NEW LUMMI ISLAND FERRY

Scantling Calculations

Prepared for: Whatcom County Public Works • Bellingham, WA

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Elliott Bay Design Group
Architectural & Engineering Services for the Marine Industry

PREPARED BY

Elliott Bay Design Group
5305 Shilshole Ave. NW, Ste. 100
Seattle, WA 98107

REVISIONS

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1 PURPOSE

This report presents the structural scantling calculations performed for the New Lummi Island Ferry (LIF). The LIF is a 184 ft x 54 ft x 13.25 ft, 34 car, 150 passenger, double-ended ferry with a maximum loaded draft of 7.50 ft. The vessel will be owned and operated by Whatcom County Public Works (WCPW).

The new ferry is intended to replace Whatcom County's current ferry (M/V WHATCOM CHIEF) on the same route between the ferry terminals on Lummi Island and the mainland at Gooseberry Point. American Bureau of Shipping Rules for Building and Classing Steel Vessels Under 90 Meters (295 Feet) in Length [1] were followed for the calculations.

2 PROCEDURE

2.1 General Overview

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

2.2 Scantling Requirements

Calculations are preformed to determine the required scantlings for all general structure throughout the vessel. Measurements are taken from the vessel drawings. 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 Scantling Requirements

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

3 ASSUMPTIONS

- The vessel hull and supporting structure is to be constructed of ABS Grade A or ASTM A36
- The vessel superstructure is to be constructed of 5086 and 6061 aluminum alloy.
- The vessel is longitudinally framed. Web frames support the longitudinal stiffeners at 4ft spacings. All web frames are sized for 4ft spacing.
- Ordinary frame spacing is 48 inches.

4 CONCLUSIONS

The scantling summary details the minimum and installed dimensions.

5 REFERENCES

[1] *Rules for Building and Classing Steel Vessels Under 90m,* American Bureau of Shipping, 2019.
[2] *Midship Section,* 19078.01-002-120-0, Rev. - , Elliott Bay Design Group
[3] *Profiles and Deck Arrangements,* 19078.01-002-101-1, Rev. -, Elliott Bay Design Group

Appendix A

Scantling Calculations Summary

SCANTLING SUMMARY

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

PLATING

Structural properties not calculated for installed members

Properties of Min. Member

Member	*Installed Nominal Member Dimensions*	*Minimum Member Dimensions*	t_{req} *(in)*	t_{req} *(in)*	t_{req} *(in)*	$t_{offered}$ *(in)*
Hull Plating						
Bottom Shell	0.375	0.375	0.318	0.248		**0.375**
Side Shell - Amidship	0.375	0.313	0.307			**0.313**
Side Shell - IWO Impact	0.500	0.375	0.358			**0.375**
Side Shell - At Ends	0.375	0.375	0.365			**0.375**
Deck Plating						
Main Deck	0.375	0.375	0.236	0.374	0.200	**0.375**
Main Deck House	0.375	0.250	0.188		0.200	**0.250**
Upper Deck	0.3125 - Aluminum	0.313	0.188	0.270	0.200	**0.313**
Deck House Top	0.3125 - Aluminum	0.250	0.170	0.245	0.200	**0.250**
Pilot House Deck	0.3125 - Aluminum	0.313	0.190	0.274	0.200	**0.313**
Pilot House Top	0.3125 - Aluminum	0.313	0.190	0.274	0.200	**0.313**
Superstructure Plating - All Aluminum						
Bulwarks	0.313	0.313	0.203	0.293	0.200	**0.313**
Superstructure Sides	0.313	0.313	0.203	0.293	0.200	**0.313**
Main Dk Inboard BHD	0.313	0.250	0.066	0.095	0.200	**0.250**
House End BHD	0.313	0.250	0.148	0.213	0.200	**0.250**
Deck House Sides	0.313	0.250	0.148	0.213	0.200	**0.250**
Pilot House Sides	0.313	0.250	0.148	0.213	0.200	**0.250**
			0.045			**0.063**

Bulkhead Plating

Collision Bulkhead, 18	0.313	0.313	0.240	0.208	0.288	**0.313**
WT BHDs 8, 14	0.313	0.313	0.240	0.175	0.280	**0.313**
Nontight BHDs (Long'l/xverse)	0.313	0.250	0.160		0.200	**0.250**

