



RULES FOR BUILDING AND CLASSING

STEEL VESSELS 2018

PART 5C SPECIFIC VESSEL TYPES (CHAPTERS 1-6)

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

In association with the harmonization of the Common Structural Rules (CSR) for Bulk Carriers and Oil Tankers, on 1 July 2015, the three Sub-parts, 5A, 5B, and 5C, of Part 5 of the *Rules for Building and Classing Steel Vessels* are as follows:

Contents

Part 5A:	General Hull Requirements (IACS CSR Part 1)
Part 5B:	Ship Types (IACS CSR Part 2)
Part 5C:	This Part is divided into two separate booklets as follows:
Chapters 1 to 6:	Tankers and Bulk Carriers not covered by Part 5A and Part 5B and Container Carriers
Chapters 7 to 13:	Passenger Vessels, Liquefied Gas Carriers, Chemical Carriers, Vessels Intended to Carry Vehicles, Water Carriers, Membrane Tank LNG Carriers, and Vessels Using Gases or other Low-Flashpoint Fuels.

Application – Oil Tankers

The structural requirements in Part 5A, Pt 1 and Part 5B, Pt 2, Ch 2 of the Rules are applicable for double hull oil tankers of 150 m in length and upward, with structural arrangements as specified in Part 5A, Pt 1, Ch 1, Sec 1, [1.3].

For oil tankers with structural arrangements not covered by Part 5A, Pt 1 and Part 5B, Pt 2, Ch 2, the requirements in Part 5C, Chapters 1 or 2, are to be complied with.

Application – Bulk Carriers

The structural requirements in Part 5A, Pt 1 and Part 5B, Pt 2, Ch 1 of the Rules are applicable for single side skin and double side skin bulk carriers of 90m in length and upward, with structural arrangements as specified in Part 5A, Pt 1, Ch 1, Sec 1, [1.2].

For vessels intended to carry ore or bulk cargoes, other than the single side skin or double side skin bulk carriers of 90 m in length and upward with structural arrangements as specified in Part 5A, Pt 1 and Part 5B, Pt 2, Ch 1, the requirements in Part 5C, Chapters 3 or 4 are to be complied with.

Application – ABS Construction Monitoring Program

These compulsory requirements for **CSR** notation are specified in Part 5C, Appendix 2.

Application – Onboard Systems for Oil Tankers and Bulk Carriers

The onboard systems for all tankers are to comply with the requirements of Part 5C, Chapter 1, Section 7, and for all bulk carriers are to comply with the requirements of Part 5C, Chapter 3, Section 7 of the Rules.

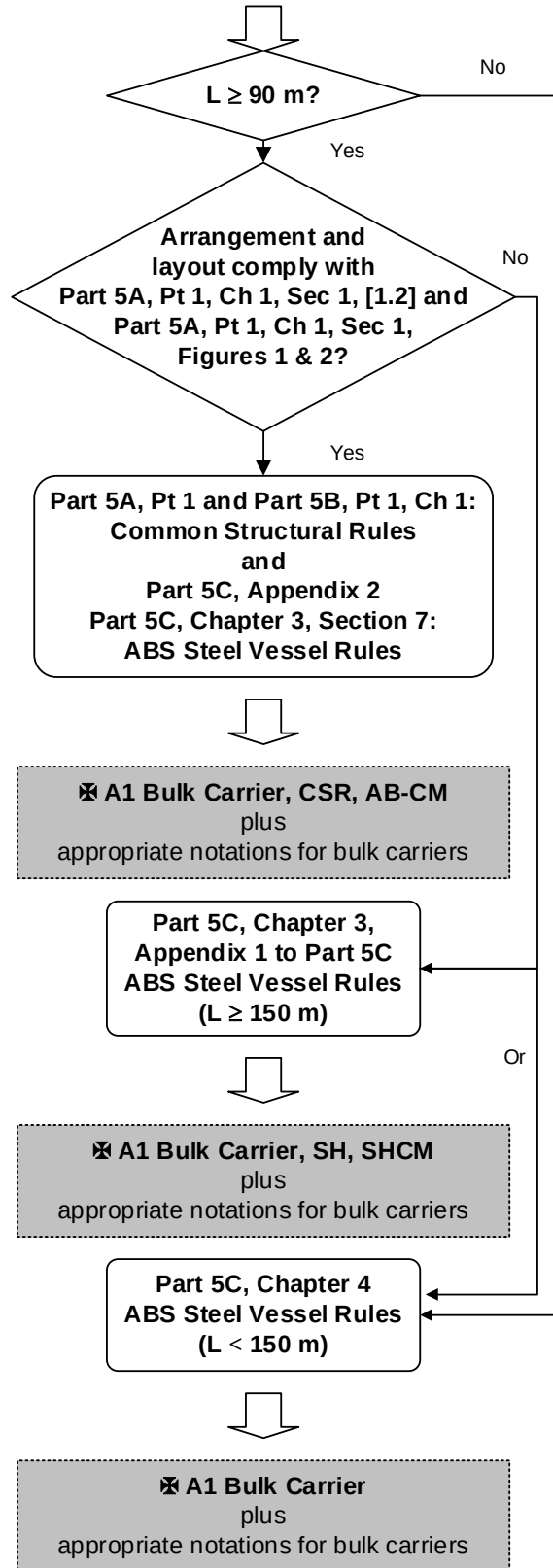
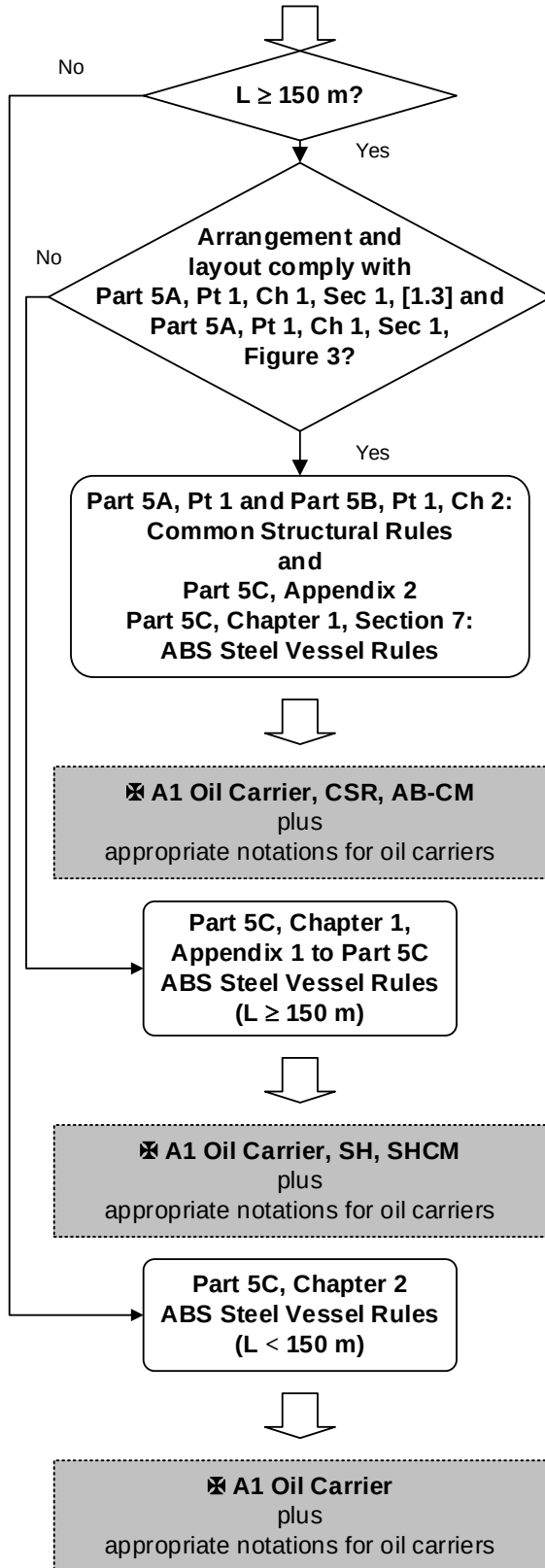
Application – References

Other Parts of the ABS Rules that are referenced within Part 5A, 5B, or 5C are also to be applied.

The following flow chart indicates the application of the Rules and typical Class Notations for tanker and bulk carrier vessels, of which arrangements and scantlings are in full compliance with the Rules:

Vessels Intended to Carry Oil in Bulk

Vessels Intended to Carry Ore or Bulk Cargoes



Rule Change Notice (2018)

The effective date of each technical change since 1993 is shown in parenthesis at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	(1996)	9 May 1996
(1999)	12 May 1999	(1995)	15 May 1995
(1998)	13 May 1998	(1994)	9 May 1994
(1997)	19 May 1997	(1993)	11 May 1993

Listing by Effective Dates of Changes from the 2017 Rules

Notice No. 1 (effective on 1 July 2017) to the 2017 Rules, which is incorporated in the 2018 Rules, is summarized below.

EFFECTIVE DATE 1 July 2017 – shown as (1 July 2017) (based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-1-1/5.35 (New)	Location of Fuel Tanks in Cargo Area	To clarify the requirements for fuel tanks used for separating machinery spaces from cargo and slop tanks, in line with IACS UR M76, Apr. 2016. (Incorporates Notice No. 1)
5C-1-1/Figure 2 (New)	Cargo Tank Block	To clarify the requirements for fuel tanks used for separating machinery spaces from cargo and slop tanks, in line with IACS UR M76, Apr. 2016. (Incorporates Notice No. 1)
5C-2-1/5.33 (New)	Location of Fuel Tanks in Cargo Area	To clarify the requirements for fuel tanks used for separating machinery spaces from cargo and slop tanks, in line with IACS UR M76, Apr. 2016. (Incorporates Notice No. 1)
5C-2-1/Figure 2 (New)	Cargo Tank Block	To clarify the requirements for fuel tanks used for separating machinery spaces from cargo and slop tanks, in line with IACS UR M76, Apr. 2016. (Incorporates Notice No. 1)

EFFECTIVE DATE 1 January 2018 – shown as (2018) (based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-1-4/13.3	Transverse Bulkhead Plating	To better consider the effect of the aspect ratio of a panel in the calculation for transverse bulkhead plating of oil tankers and to assess the structure (shedder plate, hopper plate, etc.) with a small aspect ratio
5C-1-7/25.11.1	General	To clarify the required capacity of the alternative supply.
5C-1-A1/Figure 1	Basic Design S-N Curves	To define the second segment of the S-N curves, in line with IACS Rec. No. 56.
5C-1-A5/1	General	To clarify the hull girder ultimate strength check at hull girder sections outside 0.4L amidships.
5C-3-1/1.3.3	Direct Calculations	To ensure that the critical structural details beyond 0.4L amidships can be evaluated with an improved level of accuracy for Ore Carriers.
5C-3-1/1.3.4 (New)	Full Ship FE based Fatigue Strength Assessment	To align the Rules with the revision of the <i>Guidance Notes on Springing Assessment for Container Carriers and Ore Carriers</i> that newly includes the requirements for Ore Carriers.
5C-3-3/5.7.1(c)	Accelerations	To apply the different accelerations for strength and fatigue strength check of Bulk Carriers and keep it consistent with that formula of 5C-1-3/5.7.1(c) of the <i>Steel Vessel Rules</i> for Tankers.

