- 1e-09) square inches for 2 objects
Cumulative Area Centroid = 157.14965,4.8626636,0 (+/- 1e-07,1e-09,0) for 2 surfaces
Cumulative Area Moments:
  First Moments
  x:  947.194961 (+/- 1e-07)
  y:  29.308945 (+/- 1e-08)
  z:  0 (+/- 0)
  Second Moments
  xx:  148889.453 (+/- 0.0001)
  yy:  183.56869 (+/- 1e-07)
  zz:  0 (+/- 0)
  Product Moments
  xy:  4614.77613 (+/- 1e-06)
  yz:  0 (+/- 0)
  zx:  0 (+/- 0)
  Area Moments of Inertia about World Coordinate Axes
  Ix:  183.56869 (+/- 1e-07)
  Iy:  148889.453 (+/- 0.0001)
  Iz:  149073.022 (+/- 0.0001)
  Area Radii of Gyration about World Coordinate Axes
  Rx:  5.51869413 (+/- 1e-09)
  Ry:  157.169759 (+/- 1e-07)
  Rz:  157.266618 (+/- 1e-07)
  Area Moments of Inertia about Centroid Coordinate Axes
  Ix:  41.0491503 (+/- 1e-08)
  Iy:  38.0962527 (+/- 1e-08)
  Iz:  79.145403 (+/- 1e-08)
  Area Principal Moments of Inertia about Centroid and Principal Axes
  I1:  30.5652047 ,   Direction ( 0.762860843, -0.646562707 ,0)
  I2:  48.5801984 ,   Direction ( 0.646562707, 0.762860843 ,0)
  I3:  0 ,   Direction ( 0, 0 ,1)
  Area Radii of Gyration about Centroid Coordinate Axes
  Rx:  2.60969111 (+/- 1e-09)
  Ry:  2.51407453 (+/- 1e-09)
  Rz:  3.62368023 (+/- 1e-09)
```

6x0.375 Tonnage BHD Flg



Area = 5.25 (+/- 1e-09) square inches
Area Centroid = 156.148251,-35.3357275,0 (+/- 1e-07,1e-08,0)
Area Moments:
First Moments
x: 819.778318 (+/- 1e-07)
y: -185.512569 (+/- 1e-07)
z: 0 (+/- 0)
Second Moments
xx: 128013.716 (+/- 0.0001)
yy: 6640.47173 (+/- 1e-06)
zz: 0 (+/- 0)
Product Moments
xy: -28967.4632 (+/- 1e-05)
yz: 0 (+/- 0)
zx: 0 (+/- 0)
Area Moments of Inertia about World Coordinate Axes
Ix: 6640.47173 (+/- 1e-06)
Iy: 128013.716 (+/- 0.0001)
Iz: 134654.188 (+/- 0.0001)
Area Radii of Gyration about World Coordinate Axes
Rx: 35.5647544 (+/- 1e-08)
Ry: 156.152378 (+/- 1e-07)
Rz: 160.151231 (+/- 1e-07)
Area Moments of Inertia about Centroid Coordinate Axes
Ix: 85.2501395 (+/- 1e-08)
Iy: 6.765625 (+/- 1e-09)
Iz: 92.0157645 (+/- 1e-08)
Area Principal Moments of Inertia about Centroid and Principal Axes
I1: 6.765625 , Direction (1, 1.43494579e-14 ,0)
I2: 85.2501395 , Direction (-1.43494579e-14, 1 ,0)
I3: 0 , Direction (0, 0 ,1)
Area Radii of Gyration about Centroid Coordinate Axes
Rx: 4.0296553 (+/- 1e-09)
Ry: 1.13520504 (+/- 1e-09)
Rz: 4.18650359 (+/- 1e-09)

3-2-7: Watertight Bulkheads and Doors

3 Arrangement of Watertight Bulkheads

3.1 Collision Bulkheads

3.1.1 General
A collision bulkhead is to be fitted on all vessels. It is to be intact, that is, without openings, except as permitted in 4-4-1/9.11. It is to extend, preferably in one plane, to the freeboard deck. In the case of vessels having long superstructures at the fore end, it is to be extended weathertight to the superstructure deck. The extension need not be fitted directly over the bulkheads below, provided the location of the extension meets the following requirements and the part of the deck which forms the step is made effectively weathertight.