STIFFENERS

Structural properties not calculated for installed members

Properties of Min. Member

Member	*Installed Nominal Member Dimensions*	*Minimum Member Dimensions*	SM_{req} *(in³)*	$SM_{offered}$ *(in³)*
Hull Stiffeners				
Bottom Stiffs		4x0.25 FB	1.34	**1.45**
Bilge Stiffs		3.5x0.25 FB	1.10	**1.14**
Bottom Stiffs in Tanks		5x0.25 FB	2.07	**2.19**
Side Stiffeners				
Side Shell Long'l Stiffs		8x0.25 FB	3.86	**5.22**
Deck Stiffeners				
Main Deck		120x8 Bulb Flat	3.68	**3.79**
Main Deck House		2x0.1875 FB	0.20	**0.28**
Upper Deck		2x0.1875 FB	0.15	**0.30**
Deck House Top		2x0.1875 FB	0.15	**0.31**
Pilot House Deck		2x0.1875 FB	0.14	**0.31**
Pilot House Top		2x0.1875 FB	0.14	**0.31**

Superstructure Stiffeners

Bulwarks	3.5x1/4 FB	3.5x0.25 FB	0.49	1.05	**1.06**
Superstructure Sides	3.5x1/4 FB	3.5x0.25 FB	0.49	1.05	**1.06**
Main Dk Inboard BHD	3.5x1/4 FB	3.5x0.25 FB	0.49	1.05	**1.06**
House End BHD	3.5x1/4 FB	3.5x0.25 FB	0.43	0.91	**1.11**
Deck House Sides	5x1/4 FB	5x0.25 FB	0.72	1.53	**2.06**
Pilot House Sides	5x1/4 FB	2.5x0.1875 FB	0.15	0.31	**0.44**

Bulkhead Stiffeners

Collision Bulkhead - 18	5x3x1/4 L	5 x 3.5 x 0.25 L	5.79		**6.01**
WT BHDs 8, 14	5x3x1/4 L	4 x 3 x 0.25 L	2.97		**4.03**
Nontight BHDs (Long'l/xverse)	3x2x1/4 L	3 x 3 x 0.1875 L	1.61		**2.13**

GIRDERS

Structural properties not calculated for installed members

Properties of Min. Member

Member	*Installed Nominal Member Dimensions*	*Minimum 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)*
Box Keel	48 x 0.375 web 10 x 1 flg	48 x 0.28 web, 6 x 0.55 flg	0.33	0.38	8.87	**10.00**
Hull Girders	*Failing installed members fail the section depth requirement only. They have plenty of section modulus.*					
Bottom Web Frame	18x4x0.375 FP		15.93	15.97	0.28	**61.62**
Longitudinal Girder	20x4x0.375 FP		27.65	14.88	0.27	**71.86**
Side Web Frames	20x4x0.375 FP		15.54	18.38	0.30	**72.75**
Main Deck Web Frame	15x4x0.375 FP		39.47	6.65	0.31	**45.35**
Main Deck CL Long'l Girder	18 x 0.375 web 6 x 0.75 flg		68.01	11.20	0.34	**108.82**
Main Deck Long'l Girder - 9' OCL	18x4x0.375 FP		17.44	4.90	0.00	**59.05**

House Girders

Failing installed members fail the section depth requirement only. They have plenty of section modulus.

House Mullions	6 x .25 web 4 x .625	30.76	0.00	0.00	**31.91**
Deck House Trans. Girders	6 x .25 web 4 x .25	2.64	0.00	0.00	**8.74**
Pilot House Mullions	6 x .25 web 3 x .25	5.42	0.00	0.00	**6.46**

STANCHIONS

Properties of Min. Member

Member	*Installed Nominal Member Dimensions*	*Minimum Member Dimensions*	W_{req} *(LT)*	$W_{offered}$ *(LT)*
Hull Stanchions	8" SCH 40		40.15	**53.97**

Appendix B

Scantling Calculations

3-1-1: Definitions

3 Length

3.1 Scantling Length (L)

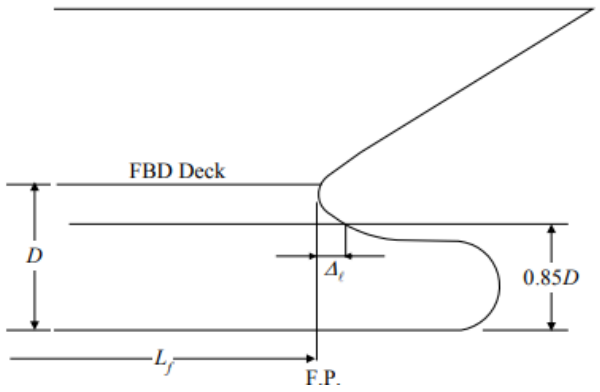
L is the distance in meters (feet) on the summer load line from the fore side of the stem to the centerline of the rudder stock. For use with the Rules, L is not to be less than 96% and need not be greater than 97% of the length on the summer load line. The forward end of L is to coincide with the fore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