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-3-3/Table 1A	Combined Load Cases for Yielding and Buckling Formulation	To align the acceleration factors c_ϕ and c_θ of Bulk Carrier with Tanker, in consideration of the configuration of ore carriers.
5C-3-3/Table 1B (New)	Combined Load Cases for Fatigue Strength Formulation	To keep the coefficients for fatigue load cases.
5C-3-3/Table 3	Design Pressure for Local and Supporting Members	To align C_ϕ and C_θ for yielding and buckling strength with SafeHull Tanker and Containership and to correct the heading angle for other longitudinal bulkhead plating to align with load parameter B_{ti} represent the sea loads in oblique seas.
5C-3-4/7.5	Bottom and Inner Bottom Longitudinals	To be consistent with 5C-1-4/7.5 for Tankers and 5C-5-4/9.5 for Container Carriers of the <i>Steel Vessel Rules</i> .
5C-3-4/9.1	Side Shell Plating	To apply the actual pressure at the lower end of each side strake, instead of applying a constant pressure at each strake equal to the pressure at the top of the bilge plate and to introduce the additional requirement t_4 for side shell plating to prevent damages due to berthing or contact loads.
5C-3-4/27 (New)	Connection of Longitudinals and Main Supporting Members	To align the Rules with the actual review practice for slot connection on the basis of the requirements in the Guide for LGC and CSRH.
5C-3-5/3.5	Plating	To align the Rules with the yielding evaluation of the plate panels adjacent to knuckle or cruciform connections for other SafeHull vessel types.
5C-3-5/5.3.1	Buckling State Limit	To align the Rules with the buckling state limit for other SafeHull vessel types.
5C-3-5/5.3.3	Ultimate Strength	To align the Rules with the buckling state limit for other SafeHull vessel types.
5C-3-5/11 (New)	Critical Areas	To align the Rules with the fatigue evaluation for other SafeHull vessel types.
5C-3-6/1.5 (New)	Aftbody, Machinery Space, and Forebody Structure	To specify minimum requirement for main supporting members in aftbody, machinery space, and forebody.
5C-3-A1/1.3	Applicability	To align with the new requirement of simplified fatigue strength assessment for ore carriers in 5C-3-A3/11.
5C-3-A1/Figure 1	Basic Design S-N Curves	To define the second segment of the S-N curves, in line with IACS Rec. No. 56.
5C-3-A3/9.21 (New)	Cargoes That May Liquefy	To provide guidance that cargoes having a moisture content in excess of the transportable moisture limit shall be only be carried in specially constructed cargo ships or in specially fitted cargo ships, in accordance with Sec.7 of IMSBC Code.
5C-3-A3/11 (New)	Rule-based Fatigue Strength Assessment	To provide a designer oriented approach to fatigue strength assessment for certain structural details, in lieu of more elaborate method as spectral-based fatigue analysis.
5C-3-A3/Table 1 (New)	Standard Design Load Cases for Fatigue Strength Assessment	To provide a designer oriented approach to fatigue strength assessment for certain structural details, in lieu of more elaborate method as spectral-based fatigue analysis.
5C-3-A3/Table 2 (New)	Standard Design Load Cases for Fatigue Strength Assessment	To provide a designer oriented approach to fatigue strength assessment for certain structural details, in lieu of more elaborate method as spectral-based fatigue analysis.
5C-3-A3/13 (New)	Critical Areas	To incorporate past experience with critical areas beyond 0.4L for ore carriers.
5C-3-A7/1	General	To clarify the hull girder ultimate strength check at hull girder sections outside 0.4L amidships.
5C-5-2/1.1	General	To specify that the requirements in Appendix 5C-5-A4a is to follow the net thickness approach in 5C-5-A4a/1.3; whereas the net thickness approach in Section 5C-5-2 is to be applicable to the requirement other than those in Appendix 5C-5-A4a.

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-5-3/1.1	Load Components	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/3	Static Loads	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/3.1	Still-water Bending Moments, Shear Forces and Torsional Moment	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 1A (Deleted)	Sign Convention for Vertical Bending Moments and Vertical Shear Forces	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 1	Sign Conventions	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 3A	Loading Pattern of Container Carrier	To allow to use the minimum weight per TEU calculated from the loading manual.
5C-5-3/Figure 3B	Loading Pattern of Container Carrier Fuel Oil Tank Located Between Cargo Hold Transverse Bulkheads	To allow to use the minimum weight per TEU calculated from the loading manual.
5C-5-3/Figure 3C	Loading Pattern of Container Carrier Fuel Oil Tank Located within Cargo Holds	To allow to use the minimum weight per TEU calculated from the loading manual.
5C-5-3/5	Wave-induced Loads	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 4 (Deleted)	Projected Area A_{DK} and Vertical Distance y_f	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 5 (Deleted)	Distribution of Vertical Wave Bending Moment Along the Ship Length	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/5.1.1	Vertical Wave Bending Moment	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/5.1.2	Vertical Wave Shear Force	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/Figure 5 (Deleted)	Distribution of Vertical Wave Shear Force along the Ship Length	To revert subsections on static and wave induced loads back to pre-IACS UR S11A text.
5C-5-3/5.1.3	Horizontal Wave Bending Moment	To provide the definition of V and V_d .
5C-5-3/9.1	Combined Load Cases for Structural Analysis	To refer to 5C-5-A5/Figure 1 and 5C-5-A5/Table 1 for the IACS UR S34 load cases.
5C-5-4/1.1	Strength Requirements	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/3.1	Hull Girder Section Modulus	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Figure 3 (Deleted)	Ends of Length L	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Figure 4 (Deleted)	Reference Coordinate System	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Table 1 (Deleted)	Values of Corrosion Addition Factor	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Table 2 (Deleted)	Corrosion Addition for One Side of a Structural Member	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Figure 5 (Deleted)	Net Sectional Properties of Supporting Members	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Figure 6 (Deleted)	Example of Failure Limit State Curve and Stress Multiplication Factor at Failure	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Table 3 (Deleted)	Load Calculation Points (LCP) Coordinates for Plate Buckling Assessment	To revert requirements back to pre-IACS UR S11A text.

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-5-4/Figure 7 (Deleted)	Load Calculation Points for Plate Buckling Assessment	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Figure 8 (Deleted)	Bending Moment M versus Curvature χ	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Table 4 (Deleted)	Permissible Hull Girder Bending Stress	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/Table 5 (Deleted)	Permissible Hull Girder Shear Stress	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/3.3 (New)	Hull Girder Moment of Inertia	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/4 (New)	Hull Girder Shearing Strength	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/9.3.1	Bottom Shell Plating	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/11.1	Side Shell Plating	To revert requirements back to pre-IACS UR S11A text and to apply the sheer strake requirement to large container carriers.
5C-5-4/13.7	Side Stringers in Double Side Structures	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/15.1	Strength Deck Plating	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/15.13	Underdeck Passageway (Second Deck)	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/15.15 (New)	Raised Lashing Platforms	To provide requirements for raised lashing platforms.
5C-5-4/17.1	Hatch Coamings	To specify that the requirements in 3-2-15/9 applicable to container carriers are to be complied with.
5C-5-4/17.3	Hatch Covers	To specify that the requirements in 3-2-15/9 applicable to container carriers are to be complied with.
5C-5-4/19.1	Tank Bulkhead Plating	To revert requirements back to pre-IACS UR S11A text.
5C-5-4/19.13.1	Tank Bulkhead Plating	To simplify the requirement for tank bulkhead plating between fuel oil tanks not contributing to hull girder bending strength.
5C-5-4/25.1	Fuel Oil Tank Top Plating	To simplify the requirement for fuel oil tank top structures not contributing to hull girder bending strength.
5C-5-6/5.5	Stem Plating	To consider the material factor in the net thickness of the plate stem, in line with CSR-H.
5C-5-A1/Figure 1	Basic Design S-N Curves	To define the second segment of the S-N curves, in line with IACS Rec. No. 56.
5C-5-A4a (New)	Longitudinal Strength Requirements	To reorganize the IACS UR S11A requirements into a relatively independent section.
5C-5-A4c/7.7.3	Bending Stress, σ_b	To specify the static pressure head applied to IACS UR S11A stiffener buckling check.
5C-5-A5/1	General	To decrease the load combination factor for external pressure by 20% to account for the fact that the full draft is not realistic for one bay empty case, and to specify the plate effective width for stiffener ultimate strength check to partially reduce the excessive amendments caused by the requirements.
5C-5-A5/Figure 1 (New)	Additional Loading Patterns of Container Carrier	To decrease the load combination factor for external pressure by 20% to account for the fact that the full draft is not realistic for one bay empty case, and to specify the plate effective width for stiffener ultimate strength check to partially reduce the excessive amendments caused by the requirements.

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
5C-5-A5/Table 1	Additional Combined Load Cases for Structural Analysis	To decrease the load combination factor for external pressure by 20% to account for the fact that the full draft is not realistic for one bay empty case, and to specify the plate effective width for stiffener ultimate strength check to partially reduce the excessive amendments caused by the requirements.
5C-6-2/1.1	Normal-strength Standard	To revert the related references back to pre-IACS UR S11A text.
5C-6-2/1.3	Hull Girder Shear and Bending Moment	To revert the related references back to pre-IACS UR S11A text.
5C-6-2/1.7	Loading Guidance	To revert the related references back to pre-IACS UR S11A text.
5C-6-2/1.11	Hull Girder Section Modulus Amidships	To revert the related references back to pre-IACS UR S11A text.
5C-6-2/1.13 (New)	Longitudinal Strength	To apply IACS UR S11A to containerships under 130 meters in length.
5C-6-A1/3	Application	To revert the requirements and references back to pre-IACS UR S11A text.
5C-6-A1/5.3	Hull Girder Stress	To revert the requirements and references back to pre-IACS UR S11A text.
5C-A2/10 (New)	Construction Standards and Control	To specify the limiting values of misalignment tolerances for cruciform joints
5C-A2/Figure 1 (New)	Median Alignment of Critical Joint	To specify the limiting values of misalignment tolerances for cruciform joints
5C-A2/Figure 2 (New)	Median Alignment of Critical Cruciform Joint	To specify the limiting values of misalignment tolerances for cruciform joints

PART 5C

Specific Vessel Types

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PART 5C

CHAPTER 1 Vessels Intended to Carry Oil in Bulk (150 meters (492 feet) or more in Length)

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PART 5C

CHAPTER 1 Vessels Intended to Carry Oil in Bulk (150 meters (492 feet) or more in Length)

SECTION 1 Introduction

1 General

1.1 Classification (1 July 2001)

In accordance with 1-1-3/3 and 1-1-3/25, the classification notation **✕ A1 Oil Carrier, SH, SHCM** is to be assigned to vessels designed for the carriage of oil cargoes in bulk, and built to the requirements of this Chapter and other relevant sections of the Rules. As used in the Rules, the term “oil” refers to petroleum products having flash points at or below 60°C (140°F), closed cup test, and specific gravity of not over 1.05. Vessels intended to carry fuel oil having a flash point above 60°C (140°F), closed cup test, and to receive classification **✕ A1 Fuel Oil Carrier, SH, SHCM** are to comply with the requirements of this Chapter and other relevant sections of the Rules, with the exception that the requirements for cofferdams, gastight bulkheads and aluminum paint may be modified.

