



GUIDE FOR

ALTERNATIVE REQUIREMENTS FOR HULL CONSTRUCTION OF VESSELS INTENDED TO CARRY VEHICLES (130 METERS OR MORE IN LENGTH)

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Foreword

This Guide provides alternative requirements to Part 5C, Chapter 10 of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)* for hull construction of vessels intended to carry vehicles, which can be applied to receive the classification notation **✱ A1 Vehicle Carrier**. The classification notation **SH, SHCM**, will only be granted when the design is based on the criteria of this Guide.

This Guide reflects industry trends by including requirements based on ABS SafeHull, total strength assessment, and hull girder ultimate strength.

This Guide becomes effective on the first day of the month of publication.

After a certain period of trial use, the criteria contained in this Guide will be incorporated and published in the *Steel Vessel Rules*. ABS encourages and welcomes at any time the submission of comments on this Guide.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



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SECTION 1 Introduction

1 General

1.1 Classification

In accordance with the requirements found in 1-1-3/3 of the *ABS Rules for Conditions of Classification (Part 1)* and 5C-10-1/1 of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*, the classification notation **✕ A1 Vehicle Carrier** is to be assigned to vessels with ro-ro cargo spaces or vehicle spaces designed for carriage of unoccupied vehicles without cargo and built to the requirements of this Guide and other relevant sections of the *Steel Vessel Rules*. In addition, the classification notation **SH, SHCM** is to be assigned to vessels complying with this Guide.

1.3 Optional Class Notation for Design Fatigue Life

Vessels designed and built to the requirements in this Guide and other relevant requirements of the Rules are intended to have a structural fatigue life of not less than 20 years. Where a vessel's design calls for a fatigue life in excess of the minimum design fatigue life of 20 years, the optional class notation **FL (year)** will be assigned at the request of the applicant. This vessel is eligible for the notation provided the excess design fatigue life is verified to be in compliance with the criteria in Appendix 3, "Rule-based Fatigue Strength Assessment" of this Guide. Only one design fatigue life value is published for the entire structural system. Where differing design fatigue life values are intended for different structural elements within the vessel, the (year) refers to the least of the varying target lives. The 'design fatigue life' refers to the target value set by the applicant, not the value calculated in the analysis.

The notation **FL (year)** denotes that the design fatigue life assessed according to Appendix 3 is greater than the minimum design fatigue life of 20 years. The **(year)** refers to the fatigue life equal to 25 years or more (in 5-year increments) as specified by the applicant. The fatigue life will be identified in the *Record* by the notation **FL (year)** (e.g., **FL(30)** if the minimum design fatigue life assessed is 30 years).

1.5 Application

1.5.1 General

Due to the similarity of structural arrangements, this Guide has many cross-references to the general requirements for hull construction in Part 3 of the *Steel Vessel Rules*, specifically the requirements found in Part 5C, Chapter 10 of the *Steel Vessel Rules* for vessels intended to carry vehicles. These cross-references are presented in a simple format throughout the Guide in order to provide quick reference to the users, (i.e., 1-2-3/4.5.6 of the Rules denotes Part 1, Chapter 2, Section 3/Subparagraph 4.5.6 of the Rules).

1.5.2 Size and Proportion

The requirements contained in this Guide are applicable to vehicle carriers for unrestricted service, having lengths of 130 meters (427 feet) or more, and having parameters within the ranges as specified in 3-2-1/1 of the *Steel Vessel Rules*.

1.5.3 Direct Calculations

The hull structure and critical structural details are to comply with the requirements of the Dynamic Loading Approach and Spectral Fatigue Analysis. For analysis using the Dynamic Loading Approach, acceptance of an equivalent method can be considered by ABS.

The racking stress of hull structure and critical details are to be evaluated using a full ship finite element model.

At the request of the Owner, the vessel will be identified in the *Record* by the notations **SH-DLA** and **SFA**.

1.5.4 SafeHull Construction Monitoring Program

For the class notation **SH, SHCM**, a Construction Monitoring Plan for critical areas, prepared in accordance with the requirements of Part 5C, Appendix 1 of the *Steel Vessel Rules*, is to be submitted for approval prior to commencement of fabrication. See Part 5C Appendix 1, "SafeHull Construction Monitoring Program" of the *Steel Vessel Rules*.

1.7 Internal Members

1.7.1 Section Properties of Structural Members

The geometric properties of structural members may be calculated directly from the dimensions of the section and the associated effective plating (see 3-1-2/13.3 of the *Steel Vessel Rules* or Section 5, Figure 3 of this Guide, as applicable). For structural members with angle θ (see Section 1, Figure 1) between web and associated plating not less than 75 degrees, the section modulus, web sectional area, and moment of inertia of the standard ($\theta = 90$ degrees) section may be used without modification. Where the angle θ is less than 75 degrees, the sectional properties are to be directly calculated about an axis parallel to the associated plating (see Section 1, Figure 1).

For longitudinals, frames and stiffeners, the section modulus may be obtained by the following equation:

$$SM = \alpha_{\theta} SM_{90}$$

where

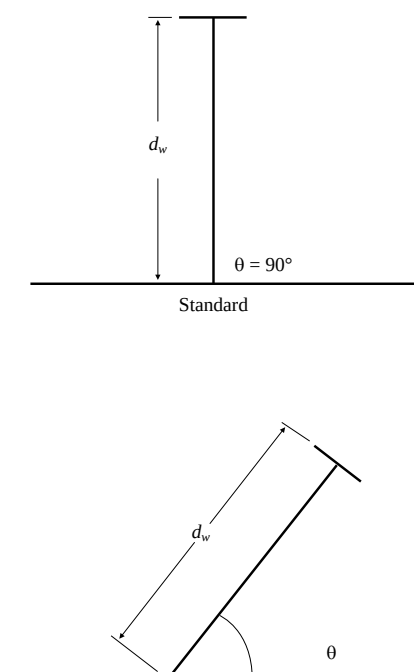
$$\alpha_{\theta} = 1.45 - 40.5/\theta$$

$$SM_{90} = \text{section modulus at } \theta = 90 \text{ degrees}$$

1.7.2 Detailed Design

The detail design of internals is to follow the guidance given in 3-1-2/15 of the *Steel Vessel Rules*. For more information, see Appendix 3 "Rule Based Fatigue Strength Assessment" of this Guide.