SLL = 179.67 ft
L = 174.28 ft

3.3 Freeboard Length (L_f)

L_f 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, L_f, 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 = 54.00 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 = 12.75 ft

7.3 Scantling Depth (D_s)

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

D_s = 13.25 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 =	7.75	ft
Design Draft	DWL =	7.75	ft
Hull Depth	D =	12.75	ft
Draft for Scantlings	draft = Max(SWL, DWL, 0.66D)	8.42	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 = 641.0 LT

11.3 Block Coefficient

C_b is the block coefficient obtained from the following equation:

$C_b = 35\Delta/LBd$

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

B_{wl} = the greatest molded breadth at summer load line

Item	Formula	Value	Units
Molded Displacement	Δ =	641.00	LT
Scantling Length	L =	174.28	ft
Draft	d =	7.75	ft
Molded Breadth	B_{wl} =	54.00	ft
Block Coefficient	C_b =	0.31	-

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

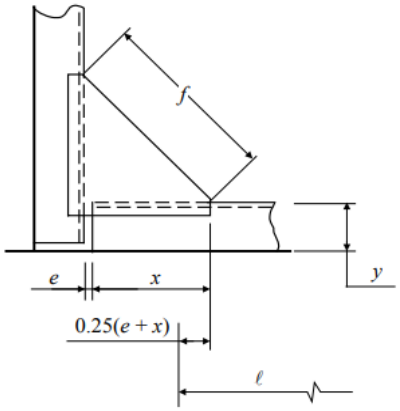


TABLE 5
Brackets

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:

$SM = C1*C2*L^2*B*(Cb + 0.7)$ ft-in²

where

C_1 = $30.67 - 0.299L$ $40 \le L < 59$ ft
= $22.40 - 0.158L$ $59 \le L < 79$ ft
= $15.20 - 0.067L$ $79 \le L < 115$ ft
= $11.35 - 0.033L$ $115 \le L < 150$ ft
= 6.4 $150 \le L < 200$ ft
= $0.0137L + 3.65$ $200 \le L < 295$ ft

C_2 = 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)

C_b = block coefficient at design draft, based on the length, L, measured on the design load waterline. C_b is not to be taken as less than 0.60.

L (ft)	B (ft)	C_b (-)	C_1 (-)	C_2 (-)	SM_{req} ($ft\text{-}in^2$)	$SM_{offered}$ ($ft\text{-}in^2$)
174.28	54.00	0.60	6.40	0.000144	1965	1894

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

LEGEND

n = Number of members
t = Thickness of member (in)
L = Length of member (in)
Y = Distance from reference axis to member area centroid (in)
θ = Angle of member relative to reference axis (deg)

I = Member moment of inertia about it's own axis (in^4)
A = Member cross sectional area (in^2)
Y_{NA} = $\sum(AY) / \sum(A)$ (in)
M = $\sum(I) + \sum(AY^2) - \sum(A * Y_{NA}^2)$
SM = M / Dist from NA to ref axis

Member	n	t	L	Y	θ	A	I	AY	AY2
Keel Plate - Center	1.0	0.500	36.0	-0.25	0.0	18.00	0.00	-4.50	1.13
Keel - Side	2.0	0.375	47.0	23.5	90.0	35.25	6,488.94	828.38	19,466.81
Keel - Flange	2.0	1.000	10.0	47.5	0.0	20.00	1.67	950.00	45,125.00
Bottom Shell	2.0	0.375	239.7	20.5	4.3	179.81	4,889.18	3,693.24	75,857.37
Side Shell	2.0	0.375	130.0	85.4	59.2	97.50	101,290.04	8,324.79	44,110.00
Side Guard - Side	2.0	0.500	15.3	148.5	90.0	15.33	299.93	2,275.76	337,950.73
Deck	1.0	0.375	648.0	158.5	0.0	243.00	2.85	38,520.36	6,106,247.47
CVK	1.0	0.750	8.0	4.0	90.0	6.00	0.00	24.00	96.00
Bottom 9.5' OCL Longitudinal Web	2.0	0.375	20.0	21.7	90.0	15.00	0.00	325.55	7,065.63
Deck 9.5' OCL Longitudinal Web	2.0	0.375	18.0	150.3	90.0	13.50	0.00	2,029.50	305,100.15
Deck 9.5' OCL Longitudinal Flg	2.0	0.375	4.0	141.2	0.0	3.00	0.00	423.45	59,769.97
					Sums	**646.39**	**112,973**	**57,391**	**7,000,790**

