



GUIDANCE NOTES ON

THE STRENGTH ASSESSMENT OF CARGO TANK STRUCTURES BEYOND 0.4L AMIDSHIPS IN OIL CARRIERS 150 METERS OR MORE IN LENGTH

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Foreword

These Guidance Notes were developed as a direct response to requests from our clients to develop an analysis procedure for the forward and aft tank structure beyond $0.4L$. This procedure is based on existing ABS SafeHull procedures included in the ABS Rules. It should be noted that ABS is currently working within IACS on the Joint Tanker Project (JTP) and some components of these Guidance Notes have been developed using JTP procedures. It is understood that this process will continue and once the JTP Rules mature, these Guidance Notes will be unified with respect to components such as the net thickness, loads, acceptance criteria, etc.

These Guidance Notes describe a strength assessment procedure for cargo tank structures beyond $0.4L$ amidships in oil carriers having L greater than 150 meters. In addition to the Rule scantlings as required by Section 5-1-6 "Hull Structure Beyond $0.4L$ Amidships" of the ABS *Rules for Building and Classing Steel Vessels* (SVR), these Guidance Notes may be optionally applied to verify the strength adequacy of main supporting members using a set of standard design load cases. Application of the procedure is required for novel structural configurations or scantlings/details.

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SECTION 1 Introduction

1 Scope of Application

These Guidance Notes describe a strength assessment procedure for cargo tank structures beyond 0.4L amidships in oil carriers 150 meters or more in length. In addition to the Rule scantlings as required by Section 5-1-6 “Hull Structure Beyond 0.4L Amidships” of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*, these Guidance Notes may be optionally applied to verify the strength adequacy of main supporting members using a set of standard design load cases. For designs with satisfactory service experience or designs that have been subjected to other forms of engineering analysis, these Guidance Notes need not be applied. However, application of these Guidance Notes is required for novel structural configurations or scantlings/details. The primary concern for main supporting members is the strength adequacy against external sea and internal liquid pressures while the hull girder load effects in these members tend to be less significant.

Cargo tank structures within 0.4L amidships are to comply with the requirements of Section 5-1-4 “Initial Scantling Criteria” of the *Steel Vessel Rules* and Section 5-1-5 “Total Strength Assessment” of the *Steel Vessel Rules* and are to be directly evaluated by using the ABS SafeHull System. The strength assessment procedure in these Guidance Notes is not applicable to cargo tank structures within 0.4L amidships.

The description of the procedure in these Guidance Notes is aided by figures for forward cargo tank structures only, but the same procedure is also applicable to aft cargo tank structures (excluding bottom slamming and green water pressures).

The parameters in these Guidance Notes are defined in ABS SafeHull units and coordinate systems. If the measurement units and/or coordinate systems are different from these specifications, conversion is to be done appropriately.

3 Overview of Strength Assessment

The core of the strength assessment procedure is the SafeHull dynamic loading concept. It is generally expected that local dynamic loads experienced by cargo tank structures beyond 0.4L amidships can be more severe than those within 0.4L amidships. Section 1, Figure 1 shows the outline of the procedure.

In these Guidance Notes, the strength assessment procedure is described in five Sections:

Section 2	SafeHull Dynamic Load Criteria
Section 3	Standard Design Load Cases
Section 4	Structural Modeling and Analysis
Section 5	Acceptance Criteria
Section 6	Documentation of Strength Assessment for Classification Review

The dynamic load criteria given in Section 2 of these Guidance Notes are consistent with those given in Section 5-1-3 “Load Criteria” of the *Steel Vessel Rules* for oil carriers. Simplifications to the dynamic load formulae are introduced with special emphasis to application of the strength assessment procedure using recognized finite element modeling/analysis/post-processing software tools such as FEMAP, PATRAN, NASTRAN and ANSYS.