On vessels with bow-doors, that part of their sloping loading ramps that form part of the extension of a collision bulkhead and are more than 2.3 m (7.5 ft) above the freeboard deck may extend forward of the limit below.

Collision bulkhead requirements for passenger vessels are as indicated in Part 5C, Chapter 7 of the Steel Vessel Rules.

3.1.2 Location
The collision bulkhead is to be located at any point not less than 0.05Lf abaft the reference point. At no point on vessels having 500 or more gross tonnage, except as specially permitted, is it to be further than 0.08Lf or 0.05Lf + 3 m (9.84 ft), whichever is greater, from the reference point.

where
Lf = freeboard length (ft)
X = Calculated position of watertight bulkhead (ft)

Member	Lf *(ft)*	dist *(ft)*	Xoffered *(ft)*
Minimum Position	182.1	9.11	11.06
Maximum Position	182.1	-	11.06

5 Construction of Watertight Bulkheads

5.1 Plating

Watertight bulkhead plating thickness is to be obtained from the following equation:

$t = sk\sqrt{(qh)}\ / c + 0.06$ in, but not less than 0.24 in or s/200+0.1in, whichever is greater

where

t = thickness, in mm (in)
s = spacing of stiffeners, in mm (in)
k = $(3.075\sqrt{(\alpha)} - 2.077)/(\alpha + 0.272)$ $(1 \leq \alpha \leq 2)$
= 1 $(\alpha > 2)$
α = aspect ratio of the panel (longer edge/shorter edge)
a = longer edge of the plate (in)
b = shorter edge of the plate (in)
q = 235/Y N/mm2 (24/Y kgf/mm2, 34,000/Y psi)
Y = specified minimum yield point or yield strength, in N/mm2 (kgf/mm2, psi), as defined in 2-1-1/13, for the higher strength material or 72% of the specified minimum tensile strength, whichever is less
h = distance from the lower edge of the plate to the deepest equilibrium waterline in the one compartment damaged condition, in m (ft)
= For passenger vessels, h is to be taken as not less than the distance to the margin line.
= For cargo vessels, h is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck as allowed in 3-1-1/13.1, in which case, h is to be not less than the distance to the designated freeboard deck at center.
c = 254 (460) for collision bulkhead
= 290 (525) for other watertight bulkheads

Member	a *(in)*	b *(in)*	α *(-)*	k *(-)*	Y *(psi)*	q *(-)*
Collision Bulkhead	24.00	126.00	5.25	1.00	34000	1.00
Transverse WT BHDs	24.00	126.00	5.25	1.00	34000	1.00
Ballast Tank BHDs	24.00	126.00	5.25	1.00	34000	1.00

Member	s *(in)*	h *(ft)*	c *(-)*	tmin *(in)*	treq *(in)*
Collision Bulkhead	24.00	10.50	460.00	0.24	0.23
Transverse WT BHDs	24.00	10.50	525.00	0.24	0.21
Ballast Tank BHDs	24.00	10.50	525.00	0.24	0.21

In general, main non-tight transverse strength bulkhead plating is to be similar to that required for watertight bulkheads. Other non-tight strength bulkheads plating is to be not less than s/150, or 4 mm (0.16 in.), whichever is greater. The section modulus of non-watertight bulkhead stiffeners is to be not less than one-half of that required by 3-2-7/5.3.

5.3 Stiffeners

The section modulus, SM of each bulkhead stiffener, in association with the plating to which it is attached, is to be not less than that obtained from the following equation:

$$SM = 0.0041chsl^2 \quad \text{in}^3$$

where

s = spacing of stiffeners, in m (ft)

l = distance, in m (ft), between the heels of the end attachments. Where horizontal girders are fitted, l is the distance from the heel of the end attachment to the first girder, or the distance between the horizontal girders.