FIGURE 1



1.9 Breaks

Special care is to be taken to provide structural reinforcements against local stresses at the ends of the cargo hold spaces, superstructures, etc., and throughout the structure in general. The main longitudinal bulkheads are to be suitably tapered at their ends. Where effective longitudinal bulkheads are provided in the poop or deckhouse, they are to be located such as to provide effective continuity between the structure in way of and beyond the main cargo spaces.

1.11 Additional Plans and Documents to be Submitted

In addition to information called for elsewhere in this Guide, plans and documents describing the following are to be submitted for review:

- Arrangement of the bow or stern ramps and movable decks, if any
- Information on masses of ramps and movable decks, if any
- Arrangement of connections of ramps, lifting, and/or hoisting appliances to the hull structures, with indication of design loads (amplitude and direction)
- Arrangements of hydraulic jacks connections to the hull, if fitted

Plans and documents describing the following are to be submitted for information:

- Arrangements of securing and locking devices
- Arrangement of vehicles including the securing and load bearing arrangements, axle load, axle spacing, number of wheels per axle, wheel spacing, and size of tire print
- Arrangements of hoisting devices
- Arrangements of hydraulic jacks, if fitted

In addition, any plans and documents required for review are to be submitted when certification or classification is requested in compliance with the *ABS Guide for Certification of Lifting Appliances*.

1.13 Units

This Guide is written in three systems of units, SI units, MKS units, and US customary units. Each system is to be used independently of any other system. Unless indicated otherwise, the format of presentation in this Guide of the three systems of units is as follows:

SI units (MKS units, US customary units)



SECTION 2 Design Consideration and General Requirements

1 General Requirements

1.1 General

The proposed scantlings are to comply with the requirements specified in this Guide. Owner's extra scantlings (i.e., Owner's specified additional thickness), as included in the vessel's design specifications, are not to be used in the evaluation. The requirements in this Guide are based on the gross scantling approach except for Subsection 4/5.

1.3 Initial Scantling Criteria

The initial thickness of plating, the section modulus of longitudinals/stiffeners, and the scantlings of main supporting members are to be determined in accordance with Section 4. The scantlings that comply with the requirements in Section 4 are to be used for further assessment as required in the following paragraphs.

1.5 Total Strength Assessment – Failure Modes

A total strength assessment of the structures, determined on the basis of the initial scantling criteria in Section 4 is to be carried out against the following three failure modes:

1.5.1 Material Yielding

The calculated stress intensities are not to be greater than the yielding state limit given in Subsection 6/5 for the applicable load cases specified in 5/3.1 and 5/3.3.

1.5.2 Buckling and Ultimate Strength

For each individual member, plate, or stiffened panel, the buckling and ultimate strength is to be in compliance with the requirements specified in Subsection 6/7 for the applicable load cases specified in 5/3.1 and 5/3.3.

1.5.3 Fatigue

The fatigue strength of structural details and welded joints in highly stressed regions is to be analyzed in accordance with Subsection 6/9 for the applicable load cases specified in 5/3.5.



SECTION 3 Dynamic Load Criteria

1 General

For strength assessment against the yielding and buckling failure modes, the dynamic load criteria represent the long-term extreme values for the North Atlantic, corresponding to a probability of exceedance of 10^{-8} . For vessels serving in more severe seas, the dynamic load criteria are to be modified. These dynamic load criteria have an implied ship speed of zero knots in extreme sea conditions with exception of the impact load criteria. The ship speed used to calculate bow wave impact, bow flare slamming, flat bottom slamming, green water and cargo sloshing are to be taken as 75% of the design speed (MCR).

For strength assessment against the fatigue failure mode, the dynamic load criteria represent the characteristic values for the North Atlantic, corresponding to a probability of exceedance of 10^{-4} . These dynamic load criteria have an implied ship speed equal to 75% of the design speed (MCR).

The following dynamic load components are to be considered in the evaluation of hull structures:

- Vertical and horizontal wave-induced bending moments
- Vertical and horizontal wave-induced shear forces
- External pressure
- Internal pressure
- Bow wave impact
- Bow flare slamming for forebody structures
- Bottom slamming for forebody structures
- Green water
- Deck loads

The load combination factors for the dynamic load components and dominant parameters are included in the load formulae in this Section, but their actual values are specified in Section 5.

3 Definitions

3.1 Symbols

B	molded breadth, in m (ft), as defined in 3-1-1/5 of the <i>Steel Vessel Rules</i>
C_b	block coefficient at the scantling draft, as defined in 3-1-1/11.3 of the <i>Steel Vessel Rules</i>
D	molded depth, in m (ft), as defined in 3-1-1/7.1 of the <i>Steel Vessel Rules</i>
d_f	scantling draft, in m (ft)
GM	metacentric height, in m (ft)
L	scantling length, in m (ft), as defined in 3-1-1/3.1 of the <i>Steel Vessel Rules</i>
L_{BP}	length between perpendiculars, in m (ft)
V	service speed, in knots
V_d	design speed (MCR), in knots

3.3 Coordinate Systems

Two sets of Cartesian coordinate systems are used to describe dynamic load criteria. When alternative coordinate systems are used, attention is to be paid to the default coordinate systems used in the dynamic load formulae.

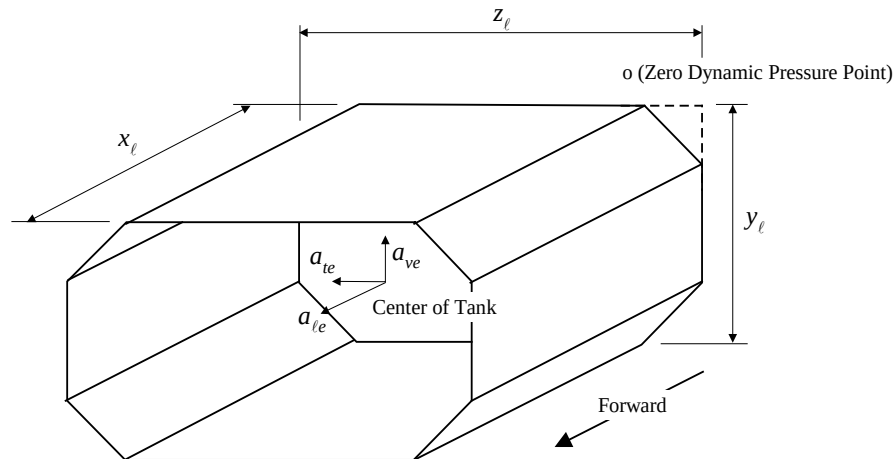
3.3.1 Ship Coordinate System for Ship Motion and External Pressure

Origin	Intersection of the AP section, waterline and centerline planes.
x_T	Longitudinal distance from AP to the center of gravity of the tank with contents, in m (ft), positive toward bow.
y_T	Vertical distance from the waterline to the center of gravity of the tank with contents, in m (ft), positive above and negative below the waterline.
z_T	Transverse distance from the centerline to the center of gravity of the tank with contents, in m (ft), positive toward starboard.
x	Longitudinal distance from the AP to the external pressure point considered, in m (ft).
x_0	Longitudinal distance from the AP to the reference station, in m (ft). The reference station is the point along the vessel's length where the wave trough or crest is located and may be taken at the mid-length of the considered tank.

