FOUNDED 1862 ABS

RULES FOR BUILDING AND CLASSING

FLOATING PRODUCTION INSTALLATIONS 2014

(Updated July 2014 – see next page)

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

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Updates

July 2014 consolidation includes:

- February 2014 version plus Corrigenda/Editorials

February 2014 consolidation includes:

- January 2014 version plus Corrigenda/Editorials

Foreword

These Rules specify the ABS requirements for building and classing Floating Production Installations (FPIs) that should be used by designers, builders, Owners and Operators in the offshore industry. The requirements contained in these Rules are for design, construction, and survey after construction of the floating installation (including hull structure, equipment and marine machinery), the position mooring system and the hydrocarbon production facilities. Floating installations of the ship-type, column-stabilized-type, tension leg platforms and spar installations are included, as well as existing vessels converted to FPIs. The requirements for optional notations for disconnectable floating installations, dynamic positioning systems and import/export systems are also provided. These Rules are to be used in conjunction with other ABS Rules and Guides, as specified herein.

The effective date of these Rules is 1 January 2014. In general, until the effective date, plan approval for designs will follow prior practice unless review under these Rules is specifically requested by the party signatory to the application for classification.

Changes to Conditions of Classification *(1 January 2008)*

For the 2008 edition, Part 1, Chapter 1, "Scope and Conditions of Classification" was consolidated into a generic booklet, entitled *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* for all units, installations, vessels or systems in offshore service. The purpose of this consolidation was to emphasize the common applicability of the classification requirements in "Part 1, Chapter 1" to ABS-classed offshore units, pipelines, risers, and other offshore structures, and thereby make "Conditions of Classification" more readily a common Rule of the various ABS Rules and Guides, as appropriate.

Thus, Part 1, Chapter 1 of these Rules specifies only the unique requirements applicable to floating production installations. These supplemental requirements are always to be used with the aforementioned *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

RULES FOR BUILDING AND CLASSING

FLOATING PRODUCTION INSTALLATIONS

CONTENTS

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Notices and General Information

CONTENTS

Notices and General Information

Introduction

1. The 2014 edition of the *Rules for Building and Classing Floating Production Installations* consists of the seven (7) Parts as shown in Table 1. In general these seven Parts subdivide these Rules into parts that are more consistent with other ABS Rules. With regard to two Parts, Part 1, and Part 2:

   a) The purpose of the generic title ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* is to reflect the expanded contents of PART 1, as a result of including consolidated requirements for "Classification" applicable to all types of and sizes of units, installations, vessels or systems in offshore service, etc., as specified in the Foreword to Part 1. Additional specific requirements are contained in Part 1 of these *Rules for Building and Classing Floating Production Installations*.

   b) The purpose of the generic title ABS *Rules for Materials and Welding* of PART 2 is to emphasize the common applicability of the requirements to ABS-classed vessels, other marine structures and their associated machinery, and thereby make PART 2 more readily a common "PART" of various ABS Rules and Guides, as appropriate.

2. The numbering system applied in the Rules is shown in Table 2.

3. The primary changes from the 2013 Rules are identified and listed in Table 3. The effective date of the indicated Rule Changes is 1 January 2014, unless specifically indicated otherwise.

4. 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

5. Until the next edition of the *Rules for Building and Classing Floating Production Installations* is published, Notices and/or Corrigenda, as necessary, will be published on the ABS website – www.eagle.org – only, and will be available free for downloading. It is not intended to publish hard copies of future Notices and/or Corrigenda to existing Rules or Guides. The consolidated edition of the *Rules for Building and Classing Floating Production Installations*, which includes Notices and/or Corrigenda using different colors for easy recognition, will be published on the ABS website only when Notices and/or Corrigenda are issued.

6. The listing of CLASSIFICATION SYMBOLS AND NOTATIONS is available from the ABS website www.eagle.org for download.

TABLE 1
Applicable Editions of Parts Comprising 2014 Rules

Rules for Building and Classing Floating Production Installations		
Notices and General Information		2014
Part 1:	Conditions of Classification (Supplement to the ABS Rules for Condition of Classification – Offshore Units and Structures) [1]	2014
Part 3:	Installation Types, Functions, Features and General Requirements	2014
Part 4:	Units Systems (Process and Import/Export)	2014
Part 5A:	Ship-Type Installations	2014
Part 5B:	Other Installation Types	2014
Part 6:	Mooring Systems	2014
Part 7:	Surveys After Construction	2014
Rules for Conditions of Classification – Offshore Units and Structures – not included [1,2]		
Part 1:	Rules for Conditions of Classification – Offshore Units and Structures	2014
Rules for Materials and Welding – not included [2]		
Part 2:	Rules for Materials and Welding	2014

Notes:

1 The requirements for conditions of classification are contained in the separate, generic ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*. Additional specific requirements are contained in Part 1 of these Rules.

2 The latest edition of these Rules is to be referred to. These Rules may be downloaded from the ABS website at www.eagle.org, Rules and Guides, Downloads or may be ordered separately from the ABS Publications online catalog at www.eagle.org, Rules and Guides, Catalog.

TABLE 2
Division and Numbering of Rules

Division	*Number*
Part	Part 1
Chapter	Part 1, Chapter 1
Section	Section 1-1-1
Subsection (see Note 1)	1-1-1/1
Paragraph (see Note 1)	1-1-1/1.1
Subparagraph	1-1-1/1.1.1
Item	1-1-1/*1.1.1(a)*
Subitem	1-1-1/*1.1.1(a)i)*
Appendix	Appendix 1-1-A1 or Appendix 1-A1-1

Note:

1 An odd number (1, 3, 5, etc.) numbering system is used for the Rules. The purpose is to permit future insertions of even-numbered paragraphs (2, 4, 6, etc.) of text and to avoid the necessity of having to renumber the existing text and associated cross-references, as applicable, within the Rules and associated process instructions, check sheets, etc.

Rule Change Notice *(2014)*

TABLE 3
Summary of Changes from the 2013 Rules

EFFECTIVE DATE 1 July 2013 – shown as *(1 July 2013)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
PART 5B	**Other Installation Types**	
5B-1-3/1.9	Penetrations	To clarify the requirements for deck and bulkhead cable penetrations. (Incorporates Notice No. 1)
5B-2-2/3.5	Penetrations	To clarify the requirements for deck and bulkhead cable penetrations. (Incorporates Notice No. 1)
5B-3-2/3.5	Penetrations	To clarify the requirements for deck and bulkhead cable penetrations. (Incorporates Notice No. 1)

EFFECTIVE DATE 1 January 2014 – shown as *(2014)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
PART 5A	**Ship-Type Installations**	
5A-1-3/1.11	Equipment	To address temporary mooring of disconnectable FPSOs or FSOs and the potential for reduced number of anchors subject to risk assessment and the approval of flag and coastal states.
5A-1-3/1.19	Bilge Keels	To specify that bilge keels deeper than 500 mm are being treated as hull interface structures, as discussed in Section 5A-1-4.
5A-3-3/1.9	Side Shell Plating	To align the requirements with 5C-1-4/9.1 of the *Steel Vessel Rules* and the wastage allowance set in 7-A-4/Table 1 of the ABS *Rules for Survey After Construction (Part 7)*.
5A-3-A4	Finite Element Analysis for Ship-Type Installations	To completely integrate all the existing Guides embedded in the current Rules into the Rules by dropping the word "Guide" from the title, changing embedded recommendations to requirements, and by sending all embedded Guides through the Committee review process.
PART 6	**Mooring Systems**	
6-1-2/13	Mooring Equipment	To provide specific requirements for mooring equipment (e.g., chain stoppers, fairleads, etc.).
6-2-1/17 (New)	Submerged Buoys Structure	To provide requirements for the submerged buoy structure used primarily for disconnectable mooring systems
PART 7	**Surveys**	
7-2-7/3.3	Column Stabilized, Tension Leg Platform and Spar Floating Production Installations	To clarify that the column-stabilized requirements apply to tension leg platforms and spar type installations.

PART

1

Conditions of Classification

(Supplement to the ABS Rules for Conditions of Classification – Offshore Units and Structures)

CONTENTS

PART

1

CHAPTER 1 Scope and Conditions of Classification

CONTENTS

PART

1

CHAPTER 1 Scope and Conditions of Classification

SECTION 1 Classification *(1 January 2008)*

The requirements for conditions of classification are contained in the separate, generic ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Additional requirements specific to floating production installations are contained in the following Sections.

PART
1

CHAPTER 1 Scope and Conditions of Classification

SECTION 2 System Classification, Symbols and Notations *(1 January 2008)*

A listing of Classification Symbols and Notations available to the Owners of vessels, offshore drilling and production units and other marine structures and systems, "List of ABS Notations and Symbols" is available from the ABS website "http://www.eagle.org".

The following classification boundaries, symbols and notations are specific to floating production installations.

1 Classification Boundaries *(1 July 2012)*

The classification of a Floating Production Installation (FPI) includes three major items: the installation, its position mooring system, and its production facilities.

Classification of additional equipment and systems may be offered if requested by the Owner. (See 3-1-1/3.)

Where Import and or Export Risers provide substantial mooring restraint, the design, construction and classification of the Riser(s) providing restraint and their connection to the seabed will require special consideration.

3 Classification Symbols and Notations *(1 July 2012)*

The Maltese Cross, ✠, symbol is assigned to Floating Production Installations for which the hull construction and/or the manufacture and installation of its machinery and components and any associated required testing, as applicable, and the on-site installation (for site specific FPIs) and commissioning tests and trials of the FPI is carried out under ABS survey. For FPIs constructed under survey of another recognized Classification Society or Authority, the Maltese Cross, ✠, symbol will be omitted from the applicable classification notations.

A1 is a classification symbol that, together with the Maltese Cross ✠ symbol, indicates compliance with the hull requirements of the ABS Rules, Guides, or their equivalent for service and survey by ABS during construction of the vessel. The symbols ✠ **A1** may be followed by appropriate FPI type notation such as the notations shown in 1-1-2/3.1 of these Rules.

3.1 New Construction

Systems that have been built, installed and commissioned to the requirements of the Rules and to the satisfaction of the ABS Surveyors, where approved by ABS for service for the specified design environmental conditions, are to be classed and distinguished in the ABS *Record* by the symbol ✠ **A1**, followed by the appropriate notation for the intended service and hull type given below:

Floating Production, Storage and Offloading System (*hull type*)
Floating Production (and Offloading) System (*hull type*)
Floating Storage and Offloading System (*hull type*)

The above class notations cover the following components:

i) *Floating Production Installation*, including its hull structure, applicable marine systems and associated equipment and machinery, safety systems and associated equipment, life saving appliances machinery under one of the above notations, subject to the requirements of these Rules.

ii) *Position Mooring System* according to the requirements of these Rules.

iii) *Topside Production Facilities* according to the requirements of the ABS *Rules for Building and Classing Facilities on Offshore Installations* (*Facilities Rules*) and these Rules.

The service notation will be appended by one of the following **(Ship-Type)**, **(Column-Stabilized)**, **(TLP)**, or **(Spar)** to indicate the hull type. The hull structural configurations of these installations are described in Section 3-1-2.

Examples of notations for installations are:

Floating Production, Storage and Offloading System (Ship-Type)

Floating Production (and Offloading) System (Ship-Type)

Floating Offshore Installation (Spar)

Floating Production (and Offloading) System (TLP)

Floating Offshore Installation (Column Stabilized)

3.3 Conversion to FPI

3.3.1 Conversion of Existing Vessel

An existing vessel is a vessel that has been issued a Certificate of Classification. When an existing vessel is converted to an FPI, and is classed under the provisions of Section 5A-2-1, it will be distinguished in the ABS *Record* by the symbol **A1**, followed by the appropriate notation for the intended service, the notation (**Ship-Type)** and the qualifier **(CI)**. If the existing vessel being converted is currently in ABS class with ✠, then the ✠ would be maintained for the converted FPI. Examples of notations are:

✠ Floating Production, Storage and Offloading System (Ship-Type) (CI)

✠ Floating Offshore Installation (Ship-Type) (CI)

3.3.2 Conversion of Vessel Design or Vessel Under Construction

3.3.2(a) A vessel's design that has been approved by ABS or another IACS member and is to be converted to an FPI, can either be classed under the provisions of 1-1-2/3.3.1 and Section 5A-2-1 as an FPI conversion, or it can be classed as a new build FPI under the provisions of 1-1-2/3.1.

3.3.2(b) A vessel under construction that has not been issued a Certificate of Classification, and its design has been approved by ABS or another IACS member, can either be classed under the provisions of 1-1-2/3.3.1 and Section 5A-2-1 as an FPI conversion, or it can be classed as a new build FPI under the provisions of 1-1-2/3.1.

3.5 Floating Offshore Installation

Where an installation is fitted with production facilities, but the optional classification of the topside production facilities is not requested, the installation will be classed and distinguished in the ABS *Record* by the symbol **✠ A1**, followed by the notation **Floating Offshore Installation (*hull type*)**, provided the installation and its position mooring system comply with the applicable requirements. On a Floating Offshore Installation (FOI), certain systems and equipment for the production facilities are to be in compliance with 4-1-1/3 of these Rules.

Where an installation is fitted with production facilities, but the optional classification of the topside production facilities is not requested, but the essential safety features of the production facilities in compliance with 4-1-1/5 are approved by ABS, the installation will be classed and distinguished in the ABS *Record* by the symbol **✠ A1**, followed by the notation **Floating Offshore Installation (hull type)**. "Production Facilities" will be indicated in the *Record*. Compliance with the applicable requirements for the installation and position mooring system is required.

In either case, the scope of classification for an FOI includes the shipboard systems, including the electrical system circuit protection for the production facilities and production fire fighting equipment. In addition, topside structures and modules are to comply with Section 5A-1-5, 5B-1-2/1.3, 5B-3-3/5.3, 5B-2-3/5.1 or 5B 2 3/5.3 as appropriate.

5 Additional Class Notations

5.1 Disconnectable System

A floating installation system that has a propulsion system and a means of disengaging the installation from its mooring and riser systems to allow the installation to ride out severe weather or seek refuge under its own power for a specified design environmental condition will be classed with the above designations and with notations **(Disconnectable) ✠ AMS** at the end. One example of such class designation is:

✠ A1 Floating Production, Storage and Offloading System (Ship-Type) (Disconnectable), ✠ AMS

See 1-1-2/7 of these Rules for **✠ AMS** notation.

5.3 Classification of Dynamic Positioning Systems *(1 July 2012)*

Dynamic positioning systems installed for station keeping purposes, will be denoted by the notation **DPS** (see the ABS *Guide for Dynamic Positioning Systems*).

5.5 Classification of Additional Equipment and Systems *(1 July 2012)*

Additional equipment and systems, such as the subsea template, Import (or Export) PLEMs and the Import (or Export) system may be considered at the Owner's request. Where the import and export systems are built in full compliance with the requirements of Part 4, Chapter 2 of these Rules, the installation will be classed and distinguished in the *Record* by the notation **IMP-EXP**. The notations **IMP** or **EXP** will be applied to the installation when only the import system or the export system, respectively, is built in full compliance with the requirements of Part 4, Chapter 2 of these Rules. These notations for import and export systems are optional.

5.7 Dynamic Loading Approach (DLA) *(1 July 2012)*

Where the system's hull structure has been built to plans reviewed in accordance with the procedure and criteria in the ABS *Guide for "Dynamic Loading Approach" for Floating Production, Storage and Offloading (FPSO) Systems* for calculating and evaluating the behavior of hull structures under dynamic loading conditions, in addition to compliance with other requirements of the Rules, the installation will be classed and distinguished in the *Record* by the notation **DLA.** The **DLA** notation will be placed after the appropriate hull classification notation. The application of the dynamic loading approach is optional.

The dynamic load components considered in the evaluation of the hull structure are to include the external hydrodynamic pressure loads, internal dynamic loads (fluids stored onboard, ballast, major equipment items, etc.) and inertial loads of the hull structure. The magnitude of the load components and their combinations are to be determined from appropriate ship motion response calculations for loading conditions that represent the envelope of maximum dynamically-induced stresses in the installation. The adequacy of the hull structure for all combinations of the dynamic loadings is to be evaluated using an acceptable finite element analysis method. In no case are the structural scantlings to be less than those obtained from other requirements in these Rules.

The basic notation **DLA** is applied when the hydrodynamic loads have been determined using the wave environment of the North Atlantic as if the installation is a trading vessel with a 20- to 25-year service life. If the wave environment of the intended site is used during the analysis, the notation will include an **S** qualifier, followed by the design return period at the defined site. For example, if the 100-year return period was used, the following may apply: **DLA (S100)**. Transit conditions to the intended site are also to be included in the DLA evaluation.

5.9 Strength Criteria for Ship-Type Installations *(1 July 2012)*

Ship-type installations of 150 meters (492 feet) or more in length that are designed and built to the requirements of Part 5A of these Rules and Section 5C-1-7 of the *Steel Vessel Rules* will be identified in the *Record* by the notation as given in 1-1-2/3 of these Rules.

The basic notation of 1-1-2/3 of these Rules is applied when the dynamic loads have been determined using the wave environment representative of unrestricted service, i.e., for North Atlantic exposure as if the installation is a trading vessel with a 20- to 25-year service life. There are several additional qualifiers, described in the following sub sections, covering site-specific wave environment, definition of the site and whether the installation has been converted from an existing vessel.

5.9.1 New Construction

For new-build ship-type installations where transit condition and site-specific environmental data have been used per these Rules in lieu of North Atlantic data, the basic notation is to be followed by the **(S)** qualifier. This qualifier will then be followed by the definition of the site. For example, **(S) Brazil Santos Basin**.

5.9.2 Conversion of Existing Vessel to FPI

For a converted installation where the trading vessel and site-specific environmental data have been used per these Rules, the basic notation is followed by the qualifier **(CI)**. The **(CI)** qualifier will be followed by the definition of the site. For example, **(CI) Brazil Santos Basin**.

5.9.3 Relocation of FPI

As site specific units, FPIs are designed and classed taking into consideration the location where they will operate and the intended period of operation. When the FPI is relocated to a new site, either within the same field or in a different operating area, or when the intended period of operation is extended, the strength of the unit is to be reassessed to satisfy that the unit will remain in compliance with applicable requirements as described below.

5.9.3(a) Relocation within the Same Field. When an FPI is relocated within the same field or the same operating area, the environmental conditions are expected to remain identical to those considered during the original classification process for the current site.

If the environmental conditions for the field or operating area have been revised since the original approval due to new environmental data or changing environmental conditions (e.g., new environmental data in the Gulf of Mexico after hurricanes Rita and Katrina), the Coastal State may require the use of new environmental conditions for the relocation, in which case the same requirements as relocation to a different operating area will apply.

The expected operating life in the new location may be within the originally considered design life or otherwise, it may extend beyond the original design life period. In the latter case, in addition to the requirements for relocation, the requirements for life extension will apply.

It is expected that relocation within the same field will require at least a new position mooring and anchoring system for the new site and probably, modifications to the process facilities.

For the relocation within the same field, without exceeding the original design life of the unit, the following actions will to be required:

- Design review and surveys related to the new position mooring system and anchoring.
- Design review and surveys related to the modifications to the process facilities, if applicable.
- Design review and surveys related to any other modifications affecting class items.
- Drydocking survey, including gauging, with steel renewals as necessary to bring the unit to a satisfactory condition to complete the remaining design life at the specific site.

Structural strength analysis and fatigue life re-evaluation for the hull structure, turret, module structures, etc. will not to be required, unless structural modifications are performed.

Design review and surveys will be based on the current ABS requirements at the time of the contract for the relocation of the unit.

For minor modifications of structures, systems or equipment, special consideration may be made in a case-by-case basis for the use of the original ABS requirements applied to the unit, when the majority of the particular structure, system or equipment remains unchanged.

5.9.3(b) Relocation to a Different Operating Area. When an FPI is relocated to an operating area where the environmental conditions are different than those at the original site, the structural strength and fatigue life of the unit will need to be reassessed for the new conditions. However, if the new location has milder environmental conditions than the current site, the reassessment may not need to be performed provided that the unit is kept under the same structural condition as in the original site and the design fatigue life of the unit is not extended.

Relocation to a different operating area will require a new position mooring and anchoring system for the new site and most probably, extensive modifications to the process facilities.

For the relocation to a different operating area, the following actions will be required:

- Structural strength analysis and fatigue life re-evaluation for the hull structure, turret, module structures, etc. (except as noted above).
- Design review and surveys related to the new position mooring system and anchoring.
- Design review and surveys related to the modifications to the process facilities.
- Design review and surveys related to any other modifications affecting class items.
- Drydocking survey, including gauging, with steel renewals as necessary to bring the unit to a satisfactory condition to complete the remaining design life at the specific site.

Design review and surveys are to be based on the current ABS requirements at the time of the contract for the relocation of the unit.

For minor modifications of structures, systems or equipment, special consideration may be made in a case-by-case basis for the use of the original ABS requirements applied to the unit, when the majority of the particular structure, system or equipment remains unchanged.

5.10 Strength Criteria for Other Installation Types *(1 July 2012)*

Installations (other than ship-type, see 1-1-2/5.9 above) that are designed and built to the requirements of Part 5B of these Rules will be identified in the *Record* by the notation as given in 1-1-2/3 of these Rules followed by additional qualifiers, described in the following Subparagraphs, covering site-specific wave environment and definition of the site.

5.10.1 New Construction

Site-specific environmental data will be indicated by the **(S)** qualifier following the basic notation of 1-1-2/3. This qualifier will then to be followed by the definition of the site. For example, **✠ A1 Floating Offshore Installation (Spar) (S) in Mississippi Canyon Block 779**.

5.10.2 Relocation of FPI

As site specific units, FPIs are designed and classed taking into consideration the location where they will be operated and the intended period of operation. When the FPI is relocated to a new site, either within the same field or in a different operating area, or when the intended period of operation is extended, the strength of the unit is to be reassessed to satisfy that the unit will remain in compliance with applicable requirements.