h = distance from the middle of l to the deepest equilibrium waterline in the one compartment damaged condition, in m (ft)

= For passenger vessels, h is to be taken as not less than the distance to the margin line.

= For cargo vessels, h is to be taken as not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case, h is to be not less than the distance to the designated freeboard deck at center.

= For all vessels, where this distance is less than 6.10 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft).

c = 0.3 for a stiffener with effective brackets at both ends of its span. An effective bracket for the application of this value of c is to have scantlings not less than shown in 3-1-2/Table 3 and is to extend onto the stiffener for a distance at least one-eighth of the length, l, of the stiffener.

= 0.43 for a stiffener with an effective bracket at one end and a clip connection or horizontal girder at the other end. An effective bracket for the application of this value of c is to have scantlings not less than shown in 3-1-2/Table 3 and is to extend onto the stiffener for a distance at least one-eighth of the length, l, of the stiffener.

= 0.56 for a stiffener with clip connections at both ends or a clip connection at one end and a horizontal girder at the other end.

= 0.6 for a stiffener between horizontal girders or for a stiffener with no end attachments.

In vessels under 46 meters (150 ft) in length, the above values for c may be 0.29, 0.38, 0.46 and 0.58, respectively, and h may be taken as the distance in meters or in feet from the middle of l to the bulkhead deck at center in every case. For vessels between 46 and 65.5 meters (150 and 215 feet), intermediate values for c may be obtained by interpolation.

The section modulus of stiffeners on collision bulkheads is to be increased by 25% over the section modulus of stiffeners on ordinary watertight bulkheads.

Member	c *(-)*	h *(ft)*	s *(ft)*	l *(ft)*	SMreq *(in³)*
Watertight BHD 16/28 - CL Vertical	0.50	9.56	2.00	9.89	3.79
WT Door Mullion - CL Vertical	0.50	9.65	2.50	8.17	3.27
Watertight BHD 16/8 - OB Vertical	0.50	10.24	2.00	9.00	3.37
Watertight BHD 16/8 Sniped	0.59	10.24	2.00	7.50	2.77
Ballast Tank BHDs - Vertical	0.50	10.60	2.00	8.25	2.93
Ballast Tank BHDs - Sniped	0.59	10.60	2.00	8.25	3.47
Collision BHD 40 - Vertical	0.59	9.23	2.00	6.83	2.07

3-2-8: Deep Tanks

3 Construction

Boundary bulkheads and tight divisions of all deep tanks are to be constructed in accordance with the requirements of this section where they exceed those of Section 3-2-7. Where the specific gravity of the liquid exceeds 1.05, the design head, h, in this section is to be increased by the ratio of the specific gravity of 1.05.

This vessel has no tanks carrying liquids denser than SG = 1.05

5 Construction

5.1 Plating

The minimum thickness of deep-tank boundary bulkheads and tight divisions is to be obtained from the following equation:

t = (sk √(qh) /460) + 0.10 in, but not less than 0.25 in or *s* /150+0.10 in, whichever is greater

where

t = thickness, in in.

s = stiffener spacing, in in

k = (3.075 α − 2.077)/(α + 0.272) (1 ≤ α ≤ 2)

1.0 (α > 2)

q = 34,000/Y psi

Y = 34000

h = the greatest of the following distances, in m (ft), from the lower edge of the plate to:

A point located at two-thirds of the distance to the bulkhead or freeboard deck, or

A point located at two-thirds the distance from the top of the tank to the top of the overflow, or

The load line, or

A point located above the top of the tank, not less than the greater of the following: 0.01L + 0.15 m (0.5 ft), where L is as defined in 3-1-1/3, or 0.46 m (1.5 ft)

Member	s *(in)*	k *(-)*	q *(-)*	h *(ft)*	treq *(in)*
Ballast Tank BHDs	24.00	1.00	1.00	12.00	0.28

3-2-9: Superstructures and Deckhouses

1 Superstructure Scantlings

1.1 Side and Top Plating

The thickness of superstructure side plating is to be not less than that obtained from the requirements of 3-2-2/5. The thickness is also not to be less than that required by 3-2-9/3.5 for exposed aft-end bulkheads. Superstructure top plating is to be in accordance with Section 3-2-3.