3.3.2 Local Coordinate System for Internal Pressure

Origin	Intersection of the vertical, horizontal and transverse planes that are tangential to the envelope of the tank. This origin is also referred to as the zero dynamic pressure point. For example, the zero dynamic pressure point in Section 3, Figure 1 is located at the upper corner of the aft transverse bulkhead on the port side, and the forward portion of the tank on the starboard side is under high dynamic pressure and is targeted for strength assessment.
x_ℓ	Longitudinal distance from the zero dynamic pressure point of the tank to the pressure point, $x_\ell = x_0 - x_p$, in m (ft).
y_ℓ	Vertical distance from the zero dynamic pressure point of the tank to the pressure point, $y_\ell = y_0 - y_p$, in m (ft).
z_ℓ	Transverse distance from the zero dynamic pressure point of the tank to the pressure point, $z_\ell = z_0 - z_p$, in m (ft).
$a_{\ell e}$	Dimensionless longitudinal acceleration
a_{te}	Dimensionless transverse acceleration
a_{ve}	Dimensionless vertical acceleration
x_0	Zero dynamic pressure point x_0 taken as: a) Forward bulkhead for $k_{cl} > 0$ b) Aft bulkhead of the tank for $k_{cl} < 0$
z_0	Zero dynamic pressure point z_0 taken as: a) Tank top towards port side for $k_{ct} < 0$ b) Tank top towards starboard side for $k_{ct} > 0$
y_0	The zero dynamic pressure point y_0 is always taken as top of tank

FIGURE 1
Tank Coordinate System for Internal Pressure



5 Vertical Wave-induced Bending Moment

The vertical wave-induced bending moment, in kN-m (tf-m, Ltf-ft), may be obtained from the following equations:

$$M_{ws} = -k_1 k_w k_p k_{cmv} m_v C_1 L^2 B (C_b + 0.7) \times 10^{-3} \quad \text{Sagging Moment}$$

$$M_{wh} = +k_2 k_w k_p k_{cmv} m_v C_1 L^2 B C_b \times 10^{-3} \quad \text{Hogging Moment}$$

where

$$k_1 = 110 \text{ (11.22, 1.026)}$$

$$k_2 = 190 \text{ (19.37, 1.772)}$$

$$C_1 = 10.75 - \left(\frac{300 - L}{100} \right)^{1.5} \quad 130 \leq L < 300 \text{ m}$$

$$= 10.75 \quad 300 \leq L < 350 \text{ m}$$

$$= 10.75 - \left(\frac{L - 350}{150} \right)^{1.5} \quad 350 \leq L < 500 \text{ m}$$

$$= 10.75 - \left(\frac{984 - L}{328} \right)^{1.5} \quad 427 \leq L < 984 \text{ ft}$$

$$= 10.75 \quad 984 \leq L < 1148 \text{ ft}$$

$$= 10.75 - \left(\frac{L - 1148}{492} \right)^{1.5} \quad 1148 \leq L < 1640 \text{ ft}$$

$$k_{cmv} = \text{load combination factor for design vertical wave-induced bending moment}$$

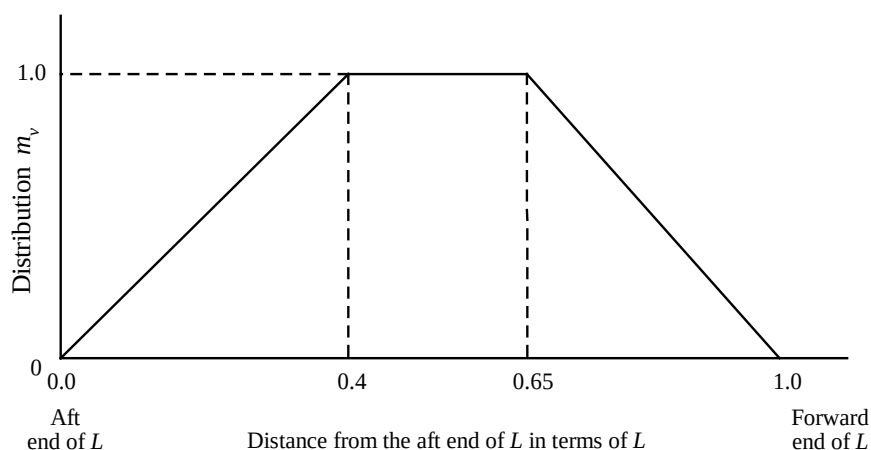
$$= 1.0 \text{ for initial scantling criteria in Section 4}$$

$$= \text{load combination factor for total strength assessment specified in Section 5, Tables 1 and 2}$$

k_p	=	load factor for adjusting the probability of exceedance
	=	1.0 for yielding and buckling strength assessment
	=	0.5 for fatigue strength assessment
m_v	=	distribution factor for vertical wave-induced bending moment (see Section 3, Figure 2)
k_w	=	$(1.84 - 0.56C_b)$ for wave sagging bending moment used in formulation and assessment of local structural elements and members in 4/5.1 and 4/5.3
	=	1.0 for wave hogging bending moment used in formulation and assessment of local structural elements and members in 4/5.1 and 4/5.3
	=	$(1.09 + 0.029V - 0.47C_b)^{0.5}$ for wave hogging and sagging bending moments used in fatigue strength formulation in Subsection 5/3 and Appendix 3
V	=	75% of the design speed, V_d , in knots

C_b is as defined in 3-1-1/11.3 of the *Steel Vessel Rules* and is not to be taken less than 0.6.