1.2 Optional Class Notation for Design Fatigue Life (2003)

Vessels designed and built to the requirements in this Chapter 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 optional notation is eligible, provided the excess design fatigue life is verified to be in compliance with the criteria in Appendix 1 of this Chapter, “Fatigue Strength Assessment of Tankers”. 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 1 of this Chapter 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.

1.3 Application

1.3.1 Size and Proportion (1997)

The requirements contained in this Chapter are applicable to double hull tankers intended for unrestricted service, having lengths of 150 meters (492 feet) or more, and having parameters within the range as specified in 3-2-1/1.

1.3.2 Vessel Types

The equations and formulae for determining design load and strength requirements, as specified in Section 5C-1-3 and Section 5C-1-4, are applicable to double hull tankers. For mid-deck or single hull tankers, the parameters used in the equations are to be adjusted according to the structural configurations and loading patterns outlined in Appendix 5C-1-A3 or Appendix 5C-1-A4. The strength assessment procedures and the failure criteria, as specified in Section 5C-1-5, are applicable to all types of tankers.

Double hull tanker is a tank vessel having full depth wing water ballast tanks or other non-cargo spaces, and full breadth double bottom water ballast tanks or other non-cargo spaces throughout the cargo area, intended to prevent or at least reduce the liquid cargo outflow in an accidental stranding or collision. The size and capacity of these wing/double bottom tanks or spaces are to comply with MARPOL 73/78 and national Regulations, as applicable.

Mid-deck tanker: Refer to 5C-1-A4/1.1, “Design Concepts”.

Single hull tanker is a tank vessel that does not fit the above definitions of *Double hull tanker* or *Mid-deck tanker*.

1.3.3 Direct Calculations

Direct calculations with respect to the determination of design loads and the establishment of alternative strength criteria based on first principles will be accepted for consideration, provided that all the supporting data, analysis procedures and calculated results are fully documented and submitted for review. In this regard, due consideration is to be given to the environmental conditions, probability of occurrence, uncertainties in load and response predictions and reliability of the structure in service. For long term prediction of wave loads, realistic wave spectra covering the North Atlantic Ocean and a probability level of 10^{-8} are to be employed.

1.3.4 SafeHull Construction Monitoring Program (1 July 2001)

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

1.5 Internal Members (2002)

1.5.1 Section Properties of Structural Members (1 July 2008)

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 or 5C-1-4/Figure 6, as applicable). For structural member with angle θ (see 5C-1-1/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 5C-1-1/Figure 1).

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

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

where

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

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

The effective section area may be obtained from the following equation:

$$A = A_{90} \sin \theta$$

where

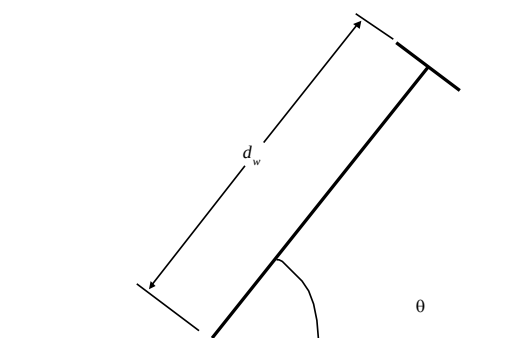
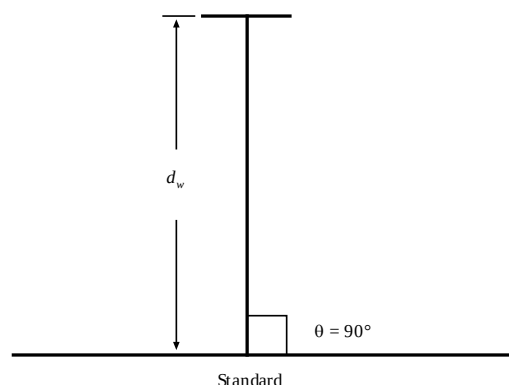
$$A_{90} = \text{effective shear area at } \theta = 90 \text{ degrees}$$

1.5.2 Detailed Design

The detailed design of internals is to follow the guidance given in 3-1-2/15 and 5C-1-4/1.5.

See also Appendix 5C-1-A1 “Fatigue Strength Assessment of Tankers”.

FIGURE 1



1.7 Breaks

Special care is to be taken to provide against local stresses at the ends of the cargo oil spaces, superstructures, etc., and throughout the structure in general. The main longitudinal bulkheads are to be suitably tapered at their ends, and effective longitudinal bulkheads in the poop are to be located such as to provide effective continuity between the structure in way of and beyond the main cargo spaces. Where the break of a superstructure lies within the midship $0.5L$, the required shell and deck scantlings for the amidship $0.4L$ may be required to be extended to effect a gradual taper of the structure, and the deck stringer plate and sheer strake are to be increased. See 5C-1-4/9.1 and 5C-1-4/9.3. Where the breaks of the forecastle or poop are appreciably beyond the amidship $0.5L$, the requirements for the deck stringer plate and sheer strake, as specified in 5C-1-4/9.1 and 5C-1-4/9.3, may be modified.

1.9 Variations

Tankers of a special type or design, differing from those described in these Rules, will be specially considered on the basis of equivalent strength.

1.11 Loading Guidance (1997)

Loading guidance is to be as required by 3-2-1/7, except that 5C-1-4/5 will apply for allowable shear stresses.

1.13 Pressure-Vacuum Valve Setting (1993)

Where pressure-vacuum valves of cargo oil tanks are set at a pressure in excess of the pressure appropriate to the length of the vessel (see 5C-1-7/11.11.2), the tank scantlings will be specially considered.

Particular attention is to be given to a higher pressure setting of pressure-vacuum valves as may be required for the efficient operation of cargo vapor emission control systems, where installed.

1.15 Protection of Structure

For the protection of structure, see 3-2-18/5.

1.17 Aluminum Paint (2014)

Paint containing greater than 10 percent aluminum is not to be used in cargo tanks, on tank decks in way of cargo tanks, and in pump rooms and cofferdams, nor in any other area where cargo vapor may accumulate.

3 Special Requirements for Deep Loading

3.1 General (2003)

Where a vessel is intended to operate at the minimum freeboard allowed by the International Convention on Load Lines, 1966 for Type-A vessels, the conditions in 5C-1-1/3.3 through 5C-1-1/3.11 are to be complied with.

3.3 Machinery Casings

Machinery casings are normally to be protected by an enclosed poop or bridge, or by a deckhouse of equivalent strength. The height of such structure is to be not less than 2.3 m (7.5 ft). The bulkheads at the forward ends of these structures are to have scantlings not less than required for bridge-front bulkheads (See 3-2-11/3). Machinery casings may be exposed, provided that they are specially stiffened and there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of 3-2-11/5.3 may, however, be permitted in the exposed machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the engine room by a second door complying with 3-2-11/5.3. The sill of the exterior door is not to be less than 600 mm (23.5 in.), and the sill of the second door is not to be less than 230 mm (9 in.).

3.5 Access (1998)

Satisfactory arrangements are to be provided to safeguard the crew in reaching all areas used in the necessary work of the vessel. See 3-2-17/3.

3.7 Hatchways

Exposed hatchways on the freeboard and forecastle decks or on the tops of expansion trunks are to be provided with efficient steel watertight covers. The use of material other than steel will be subject to special consideration.

3.9 Freeing Arrangements

Tankers with bulwarks are to have open rails fitted for at least half the length of the exposed parts of the freeboard and superstructure decks, or other effective freeing arrangements are to be provided. The upper edge of the sheer strake is to be kept as low as practicable. Where superstructures are connected by trunks, open rails are to be fitted for the entire length of the exposed parts of the freeboard deck.

3.11 Flooding (2003)

Attention is called to the requirement of the International Convention on Load Lines, 1966, that tankers over 150 m (492 ft) in freeboard length (see 3-1-1/3.3), to which freeboards less than those based solely on Table B are assigned, must be able to withstand the flooding of certain compartments.

3.13 Ventilators (2003)

Ventilators to spaces below the freeboard deck are to be specially stiffened or protected by superstructures or other efficient means. See also 3-2-17/9.

5 Arrangement (1994)

5.1 General (2017)

The arrangements of the vessel are to comply with the requirements in Annex 1 to the International Convention for the Prevention of Pollution from Ships with regard to segregated ballast tanks (Regulation 18), their protective locations (Regulation 18.12), collision or stranding considerations (Regulation 19), accidental oil outflow performance (Regulation 23), hypothetical outflow of oil (Regulation 25)*, limitations of size and arrangement of cargo tanks (Regulation 26)*, and slop tanks (Regulation 29). A valid International Oil Pollution Prevention Certificate issued by the flag administration may be accepted as evidence of compliance with these requirements.

* *Note:* Hypothetical outflow of oil (Regulation 25) and limitations of size and arrangement of cargo tanks (Regulation 26) do not apply to oil tankers delivered on or after 1 January 2010, as defined in MARPOL Annex I regulation 1.28.8.

5.3 Subdivision

The length of tanks, the location of expansion trunks and the position of longitudinal bulkheads are to be arranged to avoid excessive dynamic stresses in the hull structure.

5.5 Cofferdams

Cofferdams, thoroughly oiltight and vented, and having widths as required for ready access, are to be provided in order to separate all cargo tanks from galleys and living quarters, general cargo spaces which are below the uppermost continuous deck, boiler rooms and spaces containing propulsion machinery or other machinery where sources of ignition are normally present. Pump rooms, compartments arranged solely for ballast and fuel oil tanks may be considered as cofferdams for the purpose of this requirement.