5.11 Design Life and Design Fatigue Life *(1 July 2012)*

5.11.1 Design Life – New Construction

Floating installations designed and built to the requirements in these Rules and maintained in accordance with the applicable ABS requirements are intended to have a structural design life of not less than 20 years for a new build hull structure. Where the structural design life is greater than 20 years and the floating installation is designed for uninterrupted operation on-site without any drydocking, the nominal design corrosion values (NDCV) of the hull structure are to be increased in accordance with 5A-3-1/1.7 for ship-type installations or an acceptable equivalent criteria for non-ship-type installations. When the design life is greater than 20 years (in 5-year increments) the increased life will be identified in the *Record* by the notation **HL(*number of years*).** The **(*number of years*)** refers to a design life different than 20 years.

5.11.2 Design Fatigue Life – New Construction

Where a floating installation's design calls for a minimum design fatigue life of 20 years or in excess of the minimum design life of 20 years, the design fatigue life is to be verified to be in compliance with the fatigue criteria in these Rules. The "design fatigue life" refers to the target value set by the owner or designer, not the value calculated in the analysis.

The required fatigue strength analysis of critical details and welded joints in floating installations is to be in accordance with the criteria in Appendix 5A-3-A2 of these Rules for ship-type installations or an acceptable equivalent criteria for non-ship-type installations.

Only one design fatigue life value notation is to be assigned and published in the *Record* for the hull, hull interface structure, position mooring system and components. The hull interface structural requirements for ship-type installations are described in 5A-1-4 of these Rules and the position mooring system requirements in Part 6 of these Rules. When only the required fatigue analysis of Appendix 5A-3-A2 for ship-type installations or 5B-1-2/5, 5B-2-3/5 or 5B-3-3/5 for non-ship-type installations is performed for either unrestricted service wave environment or the transit and site specific wave environment, the class notation **FL(number of years)** and the **Year** of maturation of fatigue life in the defined site location is assigned. The fatigue life will be identified in the *Record* by the notation **FL(number of years),Year**; for example, **FL(30)**, **2041** for an FPI built in 2011 if the minimum design fatigue life specified is 30 years.

If in addition, spectral fatigue analysis (see 1-1-2/5.11) is requested by the owner or designer, only the design fatigue life notation, **SFA(number of years),Year** will be assigned and published in the *Record* for the hull and hull interface structural system. Although only the **SFA** notation is assigned, and not the **FL** notation for ship-type installations, the required fatigue analysis of Appendix 5A-3-A2 is to be performed and the calculated fatigue life is to satisfy the design fatigue life.

The **(number of years)** refers to the design fatigue life equal to 20 years or more (in 5-year increments), as specified by the applicant. Where different design fatigue life values are specified for different structural elements within the installation, such as hull structure components, hull interface structures and position mooring system components, the **(number of years)** refers to the least of the target values. In the case when spectral fatigue analysis is also applied the least of the fatigue life values calculated by the required fatigue strength analysis for the **FL** notation and the spectral fatigue analysis must satisfy the design fatigue life. The "design fatigue life" refers to the target value set by the applicant, not the value calculated in the analysis.

For example if the design fatigue life is specified as 25 years, the fatigue calculations of hull structural components must satisfy a fatigue life of 25 years. The fatigue calculations of the position mooring hull interface structures and hull mounted equipment interface structures, and position mooring system must also satisfy fatigue lives of (25 × FDF) years, where FDF are the fatigue safety factors specified in 5A-1-4/Table 1, 5B-1-2/Table 2, 5B-2-3/Table 2 or 5B-3-3/Table 2, as applicable, for hull interface structures and in 6-1-1/Table 1 for mooring lines.

5.11.3 Conversion of Existing Vessel to FPSO, FPS or FSO

When an existing vessel is converted to an FPSO, FPS or FSO in the process referred to as an FPI vessel conversion, and the ship-shaped FPSO, FPS or FSO is classed under the provisions of Section 5A-2-1, the expected minimum remaining fatigue life of the structure is to be assessed according to Section 5A-2-3 and documented by recording its value in the *Record*. The **RFL** notation will be followed by the value of the expected minimum remaining fatigue life in years, and the year of maturation of fatigue life in the defined site location in accordance with 1-1-2/5.9.2. For example, **RFL(15), 2018** indicates that the expected minimum remaining fatigue life of the structure is 15 years, which will_be reached in the year 2018. The **RFL(number of years), Year** notation as applied to an FPI vessel conversion is mandatory.

5.11.4 Relocation of FPI

When an FPI is relocated to a new site, either within the same field or in a different operating area, the fatigue life of the unit is to be reassessed to satisfy that the unit's remaining fatigue life for the new operating conditions is within the design fatigue life of the unit. The position mooring system including chain and other mooring components is also subject to reassessment if it is to be used at the new site.

5.11.5 Life Extension of FPI on the Same Site

When an FPI exceeds the design fatigue life specified in the **FL (number of years), Year** or **RFL (number of years), Year** notation for which it was classed, an evaluation is to be made and appropriate actions are to be taken to extend the fatigue life up to the new operating life of the unit under the site-specific environmental conditions.

For conversions, the design fatigue life will depend on the minimum remaining fatigue life expected from the time of the conversion. For conversions before October 2001, the remaining fatigue life is only documented in the original calculations submitted at the time of the conversion. For conversions on or after October 2001, the remaining fatigue life is indicated with the **FL** notation (before July 2003) or the **RFL** notation (on or after July 2003).

For both original build FPIs and conversions, the remaining fatigue life of the unit may be extended during the operating life of the FPI by renewals or modifications of those structural details with lower fatigue life.

For the life extension of the unit remaining in the same location, the following actions will be required:

- Verification from the original fatigue analysis that the actual fatigue values of all the structural elements of the unit are still higher than the proposed extended fatigue life; or
- New fatigue analysis covering all the structural elements (hull, turret, hull interfaces, position mooring system) in accordance with **SFA**, **FL** or **RFL** requirements, as applicable. Risers (if classed) are also to be analyzed for the extended fatigue life.
- Identification of structural elements or details with a fatigue life below the new intended design fatigue life of the unit and proposed actions to increase the fatigue life of those elements or details.
- Design review and surveys of structural modifications proposed as a consequence of the fatigue analysis.
- Enhanced survey program to monitor those structural elements or details with lower fatigue life which cannot be modified or renewed on site.
- Special Periodical survey, including Underwater Inspection, to determine the structural condition of the unit at the time of the life extension.

The new fatigue analysis and related design review and surveys, when necessary, will be based on the current ABS requirements at the time of the life extension.

For minor modifications of structures, systems or equipment, special consideration may be made in a case-by-case basis for the use of the original ABS requirements applied to the unit, when the majority of the particular structure, system or equipment remains unchanged.

Once the life extension is approved, the existing **SFA**, **FL** or **RFL** notation with year of maturation will is to be updated accordingly.

When a fatigue notation is requested, and where none of the above notations was previously assigned to the unit, the most appropriate fatigue notation for the unit will is to be assigned.

5.12 Spectral Fatigue Analysis *(1 July 2012)*

5.12.1 Design Fatigue Life – New Construction

Where more extensive use of Spectral Fatigue Analysis is performed in accordance with criteria established in Part 5A, Chapter 1 of these Rules and the ABS *Guide for the Fatigue Assessment of Offshore Structures*, the installation is to be identified in the *Record* by the notation **SFA (number of years), Year.** The fatigue analysis is performed for either unrestricted service wave environment or the transit and site specific wave environment in accordance with 1-1-2/5.9. The **(*number of years*)** refers to the design fatigue life equal to 20 years or more (in 5-year increments), as specified by the applicant. The **Year** is the year of maturation of fatigue. For example, **SFA (30), 2041** if the design fatigue life specified is 30 years, and the FPI is built in 2011. Only one minimum design fatigue life value is applied to the entire structural system. For a structural location required to have an additional factor applied to the minimum design fatigue life (say, due to safety critical function or relative difficulty of inspection, see for example, 6-2-1/13), the required minimum fatigue life for such a location is the minimum design fatigue life being applied in the project multiplied by the additional factor. The 'design fatigue life' refers to the target value set by the designer and not the value calculated in the analysis. The calculated values are usually much higher than the target value specified for design. The application of spectral fatigue analysis is optional.

5.12.2 Conversion of Existing Vessel to FPSO, FPS or FSO

When spectral fatigue analysis is applied to an existing vessel that is converted to an FPSO, FPS or FSO, the expected minimum remaining fatigue life of the structure is to be assessed according to Section 5A-2-3/3 and documented by recording its value in the *Record*. The **SFA** notation will be followed by the value of the expected minimum remaining fatigue life in years preceded by the letter **R**, and the year of maturation of fatigue life in the defined site location in accordance with 1-1-2/5.9.2. For example, **SFA (R15), 2018** indicates that the expected minimum remaining fatigue life of the structure is 15 years, which will is to be reached in the year 2018 at the defined site location. The application of spectral fatigue analysis for FPI conversions is optional.

5.13 Additional Corrosion Margin *(1 March 2006)*

Where the installation incorporates additional plate thicknesses above the required scantlings, the installation will be identified in the *Record* by the notation **AT**, followed by the description of the major hull girder component(s) that has the additional thickness. This notation will also include a number to indicate the magnitude of the additional thickness (rounded down to the nearest 0.5 mm) that has been applied, i.e., **AT(DK+0.5)**. In order to apply the notation **AT**, the additional thickness must be applied to the complete structural element throughout the tank area of the installation. This notation documents major areas of the structure that have an additional "as-built" margin on thickness to address areas subject to significant corrosion or areas where it may be desirable to increase normal corrosion margins to extend a structural member's anticipated service life. This notation is optional and is only available to new construction FPIs.

The major structural components are defined as follows:

DK	Upper deck (including stringer plate)
BS	Bottom shell (including bilge)
IB	Inner-bottom
SS	Side shell (including shear strake)
IS	Inner skin (including "hopper" sloping plating)
LB	Longitudinal bulkheads other than the inner skin
TB	Transverse Bulkhead

5.15 Hull Construction Monitoring Program *(1 July 2012)*

Ship-type installations designed and reviewed to the *FPI Rules* are to comply with the requirements of the Offshore Hull Construction Monitoring Program in Appendix 5A-3-A5 of these Rules and have the notation **OHCM**.

7 ✠ AMS Notation *(1 July 2012)*

Machinery and boilers for self-propulsion which have been constructed and installed to the satisfaction of the Surveyors to ABS's Rule requirements, when found satisfactory after trial and approved by ABS, will be classed and distinguished in the *Record* by the notation ✠ **AMS**. This notation is mandatory for classification of self-propelled floating production installations.

9 Notations for Automatic or Remote Control and Monitoring Systems

9.1 ✠ ACC or ✠ ACCU Notations *(October 2001)*

For automatic or remote control and monitoring systems of the propulsion machinery, ABS will consider additional classifications with symbols ✠ **ACC** or ✠ **ACCU**, as appropriate, provided that the applicable requirements of Part 4, Chapter 9 of the *Steel Vessel Rules* are satisfied.

9.3 ✠ AMCC or ✠ AMCCU Notations *(March 2003)*

For automatic or remote control and monitoring systems of the machinery other than the propulsion machinery as referenced in Subsection 1/1 of the ABS *Guide for Remote Control and Monitoring for Auxiliary Machinery and Systems (other than Propulsion) on Offshore Installations*, ABS will consider additional classifications with symbols ✠ **AMCC** or ✠ **AMCCU**, as appropriate, provided that the applicable requirements of the ABS *Guide for Remote Control and Monitoring for Auxiliary Machinery and Systems (other than Propulsion) on Offshore Installations* are satisfied.

11 Temporary Mooring Equipment Symbol

The symbol Ⓔ will be placed after the symbols of classification to signify that the equipment for temporary mooring of the floating installation complies with 3-4-1/3 of the *MODU Rules* or Part 3, Chapter 5 of the *Steel Vessel Rules*.

13 Conversion of Existing Vessels or Floating Structures

Modifications of existing vessels or floating structures intended for classification as Floating Installations are to be converted under ABS design review and survey.

15 Significant Change of Operating Conditions Affecting Safety of Unit or Personnel *(1 July 2012)*

In a few occasions, the operating conditions of the FPI initially considered during the classification of the unit change with time. For example, the composition of the oil coming from the well may turn sour (high concentration of hydrogen sulfide, H_2S). If these changes affect the safety of the unit or the personnel on board, the owner/operator needs to approach ABS as the changes may have an effect in the compliance with the applicable Rules and Guides and therefore, in the maintenance of class.

If it is confirmed that the changes are affecting the compliance with the applicable Rules and Guides, there are two options:

- To identify the Rule requirements that the unit has to comply with in order to maintain classification and to verify compliance by design review and survey, as applicable; or
- To perform a risk assessment with ABS participation in order to analyze the new hazards due to the changes and determine the mitigation actions required to bring the unit to an equivalent level of safety to the applicable Rules and Guides.

PART

1

CHAPTER 1 **Scope and Conditions of Classification**

SECTION 3 **Rules and the Criteria Presented for Classification** *(1 January 2008)*

1 Application

1.1 General *(1 July 2009)*

The criteria in this document are applicable to Floating Production, Storage and Offloading installations (FPSOs), as defined in Section 3-1-1 of these Rules. The criteria are also applicable to Floating Production Systems (FPSs), as defined in 3-1-1/3, Floating Storage and Offloading systems (FSOs), as defined in 3-1-1/3, or Floating Offshore Installation (FOI), as defined in 3-1-1/3, with corresponding classification notation, as indicated in Section 1-1-2 of these Rules.

The application of the criteria to systems other than the above will be considered on a case-by-case basis.

The criteria are applicable to those features that are permanent and can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in the Rules and the criteria in this document regarding other features are to be considered as guidance to the designer, builder, Owner, et al.

1.3 Application *(1 July 2009)*

These Rules have an effective date of 1 July 2009. The application of these Rules is, in general, based on the contract date for construction or conversion between the shipbuilder and the prospective owner (e.g., Rules which became effective on 1 July 2009 are not applicable to a floating production installation for which the contract for construction was signed on 30 June 2009). See also 1-1-4/3 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

In the case of conversions, structures other than hull structures (such as deckhouses), machinery equipment and/or marine systems which will remain unchanged or with minor modifications during the conversion will be considered on the basis of the original Rules used for the vessel construction as well as the safety features of the converted unit.

3 Reference Standards

Reference is made in these Rules to ABS Rules and other criteria issued by ABS and other organizations. Appendix 3-A1-2 contains a listing of such Reference Standards.

5 Risk Evaluations for Alternative Arrangements and Novel Features *(April 2004)*

Risk assessment techniques may be used to demonstrate that alternatives and novel features provide acceptable levels of safety in line with current offshore and marine industry practice. The ABS *Guide for Risk Evaluations for the Classification of Marine-Related Facilities* provides guidance to ABS clients on how to prepare a risk evaluation to demonstrate equivalency or acceptability for a proposed Floating Production Installation.

Risk evaluations for the justification of alternative arrangements or novel features may be applicable either to the installation as a whole, or to individual systems, subsystems or components. ABS will consider the application of risk evaluations for alternative arrangements and novel features in the design of the floating production installations, Verification Surveys during construction, and Surveys for Maintenance of Class.

Portions of the floating production installation or any of its components thereof not explicitly included in the risk evaluation submitted to ABS are to comply with any applicable part of the ABS Rules and Guides. If any proposed alternative arrangement or novel feature affects any applicable requirements of Flag and Coastal State, it is the responsibility of the Owner to discuss with the applicable authorities the acceptance of alternatives based on risk evaluations.

PART

1

CHAPTER 1 Scope and Conditions of Classification

SECTION 4 Submission of Plans, Data and Calculations

1 Design Plans and Data *(1 March 2006)*

Plans showing the scantlings, arrangements and details of the principal parts of the hull structure of each installation to be built under survey are to be submitted and approved before the work of construction has commenced. These plans are to clearly indicate the scantlings, joint details and welding, or other methods of connection. In general, plans are to be submitted that include the following, where applicable:

i) General Arrangement

ii) Body Plan, lines, offsets, curves of form, inboard and outboard profile

iii) Wind heeling moment curves of equivalent data

iv) *(1 July 2012)* Arrangement plan of watertight, firetight and gastight compartmentation

v) Diagrams showing the extent to which the watertight and weathertight integrity is intended to be maintained, the location, type and disposition of watertight and weathertight closures

vi) Capacity plan and tank sounding tables

vii) Summary of distributions of weights (fixed, variable, ballast, etc.) for various conditions

viii) Type, location and quantities of permanent ballast, if any

ix) Loadings for all decks

x) Transverse section showing scantlings

xi) Longitudinal sections showing scantlings

xii) Decks, including helicopter deck

xiii) Framing, shell plating, watertight bulkheads and flats, structural bulkheads and flats, tank bulkheads and flats with location of overflows and air pipes

xiv) Pillars, girders, diagonals and struts

xv) Stability columns, intermediate columns, hulls, pontoons, superstructure and deck houses

xvi) *(1 July 2012)* Arrangement and details of watertight and weathertight doors and hatches

xvii) Foundations for anchoring equipment, industrial equipment, process, and process support modules, etc., where attached to hull structure, superstructures or deckhouses

xviii) Mooring turrets and yoke arms, including mechanical details

xix) Corrosion control arrangements

xx) *(1 July 2012)* Methods and locations for nondestructive testing (submitted to attending Surveyor for review and agreement)

xxi) The plans listed in 5B-1-4/11 for column-stabilized units

xxii) *(1 March 2006)* Plans and calculations/analyses for the module structures to support production facilities

xxiii) *(1 March 2006)* Plans and calculations/analyses for module support structures

xxiv) *(1 July 2009)* Construction Monitoring Plan

3 Position Mooring System Design Documentation

The design documentation for the mooring system is to include the following, when applicable:

i) Mooring Arrangement or Pattern.

ii) Details of winching equipment.

iii) Details of anchoring system.

iv) Details of mooring line segments.

v) Connections at anchors and between mooring line segments.

vi) Details of in-line (spring) buoys.

vii) Details of buoy for CALM system.

viii) Details of SALM structures, if appropriate.

ix) Details of Turret System to show turret structure, swivel, turntable and disconnecting device.

x) Details of yoke (hard or soft) connecting the installation and CALM/SALM structure.

xi) Environmental Report.

xii) Mooring Analysis describing method of load calculations and analysis of dynamic system to determine the mooring line design loads.

xiii) Model Test report when the design loads are based on model tests in a wave basin.

xiv) Thruster specifications and calculations of a system with dynamic positioning system for thruster forces and power to counteract environmental forces. (See Sections 3-2-3 and 3-2-4.)

5 Production Facilities and Production Support Facilities *(1 July 2012)*

The following design documentation of a floating production and installation is required to be submitted, as applicable, depending on the classification notation:

i) General Arrangements showing arrangements and locations of storage tanks, machinery, equipment, living quarters, fire walls, emergency shutdown (ESD) stations, control stations, crude loading and discharge stations and the flare (see 4-1-7/3).

ii) Hazardous Area Classification Plans, as defined in 3-1-3/7 herein.

iii) Details of Storage Tank Venting and Inerting indicating arrangements for storage tank venting and inerting.

iv) Arrangements for Use of Produced Gas as Fuel showing piping and control arrangements for use of produced gas as fuel showing details of double wall or ducting arrangements for the pipe runs in way of the safe space.

v) A design specification that is to include design parameters (environmental conditions, geographical location of the unit, external loads, pressures, temperatures, etc.), standards and codes adopted throughout the design, construction and testing stages and the process description.

vi) A description of the field development plan, including well fluid properties, production rates, gas oil ratios, processing scheme, well shut-in pressures.

vii) Process flow sheets showing major process equipment components, process piping, material balance, normal pressures and temperatures at the inlet and outlet of each major component.

viii) Piping and Instrumentation Diagrams (P&IDs) indicating location of all sensing and controlling elements on the process and production support systems, sizing and material specification of piping and the associated components, maximum design pressure and temperature ratings, piping strength and flow calculations.

ix) List of electrical equipment located in hazardous areas together with the certificates issued by an independent testing laboratory to show suitability of their use in the intended location.

x) Electrical one line diagram showing ratings of all generators, motors, transformers, type and size of wires and cables. Types and rating of circuit breakers with the setting, interrupting capacity of circuit breakers and fuses.

xi) Short circuit current calculations and coordination data giving the maximum calculated short circuit current available at the main bus bars and at each point in the distribution system in order to determine the adequacy of the interrupting capacities of the protective device. A system coordination study is to be included.

xii) Safety Analysis, including Safety Analysis Function Evaluation (S.A.F.E.) charts.

xiii) Emergency shutdown system (ESD) relating to all sensing devices, shutdown valves, shutdown devices and emergency support system to their functions and showing ESD logic for the complete process and the subsea valves system.

xiv) Emergency backup and uninterrupted power source, supply and the consumers.

xv) Pressure vessel (fired and unfired) and heat exchangers, design dimensional drawings, design calculations, material specifications, pressure and temperature ratings, together with weld details and the details of their support.

xvi) Pressure relief and depressurization vent systems showing arrangements sizing of the lines, capacities of the relief valve, materials, design capacity, calculations for the relief valves, knock out drums, anticipated noise levels and gas dispersion analyses.

xvii) Complete details of flares, including pilots, igniters and water seal and design calculations, including stability and radiant heat analyses.

xviii) Schematic plans for the production support systems, including the size, wall thicknesses, maximum design working pressure and temperature and materials for all pipes and the type, size and material of valves and fittings.

xix) Compressors, pumps selection and control arrangements, including specification data sheet.

xx) Fire and gas detection system showing the location and detailed description of all power sources, sensors, annunciation and indication, set point for the alarm system.

xxi) Passive and active fire protection system indicating locations of fire walls, fire pumps and their capacities, main and backup power supply, fixed and portable fire extinguishing, and fire fighting systems and equipment. In this regard, supportive calculations are to be submitted to show the basis of capacities and quantities of fire extinguishing equipment.

xxii) Escape route plan showing escape routes to abandonment stations and survival embarkation areas.

xxiii) *(1 July 2012)* Startup and commissioning procedures detailing sequence of events for inspection, testing and startup and commissioning of equipment and system (submitted to attending Surveyor for review and agreement).

xxiv) *(1 July 2012)* Installation, Hook-up and Commissioning Procedures (submitted to attending Surveyor for review and agreement, also See Part 3, Chapter 4.)

Above items *i)*, *ii)*, *ix)*, *xiii)*, *xx)*, *xxi)*, and *xxii)*, are required to be submitted for any type of a floating production installation that is classed with or without its topsides production facilities.