3-2-2/5.1 Shell Plating - General

The side shell plating is not to be less in thickness than that obtained from the following equation:

$$t = \frac{s\sqrt{h}}{268} + 2.5 \quad \text{mm}$$

$$t = \frac{s\sqrt{h}}{485} + 0.10 \quad \text{in.}$$

where

- t = thickness, in mm (in)
- s = spacing of transverse frames or longitudinals, in mm (in)
- h = depth, in m (ft), as defined in 3-1-1/7, but not less than 0.1L or 1.18d, whichever is greater
- d = draft for scantlings, as defined in 3-1-1/9, or 0.066L, whichever is greater
- L = length of the vessel, as defined in 3-1-1/3

Member	s *(in)*	L *(ft)*	d *(ft)*	h *(ft)*	t_{req} *(in)*	t_{off} *(in)*
Superstructure Sides, Bulwarks	24.00	172.69	11.40	17.27	0.31	0.31

3-2-9/3.5: Exposed Bulkheads of Superstructures and Deckhouses

Calculations for superstructure bulkheads are included in Section 3-2-9/3.5

3-2-3: Deck Plating

Calculations for superstructure deck plating are included in Section 3-2-3.

1.3 Framing and Internal Bulkheads

Superstructure side frames are to be in accordance with 3-2-5/5.3. Bulkheads, partial bulkheads or web frames are to be fitted in the superstructure over the main hull bulkheads and elsewhere, as may be required to give effective transverse rigidity.

1.5 Breaks in Continuity

Breaks in the continuity of superstructures are to be specially strengthened (See 3-2-2/13). The arrangements in this area are to be clearly shown on the plans submitted for approval. Openings and changes in the scantlings of the decks and shell are to be kept well clear of the breaks.

1.7 Structural Support
Main bulkheads in the hull are to be arranged to provide support under the ends of the superstructures.

3 Exposed Bulkheads of Superstructures and Deckhouses
The scantlings of the exposed bulkheads of superstructures and deckhouses are to be in accordance with the following paragraphs, except that the requirements for house side stiffeners need not exceed the requirements of Section 3-2-5 for the side frames directly below the deck on which the house is located.

Special consideration may be given to the bulkhead scantlings of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse or which do not protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation or safety of the vessel.

Superstructures or deckhouses located within the midship 0.4L that have lengths greater than 0.1L are to have effective longitudinal scantlings to give a hull-girder section modulus through the superstructure or deckhouse meeting the requirements for the main hull-girder. The superstructure scantlings are to be in accordance with 3-2-9/1 and the house top and side plating of long deckhouses are to be not less than 0.009s + 0.8 mm (0.009s + 0.032 in) where s is the spacing of the deck beams in mm (in).

Partial bulkheads, deep webs, etc. are to be fitted at the ends and sides of large superstructures or deckhouses to provide resistance to racking.

In general, the first or lowest tier is that located on the freeboard deck. Where the depth to the uppermost continuous weather deck is such that the freeboard to this deck exceeds tabular freeboard by at least one standard superstructure height, deckhouses and superstructures on this weather deck may be considered second tier. Watertight bulkheads are to extend to this weather deck. This consideration of excess freeboard may be followed in a similar manner to determine third tier deckhouses or superstructures.