Distance To Extreme Fiber (in): 159.0

Distance from neutral axis (NA) to reference axis (Y_{NA}) = **88.79** in

Moment of inertia about NA (M) = **2,018,248** in^4 **14,016** in^2-ft^2

Section modulus to reference axis = **22,731** in^3 **1,894** in^2-ft

Section modulus to extreme fiber = **28,745** in^3 **2,395** in^2-ft

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)	t_{req} (in)
Bottom Shell	24.00	11.50	17.43	0.318

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
SM_R = hull girder section modulus required by 3-2-1/3, in cm2-m (in2-ft)
SM_A = 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 (-)	SM_R ($ft\text{-}in^2$)	SM_A ($ft\text{-}in^2$)	Q (-)	t_{req} (in)
Bottom Shell	24.00	55.00	1964.98	6097.57	1.00	0.25

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)	t_{req} (in)
Side Shell - Amidship	24.00	174.28	11.50	17.43	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)	t_{req} (in)
Side Shell - IWO Impact	24.00	174.28	11.50	17.43	0.36

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)	t_{req} (in)
Side Shell - At Ends	30.00	174.28	0.36

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	t_{req} (in)
Main Deck	0.20
Main Deck House	0.20
Upper Deck	0.20
Deck House Top	0.20
Pilot House Deck	0.20
Pilot House Top	0.20

3.1 All Decks

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

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/m^3 (715 kgf/m^3, 45 lbf/ft^3)], 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/m^2 (2636 kgf/m^2, 540 lbf/ft^2), this head is to be increased in proportion to the added loads which will be imposed on the structure.

Member	*s* (in)	*h* (ft)	t_{req} (in)
Main Deck	18.00	12.00	0.24

Elsewhere, the value of *h* is to be not less than that obtained from the appropriate equation below, where *L* is the length of vessel in m (ft), as defined in 3-1-1/3.

3.1.1 Exposed Freeboard Deck Having No Deck Below

$h = 0.028*L + 3.57$ ft

Member	*s* (in)	*L* (ft)	*h* (ft)	t_{req} (in)
Main Deck	32.00	174.28	8.45	0.30

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

$h = 0.028*L + 2.14$ ft

Member	*s* (in)	*L* (ft)	*h* (ft)	t_{req} (in)
Not used				

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

$h = 0.014*L + 2.86$ ft

Member	*s* (in)	*L* (ft)	*h* (ft)	t_{req} (in)
Main Deck House	17.50	174.28	5.30	0.19
Upper Deck	17.50	174.28	5.30	0.19
Deck House Top	14.00	174.28	5.30	0.17
Pilot House Deck	18.00	174.28	5.30	0.19
Pilot House Top	18.00	174.28	5.30	0.19

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)
Box Keel	0.33	0.28	8.87	7.44

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:

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

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* *(in^3)*
Box Keel	0.915	12.75	13.50	16.00	165.31
Bottom Web Frame	0.915	12.75	4.00	9.13	15.93
Longitudinal Girder	0.915	12.75	8.00	8.50	27.65
Engine Girder - NOT USED	0.915	12.00	3.17	3.00	1.28

Note: This equation is not meant for the CVK

5.3.2 Depth

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)	h_{cutout} (ft)	$h_{w\,req}$ (in)
Bottom Web Frame	9.125	0.000	15.97
Longitudinal Girder	8.500	0.000	14.88
Engine Girder - NOT USED	3.000	0.000	5.25

5.3.3 Thickness

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

$t = 0.01 * h_w + 0.12$

$t = 0.01h_w + 3$ mm

$t = 0.01h_w + 0.12$ in.