5.7 Gastight Bulkheads

Gastight bulkheads are to be provided in order to isolate all cargo pumps and piping from spaces containing stoves, boilers, propelling machinery, electric apparatus or machinery where sources of ignition are normally present. These bulkheads are to comply with the requirements of Section 3-2-9.

5.9 Cathodic Protection (1996)

5.9.1 Anode Installation Plan

Where sacrificial anodes are fitted in cargo or adjacent ballast tanks, their material, their disposition and details of their attachment are to be submitted for approval.

5.9.2 Magnesium and Magnesium Alloy Anodes

Magnesium and magnesium alloy anodes are not to be used.

5.9.3 Aluminum Anodes (2006)

Aluminum anodes may be used in the cargo tanks and tanks adjacent to the cargo tanks of tankers in locations where the potential energy does not exceed 275 N-m (28 kgf-m, 200 ft-lb). The height of the anode is to be measured from the bottom of the tank to the center of the anode, and the weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

Where aluminum anodes are located on horizontal surfaces, such as bulkhead girders and stringers, which are not less than 1 m (39 in.) wide and fitted with an upstanding flange or face flat projecting not less than 75 mm (3 in.) above the horizontal surface, the height of the anode may be measured from this surface.

Aluminum anodes are not to be located under tank hatches or Butterworth openings unless protected from falling metal objects by adjacent tank structure.

5.9.4 Zinc Anodes (2006)

There is no restriction on the positioning of zinc anodes.

5.9.5 Anode Attachment

Anodes are to have steel cores sufficiently rigid to avoid resonance in the anode support, and the cores are to be designed to retain the anode even when it is wasted.

The steel cores are to be attached to the structure by means of continuous welds at least 75 mm (3 in.) in length. Alternatively, they may be attached to separate supports by bolting. A minimum of two bolts with locknuts is to be used.

The supports at each end of an anode are not to be attached to items of structure that are likely to move independently.

Anode inserts and supports welded directly to the structure are to be arranged so that the welds are clear of stress raisers.

5.11 Ports in Pump Room Bulkheads

Where fixed ports are fitted in the bulkheads between a pump room and the machinery or other safe space, they are to maintain the gastight and watertight integrity of the bulkhead. The ports are to be effectively protected against the possibility of mechanical damage and are to be fire resistant. Hinged port covers of steel, having non-corrosive hinge pins and secured from the safe space side, are to be provided. The covers are to provide strength and integrity equivalent to the unpierced bulkhead. Except where it may interfere with the function of the ports, the covers are to be secured in the closed position. The use of material other than steel for the covers will be subject to special consideration. Lighting fixtures providing strength and integrity equivalent to that of the port covers will be accepted as an alternative.

5.13 Location of Cargo Oil Tank Openings

Cargo oil tank openings, including those for tank cleaning, which are not intended to be secured gastight at all times during the normal operation of the vessel, are not to be located in enclosed spaces. For the purpose of this requirement, spaces open on one side only are to be considered enclosed. See also 5C-1-1/5.23.

5.15 Structural Fire Protection

The applicable requirements of Section 3-4-1 are to be complied with.

5.17 Allocation of Spaces (1994)

5.17.1 Tanks Forward of the Collision Bulkhead

Tanks forward of the collision bulkhead are not to be arranged for the carriage of oil or other liquid substances that are flammable.

5.17.2 Double Bottom Spaces and Wing Tank Spaces

For vessels of 5000 metric tons (4921 long tons) deadweight and above, double bottom spaces or wing tanks adjacent to cargo oil tanks are to be allocated for water ballast or spaces other than cargo and fuel oil tanks.

5.19 Access to Upper Parts of Ballast Tanks on Double Hull Tankers (1993)

Where the structural configuration within ballast tanks is such that it will prevent access to upper parts of the tanks for required close-up examination (see 7-3-2/5.13.4) by conventional means, such as a raft on partly filled tank, permanent means of safe access is to be provided. Details of the access are to be submitted for review.

Where horizontal girders or diaphragm plates are fitted, they may be considered as forming part of a permanent access. Alternative arrangements to the above may be considered upon submission.

5.21 Access to All Spaces in the Cargo Area (1 October 1994)

Access to cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area is to be direct and from the open deck. Access to double bottom spaces may be through a cargo pump room, deep cofferdam, pipe tunnel or similar space, provided ventilation is suitable.

For access through horizontal openings, hatches or manholes, the access is to be of a size such as to allow a person wearing a self-contained, air-breathing apparatus and protective equipment (see 4-7-3/15.5) to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. In general, the minimum clear opening is not to be less than 600 mm (24 in.) by 600 mm (24 in.).

For access through vertical openings or manholes providing passage through the length and breadth of the space, the minimum clear opening is not to be less than 600 mm (24 in.) by 800 mm (32 in.) at a height of not more than 600 mm (24 in.) from the bottom shell plating unless gratings or other footholds are provided.

5.23 Duct Keels or Pipe Tunnels in Double Bottom (2000)

Duct keels or pipe tunnels are not to pass into machinery spaces. Provision is to be made for at least two exits to the open deck, arranged at a maximum distance from each other. One of these exits may lead to the cargo pump room, provided that it is watertight and fitted with a watertight door complying with the requirements of 3-2-9/9.1 and in addition complying with the following:

- i) In addition to bridge operation, the watertight door is to be capable of being closed from outside the main pump room entrance; and
- ii) A notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the vessel, except when access to the pipe tunnel is required.

For the requirements of ventilation and gas detection in duct keels or pipe tunnels, see 5C-1-7/31.17.1.

5.25 Ventilation (1996)

Holes are to be cut in every part of the structure where otherwise there might be a chance of gases being "pocketed". Special attention is to be paid to the effective ventilation of pump rooms and other working spaces adjacent to oil tanks. In general, floor plating is to be of an open type not to restrict the flow of air, see 5C-1-7/17.1 and 5C-1-7/17.5. Efficient means are to be provided for clearing the oil spaces of dangerous vapors by means of artificial ventilation or steam. For cargo tank venting, see 5C-1-7/11 and 5C-1-7/21.

5.27 Pumping Arrangements

See applicable requirements in Section 5C-1-7.

5.29 Electrical Equipment

See 5C-1-7/31.

5.31 Testing

Requirements for testing are contained in Part 3, Chapter 7.

5.33 Machinery Spaces

Machinery spaces aft are to be specially stiffened transversely. Longitudinal material at the break is also to be specially considered to reduce concentrated stresses in this region. Longitudinal wing bulkheads are to be incorporated with the machinery casings or with substantial accommodation bulkheads in the tween decks and within the poop.

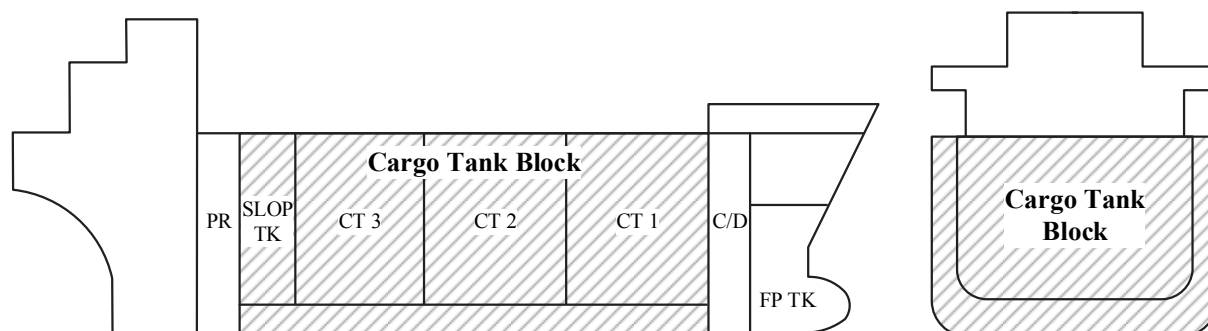
5.35 Location of Fuel Tanks in Cargo Area (1 July 2017)

Fuel tanks that have a common boundary to cargo tanks are not to be situated within the cargo tank block. Such tanks may, however, be situated at the forward and aft ends of the cargo tank block instead of cofferdams. Fuel tanks are not to extend either fully or partly into cargo or slop tanks. They may, however, be located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations. Fuel tanks are not permitted to extend into the protective area of cargo tanks required by MARPOL Annex I.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces, see 4-6-4/13. For electrical equipment, requirements to hazardous area classification are to be taken into account.

The cargo tank block, shown in 5C-1-1/Figure 2, is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank.

FIGURE 2
Cargo Tank Block (1 July 2017)



PART 5C

CHAPTER 1 Vessels Intended to Carry Oil in Bulk (150 meters (492 feet) or more in Length)

SECTION 2 Design Considerations and General Requirements

1 General Requirements (1995)

1.1 General (1995)

The strength requirements specified in this Chapter are based on a “net” ship approach. In determining the required scantlings and performing structural analyses and strength assessments, the nominal design corrosion values given in 5C-1-2/Table 1 are to be deducted.

1.3 Initial Scantling Requirements (1995)

The initial thickness of plating, the section modulus of longitudinals/stiffeners, and the scantlings of the main supporting structures are to be determined in accordance with Section 5C-1-4 for the “net” ship. These “net” ship values are to be used for further assessment as required in the following paragraph. The relevant nominal design corrosion values are then added to obtain the full scantling requirements.

1.5 Strength Assessment – Failure Modes (1995)

A total assessment of the structures, determined on the basis of the initial strength criteria in Section 5C-1-4 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 5C-1-5/3.1 for all load cases specified in 5C-1-3/9.

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 5C-1-5/5. In addition, the hull girder ultimate strength is to be in accordance with 5C-1-5/5.11.

1.5.3 Fatigue

The fatigue strength of structural details and welded joints in highly stressed regions is to be analyzed in accordance with 5C-1-5/7.

1.7 Structural Redundancy and Residual Strength (1995)

Consideration should be given to structural redundancy and hull girder residual strength in the early design stages.

In addition to other requirements of these Rules, vessels which have been built in accordance with the procedure and criteria for calculating and evaluating the residual strength of hull structures, as outlined in the *ABS Guide for Assessing Hull Girder Residual Strength*, will be classed and distinguished in the *Record* by the symbol **RES** placed after the appropriate hull classification notation.

3 Nominal Design Corrosion Values (NDCV) (1995)

3.1 General

As indicated in 5C-1-2/1.1, the strength criteria specified in this Chapter are based on a “net” ship approach, wherein the nominal design corrosion values are deducted.

The “net” thickness or scantlings correspond to the minimum strength requirements acceptable for classification, regardless of the design service life of the vessel. In addition to the coating protection specified in the Rules for all ballast tanks, minimum corrosion values for plating and structural members as given in 5C-1-2/Table 1 and 5C-1-2/Figure 1 are to be applied. These minimum values are being introduced solely for the above purpose, and are not to be construed as renewal standards.