FIGURE 2
Distribution Factor for Vertical Wave-induced Bending Moment m_v



7 Vertical Wave-induced Shear Force

The envelopes of the maximum wave-induced shear forces, F_w , expressed in kN (tf, Ltf), may be obtained from the following equations:

$$F_{wp} = +k k_w F_1 C_1 L B (C_b + 0.7) \times 10^{-2} \quad \text{For positive shear force}$$

$$F_{ws} = -k k_w F_2 C_1 L B (C_b + 0.7) \times 10^{-2} \quad \text{For negative shear force}$$

where

$$k = 30 (3.059, 0.2797)$$

$$F_1 = \text{distribution factor as shown in Section 3, Figure 3}$$

$$F_2 = \text{distribution factor as shown in Section 3, Figure 4}$$

$k_w = 1.0$ for nominal wave-induced positive and negative shear forces in determination of shearing strength in Section 4

$(1.09 + 0.029V - 0.47C_b)^{0.5}$ for positive and negative wave-induced shear forces used in fatigue strength formulation in Appendix 3

$V = 75\%$ of the design speed, V_d , in knots

C_1 is as given in Subsection 3/5.

C_b is as defined in 3-1-1/11.3 of the *Steel Vessel Rules* and is not to be taken less than 0.6.

FIGURE 3
Distribution Factor for Shear Forces F_1

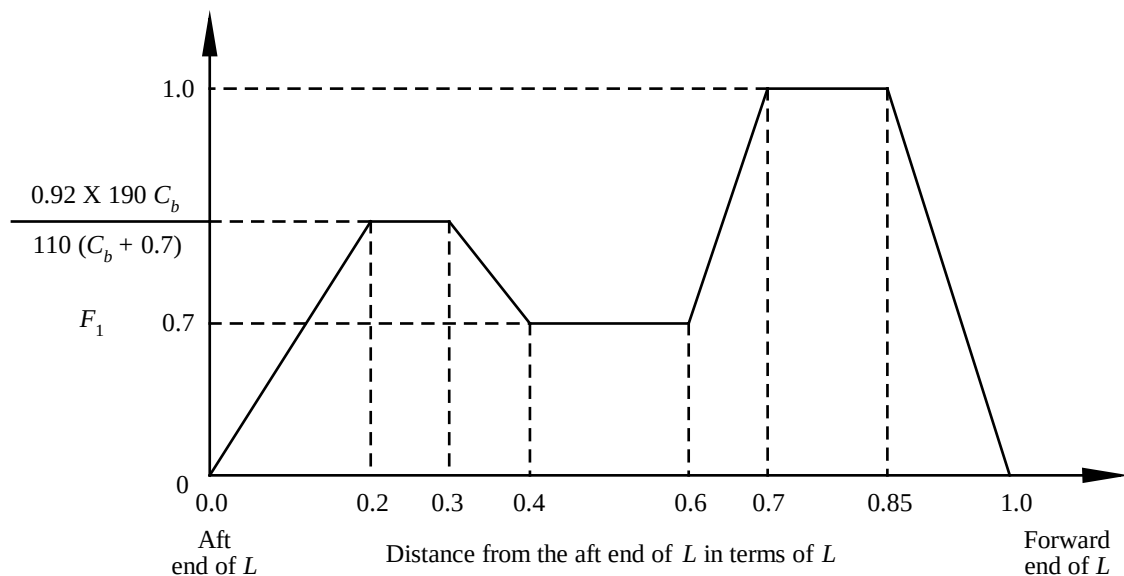
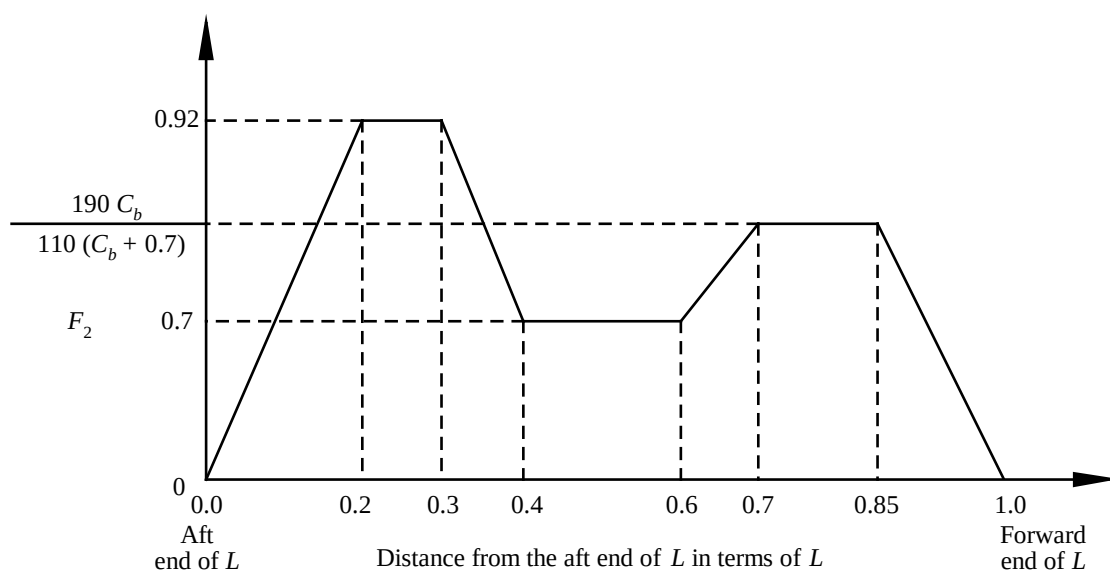


FIGURE 4
Distribution Factor for Shear Forces F_2



9 Horizontal Wave Bending Moment

The horizontal wave-induced bending moment, in kN-m (tf-m, Ltf-ft), positive (tension port) or negative (tension starboard), may be obtained from the following equation.