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)	t_{req} (in)
Bottom Web Frame	16.0	0.280
Longitudinal Girder	14.9	0.269
Engine Girder - NOT USED	5.3	0.173

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:

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

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)	SM_{req} (in^3)
Bottom Stiffs	0.800	12.75	2.00	4.00	1.34
Bilge Stiffs	0.800	10.50	2.00	4.00	1.10
Bottom Stiffs in Tanks	1.000	15.75	2.00	4.00	2.07

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

5 Transverse Side Frames

5.1 Section Modulus

The section modulus, SM, of each transverse side frame other than tween deck frames above the chine or upper turn of bilge, in association with the plating to which the frame is attached, is not to be less than that obtained from the following equation. See 3-2-5/Figure 1, 3-2-5/Figure 2 and 3-2-5/Figure 3.

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

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 decks or inner bottoms, the length l may be measured as permitted therein. Where tween decks are located above the frame, l is to be taken as the length between the toes of the brackets, except where beam knees are fitted on alternate frames, l is to be increased by one half the depth of the beam knees. l is not to be taken less than 2.1 m (7.0 ft).

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 $0.4l$, whichever is greater, plus $bh_1/33$ ($bh_1/100$).

h_1 = vertical distance, in m (ft), from the deck at the top of the 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/m^3 (45 lbf/ft^3), h_1 is to be adjusted accordingly.

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

c = 0.915 for frames having no tween decks above

= 0.90 + 5.8/l3 (0.90 + 205/l3) for frames having tween decks above

Member	c (-)	h (ft)	s (ft)	l (ft)	SM_{req} (in^3)
Side Shell Long'l Stiffs	0.915	10.50	2.00	7.00	3.86
House Mullions	0.915	10.80	8.00	9.50	29.25

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:

$SM = 0.0041 c h s l^2$ 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	0.915	6.90	4.00	12.25	15.54

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 req *(in)*	treq *(in)*
Side Web Frames	12.25	4.00	18.38	0.30

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.

11 Side Stringers

11.1 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:

$SM = 0.0041 chsl^2$ in³

where

s = sum of the half lengths, in m (ft), (on each side of the stringer) of the frames supported.

l = span, in m (ft), between web frames, or between web frame and bulkhead. Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by transverse

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

= for stringers above the lowest deck or at a similar height in relation to the design draft, not less than given in 3-2-5/5.3 appropriate to the tween deck location.

= for stringers in the peaks of vessels 61 m (200 ft) or greater in length, not less than given in 3-2-5/5.5.

c = 0.915 aft of the forepeak

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

Member	c (-)	h (ft)	s (ft)	l (ft)	SM_{req} (in^3)
Side Longitudinal Girders - NOT USEI	0.915	6.00	7.50	13.00	28.53
Not Used	0.915	6.00	7.50	9.00	13.67

11.3 Proportions

Side stringers are to have a depth of not less than 0.125l (1.5 in per ft of span l) plus one-quarter of the depth of the slot for the frames, but need not exceed the depth of the web frames to which they are attached. In general, the depth is not to be less than 2.5 times the depth of the slots, or the slots are to be fitted with filler plates. The thickness of each stringer is to be not less than 0.014L + 7.2 mm (0.00017L + 0.28 in) where L is as defined in 3-1-1/3.

Member	l (ft)	hcutout (in)	h_web req (in)	treq (in)
Side Longitudinal Girders - NOT USEI	13.00	6.00	19.50	0.32
Not Used	9.00	6.00	15.00	0.27

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:

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

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 deck
= 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 cm^2-m (in^2-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 cm^2-m^2 (in^2-ft^2)

The values of I_A 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/m^3 (715 kgf/m^3, 45 lbf/ft^3), 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/m^2 (2636 kgf/m^2, 540 lbf/ft^2), this head is to be increased in proportion to the added loads which will be imposed on the structure.

Member	Beam Type	SM_R $(in^2\text{-}ft)$	Y (-)	IA (-)	k (-)	c (-)
Main Deck	Longl					0.70
Main Deck House	Longl					0.70
Upper Deck	Longl					0.70
Deck House Top	Longl					0.70
Pilot House Deck	Longl					0.70
Pilot House Top	Longl					0.70

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)	SM_{req} (in^3)
Main Deck	0.70	1.3.1	55.00	1.46	4.00	3.68
Main Deck House	0.70	1.3.1	12.00	1.46	4.00	0.80
Upper Deck	0.70	1.3.1	3.00	1.46	4.00	0.20
Deck House Top	0.70	1.3.4	2.74	1.17	4.00	0.15
Pilot House Deck	0.70	1.3.5	2.00	1.50	4.00	0.14
Pilot House Top	0.70	1.3.6	1.50	2.00	4.00	0.14