The standard design load cases given in Section 3 of these Guidance Notes represent combinations of individual design load components defined in Section 2 of these Guidance Notes for cargo tank structures beyond 0.4L amidships. When warranted, additional design load cases are also to be analyzed to verify the strength of main supporting members against wave impact on bow, bow flare slamming and sloshing.

Section 4 of these Guidance Notes describes the finite element modeling and analysis techniques generally used for cargo tank structures beyond 0.4L amidships. These techniques may be substituted by alternative techniques. It is recommended that consultation with ABS on the alternative techniques be made before commencing structural idealization.

The acceptance criteria for the strength assessment procedure are consistent with those in Section 5-1-5 of the *Steel Vessel Rules* and also given in Section 5 of these Guidance Notes for ready reference.

Appropriate documentation of the strength assessment described in Section 6 of these Guidance Notes is essential for ABS plan approval. A complete technical report is to be prepared as supporting data of design and submitted together with the relevant plans for ABS review.

5 Coordinate Systems

Three sets of Cartesian coordinate systems are used to describe SafeHull load criteria and finite element modeling in these Guidance Notes. When alternative coordinate systems are used, attention should be paid to the default coordinate systems used in the dynamic load formulae in Section 2 of these Guidance Notes.

5.1 Ship Coordinate System for Ship Motion and External Pressure (Right Hand)

Origin	Intersection of the AP section, waterline and centerline planes.
x_T	Longitudinal distance from the AP to the center of the tank, in m, positive toward bow.
y_T	Vertical distance from the waterline to the center of the tank, in m, positive above and negative below the waterline.
z_T	Transverse distance from the centerline to the center of the tank, in m, positive toward starboard.
x	Longitudinal distance from the AP to the external pressure point considered, in m.
x_o	Longitudinal distance from the AP to the reference station, in m. 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.

5.3 Tank Coordinate System for Internal Pressure (Left Hand)

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 1, Figure 2 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.
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x_ℓ	Longitudinal distance from the zero dynamic pressure point of the tank to the pressure point, in m, positive toward bow for a fore cargo tank structure.
y_ℓ	Vertical distance from the zero dynamic pressure point of the tank to the pressure point, in m, positive downward.
z_ℓ	Transverse distance from the zero dynamic pressure point of the tank to the pressure point, in m, positive toward starboard.

5.5 Finite Element Coordinate System (Right Hand)

Origin	Intersection of the baseline, centerline and aftmost transverse planes.
X	Longitudinal distance from the origin, in cm, positive from aft to fore.
Y	Vertical distance from the origin, in cm, positive upward.
Z	Transverse (athwartship) distance, in cm, positive toward starboard.

7 Nomenclature

A_s	cross sectional area of the spring bar, in cm^2
A_{shear}	effective shear area of a hull girder cross section, in cm^2 and can be taken as the sectional area of each side shell, longitudinal bulkhead, deck, inner bottom or bottom in question
$a_{\ell e}$	effective longitudinal acceleration, in m/sec^2 , positive forward
a_{te}	effective transverse acceleration, in m/sec^2 , positive starboard
a_{ve}	effective vertical acceleration, in m/sec^2 , positive downward
B	molded breadth, in m
b_i	half breadth at the $1/10$ draft of the i -th section in the heavy ballast condition, in m
b_i^*	half width of flat of bottom at the i -th section, in m
C_b	block coefficient at the scantling draft
d_b	draft amidships in the heavy ballast condition, in m
d_f	scantling draft, in m
d_i	draft at the i -th section in the heavy ballast condition, in m
d_m	draft amidships for a specific loading condition, in m
d_{oi}	$1/10$ of the section draft of the i -th section in the heavy ballast condition, in m
f_y	minimum specified yield point of the material, in kgf/cm^2
f_u	minimum specified tensile strength of the material, in kgf/cm^2
F_{bi}	freeboard from the highest deck at side to the load waterline (LWL) at the i -th section
GM	metacentric height, in m
h_s	hydrostatic pressure head in still water, in m
k_{ce}	load combination factor for external pressure