$$M_h = \pm k k_p k_w k_{cmh} m_h C_1 L^2 D(C_b + 0.7) \times 10^{-3}$$

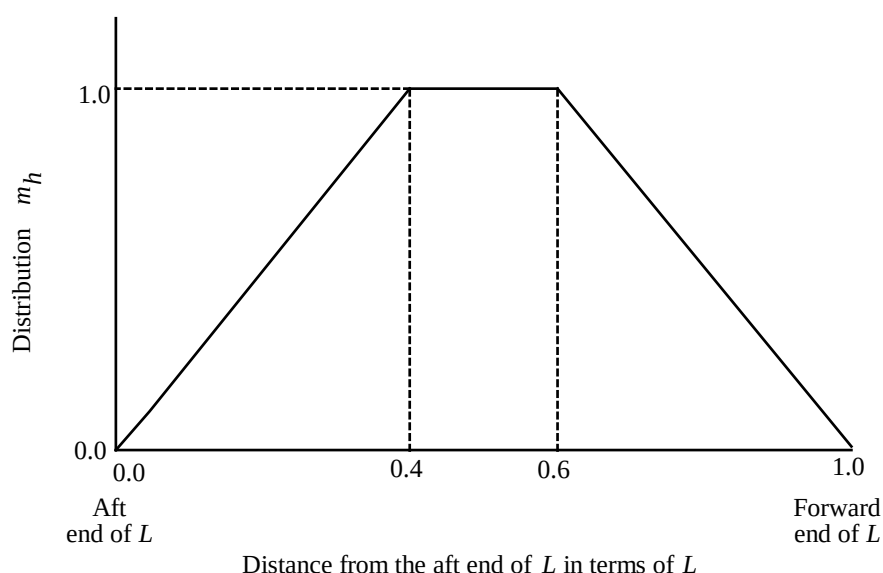
where

- k = 104.2 (10.62, 0.973)
 k_{cmh} = load combination factor for design horizontal wave-induced bending moment
 = 1.0 for initial scantling criteria in Section 4
 = load combination factor for total strength assessment specified in Section 5, Tables 1 and 2
 k_p = load factor for adjusting the probability of exceedance
 = 1.0 for yielding and buckling strength assessment
 = 0.5 for fatigue strength assessment
 m_h = distribution factor for horizontal wave-induced bending moment (see Section 3, Figure 5)
 k_w = $(1.61 - 0.47C_b)^{0.5}$ for strength formulation and assessment of local structural elements and members in 4/5.1 and 4/5.3
 $(1.09 + 0.029V - 0.47C_b)^{0.5}$ for fatigue strength formulation in Subsection 5/3 and Appendix 3
 V = 75% of the design speed, V_d , in knots

C_1 is as given in Subsection 3/5.

C_b is as defined in 3-1-1/11.3 of the *Steel Vessel Rules* and is not to be taken less than 0.6.

FIGURE 5
Distribution Factor for Horizontal Wave-induced Bending Moment m_h



11 External Pressure

The external pressure, p_e , positive toward inboard, in N/cm^2 (kgf/cm^2 , lbf/in^2), with waves approaching the hull from the starboard side can be expressed by the following equation at a given cross section:

$$p_e = \rho(h_s + 1.36 k_p k_s k_{ce} k_d \alpha C_1) \times 10^{-4} \geq 0$$

where

α	=	$0.75 - 1.25 \sin \mu$	waterline, port
	=	$0.2 - 0.4 \sin \mu + 0.1 \cos \mu$	bilge, port
	=	$0.3 - 0.2 \sin \mu$	centerline, bottom
	=	$0.4 - 0.1 \cos \mu$	bilge, starboard
	=	$1.0 - 0.25 \cos \mu$	waterline, starboard
k_d	=	$[1 + 9k_{\ell o} - 1)\cos \mu]$	for initial scantling requirement in Section 4
	=	$\left\{1 - \left[1 - \cos \frac{2\pi(x - x_o)}{L}\right] \cos \mu\right\} [1 + (k_{\ell o} - 1)\cos \mu]$	for total strength assessment requirement in Section 5
μ	=	wave heading angle, to be taken from 0° to 90° (0° for head sea, 90° for beam sea, waves approaching the hull from the starboard side)	
h_s	=	hydrostatic pressure head in still water, in m (ft)	
k_{ce}	=	load combination factor for external pressure for strength formulation and assessment of local structural elements and members, as specified in 4/5.1 and 4/5.3.	
	=	load combination factor for total strength assessment specified in Section 5, Tables 1 and 2	
k_p	=	load factor for adjusting the probability of exceedance	
	=	1.0	for yielding and buckling strength assessment
	=	0.5	for fatigue strength assessment
k_s	=	1.0	for yielding and buckling strength assessment
	=	$(1.09 + 0.029V - 0.47C_b)^{0.5}$	for fatigue strength assessment
ρ	=	specific weight of sea water in $1.005\text{N/cm}^2\text{-m}$ (0.1025 kgf/m , $0.4444\text{ lbf/in}^2\text{-ft}$)	

C_1 and is as given in Subsection 3/5 and the pressure distribution factor, $k_{\ell o}$, may be taken from Section 3, Table 1 or Section 3, Figure 6. A negative combination factor, k_{ce} , signifies that the wave trough is on the starboard side.

FIGURE 6
Pressure Distribution Function k_{lo}

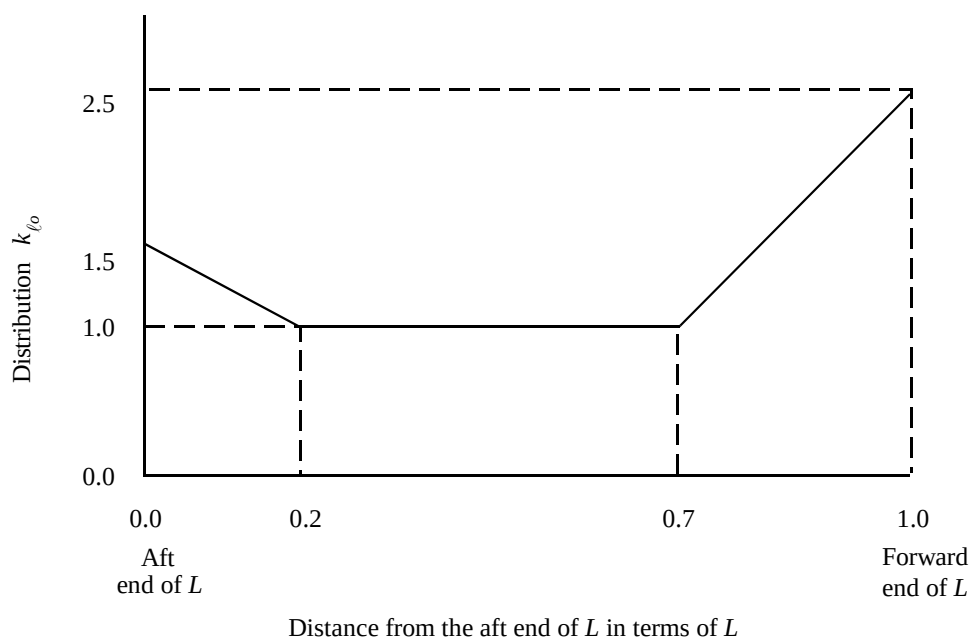


TABLE 1
 k_{lo} Coefficient

$[x_o - (L_{BP} - L)]/L$	k_{lo}	$[x_o - (L_{BP} - L)]/L$	k_{lo}	$[x_o - (L_{BP} - L)]/L$	k_{lo}
0.000	1.500	0.175	1.063	0.850	1.750
0.025	1.438	0.200 ~ 0.700	1.000	0.875	1.875
0.050	1.375	0.725	1.125	0.900	2.000
0.075	1.313	0.750	1.250	0.925	2.125
0.100	1.250	0.775	1.375	0.950	2.250
0.125	1.188	0.800	1.500	0.975	2.375
0.150	1.125	0.825	1.625	1.000	2.500