7 Marine Systems and Machinery Plans *(1 July 2012)*

Plans showing marine piping systems, electrical systems, fire fighting systems and equipment, and machinery and equipment not associated with the process facilities are to be submitted (see Section 5A-1-6, 5B-1-4, 5B-2-6 or 5B-3-6 depending on the type of installation).

Where applicable, machinery plans listed in Part 4 of the *Steel Vessel Rules* or *MODU Rules* are to be submitted. Machinery general arrangements, installation and equipment plans, are also to be submitted and approved before proceeding with the work.

9 Additional Plans

Submission of additional plans and calculations may be required when additional classification designations or certifications are requested:

Additional classification designations under 1-1-2/5, 1-1-2/9, 1-1-2/11, 1-1-2/13 of these Rules or Part 4, Chapter 2. (See Section 4-2-2 for import/export system submission requirements.)

Certifications under 1-1-2/5, 1-1-2/9, 1-1-2/11 or 1-1-2/13 of these Rules or 1-1-5/3 or 1-1-5/5 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

11 Manuals and Procedures

11.1 Operations Manual

The Operations Manual is to be submitted, providing guidance information for operating personnel regarding the following, when applicable:

Subject	*References in these Rules*
Loading Manual	3-3-1/7, 5B-1-1/5
Trim and Stability	3-3-1/9, 3-3-1/11, 5B-1-3/1

11.3 Procedures *(1 July 2012)*

Procedures are to be submitted for the following:

Subject	*References in these Rules*
Disconnecting Procedure, if applicable	3-4-1/13
Drydocking Procedure*	Section 7-3-1
Hook Up Procedures	Section 3-4-2
Installation Procedures	Section 3-4-1
Installation Manual	3-4-1/11
Import/Export System	4-2-4/7, 3-4-1/11
Lay-up and Reactivation, if applicable*	7-1-1/15
Startup and Commissioning Procedures*	Section 3-4-3
Survey and Inspection Planning Document*	7-1-1/21

* Submitted to attending Surveyor for review and agreement

PART

2

Materials and Welding

The independent booklet, ABS *Rules for Materials and Welding (Part 2)*, for steels, irons, bronzes, etc., is to be referred to. This booklet consists of the following Chapters:

Rules for Testing and Certification of Materials

Rules for Welding and Fabrication

PART

3

Installation Types, Functions, Features and General Requirements

CONTENTS

PART

3

CHAPTER 1 General Description

CONTENTS

PART
3

CHAPTER 1 General Description

SECTION 1 Basic Configurations

1 Purpose

A *Floating Installation* provides hydrocarbon processing and/or hydrocarbon storage and offloads hydrocarbons. Where discussion of the various component systems supporting hydrocarbon processing and/or storage may cause confusion with the total system, *Floating Installation* is used to generically identify the combination under discussion and refers to a site-specific installation.

The notations:

Floating Production, Storage and Offloading System

Floating Production (and Offloading) System

Floating Storage and Offloading System

Floating Offshore Installation

are based on accepted industry practice and were chosen to provide a clear description of the function of each configuration.

- **Floating Production, Storage and Offloading System** – This installation processes, stores and offloads hydrocarbons.
- **Floating Production (and Offloading) System** – This installation processes and offloads hydrocarbons without storage capacity.
- **Floating Storage and Offloading System** – This installation stores and offloads hydrocarbons without hydrocarbon processing facilities.
- **Floating Offshore Installation** – This installation may process and offload hydrocarbons and may or may not have storage capacity, but the production facilities are not classed.

3 Major Elements

A Floating Installation consists of several of the following major elements that are addressed in these Rules:

i) Installation

ii) Position mooring (or station keeping system)

iii) Production processing facilities

iv) Import/export system

Classification boundaries encompass the installation and position mooring system and may include the production facilities. Import/export systems may be classed, as well. (See Section 1-1-2 of these Rules.)

A Floating Installation classed as an **FPSO, FPS, FSO** or **FOI** includes the following elements:

	Installation	*Position Mooring System*	*Storage*	*Hydrocarbon Process System(s)*	*Import/Export System*
FPSO	✓	✓	✓	✓	Optional
FPS	✓	✓	---	✓	Optional
FSO	✓	✓	✓	---	Optional
FOI (Production Facilities not classed)	✓	✓	Safety Features Only See 4-1-1/3		Optional
FOI (with **Production Facilities** indicated in Column 5)	✓	✓	Safety Features Only See 4-1-1/5		Optional

PART
3

CHAPTER 1 General Description

SECTION 2 Installation

1 General

Installation, as used in these Rules, refers to a floating structure and the machinery, equipment and systems necessary for safety, propulsion (if fitted) and auxiliary services. The structural configurations of these installations may be ship-shaped or barge-shaped (with or without propulsion), column stabilized or any other configuration of a purpose-built floating installation.

3 Ship-Type Installations

Ship-type installations are single displacement hulls, either ship-shaped or barge-shaped, which have been designed or converted to a floating production and/or storage system. They may have propulsion machinery and/or station keeping systems.

5 Column-Stabilized Installations

Column-stabilized installations consist of surface piercing columns, submerged pontoons and a deck supported at column tops. Buoyancy is provided by the submerged pontoons, surface piercing columns and braces, if any.

7 Tension Leg Platform Installations *(1 July 2009)*

Tension leg platform (TLP) installations are vertically moored, buoyant structural systems wherein the excess buoyancy of the platform maintains tension in the mooring system. The TLPs consist of buoyant pontoons and columns, a column top frame or a topside deck and a tendon system with its seafloor foundations.

9 Spar Installations *(1 July 2009)*

Spar installations are deep draft, vertical floating structures, usually of cylindrical shape, supporting a topside deck and moored to the seafloor. The hull can be divided into upper hull, mid-section and lower hull.

11 Other Types *(1 July 2009)*

Purpose-built and new configurations belong to this category.

PART
3

CHAPTER 1 General Description

SECTION 3 Production Facilities

1 General *(1 July 2009)*

The production facilities typically consist of the processing, safety and control systems, production support systems and auxiliary equipment for processing hydrocarbon liquid and gas mixtures from wells or other sources. Generally, a production facility includes all elements located onboard the Floating Installation unit. These elements are located from (and including) the first inlet flange of the well fluid flow line above the water level inboard to (and including) the last onboard flange. Some important items related to production facilities are defined in the following paragraphs.

3 Production Support Systems

The production support systems include power generation and distribution, instrument and service air, potable water, fuel oil systems, HVAC, instrumentation, communication systems and firewater systems required to support hydrocarbon production and processing.

Production support systems may be in addition to or extensions of the normal marine utility systems found on MODUs, barges or ship-type installations. (See Part 4, Chapter 1 of these Rules and Chapter 3, Section 6 of the *Facilities Rules*.)

5 Manned Facility

A manned facility is one with permanent occupied living accommodations or one that requires the continuous presence of personnel for more than 12 hours in successive 24 hour periods.

7 Hazardous Areas: Classified Areas and Area Classification Plan

A classified area is an area in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. See 3-6/15 of the *Facilities Rules*.

An area classification plan is a set of drawings indicating extent, boundaries and classification of all classified areas.

9 Piping and Instrumentation Diagrams (P&IDs)

P&IDs show the size, design and operating conditions of each major process component, piping and valve designation and size, sensing and control instrumentation, shutdown and pressure relief devices with set points, signal circuits, set points for controllers, continuity of all line pipes and boundaries of skid units and process packages.

11 Safety Analysis Function Evaluation (S.A.F.E.) Charts

The S.A.F.E. charts list all process components and emergency support systems with their required sensing devices and the functions to be performed by each device and relate all sensing devices, shutdown valves, shutdown devices and emergency support systems to their functions.

PART

3

CHAPTER 1 General Description

SECTION 4 Position Mooring System

1 General

A Position Mooring System keeps the installation on station. The Position Mooring System includes mooring lines, connectors and hardware, winches, piles, anchors and thrusters. For a single point mooring system, the turret, turntable, disconnecting system, buoy, anchoring legs, etc., are also part of the system.

3 Spread Mooring

A spread mooring is a system with multiple catenary mooring lines anchored to piles or drag anchors at the sea bed. The other end of each line is individually attached to winches or stoppers on the installation through fairleads as necessary. A catenary mooring line may have one or more line segments, in-line buoy(s) (*spring buoy*) or sinker(s) (*clumped weight*) along the line.

5 Single Point Mooring (SPM)

A single point mooring allows the installation to weathervane. Three typical types of single point mooring systems that are commonly used are described below:

5.1 CALM (Catenary Anchor Leg Mooring)

A catenary anchor leg mooring system consists of a large buoy anchored by catenary mooring lines. The installation is moored to the buoy by soft hawser(s) or a rigid yoke structure.

5.3 SALM (Single Anchor Leg Mooring)

A single anchor leg mooring system consists of an anchoring structure with built-in buoyancy at or near the water surface and is itself anchored to the seabed by an articulated connection.

5.5 Turret Mooring

A turret mooring system consists of a number of mooring legs attached to a turret that is designed to act as part of the installation, allowing only angular relative movement of the installation to the turret, so that the installation may weathervane. The turret may be mounted internally within the installation or externally from the installation bow or stern. Typically, a spread mooring arrangement connects the turret to the seabed.

5.7 Yoke Arm

A yoke arm is a structure at the end of the installation that only allows angular relative movement between the installation and the mooring attachment to the seabed.

7 Dynamic Positioning and Thruster Assisted Systems

A dynamic positioning system is defined as all of the equipment necessary to provide a means of controlling the position and heading of a Floating Installation within predetermined limits by means of vectored thrust.

A thruster-assisted system provides controlled thrust to assist the main (usually static) mooring system and reduce component loading of the main mooring system.

PART
3

CHAPTER 1 General Description

SECTION 5 Subsea System

1 General

A subsea system is a flexible/articulated piping system providing a conduit for the hydrocarbons from the subsea pipeline to the surface components. It includes subsea pipelines, subsea well system and risers.

The definitions in this Section describe the various aspects of the classification procedure in these Rules.

3 Floating Hose

A floating hose is a floating conduit used to export hydrocarbons from a point of storage/production, either an SPM or installation's manifold to a receiving installation's manifold for transport.

5 On Bottom Flexible Flow Lines

These lines are conduit used to connect one subsea location to another subsea location prior to a vertical conveyance by the riser system to the surface.

7 Pipe Line End Manifold (PLEM)

A PLEM is the assemblage of valves and components or equipment performing the equivalent function connecting the production facilities to the pipeline carrying product to or from the shore, an offloading system or to another facility.

7.1 Import PLEM

Import PLEM is the equipment connecting to the Import Riser and the import supply line or wellhead. (In some configurations, the wellhead may provide the function of the Import PLEM.)

7.3 Export PLEM

Export PLEM is the equipment connection between the Export Riser and the product discharge line.

9 Riser

A riser is a subsea rigid and/or flexible pipe that connects the surface facilities with the sea floor and is thus the conduit for fulfilling the desired function of conveying fluids, gas, electrical power, etc.

11 Riser System

The riser system includes the entire assemblage of components, control systems, safety systems and tensioning devices that ensure the integrity of the riser throughout its operation. Riser classification boundaries are defined in Section 4-2-1 of these Rules.

13 Riser Support

Riser support comprises any structural attachments, including buoyancy devices that are used to give structural integrity to the riser or transfer load to the supporting structure.

15 Submerged Jumper Hoses

Jumper hoses are flexible lines used in conjunction with rigid risers to accommodate the relative motion between the Floating Installation and the submerged top of the riser. Jumper hoses may also be used to connect the subsea manifold to the wellhead.

PART
3

CHAPTER 2 Design Basis and Environmental Loading

CONTENTS

PART

3

CHAPTER 2 Design Basis and Environmental Loading

SECTION 1 General Design Basis

(1 July 2009) The design basis of a Floating Installation identifies, among other items, the production rate, storage capacity and loading capabilities. Since the system operation is site-specific, the environmental conditions of the site directly influence the design of such a system.

The effects of prevailing winds are to be considered to minimize the risk of vented or flared hydrocarbons to personnel, living quarters and evacuation means. Generally, atmospheric vents, flare systems and emergency gas release vents are to be arranged in such a way so that prevailing winds will carry heat and/or unburned gases away from potential ignition sources on the installation. See API RP 14J.

The design environmental conditions are to include those for the operation, installation and transit portions of the Floating Installation's design life. This Chapter specifically covers the environmental design criteria for:

i) Position Mooring System.

ii) Structural Strength and Fatigue Life Assessments.

PART

3

CHAPTER 2 Design Basis and Environmental Loading

SECTION 2 Design Documentation

The design documentation submitted is to include reports, calculations, plans and other documentation necessary to verify the structural strength of the installation itself and adequacy of the mooring system, production and other utility facilities and riser system (if included in the classification) for the intended operations.

PART

3

CHAPTER 2 Design Basis and Environmental Loading

SECTION 3 Design Conditions

The FPI is to be designed for load scenarios encountered during transit and site-specific conditions. Site-specific conditions are to include both the Design Environmental Condition and the Design Operating Condition.

1 Position Mooring System

The position mooring system of a Floating Installation is to be designed to survive in the Design Environmental Condition and operate in the Design Operating Condition. For a disconnectable mooring system, the limiting condition at which the mooring system is to be disconnected or reconnected is to be specified.

1.1 Design Environmental Condition (DEC) *(1 March 2006)*

The *Design Environmental Condition (DEC)* is defined as the extreme condition with a specific combination of wind, waves and current for which the system is to be designed.

The DEC is to be one of the following combinations that results in the most severe loading case:

- 100-year waves with associated wind and current.
- 100-year wind with associated waves and current.
- 100-year current with associated waves and wind.

In areas with high current, additional design environmental load cases may need to be considered.

The 100-year waves are normally characterized by a significant wave height with a spectral shape type and a range of associated peak wave periods.

A minimum return period of 100 years for the DEC is required for Floating Installations. A minimum return period of 50 years will be specially considered if it is accepted by the coastal state. Any environmental combinations with return periods shorter than that of the DEC which induce larger mooring load responses are also to be used in the design.

For a Floating Installation with a **Disconnectable** notation (see 1-1-2/5.1 of these Rules), the *DISconnecting Environmental Condition (DISEC)* of the mooring system is the limiting extreme environmental condition at which the installation is to be disconnected from the mooring system. However, the permanent mooring system, i.e., the mooring system alone (without the installation), is to be designed to withstand an environmental condition based on a 100-year recurrence period. An acceptable monitoring system is to be provided for tracking environmental conditions or mooring line tensions in order to assist in the decision to disconnect the installation from the mooring system.

1.3 Design Operating Condition (DOC) *(1 July 2009)*

The *Design Operating Condition (DOC)* is defined as the limiting environmental condition that would require suspension of normal operations. The return period associated with the DOC shall be the larger of: a) the value as specified by the Operator, or b) one year.

1.5 Design Installation Condition (DIC)

The *Design Installation Condition (DIC)* is defined as the limiting environmental condition that would require suspension of installation operations. Specific limits on environmental conditions affecting safe operation during the installation phases described in Part 3, Chapter 4 are to be established and documented.

1.7 Angular Separation of Wind, Current and Waves

For single point mooring systems, which allow the installation to weathervane, both collinear and non-collinear directions among wind, current and waves are to be considered. Proper angular separation for the DEC of wind, current and waves is to be determined based on the site-specific environmental study. If this information is not available, the following two angular combinations for non-collinear environments can be considered as a minimum:

i) Wind and current are collinear and both at 30 degrees to waves.

ii) Wind at 30 degrees to waves and current at 90 degrees to waves.

For spread mooring systems with limited change in installation heading angles (less than 20 degrees) under design environmental loads, the collinear environments of wind, current and waves, which are generally controlling, can be used in design.

For each design sea state, a long-crested sea without spectral energy spreading in direction is normally considered in the mooring analysis.

3 Structural Strength and Fatigue Life

3.1 Project Site *(December 2008)*

The site-specific environmental conditions, including both 100-year return period environmental events and wave scatter diagram data of wave height/period joint occurrence distribution, are to be considered for the installation's hull strength and fatigue life assessment. Fatigue life assessment is also to include the effects of on-site operational loading and unloading cycles. A minimum return period of 100 years for the design response should be used for the DEC criteria per API RP 2T. A minimum return period of 50 years for the structural response may be specially considered, provided that it is accepted by the Coastal State. Different environmental conditions may induce different worst responses on various parts of the hull structure. The wave-induced maximum motion responses and maximum structural load effects may result from different wave periods. Therefore, the following two environmental conditions are to be considered to derive the maximum motion responses and maximum structural load effects. The larger of the two values obtained from *i)* and *ii)* is to be considered the maximum response:

i) 100-year return period waves characterized by a significant wave height with a range of associated peak wave periods. Both winter storms and tropical cyclones (hurricanes or typhoons), if any, need to be considered.

ii) Wave scatter diagram data of wave height/period joint occurrence distribution. The length of time on which the data base for the wave scatter diagram data is constructed is long enough to be a reliable basis for design (preferably at least five years). The occurrence distribution is to be annualized with equal probability of occurrence for each data point. Each data point is to represent a sea state of approximately three hours in a continuous time duration of the database.

For both of the above environmental conditions the following are also to be considered:

iii) Wave directions of head seas and other directions relative to the installation heading, including the effects of wind and current, with proper probability distribution are to be considered, irrespective of the type of mooring system utilized.

iv) As appropriate, either long-crested seas or short-crested seas with spreading function are to be considered for various design issues.

3.3 Transit

The wind and wave conditions representing the environment for the transit route from the building or outfitting site (or the shipyard where the conversion modifications are made) to the project site and the time of the year are to be determined for the design of a floating installation. Except for floating installations that qualify for the **Disconnectable** classification notation, any other transit conditions occurring during the operational life of the floating installation are to be submitted for review. Prior to commencement of such a voyage, an ABS Surveyor is to attend and survey the installation to assess its condition.

As a minimum, the wind speed and significant wave height of 10-year return period are to be considered, unless a weather routing plan is to be implemented for the voyage. Seasonal effects on the design environments as appropriate for the proposed transit duration can be considered.

In addition to the check on the installation's hull strength during transit, special attention is to be paid to items such as the flare boom, crane pedestal and process equipment supports that will be subject to motion-induced loading and/or effects of green water. Motion-induced loads during transit are to be calculated and the superstructures and their supports, which are included in the scope of classification, shall be verified against these loads.

If fitted with an internal turret, special consideration is to be given to bottom slamming to preclude damage to the turret supports and bearings.

3.5 Disconnectable Installations *(1 July 2012)*

For disconnectable floating installations that are disconnected from its mooring and riser systems due to the occurrence of a limiting extreme environmental condition, the structural strength of the installation shall comply with unrestricted service (North Atlantic) conditions. However, if the disconnectable floating installation is restricted to a specific service area in proximity to its operating site location, reduced design load parameters may be applied with an appropriate limited area of disconnected service notation **Disconnectable-R (from site to designated port)** or **(from site to geographic area Lat. X1, Long. Y1; Lat. X2, Long. Y2; Lat. X3, Long. Y3; Lat. X4, Long. Y4)**, where permitted by local authorities or regulations.

3.7 Strength and Fatigue Life *(December 2008)*

Hull strength and fatigue life assessment are calculated according to Part 5A or 5B of these Rules for a given project site and transit route.

PART
3

CHAPTER 2 Design Basis and Environmental Loading

SECTION 4 Environmental Conditions

1 General

The environmental conditions for various design conditions described in Section 3-2-3 are to be submitted with adequate data for the specific site of operation. Statistical data and mathematical models that describe the range of pertinent expected variations of environmental conditions are to be employed. All data used are to be fully documented with the sources and estimated reliability of data noted.

An *environmental report* describing methods employed in developing available data into design criteria is to be submitted in accordance with 1-1-4/3 of these Rules. Probabilistic methods for short-term, long-term and extreme-value prediction are to employ statistical distributions appropriate to the environmental phenomena being considered, as evidenced by relevant statistical tests, confidence limits and other measures of statistical significance. Hindcasting methods and models are to be fully documented.

Generally, data and analyses supplied by recognized consultants will be accepted as the basis of design. Published design standards and data, if available for the location of interest, may be cited as documentation.

Specifically, the following environmental data are normally to be provided:

i) Extreme events of 100-, 10- and 1-year return period data for wind speed, significant wave height and current. A range of associated wave periods is to be considered for each specified significant wave height. Both winter storms and tropical cyclones (hurricanes or typhoons), if any, need be considered.

ii) Directional data and angular separation for extreme values of wind, waves and current.

iii) Wave spectral shape formulation.

iv) Current speed and directional variation through the water depth.

v) Wave height/period joint occurrence distribution (wave scatter diagram data with equal annual probability of occurrence for each data point).

vi) Long-term wave statistics by direction.

vii) Water depth and tidal variations, including wind and pressure effects of storms.

viii) Air and sea temperature.

ix) Ice, iceberg and snow, if any.

3 Environmental Loads

The design of a Floating Installation requires the establishment of environmental loads considering the following parameters:

Air and sea temperatures	Tides and storm surges
Currents	Waves
Ice and Snow	Wind

Other phenomena such as loop currents, tsunamis, submarine slides, seiche, abnormal composition of air and water, air humidity, salinity, ice drift and icebergs may require special considerations.

Wind tunnel and towing tank tests on the project-specific submerged hull and superstructures are preferred in determining current and wind loads. Alternatively, the following calculation procedures can also be applied.

5 Current

The current forces on the submerged hull, mooring lines, risers or any other submerged objects associated with the system are to be calculated using a current profile established in accordance with 3-2-3/1. In areas where relatively high velocity currents occur, load amplification due to vortex shedding is to be considered.

Current force, $F_{current}$, on the submerged part of any structure is calculated as the drag force by the following equation:

$$F_{current} = 1/2\ \rho_{water}\ C_D\ A_{current}\ u_c\ |u_c| \qquad \text{kN (lbf)}$$

where

ρ_{water} = density of sea water, 1.025 tonnes/m^3 (1.99 Slugs/ft^3)

C_D = drag coefficient, in steady flow (dimensionless)

u_c = current velocity vector normal to the plane of projected area, in m/s (ft/s)

$A_{current}$ = projected area exposed to current, in m^2 (ft^2)

For a Floating Installation using a ship-type configuration (e.g., tankers), current forces may be calculated (as appropriate) by using coefficients based on model test data as presented in *Prediction of Wind and Current Loads on VLCCs*, published by Oil Companies International Marine Forum (OCIMF), 1994.