k_{cl}	load combination factor for effective longitudinal acceleration
k_{cmh}	load combination factor for design horizontal wave-induced bending moment
k_{cmv}	load combination factor for design vertical wave-induced bending moment
k_{ct}	load combination factor for effective transverse acceleration
k_{cv}	load combination factor for effective vertical acceleration
$k_{c\phi}$	load combination factor for effective pitch amplitude
$k_{c\theta}$	load combination factor for effective roll amplitude
k_r	roll radius of gyration, in m
k_s	load factor for internal pressure
L	scantling length, in m
L_{BP}	length between perpendiculars, in m
ℓ_s	length of the spring bar, in cm
ℓ_t	cargo tank length between transverse bulkheads, in cm
M_{ws}	vertical sagging wave-induced bending moment, in tf-m
M_{wh}	vertical hogging wave-induced bending moment, in tf-m
M_h	horizontal wave-induced bending moment, in tf-m
m_v	distribution factor for vertical wave-induced bending moment
m_h	distribution factor for horizontal wave-induced bending moment
N	number of floors in the double bottom of the fore cargo tank
p_e	external pressure, in kgf/cm ²
p_{gi}	green water pressure on deck at the i -th section, in kgf/cm ²
p_i	internal pressure, in kgf/cm ²
p_{si}	bottom slamming pressure at the i -th section, in kgf/cm ²
p_{nslam}	nominal slamming pressure for double bottom structure, in kgf/cm ²
p_{vp}	pressure setting on pressure/vacuum relief valve, less than 0.71 kgf/cm ² for integral-gravity tanks
S_m	strength reduction factor, equal to 1.000, 0.950, 0.908 and 0.875 for mild steel, H32, H36 and H40, respectively
s_i	sum of one half of floor spacings on both sides of the i -th floor, in m
T_r	roll period, in seconds
V	75% of the design speed V_d (MCR), in knots
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)

ϕ_e	effective pitch amplitude, in deg
θ_e	effective roll amplitude, in deg
ρg	specific weight of ballast or cargo; for ballast water, 1.025 tf/m ³ is to be used and for liquid cargo, specific weight of liquid cargo is not to be less than 1.025 tf/cm ³
ω	natural angular frequency of hull girder 2-node vertical vibration in the wet mode and the heavy weather ballast draft condition, in rad/second
Δ	vessel's displacement at the scantling draft, in tf
Δ_b	vessel's displacement in the heavy ballast condition, in tf