In view of the anticipated higher corrosion rates for structural members in some regions, such as highly stressed areas, additional design margins should be considered for the primary and critical structural members to minimize repairs and maintenance costs. The beneficial effects of these design margins on reduction of stresses and increase of the effective hull girder section modulus can be appropriately accounted for in the design evaluation.

[illegible]

TABLE 1
Nominal Design Corrosion Values (NDCV) (1995)

<i>Structural Element/Location</i>		<i>Nominal Design Corrosion Values in mm (in.)</i>	
		<i>Cargo Tank</i>	<i>Ballast Tank Effectively Coated</i>
Deck Plating		1.0 (0.04)	2.0 (0.08)
Side Shell Plating		NA	1.5 (0.06)
Bottom Plating		NA	1.0 (0.04)
Inner Bottom Plating		1.5 (0.06)	
Longitudinal Bulkhead Plating	Between cargo tanks	1.0 (0.04)	N.A.
	Other Plating	1.5 (0.06)	
Transverse Bulkhead Plating	Between cargo tanks	1.0 (0.04)	N.A.
	Other Plating	1.5 (0.06)	
Transverse & Longitudinal Deck Supporting Members		1.5 (0.06)	2.0 (0.08)
Double Bottom Tanks Internals (Stiffeners, Floors and Girders)		N.A.	2.0 (0.08)
Vertical Stiffeners and Supporting Members Elsewhere		1.0 (0.04)	1.0 (0.04)
Non-vertical Longitudinals/Stiffeners and Supporting Members Elsewhere		1.5 (0.06)	2.0 (0.08)

Notes

- 1 It is recognized that corrosion depends on many factors including coating properties, cargo composition, inert gas properties and temperature of carriage, and that actual wastage rates observed may be appreciably different from those given here.
- 2 Pitting and grooving are regarded as localized phenomena and are not covered in this table.
- 3 For nominal design corrosion values for single hull and mid-deck type tankers, see Appendix 5C-1-A3 and Appendix 5C-1-A4.

PART 5C

CHAPTER 1 Vessels Intended to Carry Oil in Bulk (150 meters (492 feet) or more in Length)

SECTION 3 Load Criteria

1 General

1.1 Load Components (1995)

In the design of the hull structure of tankers, all load components with respect to the hull girder and local structure as specified in this Chapter and Section 3-2-1 are to be taken into account. These include static loads in still water, wave-induced motions and loads, sloshing, slamming, dynamic, thermal and ice loads, where applicable.

3 Static Loads (1995)

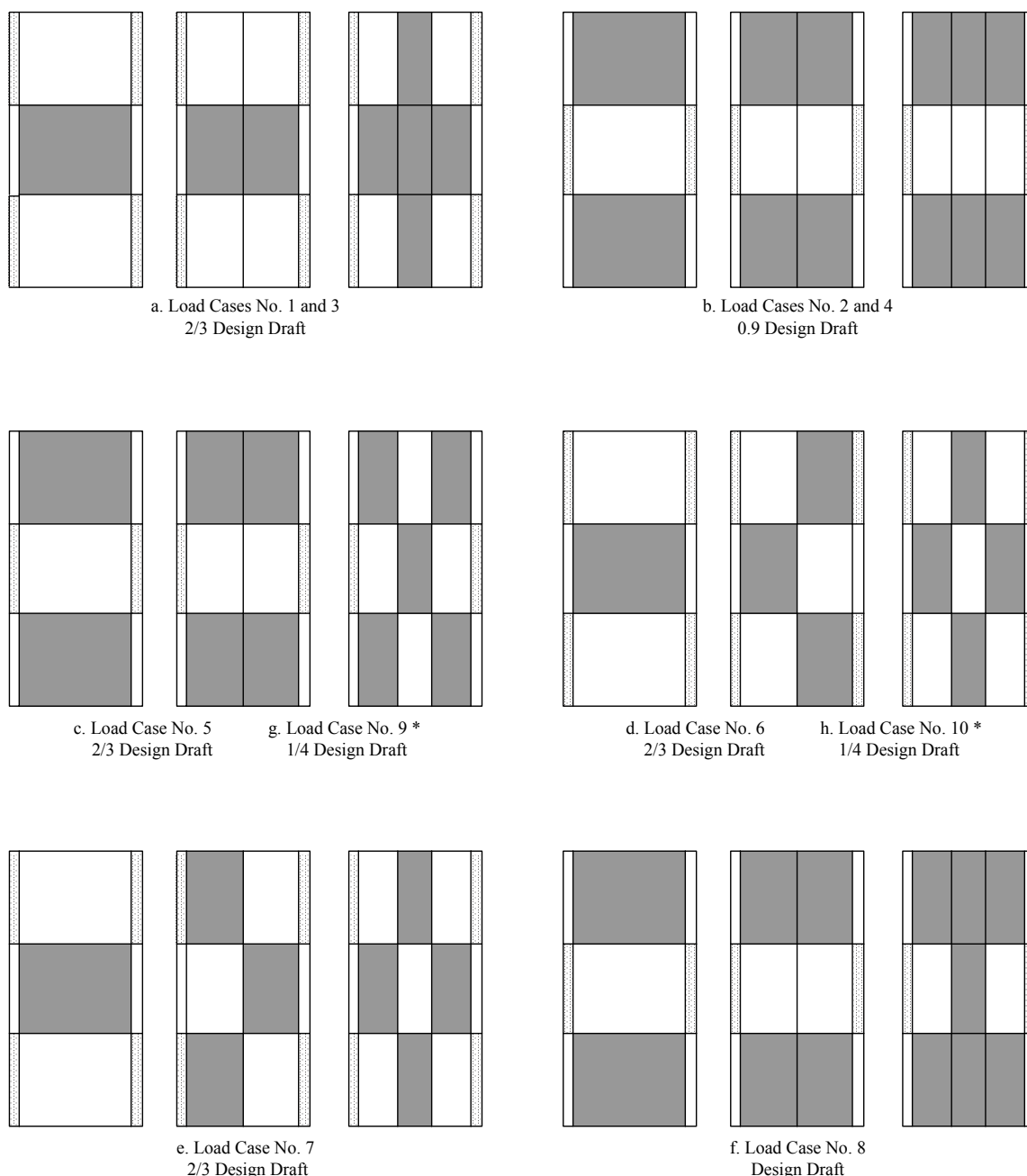
3.1 Still-water Bending Moment

For still-water bending moment calculations, see 3-2-1/3.3.

When a direct calculation of wave-induced loads [i.e., longitudinal bending moments and shear forces, hydrodynamic pressures (external) and inertial forces and added pressure heads (internal)] is not submitted, envelope curves of the still-water bending moments (hogging and sagging) and shear forces (positive and negative) are to be provided.

Except for special loading cases, the loading patterns shown in 5C-1-3/Figure 1 are to be considered in determining local static loads.

FIGURE 1
Loading Pattern (1 July 2005)



For detailed loading information see 5C-1-3/Table 1A and 5C-1-3/Table 1B.

* For L.C. 9 and 10, where static conditions, such as tank testing, that have the same load pattern as the center row of tanks resulting in a draft less than 1/4 Design Draft, the actual static condition draft is to be used. For vessels with two outer longitudinal bulkheads only (inner skin), the minimum actual static condition or tank test draft is to be used. The value of $k_s = 1.0$ is to be used in all tanks. The tanks are to be loaded considering the actual height of the overflow pipe, which is not to be taken less than 2.44 m (8 feet) above the deck at side.

(1 July 2005) For a hull structure with the main supporting members that are asymmetric forward and after the mid-tank transverse bulkheads, the above load cases are to be evaluated by turning the finite element model by 180 degrees with respect to the vertical axis.

(1 July 2005) For a hull structure that is asymmetric with respect to the centerline plane, the additional load cases mirroring the above asymmetric load case are to be evaluated.

5 Wave-induced Loads (1995)

5.1 General

Where a direct calculation of the wave-induced loads is not available, the approximation equations given below and specified in 3-2-1/3.5 may be used to calculate the design loads.

When a direct calculation of the wave-induced loads is performed, envelope curves of the combined wave and still-water bending moments and shear forces, covering all the anticipated loading conditions, are to be submitted for review.

5.3 Horizontal Wave Bending Moment and Shear Force (1995)

5.3.1 Horizontal Wave Bending Moment

The horizontal wave bending moment, positive (tension port) or negative (tension starboard), may be obtained from the following equation:

$$M_H = \pm m_h K_3 C_1 L^2 D C_b \times 10^{-3} \quad \text{kN-m (tf-m, Ltf-ft)}$$

where

m_h = distribution factor, as given by 5C-1-3/Figure 2

K_3 = 180 (18.34, 1.68)

D = depth of vessel, as defined in 3-1-1/7, in m (ft)

C_1 , L , and C_b are as given in 3-2-1/3.5.

5.3.2 Horizontal Wave Shear Force

The envelope of horizontal wave shearing force, F_H , positive (toward port forward) or negative (toward starboard aft), may be obtained from the following equation:

$$F_H = \pm f_h k C_1 L D (C_b + 0.7) \times 10^{-2} \quad \text{kN (tf, Ltf)}$$

where

f_h = distribution factor, as given in 5C-1-3/Figure 3

k = 36 (3.67, 0.34)

C_1 , L , D and C_b are as defined in 5C-1-3/5.3.1 above.

5.5 External Pressures

5.5.1 Pressure Distribution

The external pressures, p_e , (positive toward inboard), imposed on the hull in seaways can be expressed by the following equation at a given location:

$$p_e = \rho g (h_s + k_u h_{de}) \geq 0 \quad \text{N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{)}$$

where

ρg = specific weight of sea water

= 1.005 N/cm²-m (0.1025 kgf/cm²-m, 0.4444 lbf/in²-ft)

h_s = hydrostatic pressure head in still water, in m (ft)

k_u = load factor, and may be taken as unity unless otherwise specified.

h_{de} = hydrodynamic pressure head induced by the wave, in m (ft), may be calculated as follows:

= $k_c h_{di}$

where

- k_c = correlation factor for a specific combined load case, as given in 5C-1-3/7.1 and 5C-1-3/9
- h_{di} = hydrodynamic pressure head, in m (ft), at location i ($i = 1, 2, 3, 4$ or 5 ; see 5C-1-3/Figure 4)
- = $k_\ell \alpha_i h_{do}$ in m (ft)
- k_ℓ = distribution factor along the length of the vessel
- = $1 + (k_{\ell o} - 1) \cos \mu$, $k_{\ell o}$ is as given in 5C-1-3/Figure 5
- = 1.0 amidships
- h_{do} = $1.36 k C_1$ in m (ft)
- C_1 = as defined in 3-2-1/3.5
- k = 1 (1, 3.281)
- α_i = distribution factor around the girth of vessel at location i .
- = $1.00 - 0.25 \cos \mu$ for $i = 1$, at WL, starboard
- = $0.40 - 0.10 \cos \mu$ for $i = 2$, at bilge, starboard
- = $0.30 - 0.20 \sin \mu$ for $i = 3$, at bottom centerline
- = $2\alpha_3 - \alpha_2$ for $i = 4$, at bilge, port
- = $0.75 - 1.25 \sin \mu$ for $i = 5$, at WL, port
- α_i at intermediate locations of i may be obtained by linear interpolation.
- μ = wave heading angle, to be taken from 0° to 90° (0° for head sea, 90° for beam sea for wave coming from starboard)

The distribution of the total external pressure including static and hydrodynamic pressure is illustrated in 5C-1-3/Figure 6.