The external pressure may be calculated for the reference section at x_o and the pressure variation over the length of the global hold finite element model may be ignored. The reference section may be taken at the mid-length of the targeted cargo area. However, the pressure variation along the girth of the reference section is to be accounted for and can be represented by the pressure values at the following five points, as shown in Section 3, Figure 7:

- E1 waterline, port
- E2 bilge, port
- E3 centerline, bottom
- E4 bilge, starboard
- E5 waterline, starboard

A positive dynamic pressure may be assumed to vary linearly above the waterline at E1 on the port side, as illustrated in Section 3, Figure 7. The zero pressure point is defined by h_1 , which is equal to the dynamic pressure head.

When a negative dynamic pressure is found, for example, at the waterline at E5 on the starboard side in Section 3, Figure 7, the zero pressure point can be defined by h_2 , which can be calculated as follows:

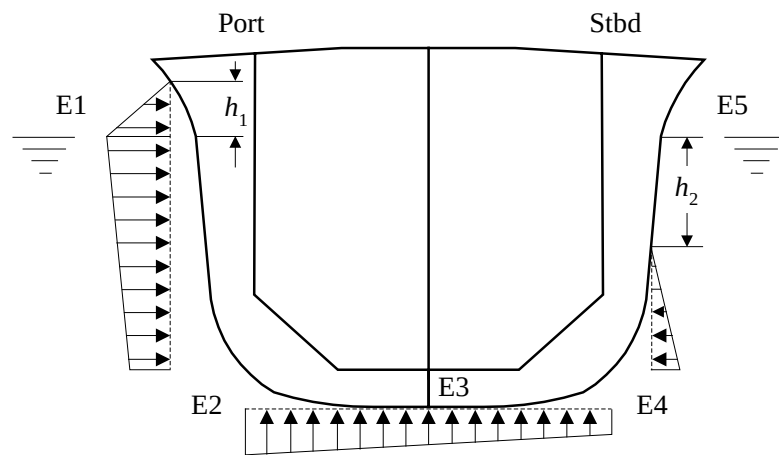
$$h_2 = d_m \frac{p_{E5}}{p_{E5} - p_{E4}}$$

The negative pressure above the zero pressure point is ignored.

The external pressure on the bottom shell plating linearly varies from pressure, p_{E2} (bilge, port), to pressure, p_{E4} (bilge, starboard). d_m is the draft at the mid-length of the targeted cargo hold for a specific loading condition, in m (ft).

The term “bottom shell plating” refers to the plating from the keel to the upper turn of the bilge amidships, but the upper turn of the bilge is not to be taken more than $0.2D$ above the baseline.

FIGURE 7
External Pressure Calculation Points



13 Internal Pressure

13.1 Ship Motions and Accelerations

In determining the cargo loads and liquid pressure, the dominant ship motions, pitch and roll, and the resultant accelerations induced by the wave are required. When a direct calculation is not available, the approximate equations given as follows may be used.

The accelerations acting on tanks are estimated at their center of gravity. a_{le} , a_{te} , and a_{ve} are the maximum dimensionless accelerations (i.e., relative to the acceleration of gravity) in the longitudinal, transverse and vertical directions, respectively and they are considered as acting separately for calculation purposes. a_{ve} does not include the component due to the static weight, a_{te} includes the component due to the static weight in the transverse direction due to rolling and a_{le} includes the component due to the static weight in the longitudinal direction due to pitching. The following formulae are given as guidance for the components of acceleration due to ship's motions in the North Atlantic.

- *Vertical acceleration:*

$$a_{ve} = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L}\right)^2 \left(\frac{x'_T}{L} - 0.45\right)^2 \left(\frac{0.6}{C_b}\right)^{1.5} + \left(\frac{0.6 z_T K^{1.5}}{B}\right)^2}$$

- Transverse acceleration:

$$a_{te} = \pm a_0 \sqrt{0.6 + 2.5 \left(\frac{x'_T}{L} - 0.45 \right)^2 + K \left(1 + 0.6K \frac{y_T}{B} \right)^2}$$

- Longitudinal acceleration:

$$a_{le} = \pm a_0 \sqrt{0.06 + A^2 - 0.25A}$$

with

$$A = \left(0.7 - \frac{L}{1200} + 5 \frac{y_T}{L} \right) \left(\frac{0.6}{C_b} \right)$$

where

$$a_0 = k_p \left[0.2 \left(\frac{V}{\sqrt{L}} \right) + \frac{(34 - 600/L)}{L} \right]$$

k_p = load factor for adjusting the probability of exceedance

= 1.0 for yielding and buckling strength assessment

= 0.5 for fatigue strength assessment

$$x'_T = x_T - (L_{BP} - L)$$

K = 1.0 in general. For particular loading conditions and hull forms, determination of K according to the formula below may be necessary.

= $13GM/B$, where $K \geq 1.0$.

GM = metacentric height, in m, to be taken as

= $GM(full)$ for $d_i = d$

If $GM(full)$ is not available, $GM(full)$ can be taken as $0.06B$.

V = 10 knots for yielding and buckling strength assessment

= 75% of the design speed for fatigue strength assessment.

13.3 Deck Load

The vertical loads on vehicle decks based on the uniform design vehicle load, in N/cm^2 (kgf/cm^2 , lbf/in^2), are not taken less than:

$$M_V = (W + m_s)(1 + k_{cv}a_{ve})$$

The transverse loads on vehicle decks, in N/cm^2 (kgf/cm^2 , lbf/in^2), are not taken less than:

$$M_T = (W + m_s)(k_{ct}a_{te})$$

The longitudinal loads on vehicle decks, in N/cm^2 (kgf/cm^2 , lbf/in^2), are not taken less than:

$$M_L = (W + m_s)(k_{cl}a_{le})$$

where

W = specified uniform design vehicle load on each deck, in N/cm^2 (kgf/cm^2 , lbf/in^2),

m_s = self-mass of deck structures under consideration, in N/cm^2 (kgf/cm^2 , lbf/in^2). The supporting stiffeners, primary supporting members are to be included in the self-mass calculation.

k_{cv} , k_{ct} , and k_{cl} are the load combination factor for effective vertical, transverse and longitudinal acceleration as defined in Section 5, Tables 1 and 2, respectively.

a_{ve} , a_{te} , and a_{le} are the accelerations at center of gravity of the plate panel under consideration obtained by 3/13.1.