7 Wind

The wind conditions for various design conditions are to be established from collected wind data and should be consistent with other environmental parameters assumed to occur simultaneously. In general, the wind speed is to be based on a recurrence period of 100 years.

The environmental report is to present wind statistics for the site of installation. The statistics are to be based on the analysis and interpretation of wind data by a recognized consultant. The report is to include a wind rose or table showing the frequency distributions of wind velocity and direction and a table or graph showing the recurrence period of extreme winds. The percentage of time for which the operational phase limiting wind velocity is expected to be exceeded during a year and during the worst month or season is to be identified.

7.1 Wind Load

The wind loading can be considered either as a steady wind force or as a combination of steady and time-varying load, as described below:

i) When wind force is considered as a constant (steady) force, the wind velocity based on the 1-minute average velocity is to be used in calculating the wind load.

ii) Effect of the wind gust spectrum can be taken into account by considering wind loading as a combination of steady load and a time-varying component calculated from a suitable wind spectrum. For this approach, the wind velocity based on 1-hour average speed is to be used for steady wind load calculation. The first approach is preferred to this approach when the wind energy spectrum cannot be derived with confidence.

Wind pressure, p_{wind}, on a particular windage of a floating installation may be calculated as drag forces using the following equations:

$$P_{wind} = 0.610\ C_s C_h V_{ref}^2 \qquad \text{N/m}^2 \qquad V_{ref} \text{ in m/s}$$

$$= 0.0623\ C_s C_h V_{ref}^2 \qquad \text{kgf/m}^2 \qquad V_{ref} \text{ in m/s}$$

$$= 0.00338\ C_s C_h V_{ref}^2 \qquad \text{lbf/ft}^2 \qquad V_{ref} \text{ in knots}$$

where

C_s = Shape Coefficient (dimensionless)

C_h = Height Coefficient (dimensionless)

The height coefficient, C_h, in the above formulation accounts for the wind velocity (V_{wind}) profile in the vertical plane. The height coefficient, C_h, is given by the following equation:

$$C_h = \left(\frac{V_z}{V_{ref}}\right)^2 \quad \text{or} \quad C_h = \left(\frac{z}{Z_{ref}}\right)^{2\beta}, \quad \text{but } C_h\,(\geq 1)$$

where the velocity of wind, V_z, at a height, z, is to be calculated as follows:

$$V_z = V_{ref}\left(\frac{z}{Z_{ref}}\right)^{\beta}$$

V_{ref} = velocity of wind at a reference elevation, Z_{ref}, of 10 m (33 feet)

β = 0.09 - 0.16 for 1-minute average wind

= 0.125 for 1-hour average wind.

The corresponding wind force, F_{wind}, on the windage is:

$$F_{wind} = p_{wind} A_{wind}$$

where

A_{wind} = projected area of windage on a plane normal to the direction of the wind, in m^2 (ft^2)

The total wind force is then obtained by summing up the wind forces on each windage.

Representative values of C_h are given in 3-2-4/Table 2 of these Rules. Wind profiles for the specific site of the Floating Installation should be used.

The shape coefficients for typical structural shapes are presented in 3-2-4/Table 1 of these Rules. To convert the wind velocity, V_t, at a reference of 10 m (33 feet) above sea level for a given time average, t, to velocity of another time average, the following relationship may be used:

$$V_t = fV_{(1\ \mathrm{hr})}$$

Example values of the factor f, based on API RP 2A, for U.S. waters are listed in 3-2-4/Table 3 of these Rules. Values specific to the site of the Floating Installation are to be used.

Wind forces can be calculated for large ship-type installations with relatively small superstructure (e.g., tankers) using the coefficients presented in the document *Prediction of Wind and Current Loads on VLCCs*, OCIMF, 1994. Additional forces due to superstructures and equipment can be calculated by the above formula and added to these results.

Wind forces on Floating Installations other than ship-type are to be calculated by the summation of wind forces on individual areas using the above formulas.

If the 1-hour average wind speed is used, the wind's dynamic effect should be separately considered. The wind energy spectrum, as recommended in API RP 2A, may be used.

9 Waves

Wave criteria are to be described in terms of wave energy spectra, significant wave height and associated period for the location at which the Floating Installation is to operate. Waves are to be considered as coming from any direction relative to the installation. Consideration is to be given to waves of less than the maximum height because the wave-induced motion responses at waves with certain periods may be larger in some cases due to the dynamic behavior of the system as a whole.

9.1 Wave Forces

The wave forces acting on a floating installation consist of three components, i.e., first order forces at wave frequencies, second order forces at frequencies lower than the wave frequencies and a steady component of the second order forces. This steady component of the wave force is called *Mean Drift Force.* The calculation of wave loading is necessary for assessing the installation motion responses and the mooring system. It requires calculations of dynamic characteristics of the installation and the hydrodynamic loading on the installation for a given environmental condition.

For structures consisting of slender members that do not significantly alter the incident wave field, semi-empirical formulations, such as Morison's equation, may be used. For calculation of wave loads on structural configurations that significantly alter the incident wave field, appropriate methods which account for both the incident wave force (e.g., Froude-Krylov force) and the forces resulting from wave diffraction are to be used. In general, application of Morison's equation may be used for structures comprising slender members with diameters (or equivalent diameters giving the same cross-sectional areas parallel to the flow) less than 20 percent of the wave lengths.

For a column-stabilized type of installation consisting of large (columns and pontoons) and small (brace members) cylindrical members, a combination of diffraction and Morison's equation can be used for calculation of hydrodynamic characteristics and hydrodynamic loading. The designer may refer to 3-1-2/1.5 of the *MODU Rules*. Alternatively, the suitable model test results or full scale measurements can be used.

Wave force calculations should account for shallow water effects which increase current due to blockage effects, change the system natural frequency due to nonlinear behavior of moorings and alter wave kinematics.

9.3 Wave-induced Motion Responses

The wave-induced response of an installation consists of three categories of response (i.e., first order (wave frequency) motions, low frequency or slowly varying motions and steady drift).

9.3.1 First Order Motions

These motions have six degrees of freedom (surge, sway, heave, roll, pitch and yaw) and are at wave frequencies that can be obtained from model tests in regular or random waves or by computer analysis in frequency or time domain.

9.3.2 Low Frequency Motions

These motions are induced by low frequency components of second order wave forces. The low frequency motions of surge, sway and yaw can be substantial, particularly at frequencies near the natural frequency of the system.

The low frequency motion-induced mooring line tension in most systems with a tanker-type installation is a dominating design load for the mooring system. The low frequency motions are to be calculated for any moored installation by using appropriate motion analysis software or by model test results of a similar vessel.

9.3.3 Steady (Mean) Drift

As mentioned above, an installation subjected to waves experiences a steady drift along with the first and second order motions. The mean wave drift force and yawing moment are induced by the steady component of the second order wave forces. Mean drift forces and yawing moments are to be calculated using appropriate motion analysis computer programs or extrapolated from model test results of a similar vessel.

11 Directionality

The directionality of environmental conditions can be considered if properly documented by a detailed environmental report.

13 Soil Conditions *(1 July 2009)*

Site investigation in general should be in accordance with Part 3, Section 6 of the ABS *Rules for Building and Classing Offshore Installations*. Soil data should be taken in the vicinity of the foundation system site. An interpretation of such data is to be submitted by a recognized geotechnical consultant. To establish the soil characteristics of the site, the foundation system borings or probings are to be taken at all foundation locations to a suitable depth of at least the anticipated depth of any piles or anchor penetrations plus a consideration for the soil variability. As an alternative, sub-bottom profile runs may be taken and correlated with at least two borings or probings in the vicinity of anchor locations and an interpretation may be made by a recognized geotechnical consultant to adequately establish the soil profile at all anchoring locations.

TABLE 1
Shape Coefficients C_s for Windages

Shape	C_s
Sphere	0.40
Cylindrical Shapes	0.50
Hull above waterline	1.00
Deck House	1.00
Isolated structural shapes (Cranes, channels, beams, angles, etc.)	1.50
Under deck areas (smooth)	1.00
Under deck areas (exposed beams and girders)	1.30
Rig derrick	1.25

TABLE 2
Height Coefficients C_h for Windages

Height above Waterline		C_h	
Meters	*Feet*	*1-min*	*1-hr*
0.0 - 15.3	0 - 50	1.00	1.00
15.3 - 30.5	50 - 100	1.18	1.23
30.5 - 46.0	100 - 150	1.31	1.40
46.0 - 61.0	150 - 200	1.40	1.52
61.0 - 76.0	200 - 250	1.47	1.62
76.0 - 91.5	250 - 300	1.53	1.71
91.5 - 106.5	300 - 350	1.58	1.78

TABLE 3
Wind Velocity Conversion Factor*

Wind Duration		*Factor "f"*
1	Hour	1.000
10	Min	1.060
1	Min	1.180
15	Sec	1.260
5	Sec	1.310
3	Sec	1.330

* The values of 3-2-4/Table 3 are most representative of U.S. waters. Site-specific data should be used. (See 3-2-4/7.1 of these Rules)

PART

3

CHAPTER 3 General Requirements

CONTENTS

PART

3

CHAPTER 3 General Requirements

SECTION 1 All Installations

1 General *(1 July 2009)*

This Chapter covers the requirements for installations (ship-type, column-stabilized, tension leg platform and spar) as defined in Section 3-1-2. Other types, as defined in 3-1-2/7, will be considered on a case-by-case basis.

This Chapter covers the requirements for installations that are newly designed or are undergoing a major conversion that affects the principal dimensions of the floating installation, or an existing vessel that is undergoing conversion to a floating installation. The application of these requirements to existing vessels undergoing conversions will be considered by ABS based on the service history, age, condition of the existing floating installation, etc.

The designer is required to submit to ABS for review all applicable design documentation, such as reports, calculations, plans and other documentation necessary to verify the structural strength of the floating installation itself (see Section 1-1-4 of these Rules). The submitted design documentation is to include the design environmental conditions (see Section 3-2-4).

3 Lightweight Data *(1 July 2012)*

The lightweight and center of gravity are to be determined for installations of all types. An inclining test will be required for the first floating installation of a series, when as near to completion as practical, to determine accurately the lightweight and position of center of gravity. An inclining test procedure is to be submitted for review prior to the test, which is to be witnessed by an ABS Surveyor. For specific requirements related to non-ship-type installations, refer to Section 5B-1-3, 5B-2-2, or 5B-3-2.

5 Maximum Draft *(1 July 2012)*

Every installation is to have marks that designate the maximum permissible draft to which the installation may be loaded. Such markings are to be placed at suitable visible locations on the hull or structure to the satisfaction of ABS. On column-stabilized installations, where practical, these marks are to be visible to the person in charge of liquid transfer operations.

Where a Load Line certificate, issued in accordance with the International Convention of Load Lines, 1966, as amended by the 1988 Protocol, is not required, marks shall be affixed to the hull that clearly show the maximum draft permitted.

Maximum draft marks are to be established under the terms of the International Convention of Load Lines, 1966. Only the summer freeboard should be applied, unless other freeboards are necessary for disconnectable ship-type units. Where minimum freeboards cannot be computed by the normal methods laid down by the convention, such as in the case of a column stabilized installation, they are to be determined on the basis of compliance with strength and stability criteria in the Rules and applicable statutory regulations.

The installation's arrangements are to comply with all applicable regulations of the International Convention on Load Lines. Where alternative method of establishing the maximum draft has been based on strength and stability calculations as described above, arrangements are to be consistent with watertight and weathertight integrity assumptions in those calculations.

7 Loading Manual (Operating Manual)

For a ship-type installation, a loading manual is to be prepared and submitted for review pertaining to the safe operation of the installation from a strength point of view. This loading manual is to be prepared for the guidance of and use by the personnel responsible for loading the installation. The manual is to include means for determining the effects of various loaded, transitional and ballasted conditions upon the hull girder bending moment and shear force and is to be furnished to the master of the installation for guidance. In addition, a loading instrument suitable for the intended service is to be installed on the installation. The check conditions for the loading instrument and other relevant data are to be submitted for review.

An operating manual is required for the marine operation of all Floating Installations, containing the information listed in Section 1-1-5 of the *MODU Rules* Supplement to the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* and 5B-1-4/11 of these Rules, as applicable. The above mentioned loading manual may be included in the overall operating manual or issued as a separate document. The loading manual, if issued as a separate document, is to be referenced in the overall operating manual**.** Further, where **Disconnectable** is requested as an additional classification notation, the operating manual is to include procedures for disconnection and reconnection of the installation to its mooring and riser system. (See 3-4-1/13 and 3-4-7/3.)

See Parts 5A and 5B and for additional requirements pertaining to each installation type.

9 Trim and Stability Booklet (Operating Manual)

In addition to the loading manual described in 3-3-1/7, a ship-type floating installation is to be provided with sufficient information to guide the master and other responsible personnel in the safe loading, transfer and discharge of cargo and ballast with respect to the hull's trim and stability. The information is to include various loaded, transitional and ballasted example conditions over the full range of operating drafts together with stability criteria to enable the responsible personnel to evaluate the intact and damage stability of any other proposed condition of loading.

This information may be prepared as a separate trim and stability booklet or may be included in the overall operating manual. If issued as a separate document, the trim and stability booklet is to be referenced in the overall operating manual**.** In addition to the booklet or section of the operating manual, the stability guidance information also may be incorporated as part of the loading instrument described in 3-3-1/7. (See 3-2-1/7 and Part 3, Chapter 3, of the *Steel Vessel Rules,* Regulation 10 of the 1966 Load Line Convention, Regulation 25 of MARPOL 73/78.)

See Parts 5A and 5B and for additional requirements pertaining to each installation type.

11 Stability *(1 July 2012)*

The intact and damage stability of the installation are to be evaluated in accordance with the requirements of the Flag and Coastal States. Ship-type installations are to comply with the IMO Code on Intact Stability, the 1966 Load Line Convention, SOLAS Convention or IMO MODU Code as applicable, and MARPOL 73/78. Non-ship-type installations are to meet the requirements in Section 5B-1-3, 5B-2-2, or 5B-3-2 of these Rules. See 3-3-1/9 of these Rules for general requirements pertaining to the makeup and issuance of loading guidance with respect to stability.

13 Engineering Analysis *(December 2008)*

Documentation necessary to verify the adequacy of the hull structure is to be submitted for review. The needed extent and types of analyses and the sophistication of such analyses vary, depending on one or a combination of the following factors:

i) The design basis of the hull structure versus the conditions to be encountered at the site for the installation.

ii) The relative lack of experience with the hull structure's arrangement, local details, loading patterns, failure mode sensitivities.

iii) Potential deleterious interactions with other subsystems of the floating offshore installation.

The required structural analyses are to employ the loads associated with the environmental conditions determined in association with Part 3, Chapter 2. These conditions include those expected during the operational life of the Floating Installation on site and those expected during the transport of the structure to the site of the installation.

For sites with relatively mild environmental conditions, it may be possible, depending on the intended service of the structure, to reduce the structural analysis effort where it is demonstrated that the hull structure satisfies the unrestricted criteria of the pertinent ABS Rules applicable to the installation type being considered. However, it may still be deemed necessary to perform and submit for review specific analyses for such considerations as the interface between the position mooring system and the hull structure, or the effects of structural support reactions from deck mounted (or above-deck) equipment modules or both, potential sloshing load effects and fatigue strength assessments of hull components where the other applied ABS Rules do not address that consideration to the extent needed for a floating offshore installation. More specific information on required structural analyses is given in Parts 5A and 5B for each type of hull structure covered by these criteria.

15 Mooring Systems and Equipment

Position mooring systems are to meet the requirements of Part 6. For temporary mooring equipment, see 1-1-2/11 and 5A-1-3/1.11 of these Rules.

17 Onboard Computers for Stability Calculations *(1 July 2012)*

The use of onboard computers for stability calculations is not a requirement of class. However, if stability software is installed onboard floating installations contracted on or after 1 July 2005, it needs to cover all stability requirements applicable to the floating installation and is to be approved by ABS for compliance with the requirements of Appendix 3-3-A2, "Onboard Computers for Stability Calculations" of the *MODU Rules*.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

CONTENTS

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 1 General

The requirements in this Chapter apply to the procedures to be submitted and the surveys to be performed for all ABS-classed Floating Installations.

Prior to carrying out the installation, the installation procedures are to be submitted for review. The installation procedures to be submitted are to include the following, where applicable.

1 General Description

General description of the entire layout of the mooring system and of the Floating Installation with risers, subsea pipelines and, as applicable, pipeline end manifolds (PLEMs).

3 Pre-installation Verification

Pre-installation verification procedures for the seabed condition in way of the installation site and contingency procedures for removing any obstacles found on site.

5 Pile or Anchor and Mooring Line Installation

Pile or anchor and mooring line installation procedures which are to include, but are not limited to, the following:

i) General preparations for installation.

ii) Rigging arrangements for piles, chaser pile and driving hammers.

iii) Work barge setup during the various phases of installation, taking into consideration the prevailing weather conditions.

iv) Anticipated pile driving resistance.

v) Pile penetration acceptance criteria established by design and pile refusal and overdrive contingency procedures.

vi) Procedure for positioning of the pile orientation toward the center of the Position Mooring System and the criteria for allowable deviations of position and orientation.

vii) Procedure for installation of the mooring line and the precautions to be taken in order to prevent any twisting of the mooring chains during installation.

viii) Procedure for installation of anchors, including piggyback anchors, if applicable, and procedure for determining the installed positions and orientations of the anchors. Criteria for allowable deviations in positioning and orientation are also to be included.

7 Tensioning and Proof Load Testing

Tensioning and proof load testing procedures of the anchor piles or anchors and chain system are to include the following:

i) Rigging arrangements for proof load tension testing of the mooring chains, anchor or pile system.

ii) Work barge setup to perform the proof load testing of the chains and anchor or pile system.

iii) Detailed tensioning procedure, including type of tensioning device to be utilized and tensioning operations.

iv) Chain retrieval and abandonment procedures during tensioning.

v) Procedure for chain proof load tensioning by ballasting the Floating Installation, if applicable.

9 Hook-up of the Anchor Chain System

Procedure for hook-up of the anchor chain system to the Floating Installation, which is to include the following:

i) Rigging and towing procedures for positioning of the Floating Installation for hook-up to the mooring system.

ii) Preferred ballast condition of the Floating Installation prior to the hook-up.

iii) Procedure for sequential hook-up of the chains, repositioning of the Floating Installation and tensioning of the chains.

iv) Method of determining the correct tension of the chains and the acceptable design tolerance.

v) Procedure for determining the positioning of the SPM system relative to the PLEM or wellhead and the acceptable design tolerance for the position of the SPM center relative to the PLEM or wellhead.

vi) Method of securing the chain turntable from movement and the overall safety precautions for the entire hook-up installation.

vii) Procedure for chain tensioning by ballasting the Floating Installation, if applicable.

11 Import/Export System Installation

The Import/Export System Installation Procedure is to be submitted for review in conjunction with the design review so that it can be verified that all appropriate installation loadings have been considered. The manual is to describe procedures to be employed during the installation of the import/export systems. In addition, the manual is to include a list of allowable environmental limits under which system installation may proceed. Abandonment procedures, retrieval procedures and repair procedures are to be supplied, when deemed necessary.

11.1 Rigid and Flexible Risers

The procedure to hook-up the import/export risers to the Floating Installation is to include the following items, where applicable:

i) Handling and rigging of the rigid and flexible riser during installation.

ii) Positioning of the work barge for the various phases of the installation.

iii) Procedure for installation of the buoyancy tank and arch support and clump weight, if applicable, including steps to avoid riser interference and precautions against damaging the riser during installation.

iv) Tie-in rigging technique for hook-up of both ends of the risers.

v) Procedure for hydrostatic testing of the risers. Hydrotest pressure and test duration are to be in accordance with API or other recognized code of practice.

11.3 Export Vessel Transfer System

The procedure for installing the export system is to include the following items, as applicable.

i) Rigging, handling and make-up of the export hose system and precautions against damage during installation.

ii) Fitting of all the necessary accessory and navigational aids.

iii) Procedure for paying out of the hose string into the sea.

iv) Procedure for filling and testing the hose string. The required design and testing pressure and testing duration are to be provided.

13 Disconnecting Procedure

For disconnectable mooring systems, the procedures for the disconnecting and connecting of the Floating Installation's mooring system are to be submitted. These procedures are to include the abandonment and retrieval of the import and export systems. (Also see 1-1-4/11 of these Rules for Operating Manual requirements.)

PART

3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 2 Hook-up Procedures Submittal

Any system component installation intentionally left incomplete to ease the installation of the Floating Installation at site is to be documented and a procedure for site hook-up and testing is to be submitted.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 3 Start-up and Commissioning Procedures Submittal

Start-up and commissioning procedures for the production system are to be submitted for review per the *Facilities Rules*.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 4 Surveys During Installation of the Mooring Systems

During installation, the requirements as contained in the following paragraphs are to be verified or witnessed, where applicable, by the attending Surveyor.

1

All mooring components are to be examined for transit damages prior to installation. Any damages found are to be dealt with to the satisfaction of the attending Surveyor.

3

All applicable components required to be certified at the manufacturers' facilities have received certification.

5

The area at and in the vicinity of the mooring site is to be surveyed by divers or remotely operated vehicles (ROVs) to ensure that there are no obstructions or debris prior to installation.

7

During the installation of the anchors or anchor piles, the following are to be verified in order, where applicable:

i) Proper locking of all connecting shackles from chains to piles or anchors and chains to chains.

ii) Sealing of all Kenter shackle locking pins.

iii) All complements of anchor chains for correct sizes and lengths.

iv) All anchor pile or anchors are installed in the designed positions and orientations and are within the allowable design tolerance.

9

The paying out of the anchor chains after the installation of the piles is to be performed in accordance with the approved procedures.

11

Unless otherwise approved by the attending Surveyor, the first pair of anchor chains to be cross-tensioned is the first pair to be installed.

13

The cross-tensioning is to be verified to ensure all pretensioning loads are in accordance with the design and there is no movement or pullout of the anchor piles.