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)	SM_{req} (in^3)
Main Deck Web Frame	0.60		44.44	4.00	9.50	39.47
Main Deck CL Long'l Girder	0.60		12.00	9.00	16.00	68.01
Main Deck Long'l Girder - 9' OCL	0.60		12.00	9.23	8.00	17.44
Deck House Trans. Girders	0.60		2.74	8.00	7.00	2.64

11.3 Proportions

The minimum depth of a deck girder or transverse supporting member is to be $58.3l$ mm ($0.7l$ 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)	$h_{w\,req}$ (in)	h_{cutout} (in)	$h_{w\,req}$ (in)	$h_{w\,req}$ (in)	$hw_{offered}$ (in)
Main Deck Web Frame	9.50	6.65	0.00	0.00	6.65	15.00
Main Deck CL Long'l Girder	16.00	11.20	0.00	0.00	11.20	18.00
Main Deck Long'l Girder - 9' OCL	8.00	5.60	1.00	2.50	5.60	18.00
Deck House Trans. Girders	7.00	4.90	0.00	0.00	4.90	6.00

Member	h_w (in)	t_{req} (in)	$t_{offered}$ (in)
Main Deck Web Frame	15.00	0.31	0.38
Main Deck CL Long'l Girder	18.00	0.34	0.38

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:

$$W_a = (k - nl/r)A$$

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 cm^2 (in^2)

Member	k (-)	n (-)	l (ft)	r (in)	A (in^2)	W_a (LTf)
Hull Stanchions	7.83	0.345	8.17	2.95	7.85	53.97

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
Hull Stanchions	0.02	9.13	55.00	4.00	40.15	PASS

3-2-7: Watertight Bulkheads and Doors

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 $s/200+0.1$ in, whichever is greater

where

t = thickness, in mm (in)

s = spacing of stiffeners, in mm (in)

k = $(3.075\sqrt{(\alpha)} - 2.077)/(\alpha + 0.272)$ $(1 \le \alpha \le 2)$

= 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/mm^2 (24/Y kgf/mm^2, 34,000/Y psi)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, 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, 18	84.00	108.00	1.29	0.90	34000	1.00
WT BHDs 8, 14	84.00	96.00	1.14	0.86	34000	1.00

Member	s (in)	h* (ft)	c (-)	t_{min} (in)	t_{req} (in)
Collision Bulkhead, 18	25.00	9.00	460.00	0.24	0.21
WT BHDs 8, 14	25.00	8.00	525.00	0.24	0.18

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.

Member	s *(in)*	treq *(in)*
Nontight BHDs (Long'l/xverse)	24.00	0.16

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:

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

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 *(in^3)*
Collision Bulkhead - 18	0.57	8.30	2.08	10.75	5.79
WT BHDs 8, 14	0.57	7.60	2.08	9.00	2.97
WT BHD 47	0.57	8.20	2.08	10.50	4.36
WT BHD 53	0.57	7.20	2.08	8.00	2.22
WT BHD 59	0.57	6.40	2.08	6.00	1.11
WT BHD 63	0.57	6.40	2.08	6.00	1.11
Nontight BHDs (Long'l/xverse)	0.39	8.40	2.00	11.00	1.61

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 = $(sk\ \sqrt{(qh)}/460) + 0.10$ in, but not less than 0.25 in or s/150+0.10 in, whichever

where

t = thickness, in in.

s = stiffener spacing, in in

k = $(3.075\ \alpha - 2.077)/(\alpha + 0.272)$ $(1 \leq \alpha \leq 2)$

1.0 $(\alpha > 2)$

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)	t_{req} (in)
Collision Bulkhead, 18	25.00	1.00	1.00	12.00	0.29
WT BHDs 8, 14	25.00	1.00	1.00	11.00	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 = $s\sqrt{(h)} / 268 + 2.55$ mm
t = $s\sqrt{(h)} / 485 + 0.10$ 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)
Bulwarks	12.00	174.28	11.50	17.43	0.20	0.31
Superstructure Sides	12.00	174.28	11.50	17.43	0.20	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.