5.5.2 Extreme Pressures

In determining the required scantlings of local structural members, the extreme external pressure, p_e , to be used, is as defined in 5C-1-3/5.5.1 with k_u as given in 5C-1-3/7 and 5C-1-3/9.

5.5.3 Simultaneous Pressures

When performing 3D structural analysis, the simultaneous pressure along any portion of the hull girder may be obtained from:

$$p_{es} = \rho g(h_s + k_f k_u h_{de}) \geq 0 \quad \text{N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{)}$$

where

k_f is a factor denoting the phase relationship between the reference station and adjacent stations considered along the vessel's length, and may be determined as follows:

$$k_f = k_{fo} \left\{ 1 - \left[1 - \cos \frac{2\pi(x - x_o)}{L} \right] \cos \mu \right\}$$

where

- x = distance from A.P. to the station considered, in m (ft)
- x_o = distance from A.P. to the reference station*, in m (ft).
- L = the vessel length, as defined in 3-1-1/3, in m (ft)

μ = the wave heading angle, to be taken from 0° to 90°

k_{fo} = ± 1.0 , as specified in 5C-1-3/Table 1.

* The reference station is the point along the vessel's length where the wave trough or crest is located and may be taken as the mid-point of the mid-hold of the three hold model.

The simultaneous pressure distribution around the girth of the vessel is to be determined based on the wave heading angles specified in 5C-1-3/7 and 5C-1-3/9.

5.7 Internal Pressures – Inertia Forces and Added Pressure Heads (1995)

5.7.1 Ship Motions and Accelerations

To determine the inertial forces and added pressure heads for a completely filled cargo or ballast tank, the dominating ship motions, pitch and roll, and the resultant accelerations induced by the wave are required. When a direct calculation is not available, the equations given below may be used.

5.7.1(a) *Pitch (1 July 2005)*. The pitch amplitude: (positive bow up)

$\phi = k_1(V/C_b)^{1/4}/L$, in deg., but need not to be taken more than 10 deg.

The pitch natural period:

$T_p = k_2 \sqrt{C_b d_i}$ seconds.

where

$k_1 = 1030$ (3378) for L in m (ft)

$k_2 = 3.5$ (1.932) for d_i in m (ft)

$V = 75\%$ of the design speed V_d , in knots for the purpose of calculating pitch and roll amplitudes for both strength and fatigue strength formulation. V is not to be taken less than 10 knots. V_d is defined in 3-2-14/3.

$d_i =$ draft amidships for the relevant loading conditions.

L and C_b are defined in 3-1-1/3.1 and 3-1-1/11.3, respectively.

5.7.1(b) *Roll (1 July 2005)*. The roll amplitude: (positive starboard down)

$\theta = C_R(35 - k_\theta C_{di} \Delta/1000)$ if $T_r > 20$ seconds.

$\theta = C_R(35 - k_\theta C_{di} \Delta/1000) (1.5375 - 0.027T_r)$ if $12.5 \leq T_r \leq 20$ seconds

$\theta = C_R(35 - k_\theta C_{di} \Delta/1000) (0.8625 + 0.027T_r)$ if $T_r \leq 12.5$ seconds

where

θ is in degrees, but need not to be taken greater than 30°.

$k_\theta = 0.005$ (0.05, 0.051)

$C_R = 1.3 - 0.025V$

$C_{di} = 1.06 (d_i/d_f) - 0.06$

$d_i =$ draft amidships for the relevant loading conditions, m (ft)

$d_f =$ draft, as defined in 3-1-1/9, m (ft)

$\Delta = k_d L B d_f C_b$ kN (tf, Ltf)

$k_d = 10.05$ (1.025, 0.0286)

L and B are as defined in Section 3-1-1.

The roll natural motion period:

$$T_r = k_4 k_r / GM^{1/2} \text{ seconds}$$

where

$$k_4 = 2 (1.104) \quad \text{for } k_r, GM \text{ in m (ft)}$$

$$k_r = \text{roll radius of gyration, in m (ft), and may be taken as } 0.35B \text{ for full load conditions and } 0.45B \text{ for ballast conditions.}$$

$$GM = \text{metacentric height, to be taken as:}$$

$$= GM (\text{full}) \quad \text{for full draft}$$

$$= 1.1 GM (\text{full}) \quad \text{for } 9/10 d_f$$

$$= 1.5 GM (\text{full}) \quad \text{for } 2/3 d_f$$

$$= 2.0 GM (\text{full}) \quad \text{for } 1/2 d_f$$

$$GM (\text{full}) = \text{metacentric height for fully loaded condition}$$

If $GM (\text{full})$ is not available, $GM (\text{full})$ may be taken as $0.12B$ for the purpose of estimation.

5.7.1(c) *Accelerations (1 July 2005)*. The vertical, longitudinal and transverse accelerations of tank contents (cargo or ballast), a_v , a_ℓ and a_t may be obtained from the following formulae:

$$a_v = C_v k_v a_o g \quad \text{m/sec}^2 \text{ (ft/sec}^2\text{)} \quad \text{positive downward}$$

$$a_\ell = C_\ell k_\ell a_o g \quad \text{m/sec}^2 \text{ (ft/sec}^2\text{)} \quad \text{positive forward}$$

$$a_t = C_t k_t a_o g \quad \text{m/sec}^2 \text{ (ft/sec}^2\text{)} \quad \text{positive starboard}$$

where

$$a_o = k_o (2.4/L^{1/2} + 34/L - 600/L^2) \quad \text{for } L \text{ in m}$$

$$= k_o (4.347/L^{1/2} + 111.55/L - 6458/L^2) \quad \text{for } L \text{ in ft}$$

$$k_o = 1.3 - 0.47C_b \text{ for strength formulation and assessment of local structural elements and members in Section 5C-1-4, 5C-1-5/1, 5C-1-3/3 and 5C-1-5/5.}$$

$$= 0.86 + 0.048V - 0.47C_b \text{ for fatigue strength formulation in 5C-1-5/7 and Appendix 5C-1-A1}$$

$$C_v = \cos \mu + (1 + 2.4 z/B) (\sin \mu)/k_v$$

$$\mu = \text{wave heading angle in degrees, } 0^\circ \text{ for head sea, and } 90^\circ \text{ for beam sea for wave coming from starboard}$$

$$k_v = [1 + 0.65(5.3 - 45/L)^2 (x/L - 0.45)^2]^{1/2} \quad \text{for } L \text{ in m}$$

$$= [1 + 0.65(5.3 - 147.6/L)^2 (x/L - 0.45)^2]^{1/2} \quad \text{for } L \text{ in ft}$$

$$C_\ell = 0.35 - 0.0005(L - 200) \quad \text{for } L \text{ in m}$$

$$= 0.35 - 0.00015 (L - 656) \quad \text{for } L \text{ in ft}$$

$$k_\ell = 0.5 + 8y/L$$

$$C_t = 1.27[1 + 1.52(x/L - 0.45)^2]^{1/2}$$

$$k_t = 0.35 + y/B$$

L and B are the length and breadth of the vessel respectively, as defined in Section 3-1-1, in m (ft).

- x = longitudinal distance from the A.P. to the station considered, in m (ft)
 y = vertical distance from the waterline to the point considered, in m (ft), positive upward
 z = transverse distance from the centerline to the point considered, in m (ft), positive starboard
 g = acceleration of gravity = 9.8 m/sec² (32.2 ft/sec²)

5.7.2 Internal Pressures

5.7.2(a) *Distribution of Internal Pressures.* (1 July 2000) The internal pressure, P_i (positive toward tank boundaries), for a completely filled tank may be obtained from the following formula:

$$p_i = k_s \rho g (\eta + k_u h_d) + p_o \geq 0 \quad \text{in N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{)}$$

$$p_o = (p_{vp} - p_n) \geq 0 \quad \text{in N/cm}^2 \text{ (kgf/cm}^2, \text{ lbf/in}^2\text{)}$$

where

$$p_{vp} = \text{pressure setting on pressure/vacuum relief valve} \leq 6.90 \text{ N/cm}^2 \text{ (0.71 kgf/cm}^2, \text{ 10.00 lbf/in}^2\text{) for integral-gravity tanks}$$

$$p_n = 2.06 \text{ N/cm}^2 \text{ (0.21 kgf/cm}^2, \text{ 3.00 lbf/in}^2\text{)}$$

$$\rho g = \text{specific weight of the liquid, not to be taken less than } 1.005 \text{ N/cm}^2\text{-m} \text{ (0.1025 kgf/cm}^2\text{-m, 0.4444 lbf/in}^2\text{-ft)}$$

$$\eta = \text{local coordinate in vertical direction for tank boundaries measuring from the top of the tanks, as shown 5C-1-3/Figure 7, in m (ft)}$$

For lower ballast tanks, a distance equivalent to $2/3$ of the distance from the top of the tank to the top of the overflow [minimum 760 mm (30 in.) above deck] is to be added to η .

$$k_s = \text{load factor – see also 5C-1-3/5.7.2(c)}$$

$$= 1.0 \text{ for structural members 1 through 10 in 5C-1-3/Table 3, and for all loads from ballast tanks}$$

$$= 0.878 \text{ for } \rho g \text{ of } 1.005 \text{ N/cm}^2\text{-m (0.1025 kgf/cm}^2\text{-m, 0.4444 lbf/in}^2\text{-ft) and } 1.0 \text{ for } \rho g \text{ of } 1.118 \text{ N/cm}^2\text{-m (0.114 kgf/cm}^2\text{-m, 0.4942 lbf/in}^2\text{-ft) and above for structural members 11 through 17 in 5C-1-3/Table 3}$$

For cargo ρg between 1.005 N/cm²-m (0.1025 kgf/cm²-m, 0.4444 lbf/in²-ft) and 1.118 N/cm²-m (0.114 kgf/cm²-m, 0.4942 lbf/in²-ft), the factor k_s may be determined by interpolation

$$k_u = \text{load factor and may be taken as unity unless otherwise specified}$$

$$h_d = \text{wave-induced internal pressure head, including inertial force and added pressure head.}$$

$$= k_c (\eta a_i / g + \Delta h_i) \quad \text{in m (ft)}$$

$$k_c = \text{correlation factor and may be taken as unity unless otherwise specified}$$

$$a_i = \text{effective resultant acceleration, in m/sec}^2 \text{ (ft/sec}^2\text{), at the point considered and may be approximated by}$$

$$= 0.71 C_{dp} [w_v a_v + w_\ell (\ell/h) a_\ell + w_t (b/h) a_t]$$

C_{dp} is as specified in 5C-1-3/5.7.2(d).

a_v , a_ℓ and a_t are as given in 5C-1-3/5.7.1(c).

w_v , w_ℓ and w_t are weighted coefficients, showing directions, as specified in 5C-1-3/Table 1 and 5C-1-3/Table 3.