<u>3.3 Stiffeners</u>

Each stiffener, in association with the plating to which it is attached, is to have section modulus, SM, not less than that obtained from the following equation:

SM = $0.00185chsl^2$ in^3

where

s = stiffener spacing, in m (ft)

l = tween deck height or unsupported length, in m (ft)

h = a[(bf) – y]c, design head in m (ft). For unprotected front bulkheads on the lowest tier, h is to be taken as not less than 9.9 m (32.5 ft), and for sides and ends of first tier, h is to be taken as not less than 3.3 m (10.8 ft). For all other bulkheads the minimum value of h is to be not less than 1.25 + L/200 m (4.1 + L/200 ft).

a = coefficient given in 3-2-9/Table 1.

b = $1.0+\left[\frac{(x/L)-0.45}{C_b+0.2}\right]^2$ where $(x/L) \le 0.45$

b = $1.0+1.5\left[\frac{(x/L)-0.45}{C_b+0.2}\right]^2$ where $(x/L) > 0.45$

Cb = block coefficient at summer load waterline, based on the vessel's length, L, as defined in 3-1-1/3, not to be taken less than 0.60 nor greater than 0.80. For aft end bulkheads forward of amidships, Cb need not be taken as less than 0.80.

x = distance, in m (ft), between the after perpendicular and the bulkhead being considered. Deckhouse side bulkheads are to be divided into equal parts not exceeding 0.15L in length, and x is to be measured from the after perpendicular to the center of each part considered.

L = length of vessel, as defined in 3-1-1/3, in m (ft)

f = $(L/10)(e^{-L/300})-[1-(L/150)^2]$ for *L*, in m, see also 3-2-9/Table 2

$(L/10)(e^{-L/984})-[3.28-L/272)^2]$ for *L*, in ft, see also 3-2-9/Table 2

y = vertical distance, in m (ft), from the summer load waterline to the midpoint of the stiffener span.

c = (0.3 + 0.7b1/B1), but is not to be taken as less than 1.0 for exposed machinery casing bulkheads. In no case is b1/B1 to be taken as less than

b1 = breadth of deckhouse at position being considered, in m (ft)

B1 = actual breadth of vessel at the freeboard deck at the position being considered, in m (ft)

Where windows are fitted in bulkheads, the spacing, s, is to be the spacing of the mullion stiffeners. The mullion stiffeners are to extend continuously from deck to deck.

Member	x (ft)	L (ft)	x/L (-)	Bulkhead Location (-)	a (-)
Mn-01 Deck Ends	42.00	172.69	0.24	6 Aft ends, aft of amidships, All tiers	0.56
Mn-01 Deck Side, Ends	55.00	172.69	0.32	5 Sides, All tiers	0.85
Mn-01 Dk Side, Window	80.00	172.69	0.46	5 Sides, All tiers	0.85
Mn-01 Dk Side, Mullions	80.00	172.69	0.46	5 Sides, All tiers	0.85
Mn-01 Dk Side, Headers	80.00	172.69	0.46	5 Sides, All tiers	0.85
Mn-01 Deck Egen Inbd	40.00	172.69	0.23	5 Sides, All tiers	0.85
Mn-01 Deck Inboard Side	80.00	172.69	0.46	5 Sides, All tiers	0.85