FIGURE 1
Outline of the Strength Assessment Procedure

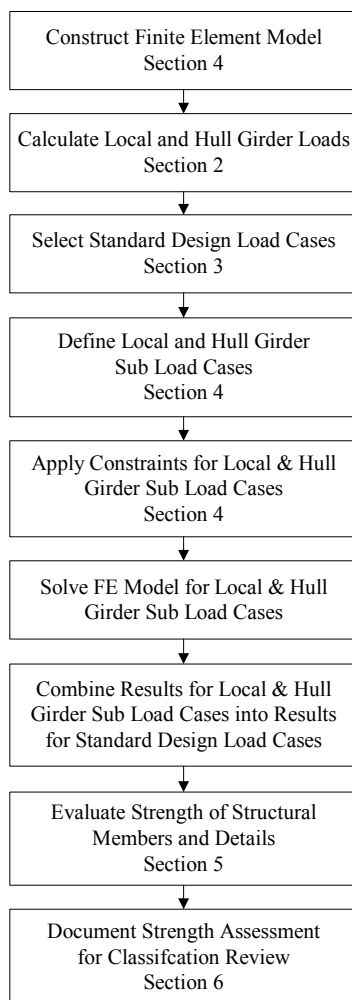
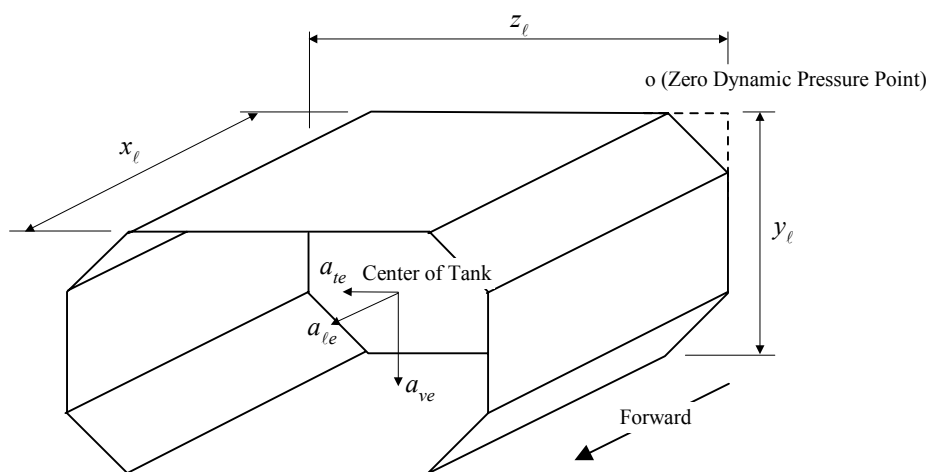


FIGURE 2
Tank Coordinate System for Internal Pressure



SECTION 2 SafeHull Dynamic Load Criteria

1 General

The dynamic load components described in this Section represent the long-term extreme values for the North Atlantic in 20 years, corresponding to a probability of exceedance of 10^{-8} . For oil carriers serving in more severe seas such as the Trans Alaskan Pipeline Service (TAPS) route, the dynamic load criteria need to be modified.

The following SafeHull dynamic load components are considered in the strength assessment procedure:

- Vertical and horizontal wave-induced bending moments
- External pressure
- Internal pressure
- Bottom slamming for fore cargo tank structures only

The formulae for vertical and horizontal wave-induced bending moments are identical to those in 3-2-1/3.5 and 5-1-3/5.3.1 of the *Steel Vessel Rules* and are included here for ready reference. The formulae for external and bottom slamming pressures are derived from 5-1-3/5.5 and 5-1-3/13.3 of the *Steel Vessel Rules* and simplified to facilitate easy application of the strength assessment procedure. Effective accelerations, pitch and roll amplitudes are first calculated, and internal pressure is expressed as a combination of these dominant parameters.

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 3 of these Guidance Notes. The parameters and coordinates used in this Section are defined in Subsections 1/5 and 1/7 of these Guidance Notes.

3 Vertical Wave-induced Bending Moment

The vertical wave-induced bending moment, in tf-m, may be obtained from the following equations:

$$M_{ws} = -11.22k_{cmv}m_vC_1L^2B(C_b + 0.7) \times 10^{-3} \quad \text{Sagging Moment}$$

$$M_{wh} = +19.37k_{cmv}m_vC_1L^2BC_b \times 10^{-3} \quad \text{Hogging Moment}$$

where

$$\begin{aligned} C_1 &= 10.75 - \left(\frac{300 - L}{100} \right)^{1.5} & 90 \leq L < 300 \\ &= 10.75 & 300 \leq L < 350 \\ &= 10.75 - \left(\frac{350 - L}{150} \right)^{1.5} & 350 \leq L < 500 \end{aligned}$$

Refer to Section 2, Figure 1 for m_v .

5 Horizontal Wave-induced Bending Moment

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

$$M_H = \pm 18.34 k_{cmh} m_h C_1 L^2 DC_b \times 10^{-3}$$

where C_1 is as given in Subsection 2/3 of these Guidance Notes. Refer to Section 2, Figure 2 for m_h .