15

Upon successful completion of the pretensioning, the subsequent hooking up of all of the chain legs to the chain stoppers in the turntable is to be verified.

17

During tensioning of the chains for the position mooring system, the relative position of the mooring system's center to the PLEM is to be verified for compliance with the design specifications and tolerance.

19

Upon completion, the chain tension is to be verified by measuring the catenary angles of the chains for compliance with the design specifications and tolerance. Any excess length of chain above the chain stoppers is to be removed, unless it is designed to be retained in the chain well.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 5 Surveys During Installation of the Import/Export System

During installation of the import/export system, the following items are to be witnessed by the Surveyor, as applicable.

1

The riser is to be examined for damage as it is being paid out, and sufficient tension is to be maintained to ensure the riser is free of deformations or buckles. The buoyancy tank and arch support are to be verified as being installed in the correct position relative to the water surface end of the riser.

3

The installation of the riser clamps on the buoyancy tank and arch support are to be monitored to ensure that the riser is adequately secured and not damaged due to excessive tightening of the clamps.

5

The installation of the end flanges of the riser is to be monitored for compliance with the approved procedures.

7

Upon completion of installation, the entire underwater complement of components is to be generally examined and verified by divers or ROVs for compliance with the reviewed design specifications and configurations. At a site with limited visibility, alternative means of verifying the installation are to be submitted for review and are to be performed to the satisfaction of the attending Surveyor.

9

Hydrotesting of the import/export system is to be performed in accordance with the approved procedure. The test pressure and duration of the hydrotest should follow the appropriate codes, such as ANSI/ ASME B31.8, API RP 2RD and RP 17B.

11

The make-up of the export floating hose string is to be verified for compliance with the approved procedures. Suitable gaskets for the hose flanges, positioning of all navigational aids, correct location of the breakaway couplings and tightening of the flange bolts are also to be verified.

13

During the paying out of the hose string, verification is to be made that the hose string bend radii are not smaller than the manufacturer's recommended limits.

15

Upon completion of installation, the entire export hose string is to be hydrostatically tested in accordance with the approved procedure and codes, such as the *OCIMF Guidelines for the Handling, Storage, Inspection, and Testing of Hoses in the Field.*

17

Subsea controls, if installed, are to be satisfactorily tested.

19

All navigational aids are to be functionally tested and proven in working order.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 6 Surveys During Hook-up

Survey during hook-up is to be performed following reviewed procedures and is to include the following, where applicable:

1

Piping hook-up is to be verified for compliance with the reviewed drawings and procedures. Welds are to be visually inspected and nondestructive testing (NDT) performed as required. Upon completion of hook-up, the affected sections are to be hydrostatically tested to 1.5 times the design working pressure and proven tight.

3

Electrical hook-up is to be verified for compliance with the approved drawings and procedures. Proper support for cables and proper sealing of cable entries to equipment are to be verified. Upon completion of the hook-up, the affected sections of the equipment and cabling are to be insulation tested and proven in order. All grounding is also to be verified as being in order.

5

Instrumentation hook-up is to be verified for compliance with the reviewed drawings and procedures. Tubing supports are to be verified. Upon completion, all systems are to be functionally tested and proven as being in order. The manufacturer's limits on bend radii for any component of the instrumentation system are to be observed.

7

Mechanical equipment hook-up is to be verified for compliance with the reviewed drawings and procedures, including the grounding of the equipment. Upon completion, all equipment is to be functionally tested and proven as being in order.

PART
3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 7 Demonstration of the Disconnectable Mooring System

1

For a disconnectable mooring system, the system's capability to disconnect free from its mooring system is to be demonstrated to the satisfaction of the attending Surveyor, in accordance with approved test procedures.

3

During the disconnect operation, the time taken to effectively free the Floating Installation from the mooring system is to be recorded in the operation manual.

PART

3

CHAPTER 4 Installation, Hook-up, and Commissioning

SECTION 8 Surveys During Start-up and Commissioning

The start-up and commissioning of hydrocarbon production systems are to be verified by the attending Surveyor. The scope of the start-up and commissioning to be verified by the Surveyor is to include the following items:

1

The start-up and commissioning operations are to be in accordance with the reviewed procedures.

3

Verify precautions for safety of personnel during commissioning, including checks of operational readiness of all life saving equipment, fire and gas detection systems, fire fighting equipment, Emergency Shutdown systems and unobstructed escape routes.

5

Verify establishment of communication procedures prior to the start of commissioning operations.

7

Verify that emergency procedures are provided to deal with contingencies, such as spillage, fire and other hazards. Drills may have to be performed to demonstrate readiness to these procedures.

9

Verify start-up and testing of all support utility systems, including main and auxiliary sources, for the process system prior to commissioning.

11

Verify proper hook-up and testing of the entire process system prior to commissioning, including the testing of entire system for leaks, the process control functions and emergency shutdown system.

13

Verify purging of the entire production system of oxygen to an acceptable level prior to the introduction of hydrocarbons into the production system.

15

Verify the introduction of hydrocarbon into the process system and the system's capability to control the flow of the well effluent in the system in a stabilized manner without undue control upsets.

17

Verify the start-up of the flare system, if applicable, including the necessary precautions taken to eliminate the risk of explosion or fire. The functional capability of the flare system is to be verified.

19

Verify that the post-commissioned process system is functioning satisfactorily for a duration of at least 12 hours.

Equipment required to be verified but not used during the initial start-up and commissioning is to be identified for verification at the next Annual Survey.

PART

3

APPENDIX 1 Abbreviations and References

CONTENTS

PART
3

APPENDIX 1 Abbreviations and References

SECTION 1 Abbreviations

API	*American Petroleum Institute*	*Appendix 3-A1-2*
ASME	*American Society of Mechanical Engineers*	*Appendix 3-A1-2*
DEC	*Design Environmental Condition*	*3-2-3/1.1*
DIC	*Design Installation Condition*	*3-2-3/1.5*
DOC	*Design Operating Condition*	*3-2-3/1.3*
FOI	*Floating Offshore Installation*	*3-1-1/1*
FPS	*Floating Production (and Offloading) System*	*3-1-1/1*
FPSO	*Floating Production, Storage, and Offloading System*	*3-1-1/1*
FSO	*Floating Storage and Offloading System*	*3-1-1/1*
HSE	*Health and Safety Executive of the United Kingdom*	*Appendix 3-A1-2*
MODU	*Mobile Offshore Drilling Unit*	*Appendix 3-A1-2*
OCIMF	*Oil Company International Marine Forum*	*Appendix 3-A1-2*
PLEM	*Pipe Line End Manifold*	*3-1-5/7*
P&ID	*Piping and Instrumentation Diagrams*	*3-1-3/9*
S.A.F.E. Chart	*Safety Analysis Function Evaluation Charts*	*3-1-3/11*
SB	*Steel Barges*	*Appendix 3-A1-2*
SPM	*Single Point Mooring*	*Appendix 3-A1-2*
SV	*Steel Vessel*	*Appendix 3-A1-2*
UWILD	*Underwater Inspection in Lieu of Drydocking Survey*	*7-3-1/3 & Appendix 3-A1-2*

PART

3

APPENDIX 1 Abbreviations and References

SECTION 2 References *(1 July 2012)*

ABS:

Facilities Rules	*The ABS Rules for Building and Classing Facilities on Offshore Installations*
MODU Rules	*The ABS Rules for Building and Classing Mobile Offshore Drilling Units*
Offshore Chain Guide	*The ABS Guide for Certification of Offshore Mooring Chain*
Single Point Mooring Rules	*The ABS Rules for Building and Classing Single Point Mooring Systems*
Steel Vessel Rules	*The ABS Rules for Building and Classing Steel Vessels*
UWILD	*The ABS Rules for Survey After Construction (Appendix 7-A-1)*
Fiber Rope Guidance Notes	*The ABS Guidance Notes on the Application of Fiber Rope for Offshore Mooring*
Risk Guidance Notes	*The ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*
Fatigue Guide	*Guide for the Fatigue Assessment of Offshore Structures*
Remote Control and Monitoring Guide	*Guide for Remote Control and Monitoring for Auxiliary Machinery and Systems (other than Propulsion) on Offshore Installations*
Risk Guide	*Guide for Risk Evaluations for the Classification of Marine-Related Facilities*
Buckling Guide	*Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*
SFA Guide	*Guide for Spectral-Based Fatigue Analysis for Floating Production, Storage and Offloading (FPSO) Installations*
DLA Guide	*Guide for "Dynamic Loading Approach" for Floating Production, Storage and Offloading (FPSO) Installations*

American Institute of Steel Construction:

AISC Code	*Manual of Steel Construction - ASD, latest edition*

American Society of Mechanical Engineers/American National Standards Institute:

B31.3	*Chemical Plant and Petroleum Refinery Piping*
B31.4	*Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohol*
B31.8	*Gas Transmission and Distribution Piping Systems*
Boiler Code	*Boiler and Pressure Vessel Code, Section VIII, latest edition.*

American Petroleum Institute:

API RP 2A	*Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms*
API RP 2 SK	*Recommended Practice for the Design and Analysis of Stationkeeping Systems for Floating Structures, Third Edition - 2005*
API RP 2Q	*Replaced by API RP 16Q*
API RP 2RD	*Recommended Practice for Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)*

API RP 2T	*Recommended Practice for Planning, Designing, and Construction Tension Leg Platforms, Third Edition - 2010*
API Bull 2U	*Bulletin on Stability Design of Cylindrical Shells, Third Edition - 2004*
API Bull 2V	*Bulletin on Design of Flat Plate Structures, Third Edition - 2004*
API Spec 9A	*Specification for Wire Rope Twenty-fifth Edition - 2004*
API RP 9B	*Recommended Practice on Application, Care, and Use of Wire Rope for Oil Field Service Twelfth Edition - 2005*
API RP 14C	*Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems on Offshore Production Platforms Seventh Edition - 2001*
API RP 14E	*Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems, Fifth Edition - 1991 (ANSI/API RP 14E-1992)*
API RP 14J	*Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities, Second Edition - 2001*
API RP 17B/ISO 13628-11	*Recommended Practice for Flexible Pipe, Fourth Edition - 2008*
API RP 500	*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I Division 1 and Division 2, Second Edition – 1997 (ANSI/API RP 500-1998)*
API RP 505	*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2, First Edition – 1997*
API RP 520	*Recommended Practice for Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*
Part I	*Sizing and Selection, Eighth Edition - 2008*
Part II	*Installation, Fifth Edition - 2005*
API Std 521/ISO 23251	*Pressure-Relieving And Depressuring Systems Fifth Edition - 2007*
API Spec 17J	*Specification for Unbonded Flexible Pipe*

Oil Companies International Marine Forum:

Guide for Prediction of Wind and Current Loads on VLCCs, 2nd Edition, 1994
Guide to Purchasing, Manufacturing, and Testing of Loading and Discharge Hoses
The OCIMF Ship to Ship Transfer Guide
Guidelines for Handling, Storage, Inspection, and Testing of Hoses in the Field

United Kingdom's Health and Safety Executive:

HSE Guidance Notes	*Offshore Installations: Guidance on DESIGN CONSTRUCTION AND CERTIFICATION, Fourth Edition, 1991, as amended*

PART

4

Process and Import/Export Systems

CONTENTS

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

CONTENTS

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 1 General

1 Installations Classed as FPSO or FPS

Hydrocarbon production and processing systems are to comply with the requirements of the *Facilities Rules* and Sections 4-1-2 through 4-1-11 of these Rules.

3 Installations Classed as FSO or FOI (Production Facilities not Classed) *(1 July 2012)*

The entire production facility need not comply with the requirements of this Chapter. However, the following systems and equipment for the production facilities are to be in accordance with the requirements of the *Facilities Rules*.

System/Equipment	*Facilities Rules Section*
Facility Layout	3-3/5
Area Classification	3-6/15
Electrical System Circuit Protection	3-6/5.9
Electrical Installations in Classified Areas	3-6/15
Fire Water Systems	3-8/5.1
Dry Chemical Systems, as applicable	3-8/5.3
Fixed Fire Extinguishing Systems	3-8/5.5
Paint Lockers, Laboratory Spaces, and Flammable Material Store Rooms	3-8/5.7
Emergency Control Station	3-8/5.11
Operation After Facility Total Shutdown	3-8/5.13
Portable and Semi-portable Extinguishers	3-8/5.15
Gas and Fire Detection Systems	3-8/7
Structural Fire Protection	3-8/9
Muster Areas	3-8/11
Means of Escape	3-8/13
Lifesaving Requirements	3-8/15
Personnel Safety Equipment and Safety Measures	3-8/17

For installations with the **FOI** classification symbol equipment certification is required for equipment in the above listed systems.

5 Installations Classed as FSO or FOI (with Production Facilities Indicated in the *Record*)

The entire production facility need not comply with the requirements of this Chapter. However, safety features are to be in accordance with the following requirements of the *Facilities Rules* in addition to the requirements in 4-1-1/3.

System/Equipment	*Facilities Rules Section*
Facility Layout	3-3/5
Safety System	3-3/13.3
Process Shutdown Systems	3-7/13

PART
4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 2 Scope

This Chapter is applicable to the following:

i) Systems that process hydrocarbon liquids, gases or mixtures from completed wells.

ii) Production support systems associated with the process system, such as water, steam, hydraulics, pneumatics and power supply to the process.

iii) Fire protection systems for the protection of the process equipment and the process area.

iv) Systems that are utilized for stimulation of a completed well, such as chemical, gas or water injection downhole through a Christmas tree.

v) Power generation systems for export purposes.

vi) Electrical systems and components associated with the process facilities.

vii) Systems other than those mentioned above, such as methanol production and/or processing, and desalination, will be the subject of special consideration.

The scope of the hydrocarbon process system is defined in Section 3-1-3 of these Rules. The scope of the hydrocarbon process system may also include the controls for the well head and subsurface safety valve, if these are included in the process safety shutdown system.

PART
4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 3 Installations

Hydrocarbon production systems are typically installed on the following types of installations.

1 Ship-Type Installations – Oil Carriers

Where tankers are to retain the propulsion capability for rapid deployment in the event of environmental conditions exceeding the approved design environmental criteria, the flow lines and the export lines are to be fitted with quick disconnect systems. The documentation regarding the disconnecting procedure is to be submitted for review. For detailed requirements for the disconnect system of the process lines and the mooring systems, see 4-1-8/15.

3 Column-Stabilized Installations, Tension Leg Platforms, and Spar Installations *(1 July 2009)*

These installations may be used simultaneously for operations other than hydrocarbon processing, such as drilling.

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 4 Subsea Equipment *(1 July 2012)*

Subsea equipment is not a part of the classification boundaries as defined in 1-1-2/1 of these Rules. However, subsea equipment may be classed if desired by the Owner, provided these items are approved by ABS for compliance with the requirements of the *Facilities Rules* and applicable Sections of these Rules.

ABS is prepared to certify the subsea equipment if the manufacturers/owners wish to obtain ABS certification. The design, construction and testing of the subsea equipment are to be in accordance with 3-3/17.19 of the *Facilities Rules.*

For a unit that has the riser system classed by ABS, the riser installation winch needs to comply with the following:

i) For a winch that is on board for the installation of the risers only (and removed after installation), the equipment does not need to be reviewed by ABS. However, the supporting structure needs to be designed to provide satisfactory strength for the reaction forces specified by the manufacturer or the maximum anticipated loads during the installation process.

ii) If the riser installation winch is to remain on board after the installation, the equipment will need to be in compliance with recognized industry standards. The manufacturer will need to submit details to demonstrate compliance with the industry standards, either in the form of certificates issued by recognized certification bodies or by submitting details and calculations to ABS for review and approval.

PART
4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 5 Other Codes and Standards

Use of national or international standards or codes other than those listed herein in the design and construction of the equipment and components is subject to prior approval and acceptance by ABS. The standards or codes being applied are to be adhered to in their entirety.

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 6 Non-Standard Equipment

Equipment not designed to a recognized standard may be accepted based on approval of detailed design calculations and testing results that verify the integrity of the equipment which is submitted for review and found satisfactory.

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 7 Design and Construction

1 General

Hydrocarbon process systems and associated equipment are to be designed to minimize the risk of hazards to personnel and property. This criterion is implemented by complying with the *Facilities Rules*, as well as these Rules. The implementation of this criterion is intended to:

i) Prevent an abnormal condition from causing an upset condition.

ii) Prevent an upset condition from causing a release of hydrocarbons.

iii) Safely disperse or dispose of hydrocarbon gasses and vapors released.

iv) Safely collect and contain hydrocarbon liquids released.

v) Prevent formation of explosive mixtures.

vi) Prevent ignition of flammable liquids or gasses and vapors released.

vii) Limit exposure of personnel to fire hazards.

3 Arrangements

General arrangement drawings are to be submitted for review, in accordance with 1-1-4/5 of these Rules. The arrangements depicted are to comply with Subsections 3-3/5 and 3-8/9 of the *Facilities Rules*, applicable Sections of these Rules, and the *Steel Vessel Rules* or the *MODU Rules,* as applicable.

5 Structural Considerations *(1 March 2006)*

Structure that supports production facilities or forms an integral part of the equipment is to be designed to a recognized standard. Plans and calculations are to be submitted for ABS review. Process liquid weights and dynamic loads due to installation motions and other loads, such as wind imposed loads, are to be considered. (See Section 5A-1-5.)

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 8 Process System

1 Submittals

The various data and plans that are to be submitted to ABS for review are listed in 1-1-4/5 of these Rules.

3 Piping System and Manifolds

Piping of the process and process support systems are to comply with the requirements of API 14E and ASME/ANSI B31.3 and B31.1, as applicable. Refer to Chapter 3, Sections 3 and 4 of the *Facilities Rules*.

5 Pressure Relief and Depressurization Systems

Pressure relief and depressurization systems are to comply with API RP 520 and API RP 521. Refer to 3-3/11 of the *Facilities Rules*.

7 Process Equipment and Vessels

Process equipment and vessels are to comply with the applicable requirements in 3-3/17 and 5-1/3 of the *Facilities Rules*.

9 Prime Movers

Internal combustion engines and gas or steam turbines are to comply with 3-4/3.9 and 5-1/3 of the *Facilities Rules*.

11 Safety Systems

Safety systems are to comply with 3-3/7.3 and 3-3/9 of the *Facilities Rules*. Specific items to be addressed are as follows:

i) The process safety and shutdown system is to comply with API RP 14C.

ii) Fire detection and gas detection is to comply with API RP 14C and API RP 14G, respectively. The location of the fire and gas detectors is to be to the satisfaction of the attending Surveyors.

iii) The process safety shutdown system is required to shut down the flow of hydrocarbon from all wells and process systems. The discharge of processed hydrocarbons to the export lines is also to be controlled by the process safety shutdown system. Redundancy is to be provided in the power source to the process safety shutdown system such that upon failure of the main power source, the secondary power source is brought online automatically.

13 Control System

Control systems, in general, are to comply with Chapter 3, Section 7 of the *Facilities Rules*. Additionally, computer based control systems are to comply with the following:

i) The control system is to be totally independent of the alarm and monitoring system.

ii) Where computers are utilized for monitoring, alarm and control, the arrangements are to be such that a fault in one of these functions will not impair the capability of other functions.

iii) The computer system for monitoring alarms and control is to include redundancy arrangements in order to maintain continued operation of the hydrocarbon process system.

15 Quick Disconnect System

Where the Floating Installation is fitted with a quick disconnect system, the control of this system is to be totally independent of the process safety shutdown system required for the hydrocarbon process system. However, the source of power for the process safety shutdown system and controls for the quick disconnect system need not be totally independent, provided that the failure in one system does not render the other system ineffective, e.g., failure through leakage in the hydraulic or pneumatic control lines.

Means are to be provided for the activation of the quick disconnect system from the control station and locally in the vicinity where the disconnect arrangements are located.

The disconnect arrangement is to be designed such that upon its activation, all process flow to the Floating Installation is automatically stopped immediately without leakage of process fluids.

17 Electrical Installations

Electrical installations for the hydrocarbon process system are to comply with the requirements of Chapter 3, Section 6 of the *Facilities Rules*.

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 9 Hazardous Area Classification

Hazardous areas are to be delineated and classified, as required by 3-6/15 of the *Facilities Rules*. In general, API RP 500 or 505 is to be applied to process areas, and the *Steel Vessel Rules* or the *MODU Rules* are applied to non-process areas, as modified by 3-6/15 of the *Facilities Rules*.

PART
4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 10 Fire Protection

Fire extinguishing systems and fire fighting equipment associated with the hydrocarbon process facilities are to comply with Chapter 3, Section 8 of the *Facilities Rules*.

PART

4

CHAPTER 1 Hydrocarbon Production and Process Systems

SECTION 11 Fabrication and Testing

Inspection and testing of hydrocarbon process and associated equipment at the manufacturer's facility are to be in accordance with 5-1/Table 1 of the *Facilities Rules*. Construction and fabrication is to be performed in accordance with approved plans and procedures. Representative survey interventions are listed as follows.

1 Pressure Vessels, Accumulators, Heat Exchangers, Separators and Manifolds

i) The construction, fabrication and material are in accordance with design codes shown on the approved plans.

ii) Witness weld procedure and welder performance qualification tests.

iii) Visual inspection of weld joints, witness nondestructive testing.

iv) Fit up and joining of all pipe connections and pipe supporting arrangement.

v) Dimensional inspection during fit-up and after completion.

vi) Internal examination.

vii) Witness calibration of hydrostatic testing equipment.

viii) Witness hydrostatic tests.

3 Pumps, Compressors and Diesel/Gas Engines

i) Witness mechanical running tests.

ii) Witness testing of auxiliary equipment and protective devices (controls, filters, coolers, oil pumps, alarms, trips, governors).

5 Motors and Generators

i) Functional running test for machines greater than 100 kW.

ii) Witness testing of auxiliary equipment and protective devices.

7 Switchboards and Control Panels

Inspection and witness testing at the manufacturer's facility is not required for switchboards and control panels. These components will be accepted for use, provided they have been designed and constructed to a recognized national or international code or standard.

Control and alarm panels for fire protection and safety systems are to be function-tested at the manufacturer's facility. These tests are to be conducted in the presence of the Surveyor.