01-Bridge Deck Ends	70.00	172.69	0.41	2 Unprotected front Second tier	1.44
01-Bridge Deck Side	82.00	172.69	0.47	5 Sides, All tiers	0.85
Pilot House Ends	70.00	172.69	0.41	3 Unprotected front Third tiers	0.85
Pilot House Side	82.00	172.69	0.47	5 Sides, All tiers	0.85
Pilot House Mullion	82.00	172.69	0.47	5 Sides, All tiers	0.85

Member	Cb (-)	b (-)	f (-)	b1 (ft)	B1 (ft)	c (-)
Mn-01 Deck Ends	0.60	1.08	11.61	45.00	46.00	0.98
Mn-01 Deck Side, Ends	0.60	1.03	11.61	45.00	46.00	1.00
Mn-01 Dk Side, Window	0.60	1.00	11.61	45.00	46.00	0.98
Mn-01 Dk Side, Mullions	0.60	1.00	11.61	45.00	46.00	0.98
Mn-01 Dk Side, Headers	0.60	1.00	11.61	45.00	46.00	0.98
Mn-01 Deck Egen Inbd	0.60	1.09	11.61	32.00	46.00	0.79
Mn-01 Deck Inboard Side	0.60	1.00	11.61	24.00	46.00	0.67
01-Bridge Deck Ends	0.60	1.00	11.61	32.00	46.00	0.79
01-Bridge Deck Side	0.60	1.00	11.61	32.00	46.00	0.79
Pilot House Ends	0.60	1.00	11.61	24.00	46.00	0.67
Pilot House Side	0.60	1.00	11.61	24.00	46.00	0.67
Pilot House Mullion	0.60	1.00	11.61	24.00	46.00	0.67

Member	y	h	s	l	SM_{req}	SM_{off}
	(ft)	*(ft)*	*(ft)*	*(ft)*	*(in³)*	*(in³)*
Mn-01 Deck Ends	11.00	10.80	2.00	9.96	3.90	3.95
Mn-01 Deck Side, Ends	11.00	10.80	2.00	9.96	3.96	4.03
Mn-01 Dk Side, Window	11.00	10.80	2.00	3.08	0.37	0.63
Mn-01 Dk Side, Mullions	11.00	10.80	8.00	9.96	15.61	16.05
Mn-01 Dk Side, Headers	11.00	10.80	3.83	8.00	4.83	5.27
Mn-01 Deck Egen Inbd	11.00	10.80	2.00	9.96	3.12	3.95
Mn-01 Deck Inboard Side	11.00	10.80	2.00	9.96	2.64	2.73
01-Bridge Deck Ends	20.50	4.96	2.00	9.00	1.17	1.59
01-Bridge Deck Side	20.50	5.66	2.00	9.00	1.34	1.59
Pilot House Ends	29.17	4.96	2.00	9.00	0.99	1.57
Pilot House Side	29.17	5.66	2.00	9.00	1.13	1.57
Pilot House Mullion	29.17	5.66	4.00	9.50	2.52	2.64

3.5 Plating

The plating is to be not less in thickness than that obtained from the following equation:

$$t = 3s\sqrt{h} \quad \text{mm}$$

$$t = s\sqrt{h}/50 \quad \text{in.}$$

where

s and h are as defined in 3-2-9/3.3 above. When determining h, y is to be measured to the middle of the panel. In no case is the thickness for bulkheads, other than the lowest tier, to be less than 5.0 mm (0.20 in). In addition, the thicknesses are to be not less than the following:

For the lowest tier and for deckhouses on the forecastle deck:

For front bulkheads:

$$t = (s/0.60)(6 + 0.02L) \quad \text{mm}$$

$$t = (s/1.97)(0.24 + 0.00024L) \quad \text{in.}$$

For side and end bulkheads:

$$t = (s/0.60)(5 + 0.02L) \quad \text{mm}$$

$$t = (s/1.97)(0.20 + 0.00024L) \quad \text{in.}$$

Where L is as defined in 3-2-9/3.3 and s is as defined in 3-2-9/3.3, but is not to be taken less than 0.60 m (1.97 ft).