7 External Pressure

The external pressure, p_e , positive toward inboard, in kgf/cm², with waves approaching the hull from the starboard side can be expressed by the following equation at a given cross section:

$$p_e = \rho g (h_s + 1.36 k_{ce} k_d \alpha C_1) \times 10^{-1} \geq 0$$

where

$$\begin{aligned} \alpha &= 0.75 - 1.25 \sin \mu && \text{waterline, port} \\ &= 0.2 - 0.4 \sin \mu + 0.1 \cos \mu && \text{bilge, port} \\ &= 0.3 - 0.2 \sin \mu && \text{centerline, bottom} \\ &= 0.4 - 0.1 \cos \mu && \text{bilge, starboard} \\ &= 1.0 - 0.25 \cos \mu && \text{waterline, starboard} \end{aligned}$$

$$k_d = \left\{ 1 - \left[1 - \cos \frac{2\pi(x - x_o)}{L} \right] \cos \mu \right\} [1 + (k_{\ell o} - 1) \cos \mu]$$

C_1 is as given in Subsection 2/3 and the pressure distribution factor, $k_{\ell o}$, may be taken from Section 2, Table 1 or Section 2, Figure 3. Combination factor, k_{ce} , is found in Section 3, Table 1. A negative combination factor, k_{ce} , signifies that the wave trough is on the starboard side.

TABLE 1
 $k_{\ell o}$ Coefficient

$[x_o - (L_{BP} - L)]/L$	$k_{\ell o}$	$[x_o - (L_{BP} - L)]/L$	$k_{\ell o}$	$[x_o - (L_{BP} - L)]/L$	$k_{\ell o}$
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 finite element model may be ignored. The reference section may be taken at the mid-length of the targeted cargo tank. However, the pressure variation along the girth of the reference section should be accounted for and can be represented by the pressure values at the following five points, as shown in Section 2, Figure 4:-

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 2, Figure 4. The zero pressure point is defined by h_1 , which is equal to the dynamic pressure head or freeboard, whichever is less. However, when the vessel is in a deeper draft (see Standard Load Case 5 in Section 3), the nominal green water pressure imposed on the deck in the region from the FP to $0.25L$ aft, including the extension beyond the FP, is to be calculated at the reference section:

$$p_{gi} = 0.2 \left[0.44 A_i \left(\frac{VL}{C_b} \right)^{1/2} - F_{bi} \right]^{1/2}, \text{ not to be less than } 0.21 \text{ kgf/cm}^2$$

A_i is given in Section 2, Table 2.

When a negative dynamic pressure is found, for example, at the waterline at E5 on the starboard side in Section 2, Figure 4, the zero pressure point can be defined by h_2 , which can be calculated as follows: The negative pressure above the zero pressure point is ignored.

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

The external pressure on the bottom shell plating linearly varies from pressure, p_{E2} (bilge, port), to pressure, p_{E4} (bilge, starboard). 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.

9 Internal Pressure

To determine the inertial forces and added pressure heads for a completely filled cargo or ballast tank, the dominating ship motion parameters (pitch, roll and accelerations) induced by waves are to be calculated.

9.1 Effective Pitch Amplitude

$$\phi_e = 731.3 \left(\frac{V}{C_b} \right)^{1/4} / L$$

ϕ_e need not to be taken more than 7.1 degrees.

9.3 Effective Roll Amplitude

$$\theta_e = \begin{cases} 0.71 C_R (35 - 0.05 C_{di} \Delta / 1000) & T_r > 20 \text{ sec} \\ 0.71 C_R (35 - 0.05 C_{di} \Delta / 1000) (1.5375 - 0.027 T_r) & 12.5 \leq T_r \leq 20 \text{ sec} \\ 0.71 C_R (35 - 0.05 C_{di} \Delta / 1000) (0.8635 + 0.027 T_r) & T_r < 12.5 \text{ sec} \end{cases}$$

θ_e need not to be taken more than 21.3 degrees.