9 Process and Process Support Piping

Fabrication, inspection and testing of process and utility piping is to be performed to the satisfaction of the attending Surveyor.

PART

4

CHAPTER 2 Import and Export Systems

CONTENTS

PART

4

CHAPTER 2 Import and Export Systems

SECTION 1 General

(1 July 2012) This Chapter applies to import and export systems utilized in Floating Installations when the class notations specified in 1-1-2/5.5 are requested. These systems include rigid and flexible risers, connecting flow lines, submerged jumpers and floating offloading hoses. (See Section 3-1-5 for definitions of related items.)

1 Riser Classification Boundaries *(1 July 2009)*

The import/export system is assumed to consist of only rigid, flexible hose/pipe or a combination of both rigid and flexible hose/pipe, and associated riser components, such as the tensioning system, buoyancy modules, line buoys, permanent clamps, anchoring systems and safety control systems.

In a typical Floating Installation import (or export) system, the applicable starting and termination points are the riser's connection point to the PLEM and the riser's connection point to the installation or floating structure. The connection points are typically the discharge (or input) flange of the PLEM and the input (or discharge) flange of the installation or floating structure.

For export vessel transfer systems, the connection points are the discharge flange of the installation or floating structure and the end connection to the input flange onboard the export vessel (see 4-2-4/7 of these Rules).

1.1 The Import System

The *Import System* is to include the import risers starting from the Import PLEM, but not including the Import PLEM.

For a typical flexible riser system, the import riser may start at the PLEM/wellhead flanges and terminate at the input flange of the installation or floating structure.

1.3 The Export System

The *Export System* is to include the export risers that may start from the discharge flanges of the installation or floating structure and terminate at the Export PLEM, but not including the Export PLEM.

The criteria given here for Import Risers are applicable to Export Risers where classification is requested.

Where Import and/or Export Risers induce mooring restraint to the floating installation, design, construction and classification of the Riser(s) providing restraint and their connection to the seabed will require special consideration.

3 Basic Design Considerations

The import/export system is to be designed to maintain its integrity under the most unfavorable combination of external environmental loads, internal loads due to fluid contents, pressure and temperature and accidental loads. This is accomplished by ensuring that riser system design is consistent and compatible with the design philosophy used for the Floating Installation.

The dynamic response of the import/export system is to be investigated to the level of detail necessary to ensure that interference between the floating production installation and the associated mooring system does not affect the integrity of the installation or the import/export system. Where conditions are such that analytical investigation (vortex induced vibration analysis, for example) is not adequate to account for installation interference or interference due to multiple riser configurations, etc., model testing or other means of verification are to be performed and requested documentation provided to ABS for review.

The riser is to survive the maximum installation offset, as defined in 6-1-1/3.3.

PART

4

CHAPTER 2 Import and Export Systems

SECTION 2 Submission of Plans and Design Data

Documentation outlining the design, manufacture, installation and operating assumptions applicable to the project is to be submitted for review at the initiation of the project. The following summarizes the typical information that is required to help ensure that the design basis and criteria selection is consistent with the design philosophy. In general, the following are to be submitted for review:

i) Site plan indicating bathymetric features, the location of obstructions to be removed, the location of permanent manmade structures and other important features related to the characteristics of the sea floor.

ii) Material specifications for the import/export system, its supports and coatings.

iii) Pipe manufacture, testing and quality control procedures.

iv) Flow diagrams indicating temperature and pressure profiles.

v) Specifications and plans for instrumentation, control systems and safety devices.

vi) Specifications and plans for installation, field testing, inspection, anticipated component replacement and continued maintenance of the riser system.

vii) Environmental and geotechnical report.

PART

4

CHAPTER 2 Import and Export Systems

SECTION 3 Environmental Considerations

The environmental loadings are to be calculated in accordance with the methods in Part 3, Chapter 2.

PART

4

CHAPTER 2 Import and Export Systems

SECTION 4 System Design and Analysis

1 General

The design of the import/export system should consider all modes of operating, testing, survival and accidental events. The import/export system should be analyzed to determine its response to the design events. Each individual component should be examined for its strength and suitability for the service conditions.

3 Rigid Risers

3.1 Design Analysis

The analysis of a rigid riser is to follow the appropriate sections of API RP 2RD and API RP 2T for all relevant design load cases. The establishment of the critical design condition must be verified by a suitable verified program that properly simulates the dynamic response of the entire system operating under the required design condition.

The following items, as applicable, are to be appropriately accommodated in the analysis:

i) Environmental conditions

ii) Boundary conditions

iii) Riser configuration

iv) Riser joint properties

v) Buoyancy devices

vi) Installation motion (RAOs)

vii) Applicable site conditions

viii) Effects of internal contents

ix) Pressure testing and accidental conditions

3.3 Design Limits

Rigid risers are to be designed against the following limits based on the design load cases being investigated.

Maximum Stress, Stability and Buckling. Allowable stresses in plain pipe are to be limited, per API RP 2RD. Overall stability of the riser and local pipe buckling should be evaluated.

Maximum Deflection. Acceptable limits of maximum deflection are to be determined considering the inherent limitations of riser components, equipment used in the riser and the need to avoid interference with the Floating Installation.

Fatigue and Fracture. The riser system is to be designed to ensure that an adequate margin of safety is available for critical components to counteract the effects of fatigue caused by cyclic fluctuations (due to both internal and external loads) over the anticipated life of the system.

The cumulative damage calculated by the use of Miner's Rule is to be 0.1 or less for a critical component which cannot be easily inspected or repaired. For non-critical components which can be easily inspected, the cumulative damage should be 0.3 or less.

5 Flexible Risers

5.1 In-place Analysis

The in-place analysis is to address all design load cases using motions consistent with the mooring analysis. The scope of the in-place analysis, as a minimum, should include the following:

i) On-bottom stability for flexible flow lines

ii) Static and dynamic analysis for flexible riser

iii) A system dynamic analysis to ensure:

1. Maximum tension and minimum radius of curvature are within the manufacturer's recommendations.
2. Suspended portions of the flexible pipe (e.g., sag bends) are not allowed to bounce on the sea floor or experience compression that might cause kinks.
3. Suspended flexible pipes are not allowed to chafe against each other, the installation body or mooring lines.

iv) Flow-induced motion analysis.

v) Flexible pipe layer stress analysis.

vi) The stresses in the flexible pipe layers shall comply with the requirements of API SPEC 17J for the applicable design load cases.

vii) Mechanical gripping devices should not cause damage to the weaker exterior layer.

viii) Service life analysis.

ix) Corrosion protection system design.

5.3 Design Limits

Design limits established for the riser system are to be determined in accordance with API RP 17B and confirmed by performance/acceptance testing during the manufacture of the flexible riser and the associated components. Where sufficient test data and service history exist to confirm a component's capability, ABS may consider the acceptance of this documentation in lieu of performance/ acceptance testing.

7 Export Vessel Transfer System *(December 2008)*

This system may be classed if requested. Export of fluid to an export vessel is usually limited to stabilized crude oil and is usually accomplished by: (1) Side-by-side transfer, (2) Tandem transfer, or (3) Single Point Moored Buoy via, for example, a floating hose or riser. For certification of these systems, ABS requires compliance to OCIMF Standards and MARPOL. The OCIMF Standard is applicable for operating pressures not greater than 15 bar gauge. In complying with these standards, ABS requires the Owner to observe the guidelines as given in *The OCIMF Guide to Purchasing, Manufacturing, and Testing of Loading and Discharge Hoses for Offshore Moorings*. The operation and safety considerations for transfer of crude are to be contained in the Floating Installation's operations manual and be consistent with the requirements outlined in *The OCIMF Ship to Ship Transfer Guide* and Chapter 6.

9 System Components

All system components are to be designed in accordance with the appropriate criteria issued by the API. The specification for the design and manufacture of the components is to be submitted. The specification is to include at a minimum the performance criteria established from the riser design and analysis and give explicit acceptance criteria needed to ensure the compliance to these criteria.

11 Installation Analysis

The installation analysis is to address all aspects of the installation procedure discussed in 3-4-1/11. Calculations to demonstrate the structural integrity of the riser and its auxiliary components are to be submitted for review.

The riser pipe is to be checked for all installation loads, tension and bending combination (bending from chute, sleeve, roller or drum) and loads caused by the installation of auxiliary components.

Loads from mechanical gripping devices, such as clamps and tensioners, are to be checked and are not to cause damage to the weaker exterior layer of the flexible pipe.

PART

4

CHAPTER 2 Import and Export Systems

SECTION 5 Materials

1 Material for Rigid Risers

Material and dimensional standards for steel pipe are to be in accordance with ANSI/ASME B31.4 and B31.8, API RP 2RD and/or other suitable standards approved for the intended application by ABS with respect to chemical composition, material manufacture, tolerances, strength and testing requirements.

3 Material for Flexible Risers

The guidelines in API RP 17B and API SPEC 17J may be used to assess the adequacy of the material standards for flexible risers.

PART
5A

Ship-Type Installations

CONTENTS

PART

5A

CHAPTER 1 Design Considerations

CONTENTS

PART
5A

CHAPTER 1 Design Considerations

SECTION 1 General

1 Introduction *(1 July 2012)*

The design and construction of the hull, superstructure and deckhouses of ship-type installations that are new builds or conversions are to be based on the applicable requirements of Part 5A of these Rules and where referenced in the *Steel Vessel Rules*. Part 5A of these Rules reflects the different structural performance and demands expected for an installation transiting and being positioned at a particular site on a long-term basis compared to that of a vessel engaged in unrestricted seagoing service.

The design criteria for new build or conversions of ship-type installations are located in Part 5A, Chapters 1 and 3, with additional design criteria for ship-type conversions in Part 5A, Chapter 2 of these Rules, which are applicable to installations of 150 meters (492 feet) or more in length. Part 5A, Chapter 4 applies to installations under 150 meters in length. In addition, the applicable criteria contained in the Load Line, SOLAS and MARPOL Conventions issued by the International Maritime Organization are to be considered. It is further suggested that the local authorities having jurisdiction where the installation is to operate be contacted to obtain any further criteria that are applicable to the floating installations.

Note: These Rules are applicable to installations not exceeding 500 m (1640 ft) in length, *L*, having breadths not exceeding one-fifth of the length nor 2.5 times the depth to the strength deck. Installations beyond these proportions will be reviewed on a case-by-case basis.

The design criteria contained in Part 5A, Chapter 3 are applied in two phases. The first phase provides the basic hull design to reflect overall hull girder and local structural component strength, including fatigue strength. This is referred to as the *Initial Scantling Evaluation (*or *ISE)* phase. For ship-type conversions, the reassessed and renewal scantlings are calculated in the *ISE* phase, as described in Section 5A-2-2. The reassessed scantlings are the required scantlings for the site-specific location and transit condition, and are used to establish the minimum renewal scantlings of an FPI conversion. The second phase requires the performance of finite element structural analyses using either a three cargo tank-length model or cargo block-length model to validate the selected scantlings from the first phase. This is referred to as the *Total Strength Assessment (*or *TSA)* phase. For ship-type conversions, the *TSA* phase is used to validate the reassessed scantlings obtained in the *ISE* phase.

Performance of additional structural analyses can lead to the granting of the optional **DLA** classification notation, which signifies that the design meets the Dynamic Load Approach criteria. Also, the optional **SFA** classification notation can be granted, which signifies that the design satisfies fatigue strength criteria based on Spectral Fatigue Analysis.

The application of the design criteria in Part 5A, Chapter 3 to reflect the site-dependent nature of the floating offshore installation is accomplished through the introduction of a series of Environmental Severity Factors (ESFs). Reference is to be made to 5A-1-2/1 and Section 5A-3-2 for the applicable structural design and analysis criteria that have been modified to reflect site-specific service conditions.

3 Definitions *(1 July 2009)*

3.1 Ship-type Installation

See Section 3-1-2 for the description of a ship-type installation. For installations that are considered ship-type, the definitions of primary characteristics of the installation can be found in Section 3-1-1 of the *Steel Vessel Rules*.

3.3 Environmental Severity Factor

Environmental Severity Factors are adjustment factors for the dynamic components of loads and the expected fatigue damage that account for site-specific conditions as compared to North Atlantic unrestricted service conditions. See Section 5A-3-2 and Appendix 5A-3-A1 for description of the concept, application and determination of Environmental Severity Factors.

3.5 Hull Interface Structure

The interface between the position mooring system and the hull structure, and between deck-mounted equipment modules and the hull structure, is the hull interface structure. The interface structure is defined as the attachment zone of load transmission between the main hull structure and hull-mounted equipment. See Section 5A-1-4 for additional information on hull interface structure.

5 Structural Arrangement *(1 July 2009)*

The general arrangement and subdivision of the installation are to comply with applicable requirements of Section 3-2-9 of the *Steel Vessel Rules* and Part 5A, Chapter 3 of these Rules. Reference should also be made to the 1966 Load Line Convention and MARPOL 73/78.

7 Limit States *(1 July 2009)*

7.1 General

The structural strength assessments indicated in 5A-1-1/Table 1 are covered by the requirements of these Rules.

In the case of installations sited at locations where the environmental conditions are less than that used for unrestricted service conditions, adjustments to the loadings and load effects produced by the site-specific long-term environment at the installation site can be applied to the assessment of hull strength and fatigue life. This is done by incorporating the Environmental Severity Factors (ESFs) for a given project site and the proposed transit route.

TABLE 1
Structural Strength Assessment *(1 July 2009)*

		Yielding Check	*Buckling Check*	*Ultimate Strength Check*	*Fatigue Check*
Local Structures	Plating	✓	✓	✓ (1)	—
	Stiffeners	✓	✓	✓ (2)	✓ (3)
Primary supporting members		✓	✓	✓	✓ (3)
Hull girder		✓	✓ (4)	✓	—
Hull interface structures		✓	✓ (5)	✓ (6)	✓ (7)

Notes:

✓ indicates that the structural assessment is to be carried out.

1 The ultimate strength check of plating is included as part of the buckling check of plating.

2 The ultimate strength check of stiffener is included as part of the buckling check of stiffeners.

3 The fatigue check of longitudinal stiffeners and primary supporting members is the fatigue check of connection details of these members.

4 The buckling check of stiffeners and plating included in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

5 The buckling check is to follow the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*.

6 The ultimate strength check of plating and stiffeners is included as part of the buckling check of plating and stiffeners, in accordance with the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*.

7 The fatigue check is to follow the ABS *Guide for Fatigue Assessment for Offshore Structures*.

7.3 Limit States

The verification that the structural design is in compliance with these Rules requires that the design be checked against a set of limit states beyond which the installation's hull structure and mooring system are no longer considered adequate.

7.3.1 Serviceability Limit State

Serviceability limit state, which addresses the structure's performance during its normal use, includes:

- Local damage which may reduce the working life of the structure or affect the efficiency of structural members
- Unacceptable deformations which affect the efficient use of structural members or the functioning of equipment
- Motions or accelerations that can exceed the range of effective functionality of topside equipment

7.3.2 Ultimate Limit State

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- Attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations
- Instability of the whole structure or of a significant part of it.

7.3.3 Fatigue Limit State

Fatigue limit state relates to the possibility of failure due to cyclic loads.

7.3.4 Accidental Limit State

Accidental limit state considers the flooding of any one cargo tank without progression of the flooding to the other compartments

7.5 Strength Criteria

7.5.1 Serviceability Limit State

For the serviceability limit state design check in accordance with the partial factor design format, all partial safety factors are equal to unity. See 5A-3-4/3 and 5A-3-4/5.

- For the yielding check of the hull girder, the stress corresponds to a load at 10^{-8} probability level.
- For the yielding check and buckling check of plating constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.
- For the yielding and buckling check of stiffeners, the stress corresponds to a load at 10^{-8} probability level

7.5.2 Ultimate Limit State

For the ultimate limit state design check of the strength of the hull girder in accordance with the partial factor design format, the ultimate strength of the hull girder is to withstand the maximum total still-water and wave sagging and hogging vertical bending moments obtained by multiplying a partial safety factor on the maximum still water sag and hog bending moments and a partial safety factor on the maximum sag and hog vertical wave bending moments as specified in 5A-3-3/3.5.

- The ultimate strength of the plating between ordinary stiffeners and primary supporting members is to withstand the loads due to the maximum total bending moment.
- The ultimate strength of the ordinary stiffener is to withstand the loads due to the maximum total bending moment.

7.5.3 Fatigue Limit State

For the fatigue limit state design check in accordance with the partial factor design format, all partial safety factors are equal to unity. The fatigue life of representative structural details, such as connections of ordinary stiffeners and primary supporting members, is obtained from reference pressures at 10^{-4} probability level. See 5A-3-4/9 and Appendix 5A-3-A2.

7.5.4 Accidental Limit State

Longitudinal strength of hull girder in cargo tank flooded condition is to be assessed in accordance with 5A-2-1/5.5.2.

7.7 Strength Check for Impact Loads

Structural strength shall be assessed against impact loads such as forward bottom slamming, bow impact, green water on deck and sloshing loads in cargo or ballast tanks.

PART
5A

CHAPTER 1 Design Considerations

SECTION 2 Longitudinal Strength *(1 July 2009)*

1 Longitudinal Hull Girder Strength *(1 July 2012)*

Longitudinal strength is to be based on Section 3-2-1 of the *Steel Vessel Rules*. The required hull girder section modulus for 0.4L amidships is to be the greater of the values obtained from the following equation or the minimum section modulus $SM_{\min}$ in the table below:

$$SM = M_t/f_p \quad \text{cm}^2\text{-m (in}^2\text{-ft)}$$

where

M_t = total bending moment, as described below

f_p = nominal permissible bending stress

= 17.5 kN/cm^2 (1.784 tf/cm^2, 11.33 Ltf/in^2)

The total bending moment, M_t is to be considered as the maximum algebraic sum of the maximum still water bending moment (M_{sw}) for operation on site or in transit combined with the corresponding wave-induced bending moment (M_w) expected on-site and during transit to the installation site. Due account is to be given to the influence of mooring loads and riser weights in calculating the vertical still water bending moments and shear forces.

In lieu of directly calculated wave-induced hull girder vertical bending moments and shear forces, recourse can be made to the use of the Environmental Severity Factor (ESF) approach (see 5A-3-2/1.1 and Appendix 5A-3-A1) , which can be applied to modify the *Steel Vessel Rules* wave-induced hull girder bending moment and shear force formulas (see 5A-3-2/5.2 and 5A-3-2/5.2).

Depending on the value of the Environmental Severity Factor, β_{vbm}, for vertical wave-induced hull girder bending moment (see 5A-3-A1/3 of these Rules), the minimum hull girder section modulus, $SM_{\min}$, of the installation, as specified in 3-2-1/3.7.1(b) of the *Steel Vessel Rules*, may vary in accordance with the following:

β_{vbm}	$SM_{\min}$
<0.7	$0.85SM_{svr}$
0.7 to 1.0	$(0.5 + \beta_{vbm}/2)SM_{svr}$
> 1.0	SM_{svr}

Where SM_{svr} = minimum hull girder section modulus as required in 3-2-1/3.7.1(b) of the *Steel Vessel Rules*

3 Hull Girder Ultimate Strength *(1 July 2009)*

The hull girder ultimate longitudinal bending capacities for either hogging or sagging conditions are to be evaluated in accordance with Appendix 5A-3-A3. The hull girder ultimate bending capacity for the design environmental condition (DEC) is to satisfy the limit state specified in 5A-3-3/3.5.

PART
5A

CHAPTER 1 Design Considerations

SECTION 3 Structural Design and Analysis of the Hull *(1 July 2009)*

1 Structural Design of the Hull *(December 2008)*

The design of the hull is to be based on the applicable requirements of Part 5A, Chapters 3 or 4 of these Rules, depending on the hull length and where referenced the *Steel Vessel Rules*. For ship-type installations over 150 meters (492 feet) in length, Part 5A, Chapter 3 is the primary reference. Where the conditions at the installation site are less demanding than those for unrestricted service that are the basis of the *Steel Vessel Rules*, the design criteria for various components of the hull structure may be reduced, subject to the limitations indicated below to reflect these differences. However, when the site conditions produce demands that are more severe, it is mandatory that the design criteria are to be increased appropriately.

5A-3-2/1.1 presents an explanation of the Environmental Severity Factor (ESF) concept, which is used to adjust the unrestricted service criteria of the *Steel Vessel Rules*.

In the application of the modified criteria, no minimum required value of any net scantling is to be less than 85 percent of the value obtained had all the ESF Beta values been set equal to 1.0 (which is the unrestricted service condition). In view of this, for an FPSO converted from a vessel, where the total bending moment for unrestricted service conditions is used for determination of the minimum required value of any net scantling, the total bending moment should consist of the maximum still water bending moment of the existing vessel and the wave-induced bending moment with all the beta values set equal to 1.0.

The loads arising from the static tank testing condition are also to be directly considered in the design. In some instances, such conditions might control the design, especially when the overflow heights are greater than normally encountered in oil transport service, or the severity of environmentally-induced load components and cargo specific gravity are less than usual.

1.1 Hull Design for Additional Loads and Load Effects

The loads addressed in this Subsection are those required in the design of an installation in Part 5A, Chapters 3 or 4, depending on the length of the installation. Specifically, these loads are those arising from liquid sloshing in hydrocarbon storage or ballast tanks, green water on deck, bow impact due to wave group action above the waterline, bowflare slamming during vertical entry of the bow structure into the water, bottom slamming and deck loads due to on-deck production facilities. All of these can be treated directly by reference to Part 5A, Chapters 3 or 4. However, when it is permitted to design for these loads and load effects on a site-specific basis, the formulations given in Section 5A-3-2 reflect the introduction of the Environmental Severity Factors (ESFs-Beta-type) into the Rule criteria. The paragraphs below give the location in Section 5A-3-2 where the adjusted load formulations are presented.

1.1.1 Sloshing of Produced or Ballast Liquids *(December 2008)*

For ship-type installations, it is typical that the tanks may be subjected to partial filling levels. For tanks where partial filling is intended, sloshing analyses are to be performed. Firstly, the sloshing analysis is to determine if the sloshing natural periods of the anticipated filling levels in each tank are close to the installation's pitch and roll motion periods. It is recommended that the periods of the fluid motions in each tank for each anticipated filling level are at least 20 percent greater or smaller than those of the relevant installation's motion. This range of installation natural periods constitutes the "critical" range. If the natural periods of the tanks and installation are sufficiently separated, then no further analyses are required. However, when the tanks are to be loaded within "critical" filling levels, then additional analyses are to be performed in order to determine the adequacy of the structure for the internal pressures due to sloshing.