Δh_i = added pressure head due to pitch and roll motions at the point considered, in m (ft), may be calculated as follows

i) for bow down and starboard down ($\phi_e < 0$, $\theta_e > 0$)

$$\Delta h_i = \xi \sin(-\phi_e) + C_{ru} (\zeta_e \sin \theta_e \cos \phi_e + \eta_e \cos \theta_e \cos \phi_e - \eta)$$

$$\zeta_e = b - \zeta$$

$$\eta_e = \eta$$

ii) for bow up and starboard up ($\phi_e > 0$, $\theta_e < 0$)

$$\Delta h_i = (\ell - \xi) \sin \phi_e + C_{ru} (\zeta_e \sin(-\theta_e) \cos \phi_e + \eta_e \cos \theta_e \cos \phi_e - \eta)$$

$$\zeta_e = \zeta - \delta_b$$

$$\eta_e = \eta - \delta_h$$

ξ , ζ , η are the local coordinates, in m (ft), for the point considered with respect to the origin in 5C-1-3/Figure 7.

C_{ru} is as specified in 5C-1-3/5.7.2(d).

δ_b and δ_h are local coordinates adjustments, in m (ft), for the point considered with respect to the origin shown in 5C-1-3/Figure 7.

where

$$\theta_e = 0.71 C_\theta \theta$$

$$\phi_e = 0.71 C_\phi \phi$$

$$\ell = \text{length of the tank, in m (ft)}$$

$$h = \text{depth of the tank, in m (ft)}$$

$$b = \text{breadth of the tank considered, in m (ft)}$$

ϕ and θ are pitch and roll amplitudes, as given in 5C-1-3/5.7.1(a) and 5C-1-3/5.7.1(b)

C_ϕ and C_θ are weighted coefficients, showing directions as given in 5C-1-3/Table 1 and 5C-1-3/Table 3

Where pressure-vacuum valves of cargo tanks are set at greater than 2.06 N/cm² (0.21 kgf/cm², 3 lbf/in²), the value of P_i is to be increased appropriately.

5.7.2(b) Extreme Internal Pressure. For assessing local structures at a tank boundary, the extreme internal pressure with k_u , as specified in 5C-1-3/7, is to be considered.

5.7.2(c) Simultaneous Internal Pressures (1 July 2000). In performing a 3D structural analysis, the internal pressures may be calculated in accordance with 5C-1-3/5.7.2(a) and 5C-1-3/5.7.2(b) above for tanks in the mid-body. For tanks in the fore or aft body, the pressures should be determined based on linear distributions of accelerations and ship motions along the length of the vessel.

Note: In performing a 3D structural analysis, k_s in 5C-1-3/5.7.2(a) is to be taken as:

$$\begin{aligned} k_s &= 1.0 \text{ for all loads from ballast tanks} \\ &= 0.878 \text{ for } \rho g \text{ of } 1.005 \text{ N/cm}^2\text{-m (0.1025 kgf/cm}^2\text{-m, 0.4444 lbf/in}^2\text{-ft) and} \\ &\quad 1.0 \text{ for } \rho g \text{ of } 1.118 \text{ N/cm}^2\text{-m (0.114 kgf/cm}^2\text{-m, 0.4942 lbf/in}^2\text{-ft) and above} \\ &\quad \text{for all loads from cargo tanks} \end{aligned}$$

For cargo ρg between 1.005 N/cm²-m (0.1025 kgf/cm²-m, 0.4444 lbf/in²-ft) and 1.118 N/cm²-m (0.114 kgf/cm²-m, 0.4942 lbf/in²-ft), the factor k_s may be determined by interpolation

5.7.2(d) Definition of Tank Shape and Associated Coefficients

i) J-shaped Tank

A tank having the following configurations is considered as a “J-shaped” tank.

$$b/b_1 \geq 5.0 \text{ and } h/h_1 \geq 5.0$$

where

b = extreme breadth at the tank top of the tank considered

b_1 = least breadth of wing tank part of the tank considered

h = extreme height of the tank considered

h_1 = least height of double bottom part of the tank considered

as shown in 5C-1-3/Figure 7.

The coefficients C_{dp} and C_{ru} are as follows:

$$C_{dp} = 0.7$$

$$C_{ru} = 1.0$$

ii) Rectangular Tank

The following tank is considered as a rectangular tank:

$$b/b_1 \leq 3.0 \text{ or } h/h_1 \leq 3.0$$

The coefficients C_{dp} and C_{ru} of the tank are as follows:

$$C_{dp} = 1.0$$

$$C_{ru} = 1.0$$

iii) U-shaped Tank

A half of a “U-shaped” tank, divided at the centerline, should satisfy the condition of a “J-shaped” tank.

The coefficients C_{dp} and C_{ru} are as follows:

$$C_{dp} = 0.5$$

$$C_{ru} = 0.7$$

iv) In a case where the minimum tank ratio of b/b_1 or h/h_1 whichever is lesser, is greater than 3.0 but less than 5.0, the coefficients C_{dp} and C_{ru} of the tank are to be determined by the following interpolation:

J-shaped Tank in head and non-head seas, U-shaped Tank in head seas:

$$C_{dp} = 1.0 - 0.3 (\text{the min. tank ratio} - 3.0) / 2.0$$

U-shaped Tank in non-head seas:

$$C_{dp} = 1.0 - 0.5 (\text{the min. tank ratio} - 3.0) / 2.0$$

U-shaped Tank:

$$C_{ru} = 1.0 - 0.3 (\text{the min. tank ratio} - 3.0) / 2.0$$

v) For non-prismatic tanks mentioned above, b_1 , h and h_1 are to be determined based on the extreme section.

FIGURE 2
Distribution Factor m_h (1995)

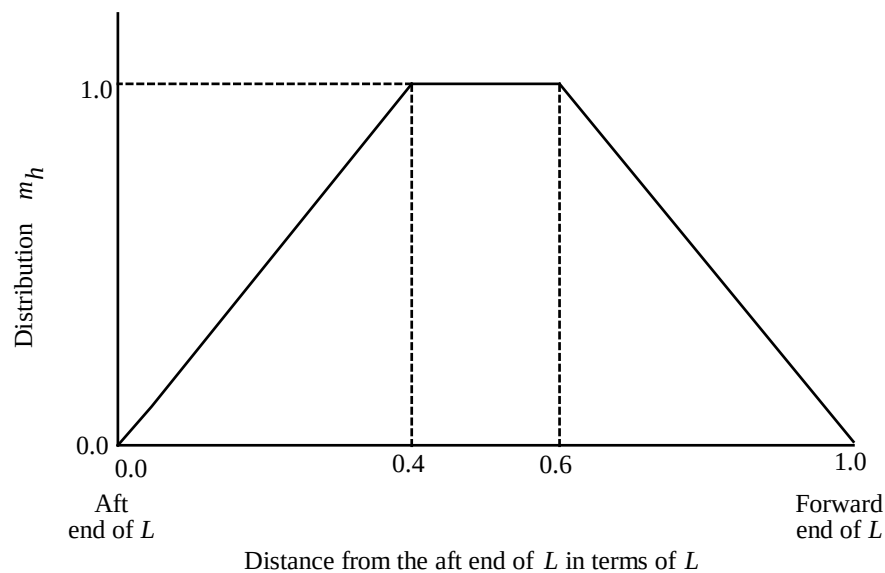


FIGURE 3
Distribution Factor f_h (1995)

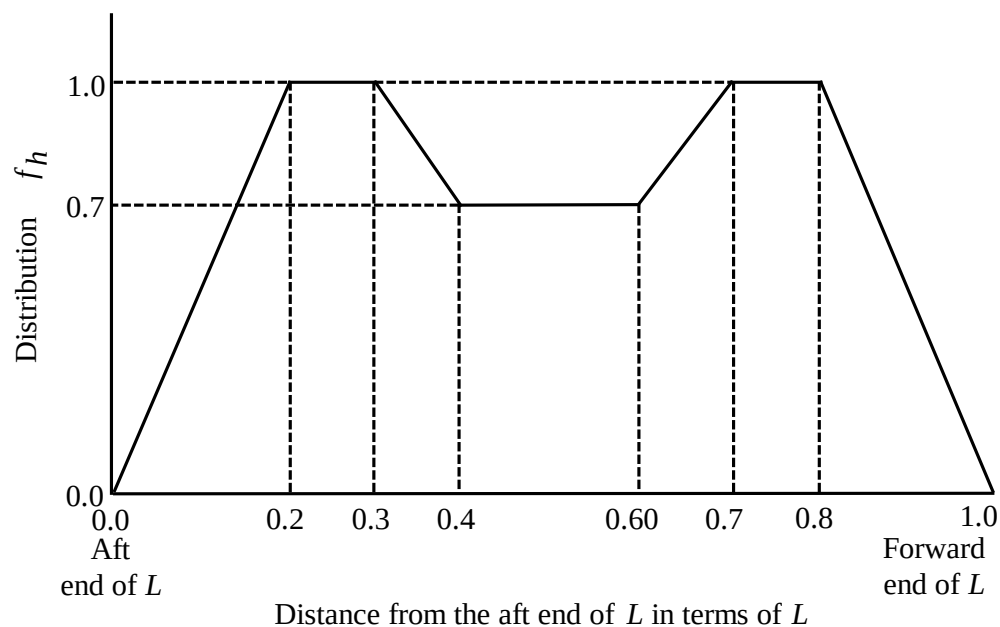
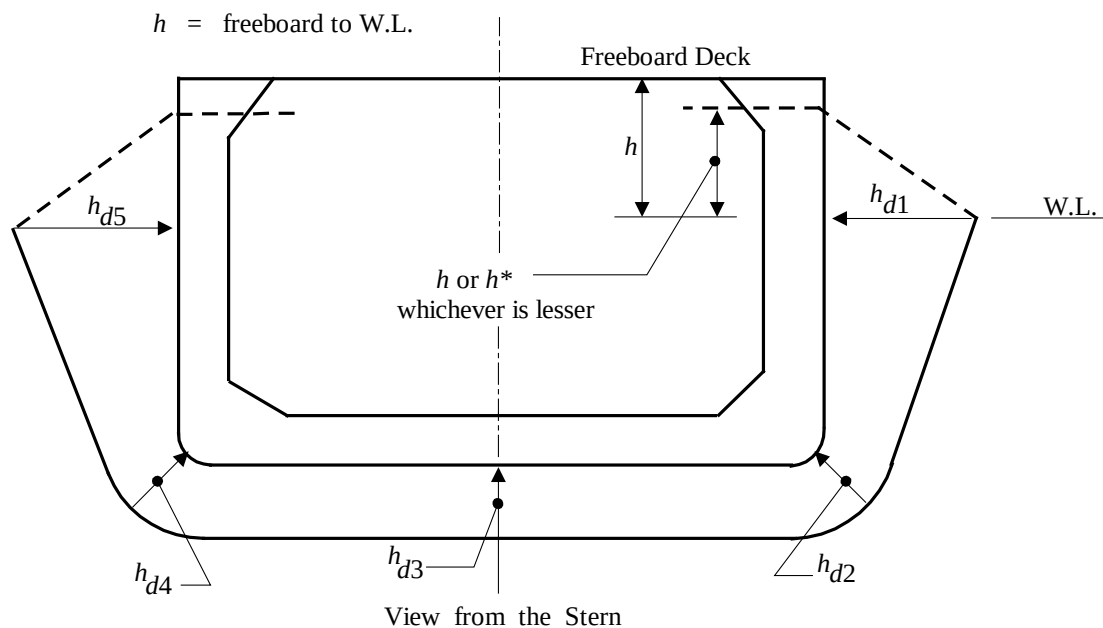