13.5 Internal Pressure Formula for Strength Assessment

For finite element strength assessment, the internal pressure acting on ballast tanks corresponds to the instantaneous value when one dominant load parameter attains its maximum value. The internal pressure, p_i , positive toward outboard, for a completely filled tank, in N/cm^2 (kgf/cm^2 , lbf/in^2), may be obtained from the following formula:

$$p_i = \rho[(k_{cl} a_{le} x_\ell + k_{ct} a_{te} z_\ell + k_{cv} a_{ve} y_\ell) + y_\ell] + p_o$$

where

k_{cl} = load combination factor for effective longitudinal acceleration

k_{ct} = load combination factor for effective transverse acceleration

k_{cv} = load combination factor for effective vertical acceleration

ρ = specific weight of ballast in N/cm^2 (kgf/cm^2 , lbf/in^2); for ballast water, $1.005N/cm^2\cdot m$, ($0.1025 kgf/cm^2\cdot m$, $0.4444 lbf/in^2\cdot ft$) is to be used.

The design pressure p_o is to be taken as the static pressure head corresponding to two thirds of the distance from the top of the tank to the top of the overflow.



SECTION 4 Initial Scantling Criteria

1 Longitudinal Strength

1.1 General

The requirements in 5C-10-2/1.1 of the *Steel Vessel Rules* are to be complied with.

The contribution of hull structures (up to the upper most strength deck) to the hull girder strength are to be evaluated by a full ship based finite element pure bending analysis.

Two load cases inducing constant or unit bending moment along the full length of the ship are to be introduced to calculate the pure global bending stresses for hogging and sagging conditions. The calculated pure bending normal stress level in each elements of interest may be scaled by the total bending moment (maximum algebraic sum of still-water bending moment envelope curve and wave-induced bending moment). The adjusted pure bending stresses are not greater than the allowable stresses as specified in 3-2-1/7.3 of the *Steel Vessel Rules* as applicable.

Special attention shall be given to the members around the openings, transition zone and structural discontinuities of longitudinal structures.

The effect of hull structure self-weight and deck load are to be considered in the full ship based finite element analysis for hull girder strength.

1.3 Bending Moments and Shear Forces

The requirements in 5C-10-2/1.3 of the *Steel Vessel Rules* are to be complied with.

1.5 Hull Girder Shearing Strength

The shearing strength of the hull structure is to be calculated in accordance with 3-2-1/3.9, 3-2-1/5 and 3-2-1/19 of the *Steel Vessel Rules* with vertical wave shear force obtained from the equations specified in Subsection 3/7 of this Guide.

1.7 Buckling Strength

The requirements in 5C-10-2/1.5 of the *Steel Vessel Rules* are to be complied with.

Alternatively, the approach and criteria specified in Subsection 6/7 and Appendix 2 of this Guide are to be used to check the buckling strength. In addition, for the longitudinally stiffened plating, the net thickness is to be not less than the requirement calculated from t_3 specified in Section 4/5.1. For deck plating, the coefficient c for t_3 calculation is not be taken less than $0.2Q^{1/2}$.

1.9 Hull Girder Ultimate Strength

The hull structure is to be verified for compliance with hull girder ultimate strength requirements in Appendix 5C-3-A7 of the *Steel Vessel Rules* with the wave-induced bending moment defined in Subsection 3/5 of this Guide.

3 Bottom Structure

In general, bottom structures are to be in accordance with Section 3-2-4 of the *Steel Vessel Rules*.

The thickness of center girders, if fitted, is not to be less than t specified below:

$$t = 0.85 \times (0.056L + 5.5) \text{ mm} \quad \text{for } L \leq 427 \text{ m}$$

$$t = 0.85 \times (0.00067L + 0.22) \text{ in.} \quad \text{for } L \leq 1400 \text{ ft}$$

The thickness of sider girders and solid floors is not to be less than t specified below:

$$t = 0.85 \times (0.036L + 4.7 + c) \text{ mm} \quad \text{for } L \leq 427 \text{ m}$$

$$t = 0.85 \times (0.00043L + 0.185 + c) \text{ in.} \quad \text{for } L \leq 1400 \text{ ft}$$

where

$$\begin{aligned} c &= 1.5 \text{ mm (0.06 in.)} && \text{for floors where the bottom shell and inner bottom are longitudinally framed} \\ &= 0 \text{ mm (in.)} && \text{for side girders and brackets, and for floors where the bottom shell and inner bottom are transversely framed} \end{aligned}$$

5 Side Construction

5.1 Shell Plating

The requirements in 5C-10-2/9.3 of the *Steel Vessel Rules* are to be complied with.

Alternatively, the shell plating may be evaluated by the following criteria. The requirements in Subsection 4/13 are also to be complied with if the shell plating forms the deep tank boundaries.

The net thickness of the longitudinally framed side shell plating, in addition to compliance with 4/1.3, 4/1.5, 4/1.7 and 4/1.9, is to be not less than t_1 , t_2 , and t_3 specified below for the midship 0.4L:

$$t_1 = 0.73s(k_1p/f_1)^{1/2} \text{ mm (in.)}$$

$$t_2 = 0.73s(k_2p/f_2)^{1/2} \text{ mm (in.)}$$

$$t_3 = cs(S_m f_y/E)^{1/2} \text{ mm (in.)}$$

where

$$\begin{aligned} s &= \text{spacing of side longitudinals, in mm (in.)} \\ k_1 &= 0.342 \\ k_2 &= 0.500 \\ p &= \text{nominal pressure in full draft condition with wave heading angle of } 60^\circ \text{ and } k_{ce} = 1.0, \text{ in N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{), at the lower edge of each plate strake, as specified in Subsection 3/11.} \\ f_1 &= \text{permissible bending stress, in longitudinal direction, in N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{)} \\ &= [0.835 - 0.40\alpha_1(SM_{RB}/SM_B)(y/y_b)]S_m f_y, \text{ below neutral axis, where } SM_B/SM_{RB} \text{ is not to be taken more than 1.4} \\ &= [0.835 - 0.52\alpha_2(SM_{RD}/SM_D)(y/y_n)]S_m f_y, \text{ above neutral axis} \\ f_1 &\text{ is not to be taken greater than:} \\ &0.43S_m f_y && \text{for } L \geq 210 \text{ m (689 ft)} \\ &[0.43 + (210 - L)/2600]S_m f_y && \text{for } L < 210 \text{ m} \\ &[0.43 + (689 - L)/8531]S_m f_y && \text{for } L < 689 \text{ ft} \end{aligned}$$