The extent of sloshing analyses is indicated in 5A-3-2/11. Reference can be made to Section 5A-3-2 on adjustments that could be used to modify the amplitudes of the ocean-based sloshing criteria. However, it should be borne in mind that the sloshing assessment criteria of Section 5A-3-2 are derived considering an unrestrained freely floating hull subjected to wave energy spectra representing the open ocean. Mooring restraints, potential hull weathervaning and different wave energy characterizations (e.g., energy spectra for ocean swells, tropical cyclonic storms and water depth effects) may need to be additionally considered by the designer when establishing the installation's motions for sloshing-induced loading analysis.

1.1.2 Green Water Loads on Deck

When it is permitted to base the design on a site-specific modification of the *Steel Vessel Rules*, reference is to be made to 5A-3-2/13.7 of these Rules.

1.1.3 Bow Impact

When it is permitted to base the design on a site-specific modification of the *Steel Vessel Rules*, reference is to be made to 5A-3-2/13.1 of these Rules.

1.1.4 Slamming

When it is permitted to base the design on a site-specific modification of the *Steel Vessel Rules*, reference is to be made to 5A-3-2/13.3 and 5A-3-2/13.5 of these Rules.

1.1.5 Deck Loads *(December 2008)*

Deck loads due to on-deck production facilities for on-site and transit conditions are referenced in 5A-3-2/15 of these Rules.

1.3 Superstructures and Deckhouses *(December 2008)*

The designs of superstructures and deckhouses are to comply with the requirements of Section 3-2-11 of the *Steel Vessel Rules*. The structural arrangements of 3-2-11/9 of the *Steel Vessel Rules* for forecastle decks are to be satisfied.

The design of buildings on top of the topside module is to be in accordance with the applicable requirements of the *Offshore Installation Rules*.

1.5 Helicopter Decks *(1 July 2009)*

The design of the helicopter deck structure is to comply with the requirements of 3-2-2/3 of the *MODU Rules*. In addition to the required loadings defined in 3-2-2/3 of the *MODU Rules*, the structural strength of the helicopter deck and its supporting structures are to be evaluated considering the DOC and DEC environments, if applicable.

1.7 Protection of Deck Openings

The machinery casings, all deck openings, hatch covers and companionway sills are to comply with 5A-3-1/3 and 5A-4-1/3 of these Rules.

1.9 Bulwarks, Rails, Freeing Ports, Ventilators and Portlights

Bulwarks, rails, freeing ports, portlights and ventilators are to meet the requirements of Section 3-2-17 of the *Steel Vessel Rules*.

1.11 Equipment *(2014)*

The provision of equipment on the installation is optional, except as noted below. For guidance on the requirements for temporary mooring equipment (anchor, chains, windlasses or winches, hawse pipe, etc.), refer to Section 3-5-1 of the *Steel Vessel Rules*.

Self-propelled disconnectable installations are to comply with Section 3-5-1 of the *Steel Vessel Rules*. Consideration may be given to arrangement with a single anchor subject to satisfactory submittal of a risk analysis to address conditions under which the installation may proceed toward shore, and with the agreement of the flag and coastal states. Any vessel entering piloted, restricted, or congested waters with only one anchor will require a tug escort regardless of the risk assessment findings, and this will be noted as an operating restriction on the Class certificate.

1.13 Materials and Welding *(December 2008)*

For a minimum design service temperature of 0°C and above, ship-type installations are to be constructed from steel selected in accordance with Part 3 of the *Steel Vessel Rules*. For a minimum design service temperature lower than 0°C, ship-type installations are to be constructed from steel selected in accordance with Part 3 of the *MODU Rules* with the provision that the steel selection is not to be less conservative than that of Part 3 of the *Steel Vessel Rules*. The structural application categories defined in Part 3 of the *Steel Vessel Rules* are to be used with the steel selection criteria in Part 3 of the *MODU Rules* by applying the following correlations:

i) Class I correlates with Secondary

ii) Class II correlates with Primary

iii) Class III correlates with Special

The steel selection criteria footnotes of Part 3 of the *Steel Vessel Rules* are to be implemented, as appropriate, and are to supplant less severe steel selection criteria of Part 3 of the *MODU Rules* for equivalent structure.

Underdeck and hull interface plating or bracket structures attached to the deck or hull should have the same or compatible material grade as the deck or hull structure, respectively.

The topside facilities (production deck) are to be constructed from steel selected in accordance with the ABS *Rules for Building and Classing Offshore Installations (Offshore Installations Rules)*.

Turret and SPM buoy mooring systems are to be constructed from steel selected in accordance with the *MODU Rules*.

Tower mooring systems are to be constructed from steel selected in accordance with the *Offshore Installations Rules*.

All fabrication and welding are to comply with the requirements in Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)*. The weld type and sizing are to be shown on the scantling drawings or in the form of a welding schedule and are to comply with the requirements that govern the steel selection.

1.15 Machinery and Equipment Foundations

Foundations for equipment subjected to high cyclic loading, such as mooring winches, chain stoppers and foundations for rotating process equipment, are to be analyzed to verify they provide satisfactory strength and fatigue resistance. Calculations and drawings showing weld details are to be submitted to ABS for review.

1.17 Additional Considerations for Disconnectable Systems

1.17.1 Machinery Space and Tunnel

Requirements for machinery spaces with regard to engine foundations, tunnels and tunnel recesses are given in Section 3-2-12 of the *Steel Vessel Rules*, as modified by 5A-3-1/5.33 and 5A-4-1/5.31 of these Rules.

1.17.2 Keels, Stems, Stern Frames and Rudder Horns

Requirements for stems, stern frames, shoe pieces, rudder horns and gudgeons are given in Section 3-2-13 of the *Steel Vessel Rules*. Additional requirements for ice strengthening are given in Part 6 of the *Steel Vessel Rules*.

1.17.3 Rudders and Steering Gears

For installations with steering capabilities, the requirements for rudder stocks, couplings, pintles, plating, steering gears, etc., are given in Section 3-2-14 and Part 4, Chapter 3 of the *Steel Vessel Rules*. Ice-strengthened installations are to comply with 6-1-1/43 or 6-1-2/27 of the *Steel Vessel Rules*, as applicable.

1.19 Bilge Keels *(2014)*

For bilge keels 500 mm or less in depth, the requirements are given in Part 5A, Section 11/3.3 of the *Steel Vessel Rules*.

In addition to the requirements included in the above *Steel Vessel Rules* section, bilge keels greater than 500 mm in depth with single web or closed construction form are to be considered as hull interface structures and analyzed in accordance with design criteria as specified in Section 5A-1-4. When a direct structural analysis approach is applied for the bilge keel and supporting structures, hydrodynamic drag loads due to wave dynamics and hull's motion may be calculated either by model experiments or numerical simulation using three-dimensional flow analysis for the transit condition and site-specific operating condition. The methodology and test procedures and measurements or analysis methods are to be fully documented and submitted for review.

1.21 Sea Chests *(December 2008)*

Structural requirements for sea chests are given in 3-2-4/17.1 of the *Steel Vessel Rules.*

3 Engineering Analyses of the Hull Structure

3.1 General *(1 July 2009)*

The criteria in this Subsection relate to the analyses required to verify the scantlings selected in the hull design in 5A-1-3/1. Depending on the specific features of the offshore installation, additional analyses to verify and help design other portions of the hull structure will be required. Such additional analyses include those for the deck structural components supporting deck-mounted equipment and the hull structure interface with the position mooring system. Analysis criteria for these two situations are given in Section 5A-1-4.

3.3 Strength Analysis of the Hull Structure *(1 July 2012)*

For installations of 150 m (492 feet) in length and above, the required strength assessment of the hull structure is to be based on a three cargo tank length finite element model amidships where the strength assessment is focused on the results obtained from structures in the middle tank. For FPI conversions, as an alternative, a complete hull length or full cargo block length finite element model can be used in lieu of the three cargo tank length model as described in 5A-2-1/5.6. Details of the required Finite Element Method (FEM) strength analysis are indicated in 5A-3-4/11 and Appendix 5A-3-A4 of these Rules. The net scantlings used in the strength analysis of new build FPI and conversions to FPI differ as follows:

i) For new build FPI, a three cargo tank length finite element strength analysis is performed using the new build net scantlings obtained by deducting the nominal design corrosion values in 5A-3-1/Table 1 from the new build design scantlings.

ii) For FPI conversions, a three-cargo tank length, or alternatively a complete hull length or full cargo block length finite element strength analysis is performed using the reassessed net scantlings obtained by deducting the nominal design corrosion values in 5A-3-1/Table 1 from the reassessed scantlings as determined in Section 5A-2-2.

When mooring and riser structures are located within the extent of the FE model, the static mass of the mooring lines and risers may be represented by a mass for which gravity and dynamic accelerations can be calculated and added to the FE model. The resulting dynamic loads shall be compared to the mooring and riser analysis results to verify that the dynamic effects are conservatively assessed in the hull FE analysis.

For installations less than 150 m (492 feet) in length, it is recommended that a Finite Element Method (FEM) analysis be performed if the installation is of double hull construction or of unusual design (see 5A-4-1/1.3.3 of these Rules). When the design is permitted to be based on site-specific environmental conditions, the load components to be used in the strength analyses can be determined using 5A-1-2/1, 5A-1-3/1 and Section 5A-3-2 of these Rules.

Generally, the strength analysis is performed to determine the stress distribution in the structure. To determine the local stress distribution in major supporting structures, particularly at intersections of two or more members, fine mesh FEM models are to be analyzed using the boundary displacements and load from the 3D FEM model. To examine stress concentrations, such as at intersections of longitudinal stiffeners with transverses and at cutouts, fine mesh 3D FEM models are to be analyzed.

The accidental load condition, where a cargo tank is flooded, is to be assessed for longitudinal strength of the hull girder consistent with load cases used in damage stability calculations.

3.5 Three Cargo Tank Length Model *(1 July 2009)*

3.5.1 Structural FE Model *(1 July 2012)*

The three cargo tank length FE model is considered representative of cargo and ballast tanks within the 0.4*L* amidships. The same FE model may be used for hull structures beyond 0.4*L* amidships with modifications to the hull geometry, plate and stiffener properties and the applied loads, provided that the structural configurations are considered as representative of the location under consideration. Where the tanks in the 0.4*L* amidships are of different lengths, the middle tank of the FE model is to represent the cargo tank of the greatest length.

The assessment of the hull structure to resist hull girder vertical shear loads in the forward and aft cargo block regions may be based on the midship cargo tank finite element model with modifications to the structural properties, where appropriate. The strength assessment is calculated according to Section 5A-3-4 for the load cases described in 5A-1-3/3.5.3.

For FPI conversions, reassessed net scantlings are to be used in the finite element model, and are obtained by deducting the nominal design corrosion margins from the reassessed scantlings of the structure. For FPI conversions, as an alternative, a complete hull length or full cargo block length finite element model can be used in lieu of the three cargo tank length model.

Details of the modeling, mesh size, element types used and boundary conditions are described in Appendix 5A-3-A4. Detailed local stress assessment using fine mesh models to evaluate highly stressed critical areas are to be in accordance with 5A-3-A4/21.

3.5.2 Load Conditions

In the strength analyses of the three cargo tank length model, the following loading conditions are to be used:

General Loading Patterns. The FEM analysis is to be performed in accordance with the loading patterns specified in Section 5A-3-2 of these Rules. The loading patterns included in Section 5A-3-2 are intended to represent the envelope of worst case loading patterns for local load structural design purposes and may not necessarily represent the actual operating loading patterns of the FPI. The actual loading patterns for the installation are to be reviewed to verify that there are no other patterns producing more severe loading. If any worse governing loading patterns than those specified in Section 5A-3-2 exist, these loading patterns are to be included in the analyses. The structural responses for the still water conditions are to be calculated separately to establish reference points for assessing the wave-induced responses. Topside loads are also to be included in the load cases.

Loading patterns to be used for double hull, double side with single bottom and single hull installations are specified in Section 5A-3-2 of these Rules. In addition to the specified loading patterns and cargo densities, inspection and repair, transit, and static conditions representing tank testing, inspection and repair, and transit are also to be investigated.

Static Loading Conditions for New Construction. The tank loading patterns of Load Cases No. 9 and 10 specified in Part 5A, Chapter 3 of these Rules are to be analyzed considering static conditions and seawater (Specific Gravity = 1.025) at minimum draft. 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. The external drafts for these load cases are to be taken as 25 percent of the scantling draft. However, Notes (1) and (2) below are applicable.

Notes:

1. Where the actual minimum static condition with the tank loading pattern as the center row of tanks results in a draft less than specified, the actual loading condition draft is to be used.
2. For an installation with two outer longitudinal bulkheads only (inner skin), i.e., one tank across between the inner skin bulkheads, the minimum actual loading condition draft is to be used.

Static Loading Conditions for FPI Conversions. The tank loading patterns of Load Cases No. 9 and 10 specified in Part 5A, Chapter 3 of these Rules are to be analyzed considering static conditions and seawater (Specific Gravity = 1.025) at minimum draft. The tanks are to be loaded to the top of access hatches for cargo tanks, or 760 mm above deck for ballast tanks. If the actual tank condition results in a static pressure head higher than specified, the actual pressure head is to be used. The external drafts for these load cases are to be taken as 30 percent of the scantling draft. However, Notes (1) and (2) of the above paragraph are applicable.

Inspection and Repair Conditions. Loading patterns representing inspection and repair conditions are also to be investigated. Inspection and repair conditions are to be analyzed using a minimum 1-year return period design operating condition load and a minimum specific gravity of cargo fluid of 0.9. Other aspects of the loading pattern, modeling, acceptance criteria, etc., indicated in Part 5A, Chapter 3 of these Rules are to be followed.

Transit Conditions. The transit condition is to be analyzed using the actual tank loading patterns in association with the anticipated environmental conditions based on a minimum 10-year return period to be encountered during the voyage (see 3-2-3/3.3 of these Rules).

3.5.3 Load Cases

The tank loading patterns as described above and specified in Section 5A-3-2 are to be applied. These loading patterns are intended to represent the envelope of worst case loading patterns for local load structural design purposes and may not necessarily represent the actual operating loading patterns of the FPI. The structural responses for the still water conditions are to be calculated separately to establish reference points for assessing the wave-induced responses. Additional loading patterns may be required for special or unusual operational conditions or conditions that are not covered by the loading patterns specified in Section 5A-3-2. Topside loads are also to be included in the load cases.

3.7 Fatigue Analysis *(1 July 2009)*

For all installations of 150 m and above, the extent of fatigue analysis required is indicated in 5A-3-4/9 of these Rules. For installations of less than 150 m, the requirements are indicated in 5A-4-1/1.5 of these Rules.

For the three cargo tank length model, the fatigue assessment is to be performed applying Appendix 5A-3-A2 of these Rules.

For the cargo block model, the fatigue assessment is to be performed based on spectral fatigue analysis applying the latest edition of the ABS *Guide for Spectral-Based Fatigue Analysis for Floating Production, Storage and Offloading (FPSO) Installations.*

The fatigue strength of welded joints and details at terminations located in highly stressed areas and in fatigue prone locations are to be assessed, especially where higher strength steel is used. These fatigue and/or fracture mechanics analyses, based on the combined effect of loading, material properties, and flaw characteristics are performed to predict the service life of the structure and determine the most effective inspection plan. Special attention is to be given to structural notches, cutouts, bracket toes, and abrupt changes of structural sections.

Consideration is also to be given to the following analyses:

i) The cumulated fatigue damage during the transit voyage from the fabrication or previous site for an existing FPI to the operation site is to be included in the overall fatigue damage assessment.

ii) The stress range due to loading and unloading cycles is to be accounted for in the overall fatigue damage assessment. See 5A-3-A2/15.

3.9 Acceptance Criteria

The total assessment of the structure is to be performed against the failure modes of material yielding, buckling, ultimate strength and fatigue. The reference acceptance criteria of each mode are given as follows:

3.9.1 Material Yielding

For installation lengths of 150 m and above, the criteria are indicated in 5A-3-4/3.1 of these Rules.

For installation lengths of less than 150 m, the criteria are indicated in 5A-4-2/13.3 and 5A-4-2/13.7 of these Rules.

3.9.2 Buckling and Ultimate Strength of Plate Panels, Stiffeners and Longitudinals

For installation lengths of 150 m and above, the criteria is indicated in 5A-3-4/5 of these Rules.

For installation lengths of less than 150 m, the criteria are indicated in 3-2-1/19 of the *Steel Vessel Rules* and Appendix 5A-2-A1 of these Rules.

3.9.3 Fatigue

The required target fatigue life as indicated in 1-1-2/5.10.1 and 5A-3-A2/5.1 of these Rules is 20 years. Appendix 5A-3-A2 is also referred to for installations with lengths less than 150 m. Direct application of the Appendix will result in the evaluation of members for stress ranges of an unrestricted trading service vessel. In the absence of more detailed environmental data, stress ranges are to be obtained in consideration of the unrestricted service environment. When the site-specific wave environment is used and produces less severe fatigue demand than the unrestricted service environment, credit can be given to the less severe environment by increasing the expected fatigue life. For site-specific environmental conditions producing more severe fatigue demand than the unrestricted service environment, the site-specific environmental data are to be used, and the calculated fatigue life is to be not less than 20 years.

Due to the structural redundancy and relative ease of inspection inherent in typical hull structures of ship-type installations, there is generally no further need to apply additional factors of safety above what is already built into the fatigue classification curves cited in Appendix 5A-3-A2. However, for areas of the structure which are non-inspectable or "critical", such as in way of the connections to the mooring or production systems (see Section 5A-1-4), additional factors of safety should be considered.

For existing installations that are employed in floating installation service, the estimated remaining fatigue lives of the critical structural details are to be assessed and the supporting calculations submitted for review. Special consideration is to be given to the effects of corrosion and wastage on the remaining fatigue life of existing structures.

Any areas determined to be critical to the structure are to be free of cracks. The effects of stress risers should be determined and minimized. Critical areas may require special analysis and survey.

3.11 Renewal Scantlings *(1 July 2012)*

3.11.1 New Construction

Future steel renewals are to be based on the FPI required new build scantlings considering the wastage allowance as determined by the smaller of the % wastage allowance (see 5A-2-2/Table 1) or the allowable wastage based on buckling strength (see Appendix 5A-2-A1).

3.11.2 Conversion of Existing Vessel to FPI

Future steel renewals for FPI conversions are to be based on the FPI required scantlings, regardless of the original design renewal scheme. The process of determining the required and renewal scantlings, as described in 5A-2-2 for an FPI vessel conversion, requires a reassessment of the vessel's scantlings based on transit condition and the specific site of the installation.

PART

5A

CHAPTER 1 Design Considerations

SECTION 4 Design and Analysis of Other Major Hull Structural Features *(1 July 2009)*

1 General *(December 2008)*

The design and analysis criteria to be applied to the other pertinent features of the hull structural design are to conform to these Rules or to recognized practices acceptable to ABS. For many ship-type installations, the hull design will need to consider the interface between the position mooring system and the hull structure or the effects of structural support reactions from deck-mounted (or above-deck) equipment modules, or both. The interface structure is defined as the attachment zone of load transmission between the main hull structure and hull mounted equipment, such as topside module stools, crane pedestals and foundations, riser porches, flare boom foundation, gantry foundation, mooring and offloading, etc. The zone includes components of the hull underdeck structures in way of module support stools and foundations, such as deck transverse web frames, deck longitudinals and upper parts of longitudinal and transverse bulkhead structures, as well as foundations of the hull-mounted equipment. These components of the interface structure should comply with the criteria indicated in 5A-1-4/7.

The criteria to be applied for the interface structures are presented below. When it is permitted to base the design of the ship-type offshore installation on site-specific environmental conditions, reference is to be made to 5A-1-3/1, 5A-1-2/1.1 and Section 5A-3-2 of these Rules regarding how load components can be adjusted.

Criteria applicable to the position mooring (e.g., turret) structure itself is given in Section 6-2-1, and the above (or on) deck equipment or module structure is referred to in 4-1-7/5.

3 Hull Interface Structure

The basic scantlings in way of the hull interface structure is to be designed based on the first principle approach and meet the requirements of Section 3-2-1 of the *MODU Rules* strength criteria, the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures* and the ABS *Guide for the Fatigue Assessment of Offshore Structures*, or equivalent national industry standards recognized and accepted by ABS, such as API Standards. Welding design of hull interface structure connections is to be developed based on Section 3-2-6 of the *MODU Rules* or a direct calculation approach. Material grades for the above-deck interface structure are to be selected as per Section 3-1-3 of the *MODU Rules* requirements. The material grades for the hull structure components, such as deck and frame structures, are to be selected as per Part 3 of the *Steel Vessel Rules*.

The verification of the hull interface structure as defined above is to be performed using direct calculation of local 3-D hull interface finite element models, developed using gross scantlings and analyzed with load conditions and load cases described in the following sections.

3.1 Position Mooring/Hull Interface Modeling

A FEM analysis is to be performed and submitted for review:

3.1.1 Turret or SPM Type Mooring System, External to the Installation's Hull

If the mooring system is of the turret or SPM type, external to the installation's hull, the following applies:

i) *Fore end mooring.* The minimum extent of the model is from the fore end of the installation, including the turret structure and its attachment to the hull, to a transverse plane after the aft end of the foremost cargo oil tank in the installation. The model can be considered fixed at the aft end of the model. The loads modeled are to correspond to the worst-case tank loads, seakeeping loads as determined for both the transit condition and the on-site design environmental condition (DEC), ancillary structure loads, and mooring and riser loads for the on-site DEC, where applicable. The design operating condition (DOC) may also need to be considered for conditions which may govern.

ii) *Aft end mooring.* The minimum extent of the model is from the aft end of the installation, including the turret structure and its attachment to the hull structure, to a transverse plane forward of the fore end of the aft most cargo oil tank in the hull. The model can be considered fixed at the fore end of the model. The loads modeled are to correspond to the worst-case tank loads, seakeeping loads as determined for both the transit condition and the on-site design environmental condition (DEC), ancillary structure loads, and mooring and riser loads for the on-site DEC, where applicable.