FIGURE 4
Distribution of h_{di} (1995)



Note: $h^* = k_u k_c h_{d1}$ for nominal pressure
 $h^* = k_f k_u h_{d1}$ for simultaneous pressure

FIGURE 5
Pressure Distribution Function $k_{\ell o}$ (1995)

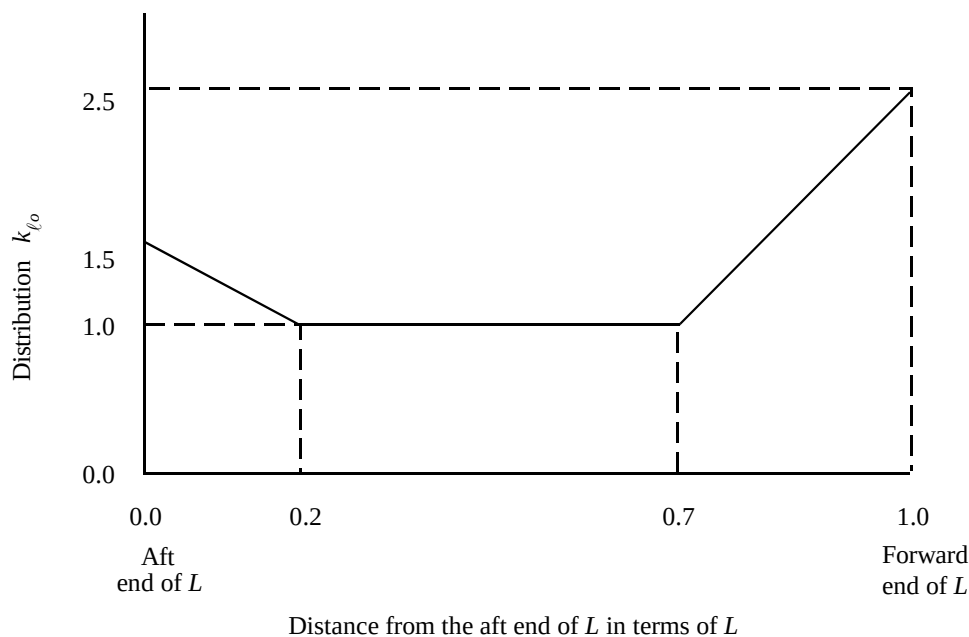


FIGURE 6
Illustration of Determining Total External Pressure (1997)

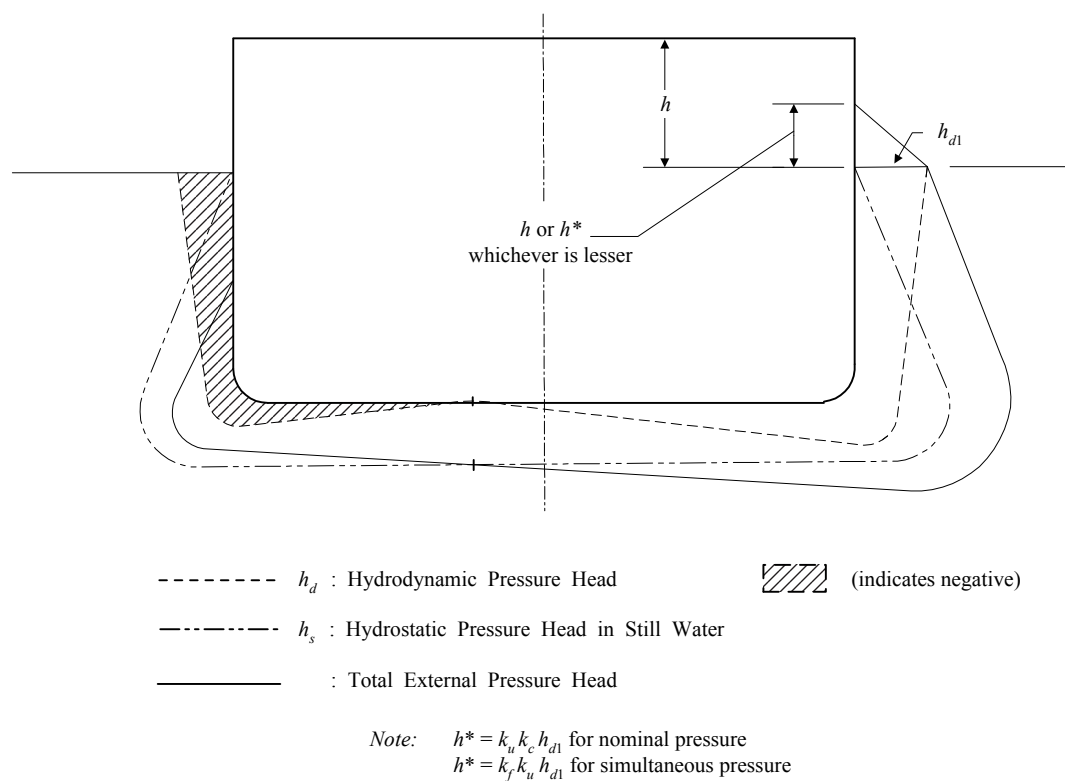
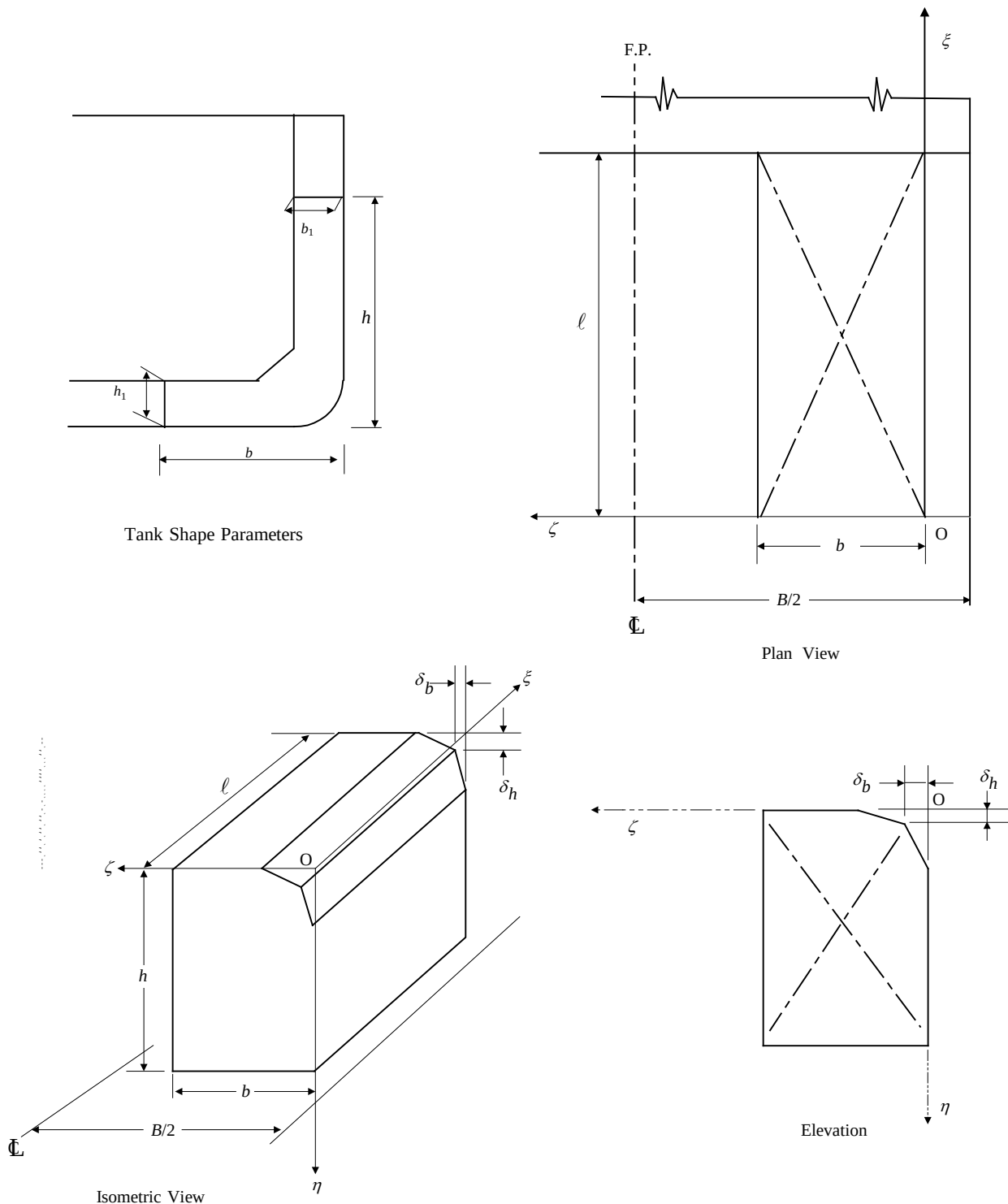


FIGURE 7
Definition of Tank Geometry (1995)



For lower ballast tanks, η is to be measured from a point located at $2/3$ the distance from the top of the tank to the top of the overflow (minimum 760 mm above deck).