Member	x (ft)	L (ft)	x/L (-)	Bulkhead Location (-)	a (-)
Mn-01 Deck Ends	42.00	172.69	0.24	6 Aft ends, aft of amidship	0.56
Mn-01 Deck Side, Ends	55.00	172.69	0.32	5 Sides, All tiers	0.85
Mn-01 Dk Side, Window	80.00	172.69	0.46	5 Sides, All tiers	0.85
Mn-01 Deck Egen Inbd	40.00	172.69	0.23	5 Sides, All tiers	0.85
Mn-01 Deck Inboard Side	80.00	172.69	0.46	5 Sides, All tiers	0.85
01-Bridge Deck Ends	70.00	172.69	0.41	2 Unprotected front Secon	1.44
01-Bridge Deck Side	82.00	172.69	0.47	5 Sides, All tiers	0.85
Pilot House Ends	70.00	172.69	0.41	3 Unprotected front Third	0.85
Pilot House Side	82.00	172.69	0.47	5 Sides, All tiers	0.85

Member	Cb (-)	b (-)	f (-)	b1 (ft)	B1 (ft)	c (-)
Mn-01 Deck Ends	0.52	1.08	11.61	45.00	46.00	0.98
Mn-01 Deck Side, Ends	0.52	1.03	11.61	45.00	46.00	0.98
Mn-01 Dk Side, Window	0.52	1.00	11.61	45.00	46.00	0.98
Mn-01 Deck Egen Inbd	0.52	1.09	11.61	32.00	46.00	0.79
Mn-01 Deck Inboard Side	0.52	1.00	11.61	24.00	46.00	0.67
01-Bridge Deck Ends	0.52	1.00	11.61	32.00	46.00	0.79
01-Bridge Deck Side	0.52	1.00	11.61	32.00	46.00	0.79
Pilot House Ends	0.52	1.00	11.61	24.00	46.00	0.67
Pilot House Side	0.52	1.00	11.61	24.00	46.00	0.67

Member	y (ft)	h (ft)	s (ft)	treq (in)	toffered (in)
Mn-01 Deck Ends	11.00	10.80	2.00	0.13	0.250
Mn-01 Deck Side, Ends	11.00	10.80	2.00	0.13	0.313
Mn-01 Dk Side, Window	11.00	10.80	2.00	0.13	0.313
Mn-01 Deck Egen Inbd	11.00	10.80	2.00	0.13	0.250
Mn-01 Deck Inboard Side	11.00	10.80	2.00	0.13	0.250
01-Bridge Deck Ends	20.50	4.96	2.00	0.09	0.250
01-Bridge Deck Side	20.50	10.80	2.00	0.13	0.250
Pilot House Ends	29.17	4.96	2.00	0.09	0.188
Pilot House Side	29.17	10.80	2.00	0.13	0.188

Appendix C

Equivalent Moment of Inertia and Shear Area

Equivalent Section Calculation

Equivalent moment of inertia calculations

Member	*Member Dimensions*	*SM $_{req}$ (in³)*	*d_web (in)*	*t_web (in)*	*Shear Area*	*MOI*
Bottom Trsv. Web (CL@Fr 0,4,8,12,24)	17.5x0.3 web w/ 1.05x0.25 flg	31.51	17.50	0.30	5.16	481.45
Bottom Trsv. Web (O/B)	14.33x0.26 web w/ 1.05x0.25 flg	19.65	14.33	0.26	3.77	251.37
Bottom Trsv. Half Frames (5'-12' OCL)	12.25x0.24 web w/ 1.05x0.25 flg	5.15	12.25	0.24	2.97	153.00

Member	*Member Dimensions*	*SM $_{off}$ (in³)*	*d_web (in)*	*t_web (in)*	*Shear Area*	*MOI*	
Bottom Trsv. Web (CL@Fr 0,4,8,12,24)	14.625 x 0.3125 web 6 x 0.375 flg	54.01	14.63	0.38	5.63	626.76	pass
Bottom Trsv. Web (O/B)	14x3x0.3125 FP	30.38	14.00	0.31	4.38	355.40	pass
Bottom Trsv. Half Frames (5'-12' OCL)	10.05x3x0.3125 FP	18.14	10.05	0.31	3.14	154.34	pass

Equivalent shear area

	Rule Minimum Shear Area				Offered Shear Area				
Member	*d_web (in)*	*t_web (in)*	*cutout (in)*	*Shear Area*	*d_web (in)*	*t_web (in)*	*cutout (in)*	*Shear Area*	
Main Deck Webs (CL)	7.00	0.30	2.80	1.2	14	0.3125	6.50	2.3	pass
Main Deck Webs (5'-12' OCL)	4.90	0.30	1.96	0.882	14	0.3125	6.50	2.34375	pass
Main Deck Webs (O/B)	6.65	0.30	2.66	1.197	14	0.3125	6.50	2.34375	pass