3.3 Stiffeners

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 $(x/L) > 0.45$

C_b = 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, C_b need not be taken as less

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 = $(0.3 + 0.7b_1/B_1)$, but is not to be taken as less than 1.0 for exposed machinery casing bulkheads. In no case is b_1/B_1 to be taken as less than 0.25

b_1 = breadth of deckhouse at position being considered, in m (ft)

B_1 = 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 (-)
Bulwarks	168.00	174.28	0.96	5 Sides, All tiers	0.85
Superstructure Sides	161.33	174.28	0.93	5 Sides, All tiers	0.85
Main Dk Inboard BHD	136.00	174.28	0.78	5 Sides, All tiers	0.85
House End BHD	136.00	174.28	0.78	5 Sides, All tiers	0.85
House Mullions	136.00	174.28	0.78	5 Sides, All tiers	0.85
Pilot House Mullions	87.14	174.28	0.50	3 Unprotected front	0.85
Pilot House Sides	87.14	174.28	0.50	4 Protected front All tiers	0.85

Member	C_b (-)	b (-)	f (-)	b_1 (ft)	B_1 (ft)	c (-)
Bulwarks	0.60	2.54	11.73	53.00	54.00	0.99
Superstructure Sides	0.60	2.32	11.73	53.00	54.00	0.99
Main Dk Inboard BHD	0.60	1.64	11.73	53.00	54.00	0.99
House End BHD	0.60	1.64	11.73	53.00	54.00	0.99
House Mullions	0.60	1.64	11.73	53.00	54.00	0.99
Pilot House Mullions	0.60	1.01	11.73	16.00	54.00	0.51
Pilot House Sides	0.60	1.01	11.73	16.00	54.00	0.51

Member	y (ft)	h (ft)	s (ft)	l (ft)	SM_{req} (in^3)	SM_{off} (in^3)
Bulwarks	10.00	16.67	1.00	4.00	0.49	1.06
Superstructure Sides	10.00	14.49	1.00	4.00	0.43	2.06
Main Dk Inboard BHD	19.00	10.80	2.25	4.00	0.72	1.06
House End BHD	27.00	10.80	1.67	9.52	3.02	1.11
House Mullions	27.00	10.80	8.00	9.52	14.49	31.91
Pilot House Mullions	27.00	4.97	8.00	8.58	5.42	6.46
Pilot House Sides	27.00	4.97	1.00	4.00	0.15	0.44

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 (-)
Bulwarks	168.00	174.28	0.96	5 Sides, All tiers	0.85
Superstructure Sides	161.33	174.28	0.93	1 Unprotected front Lowe	2.44
Main Dk Inboard BHD	136.00	174.28	0.78	5 Sides, All tiers	0.85
House End BHD	136.00	174.28	0.78	5 Sides, All tiers	0.85
Pilot House Sides	87.14	174.28	0.50	4 Protected front All tiers	0.85

Member	C_b (-)	b (-)	f (-)	b_1 (ft)	B_1 (ft)	c (-)
Bulwarks	0.31	2.54	11.73	53.00	54.00	0.99
Superstructure Sides	0.31	2.32	11.73	53.00	54.00	0.99
Main Dk Inboard BHD	0.31	1.64	11.73	53.00	54.00	0.99
House End BHD	0.31	1.64	11.73	53.00	54.00	0.99
Pilot House Sides	0.31	1.01	11.73	16.00	54.00	0.51

Member	y (ft)	h (ft)	s (ft)	t_{req} (in)	$t_{offered}$ (in)
Bulwarks	10.00	16.67	1.00	0.08	0.250
Superstructure Sides	10.00	41.43	1.00	0.13	0.250
Main Dk Inboard BHD	19.00	10.80	1.00	0.07	0.250
House End BHD	27.00	10.80	2.25	0.15	0.250
Pilot House Sides	27.00	4.97	1.00	0.04	0.063

5 Enclosed Superstructures

5.3 Sills of Access Openings

Except as otherwise provided in these Rules, the height of the sills of access openings in bulkheads at the ends of enclosed superstructures is to be at least 380 mm (15 in) above the deck. See 3-2-12/Table 1 for required sill heights.

7 Open Superstructure

Superstructures with openings which do not fully comply with 3-2-9/5 are to be considered as open superstructures. See also 3-2-14/5.7.

9 Deckhouses

Deckhouses are to comply with 3-2-9/3. Bulkheads are to be arranged as necessary in the main hull to support deckhouses.