f_2	=	permissible bending stress, in the vertical direction, in N/cm ² (kgf/cm ² , lbf/in ²)
	=	$0.80S_m f_y$
α_1	=	$S_{m1} f_{y1} / S_m f_y$
α_2	=	$S_{m2} f_{y2} / S_m f_y$
S_m	=	strength reduction factor of the side shell plating under consideration
	=	1.0 for ordinary mild steel
	=	0.95 for Grade H32 steel
	=	0.908 for Grade H36 steel
	=	0.875 for Grade H40 steel
S_{m1}	=	strength reduction factor of the bottom flange of the hull girder
S_{m2}	=	strength reduction factor of the strength deck flange of the hull girder
f_y	=	minimum specified yield point of the side shell plating, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{y1}	=	minimum specified yield point of the bottom flange of the hull girder, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{y2}	=	minimum specified yield point of the strength deck flange of the hull girder, in N/cm ² (kgf/cm ² , lbf/in ²)
SM_{RD}	=	required gross hull-girder section modulus based on the material factor of the strength deck flange of the hull girder, in accordance with 4/1.1 and 4/1.3, with k_w defined in Subsection 3/5 for the purpose of calculating M_w (sagging and hogging), based on the material factor of the strength deck flange of the hull girder, in cm ² -m (in ² -ft)
SM_D	=	design (actual) gross hull girder section modulus at the strength deck amidships, in cm ² -m (in ² -ft)
c	=	$0.7N^2 - 0.2$, not to be taken less than $0.4Q^{1/2}$
N	=	$R_d(Q/Q_d)^{1/2}$ for the sheer strake
	=	$R_d[(Q/Q_d)(y_d/y_n)]^{1/2}$ for other locations above neutral axis
	=	$R_b[(Q/Q_b)(y_d/y_n)]^{1/2}$ for locations below neutral axis
R_d	=	$(SM_{RDS})/(SM_D)^{1/2}$
R_b	=	$(SM_{RBH})/(SM_B)^{1/2}$
SM_{RDS}	=	required gross hull girder section modulus for sagging bending moment based on the material factor of the upmost strength deck flange of the hull girder, in accordance with 4/1.1 and 4/1.3, with k_w defined in Subsection 3/5 for the purpose of calculating M_w (sagging), based on material factor of the strength deck flange of the hull girder, in cm ² -m (in ² -ft)
SM_{RBH}	=	required gross hull girder section modulus for hogging bending moment based on the material factor of the bottom flange of the hull girder, in accordance with 4/1.1 and 4/1.3, with k_w defined in Subsection 3/5 for the purpose of calculating M_w (hogging), based on the material factor of the bottom flange of the hull girder, in cm ² -m (in ² -ft)

Q, Q_b, Q_d	=	material conversion factor for the side shell plating, the bottom flange and the strength deck flange of the hull girder, respectively
	=	1.0 for ordinary mild steel
	=	0.78 for Grade H32 steel
	=	0.72 for Grade H36 steel
	=	0.68 for Grade H40 steel
y	=	vertical distance, in m (ft), measured from the neutral axis of the hull girder transverse section to the lower edge of the side shell strake
y_a	=	vertical distance, in m (ft), measured from the neutral axis of the hull girder transverse section to the lower edge (upper edge) of the side shell strake, when the strake under consideration is below (above) the neutral axis.
y_b	=	vertical distance, in m (ft), measured from the upper turn of bilge to the neutral axis of the section
y_n	=	vertical distance, in m (ft), measured from the bottom (deck) to the neutral axis of the hull girder transverse section, when the strake under consideration is below (above) the neutral axis
SM_{RB}	=	required gross hull girder section modulus based on material factor of the bottom flange of the hull girder, in accordance with 4/1.1 and 4/1.3, with k_w defined in Subsection 3/5 for the purpose of calculating M_w (sagging and hogging), based on the material factor of the strength deck flange of the hull girder, in $\text{cm}^2\text{-m}$ ($\text{in}^2\text{-ft}$)
SM_B	=	design (actual) gross hull girder section modulus at the bottom, amidships in $\text{cm}^2\text{-m}$ ($\text{in}^2\text{-ft}$)
E	=	modulus of elasticity of the material, may be taken as $2.06 \times 10^7 \text{ N/cm}^2$ ($2.1 \times 10^6 \text{ kgf/cm}^2$, $30 \times 10^6 \text{ lbf/in}^2$) for steel

t_1 and t_2 , as calculated for each plate, need not to be taken in excess of those calculated at the upper turn of the bilge, respectively, as adjusted for the spacing of the longitudinals and the material factors.

In addition, the net thickness of the side shell plating is not to be taken less than t_4 , obtained from the following equation:

$$t_4 = 120(s/1000 + 0.3)[Bd/(S_m f_y)^2]^{1/4} + 0.5 \text{ mm}$$

$$t_4 = 9.7(s/39.4 + 0.3)[Bd/(S_m f_y)^2]^{1/4} + 0.02 \text{ in.}$$

where

s	=	spacing of side frames, in mm (in.)
B	=	breadth of vessel, as defined in 3-1-1/5 of the <i>Steel Vessel Rules</i> , in m (ft)
d	=	molded draft, as defined in 3-1-1/9 of the <i>Steel Vessel Rules</i> , in m (ft)

All other parameters are as defined above.

The net thickness, t_4 , is to be applied to the following extent of the side shell plating:

Longitudinal extent: between a section aft of amidships where the breadth at the waterline exceeds $0.9B$, and a section forward of amidships where the breadth at the waterline exceeds $0.6B$

Vertical extent: between 300 mm (12 in.) below the lowest ballast waterline to $0.25d$ or 2.2 m (7.2 ft), whichever is greater, above the summer loadline.

The net thickness, t_3 , may be determined based on S_m and f_y of the hull girder strength material required at the location under consideration. Where the approach and criteria specified in Subsection 6/7 and Appendix 2 are to be alternatively used for the buckling evaluation, the shell plating is to be complied with t_3 requirement.