The closing appliances for the openings in deckhouse bulkheads are to comply with 3-2-9/5.1. Doors for access openings into deckhouses are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements, permanently attached to the bulkhead or to the doors themselves, and the doors are to be arranged so that they can be operated from both

10 Aluminum Deckhouses

10.1 Scantling Correction

Where deckhouses are constructed of aluminum alloys, the required plate thickness and stiffener section modulus, SM, are first to be determined as required for steel deckhouses, and are then to be increased by the material factor, Q_0, as indicated below.

For all deck and bulkhead plating and stiffeners, the required thickness and section modulus for aluminum alloy plate and shapes are obtained from the following equations:

where

t_{al} = minimum thickness of aluminum plate

t_s = required plate thickness for steel obtained from 3-2-3/3 for decks a 9/3.5 for side and end bulkheads

SM_{al} = minimum section modulus of aluminum stiffeners

SM_s = minimum section modulus of steel stiffeners, as determined from 3-2-6/3 for deck stiffeners and 3.2.9/3.3 for bulkhead stiffeners

Q = material factor, as determined from 3-2-9/10.3 below

Q_0 = material factor, as determined from 3-2-9/10.3 below

Deck Plating:

$$t_{al} = \frac{0.9(Q + \sqrt{Q})}{2} t_s$$

Member	t_s (in)	Q (-)	t_{al} req (in)	t_{al} offered (in)
Upper Deck	0.19	1.84	0.27	0.3125 - Aluminum
Deck House Top	0.17	1.84	0.25	0.3125 - Aluminum
Pilot House Deck	0.19	1.84	0.27	0.3125 - Aluminum
Pilot House Top	0.19	1.84	0.27	0.3125 - Aluminum

Bulkhead Plating

Member	t_s (in)	Q (-)	t_{al} req (in)	t_{al} offered (in)
Bulwarks	0.20	1.84	0.29	0.31
Superstructure Sides	0.20	1.84	0.29	0.31
Main Dk Inboard BHD	0.07	1.84	0.09	0.31
House End BHD	0.15	1.84	0.21	0.31
Deck House Sides	0.15	1.84	0.21	0.31
Pilot House Sides	0.15	1.84	0.21	0.31

Deck and Bulkhead Stiffeners

Member	SM_s (in^3)	Q_0 (-)	SM_{al} req (in^3)	SM_{al} offered (in^3)
Bulwarks	0.49	2.36	1.05	1.06
Main Dk Inboard BHD	0.49	2.36	1.05	1.06
House End BHD	0.43	2.36	0.91	1.11
Deck House Sides	0.72	2.36	1.53	2.06
Pilot House Sides	0.15	2.36	0.31	0.44
House Mullions	14.49	2.36	30.76	31.91
Deck House Trans. Girders	2.64	2.36	5.62	8.74
Pilot House Mullions	5.42	2.36	11.51	6.46

10.3 Material Factors

The material factor, Q, is obtained from the following equation:

$Q = 0.9 + (120/Y_{al})$ SI Units

$Q = 0.9 + (12/Y_{al})$ MKS Units

$Q = 0.9 + (17000/Y_{al})$ U.S. Units

but is not to be taken as less than Q_0 below.

Member	Y_{al} (psi)	Q_0 (-)	Q (-)
Generic			
Decks	18000.00	1.59	1.84
Cut Plates	14000.00	1.88	2.11
Shapes	15000.00	2.36	2.03

The material factor, Q0, is obtained from the following equation:

$Q_0 = 635/(\sigma_y + \sigma_u)$ SI Units

$Q_0 = 65/(\sigma_y + \sigma_u)$ MKS Units

$Q_0 = 92000/(\sigma_y + \sigma_u)$ U.S. Units

where

Y_{al} = minimum yield strength of the welded aluminum alloy under consideration at 2% offset in a 254 mm (10 in.) gauge length, in N/mm2 (kgf/mm2, psi), in accordance with the requirements of the table below

σ_u = minimum ultimate strength of the welded aluminum alloy under consideration, in N/mm2 (kgf/mm2, psi), in accordance with the table

σ_y = minimum yield strength of the welded aluminum alloy under consideration, in N/mm2 (kgf/mm2, psi), in accordance with the table below

Member	Aluminum Alloy		σ_u (psi)	σ_y (psi)	Q_0 (-)
Generic					
Decks	5083.00		40000.00	18000.00	1.59
Cut Plates	5086.00		35000.00	14000.00	1.88
Shapes	6061.00		24000.00	15000.00	2.36