3.1.2 Mooring System Internal to the Installation Hull (Turret Moored)

If the mooring arrangement is internal to the installation hull (turret-moored), the following applies:

i) *Fore end turret.* The model is to extend from the fore end of the installation to the after end of the cargo tank or hold aft of the one containing the turret. The model can be considered fixed at the aft end of the model. The loads modeled are to correspond to the worst-case tank loads, seakeeping loads as determined for either the transit condition or the on-site design environmental condition (DEC), ancillary structure loads, and mooring and riser loads for the on-site DEC, where applicable. The design operating condition (DOC) may also need to be considered for conditions which may govern.

ii) *Midship turret.* The model can be a 3-tank model similar to that described in 5A-3-4/11 of these Rules where the turret is located in the center tank of the model. Hull girder loads are to be applied to the ends of the model. The loads modeled are to correspond to the worst-case tank loads, seakeeping loads as determined for either the transit condition or the on-site design environmental condition (DEC), ancillary structure loads, and mooring and riser loads for the on-site DEC, where applicable. The design operating condition (DOC) may also need to be considered for conditions which may govern.

iii) As a minimum, the following two cargo loading patterns that result in the worst load effects on the hull structure are to be considered:

- Maximum internal pressure for fully filled tanks adjacent to the hold containing the turret, with the other tanks empty and minimum external pressure, where applicable. (See 5A-1-4/Figure 1)
- Empty tanks adjacent to the hold containing the turret, with the other tanks full and maximum external pressure, where applicable. (See 5A-1-4/Figure 2)

The interface structure is to be assessed for yielding, buckling and fatigue strength, and should include all structural members and critical connections within the hold containing the turret as well as the hold boundaries and their attachments.

FIGURE 1
Loading Pattern 1 with 2/3 Scantling Draft *(December 2008)*

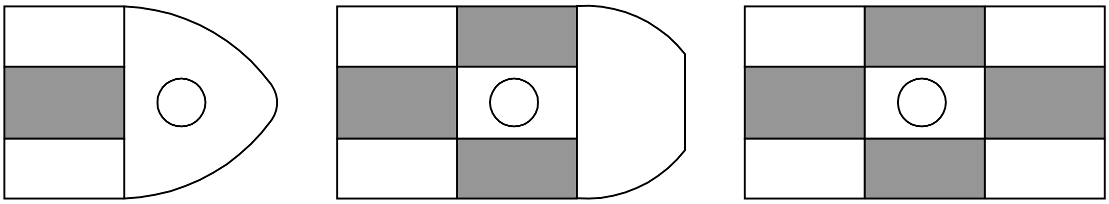
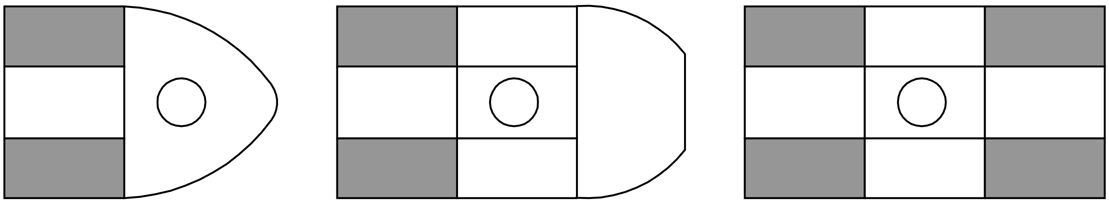


FIGURE 2
Loading Pattern 2 with Scantling Draft *(December 2008)*



3.1.3 Spread Moored Installations

The local foundation structure and installation structure are to be checked for the given mooring loads and hull structure loads, where applicable, using an appropriate FEM analysis. The mooring loads to be used in the analysis are to be based on the on-site design environmental condition (DEC) for hull structure, and the mooring loads for the on-site DEC and breaking strength of the mooring lines. The design operating condition (DOC) may also need to be considered for conditions which may govern.

3.3 Hull Mounted Equipment Interface Modeling

3.3.1 Topside Module Support Stools and Hull Underdeck Structures

The topside module support stools and hull underdeck structures in way of module support stools, such as deck transverse webs, deck longitudinals, longitudinal and transverse bulkheads, are to be assessed for the most unfavorable load combinations of topside stool reactions and hull structure loads, where applicable, using an appropriate FEM analysis. The load combinations of topside stool reactions and hull structure loads are to be consistent with those assumed in the module analysis (refer to Section 5A-1-5). The finite element model extent is to be sufficiently large to minimize the cut boundary effects. The openings in way of critical areas are to be incorporated into the FEM model to investigate their effects. The loads for the on-site design operating condition (DOC), on-site design environmental condition (DEC) and transit condition are to be taken into account. Topside production and support systems are to be empty in transit condition. Special attention is to be given to the cutouts in deck transverse webs in way of topside module stools. The strength analysis for the typical cutout with the maximum topside stool reactions using a local fine mesh FEM model is to be carried out and submitted for review.

3.3.2 Other Hull Mounted Equipment Foundation Structures

Other hull mounted equipment foundations, such as crane pedestals and foundations, riser porches, flare boom foundations, gantry foundations, offloading equipment foundations, etc., and hull vessel structure in way of the foundations are to be checked for the given functional loads, environmental loads and hull structure loads, where applicable, using an appropriate FEM analysis. The finite element model extent is to be sufficiently large to minimize the cut boundary effects. Openings such as cutouts in way of critical areas are to be incorporated into the FEM model. The loads for the on-site design operating condition (DOC), on-site design environmental condition (DEC) and transit condition are to be taken into account in the analysis. All equipment is to be in the stowed position for the transit condition.

5 Loads

5.1 Load Conditions

For all conditions, the primary hull girder load effects are to be considered, where applicable.

5.1.1 Site Design Environmental Condition (DEC)

For non-disconnectable FPSOs or FSOs:

- Site DEC with hull design return period, and severe storm functional dead and live loads, as applicable, with $^1/_3$ stress increase allowable (i.e., 0.8*f_y)

For disconnectable FPSOs and FSOs:

- Site Disconnectable Environmental Condition (DISEC), Client-specified site year return loads (See 3-2-3/1.1), and severe storm functional, dead and live loads (i.e., excluding tropical cyclones), as applicable, with $^1/_3$ stress increase allowable (i.e., 0.8*f_y)

For the DEC and DISEC load conditions, the following assumptions are applicable:

- Topside Production Facility modules are in wet condition for all site conditions and in dry conditions for unrestricted service and transit conditions.
- Cranes are in stowed position
- Mooring loads in the most severe hull loading condition are determined from the site mooring load analysis for the following conditions:
  - All lines are intact
  - One line is damaged
  - For each individual line and associated fairlead, chock, chain stopper etc., the strength is to be assessed under the breaking strength of the line/chain with a Utilization Factor, *UF* = 0.8 for component stress, 0.9 for Von Mises element stress and 0.8 for buckling stress, in the case that the mooring loads in the above two conditions are not available.

Note: FE analysis requirements for the position mooring/hull interface described 5A-1-4/3.1 are to be met. In addition for the internal turret, the longitudinal strength calculations (i.e., Hull Girder longitudinal bending & shear strength and IACS buckling strength checks (UR S11.5), as per 5A-1-2/1 of these Rules and Section 3-2-1 and Appendix 3-2-A4 of the *Steel Vessel Rules*, for the hull girder section in way of the internal turret), for all applicable conditions, are to be submitted for review and approval.

5.1.2 Site Design Operating Condition (DOC)

Site DOC with maximum functional live loads under site operation without $^1/_3$ stress increase allowable (i.e., 0.6*f_y). Special consideration should be given to the following:

- Limiting environmental condition, specified by designer/operator, that would require suspension of normal operations, is to be minimum 1-year return as per these Rules.
- Deck support stools for topside production facility modules are in wet condition.
- Crane functional loads are as per API RP 2A and API Spec 2C Practices.
- Position mooring hull interface

5.1.3 Transit Condition

For transit (topside production facility in dry condition), it is the shipyard's and/or designer's responsibility to specify the design parameters for the transit condition. There are generally four approaches available:

- Specified maximum seasonal weather routing condition;
- Maximum 10-year return response based on the worst environmental conditions and associated wave scatter diagram along the transit route,

- Maximum 10-year return response based on a composite wave scatter diagram,
- North Atlantic service condition, with a minimum 10-year return period, using the IACS standard wave data where the transit route is not yet defined or finalized.

5.1.4 Damage Condition

Damaged Conditions (as applicable) with static deadweight and functional loads only, for a minimum 1-year return period DOC caused by accidental flooding.

5.3 Inertial Load Cases

The long-term and short-term DLP (Dominant Load Parameter) values can be calculated either using the ABS Eagle FPSO SEAS module or by using direct seakeeping/hydrodynamic calculations using 3D diffraction radiation program. The DLP values are to be selected for the most unfavorable structural response. Maximum accelerations are to be calculated at the center of gravity of the most forward and aft and midship topside production facility modules. The load cases are to be selected to maximize each of the following DLPs together with other associated DLP values.

- Max. Vertical Bending Moment
- Max. Shear Force
- Max. Vertical Acceleration
- Max. Lateral Acceleration
- Max. Roll

Alternatively, the number of load cases can be reduced by assuming that all maximum DLP values occur simultaneously, which is a conservative assumption.

5.5 Hull Girder Load Cases

As a minimum, the following two hull girder load cases are to be analyzed:

- Maximum hull girder sagging moment (i.e., generally full load condition)
- Maximum hull girder hogging moment (i.e., generally ballast, tank inspection or partial loading condition)

7 Acceptance Criteria

7.1 Yielding Checks

7.1.1 For DEC 100-Years Return Periods, Transit 10-Year Return Period and/or North Atlantic Loads:

i) For one-stiffener spacing element size FE analysis:

f_e (Von Mises) < $0.9f_y$ plate membrane stresses at element centroid

f_{1x} (axial stress) < $0.8f_y$ bar and beam elements

f_{xy} (shear) < $0.53f_y$

ii) *(1 July 2012)* The effects of notches, stress risers and local stress concentrations are to be taken into account when considering load carrying elements. When stress concentrations are considered to be of high intensity in certain elements, the acceptable stress levels will subject to special consideration. The following guidance may be used in such circumstances.

For local detail FE model analyses (localized highly stressed area, 50 × 50 mm approximate element size):

- f_e small area < $1.25S_m f_y$
- f_{1x} element stress < $1.25S_m f_y$

7.1.2 For DOC (Deadweight + Maximum Functional Loads), with 1-Year Minimum Return Period Loads *(1 July 2009)*:

i) For one-stiffener spacing element size FE analysis:

$f_e < 0.7f_y$ plate membrane stresses at element centroid

$f_{1x} < 0.6f_y$ bar and beam elements

$f_{xy} < 0.4f_y$

Note: These load cases often govern for benign environmental loads.

ii) *(1 July 2012)* For local detail FE model analyses (localized highly stressed area, 50 × 50 mm approximate element size):

- f_e small area < $0.97S_m f_y$
- f_{1x} element stress < $0.97S_m f_y$

7.1.3 For Damaged Condition *(1 July 2009)*:

Same as above for a minimum 1-year return period, except for the following, as applicable:

i) For one-stiffener spacing element size FE analysis:

$f_e < 0.9f_y$ plate membrane stresses at element centroid

$f_e < 0.8f_y$ bar and beam elements

$f_{xy} < 0.53f_y$

ii) *(1 July 2012)* For local detail FE model analyses (localized highly stressed area, 50 × 50 mm approximate element size):

- f_e small area < $1.25S_m f_y$
- f_{1x} element stress < $1.25S_m f_y$

where

S_m = 1.0 for mild steel

= 0.95 for Grade HT32 steel

= 0.908 for Grade HT36 steel

= 0.875 for Grade HT40 steel

For material grades other than the above, the allowable stresses will be specially considered.

7.3 Buckling Checks

ABS buckling criteria included in the latest edition of the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures* are to be used with the following:

- Buckling strength to be calculated using gross scantlings,
- Utilization Factor, *UF*:

  UF = 0.8 or *SF* =1.25 for onsite DEC, transit condition and/or North Atlantic condition

  UF = 0.6 or *SF* =1.67 for onsite DOC

  UF = 0.8 or *SF* =1.25 for damage condition

  UF determined on a case-by-case basis for other special conditions

7.5 Fatigue Calculations

7.5.1

The fatigue damage/life calculations are to be carried out as per the latest edition of the ABS *Guide for Fatigue Assessment of Offshore Structure*s. The fatigue calculations are to be carried out for the intended design operating life of the installation. Where the external interface connections are subjected to water immersion, the S-N curves in seawater with (CP) Cathodic Protection or (FC) Free Corrosion are to be used, as applicable. If the simplified fatigue calculation approach is to be used and the long-term Weibull distribution parameter is not available for the hull interface, then a Weibull parameter is to be developed for the specific location under consideration.

The safety factors for fatigue life for hull interface connections are to be in accordance with 5A-1-4/Table 1 shown below.

TABLE 1
Safety Factors for Fatigue Life of Hull Interface Structures *(1 July 2012)*

Importance	*Inspectable and Repairable*	
	Yes	*No*
Non-Critical	2	5
Critical	3	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

7.5.2 Position Mooring Hull Interface

Structural members in way of the turret structure or other mooring structure are to be effectively connected to the adjacent structure in such a manner as to avoid hard spots, notches and other harmful stress concentrations.

Special attention is to be given to cutouts, bracket toes and abrupt changes of structural sections. These areas are considered to be critical to the vessel and are to be free of cracks. The effects of stress risers in these areas are to be determined and minimized.

The FE model used to perform the turret/hull integration strength analysis may also be used for the fatigue screening evaluation of the turret/hull interface structure to identify the critical fatigue details using the F or F2 Class S-N curves and appropriate safety factors. The refined stress analysis should be performed for the critical areas that fail to meet the screening, and the use of the hot spot approach as specified in the ABS *Guide for the Fatigue Assessment of Offshore Structures* is considered to be acceptable.

The fatigue cyclic loads are to correspond to the worst-case tank dynamic loads, seakeeping loads, inertia loads due to the vessel motion, and mooring and riser dynamic loads, where applicable. Different wave headings and vessel tank loading patterns should be considered and the fraction of the total time for each base wave heading and each tank loading pattern can be used directly.

The frequency difference between wave frequency stress response and low frequency stress response imposed by mooring lines and risers should be considered. Although the low frequency stress response has negligible effects on most hull structural details, it becomes significant and may have the dominant contribution to the fatigue damage of structural components in the mooring system, risers and their interface with the hull. When the wave frequency and low frequency stress responses are obtained separately, the method of simple summation of fatigue damages from the two frequency stress responses does not account for the coupling effects (i.e., the augmentation of the low frequency response by the wave frequency response is non-conservative and therefore should not be used).

There is an alternative method, which is both conservative and easy to use, that is known as the combined spectrum method. In this method, the stress spectra for the two frequency bands are combined. The RMS and the mean up-crossing frequency of the combined stress process are given, respectively, as follows:

$$\sigma_c = (\sigma_w^2 + \sigma_\ell^2)^{1/2}$$

$$f_{0c} = (f_w^2\sigma_w^2 + f_{0\ell}^2\sigma_\ell^2)^{1/2}/\sigma_c$$

where

σ_w = RMS of the wave-frequency stress component

σ_ℓ = RMS of the low-frequency stress component

f_{0w} = mean up-crossing frequency of the wave-frequency stress component

$f_{0\ell}$ = mean up-crossing frequency of the low-frequency stress component

However, if both frequency components of stress range are significant, the above-mentioned combination method may be too conservative since the wave-frequency contribution is expected to dominate, thus controlling the mean up-crossing frequency of the combined stress process. To eliminate the conservatism, a correction factor given below can be applied to the calculated fatigue damage of the sea state:

$$\frac{f_{0p}}{f_{0c}}\left[\lambda_\ell^{(m/2)+1}\left(1-\sqrt{\frac{\lambda_w}{\lambda_\ell}}\right)+\sqrt{\pi\lambda_\ell\lambda_w}\,\frac{m\Gamma(m/2+1/2)}{\Gamma(m/2+1)}\right]+\left(\frac{f_{0w}}{f_{0c}}\right)\lambda_w^{m/2}$$

where

λ_1 = σ_ℓ^2/σ_c^2

λ_w = σ_w^2/σ_c^2

f_{0p} = $(\lambda_\ell^2 f_{0\ell}^2 + \lambda_\ell\lambda_w f_{0w}^2\delta_w^2)^{1/2}$ with $\delta_w = 0.1$

m = slope parameter of the S-N curve

$\Gamma(\ )$ = complete gamma function

7.5.3 Hull-Mounted Equipment Interface

The procedure for the fatigue evaluation of the turret/hull integration structure can also be applied to deck-mounted equipment interface structures in which the wave-induced hull girder loads, external hydrodynamic pressure, and inertia loads due to the vessel motion as well as the specified equipment fatigue loads should be taken into account.

Special attention is to be given to the cutouts in deck transverse webs in way of topside module stools. Where applicable, the detail fatigue evaluation for the typical cutout with the maximum topside stool dynamic reactions is to be carried out and submitted for review.

PART

5A

CHAPTER 1 Design Considerations

SECTION 5 Modules on Deck *(1 July 2009)*

1 General *(December 2008)*

The structural strength design of deck modules on ship-type installations is to be in accordance with 5B-3-3/5.3.1 through 5B-3-3/5.3.4 and 5B-3-3/5.3.6, wherever applicable. The relative deformations among module supports (e.g., stools) and the rigidity of supports and ship-type installation hull/deck, as well as hull deformations, are to be included in the analysis if their effects on the module are significant.

The module structures above their supports are to be analyzed and shown explicitly on the drawings so that the construction of the module supports can be consistent with those assumed in the structural analysis. The module design reactions and conditions are to be assessed for the most unfavorable load combinations of topside stool reactions and hull structure loads. The design requirements for module supports are given in 5A-1-3/1.13 and 5A-1-4/5.

Fatigue analysis of the modules on ship-type installations is not required. However, fatigue analysis of the topside module/hull interface is required (see 5A-1-4/7.5).

The structural fire protection aspects of the design of deck modules on a ship-type installation, including the arrangement of the hydrocarbon process area, are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*.

The designs of the piping system on the ship-type installation deck are to comply with Part 4, Chapter 2 of the *MODU Rules* and applicable requirements of the *Facilities Rules*.

PART
5A

CHAPTER 1 Design Considerations

SECTION 6 Other Systems *(1 July 2009)*

1 Other Systems

Other systems are to comply with the applicable requirements as prescribed in the following Paragraphs.

1.1 Marine Piping Systems

Marine piping systems are those systems that are required to conduct marine operations and are not associated with the process facilities. These systems include, but are not limited to, bilge, ballast, tank venting, sounding and fuel oil. Marine piping systems on ship-type installations are to be in accordance with the applicable requirements of Part 4, Chapter 6 of the *Steel Vessel Rules* and Chapter 3, Section 5 of the *Facilities Rules*, as applicable.

1.3 Electrical Systems

Electrical systems on ship-type installations are to comply with the applicable requirements of Part 4, Chapter 8 of the *Steel Vessel Rules* and Chapter 3, Section 6 of the *Facilities Rules*. For area classification requirements, refer to Section 4-1-9 of these Rules.

1.5 Fire Fighting Systems and Equipment

Fire fighting systems and equipment for service functions not associated with the process facilities are to be in accordance with the applicable requirements of Part 4, Chapter 7 of the *Steel Vessel Rules*. Fire fighting systems and equipment for protection of hydrocarbon process and associated systems are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*.

1.7 Machinery and Equipment

Machinery and equipment not associated with the process facilities are to be in accordance with the applicable requirements of Part 4, Chapters 2, 4, and 6 of the *Steel Vessel Rules*. Machinery and equipment forming a part of the hydrocarbon processing facilities are to be in accordance with applicable requirements of the *Facilities Rules*. Refer to Part 4, Chapter 1 of these Rules regarding process-related machinery and equipment.

1.9 Hydrocarbon Storage in Hull Tanks *(1 July 2012)*

If the ship-type installation is designed to store hydrocarbons in hull tanks, criteria for hull storage of hydrocarbons are to meet flag and coastal state requirements and applicable international requirements. The designs for scantlings and strength for such storage tanks are to be in accordance with Part 5A, Chapter 3. See 3-5/5.9 of the *Facilities Rules* for the storage facility arrangement requirements.

PART

5A

CHAPTER **2 Additional Design Considerations for Conversions to FPI**

CONTENTS

PART
5A

CHAPTER **2 Additional Design Considerations for Conversions to FPI**

SECTION **1 General**

1 Introduction

The conversion of an existing vessel to a ship-type FPI is referred to as an *FPI Conversion*.

The direct application of the criteria contained in Sections 3-3-1 and Part 5A, Chapter 1 as the basis of acceptance of the hull structure of an existing vessel for FPI service will result in classification notations as described in 1-1-2/3.3 and 1-1-2/5. However, modified acceptance criteria, given in this Section, may be used for some aspects of the vessel's structural design as a conversion to FPI service. This Section applies to both the *'Change of Class Designation'* and *'Transfer of Class'* situations where the acceptance of the existing vessel's hull structure as an FPI conversion is pursued. *'Change of Class Designation'* refers to an existing vessel classed by ABS which is being converted to FPI service. *'Transfer of Class'* refers to a vessel transferring into ABS's classification from another IACS member Society.

5A-2-1/Figure 1 is a diagram depicting the conversion procedure given in this Section.

3 General *(December 2008)*

All applicable criteria contained in these Rules are to be used in the classification of an FPI conversion, except that some criteria (primarily in Section 3-3-1 and Part 5A, Chapter 1) can be modified. Specific modifications are given below for the affected criteria.

The major criteria differences for the FPI conversion arise in the acceptance of the hull structure. The design of the hull structure relates to hull girder longitudinal strength and local scantling selection. Specific changes that will accommodate the use of the acceptance criteria for an FPI conversion are given in 5A-2-1/5. The principal differences in the modified criteria are summarized as:

i) The hull girder strength and acceptability of local scantlings follow the Rule approach (it is noted that there are several valid bases to do this under ABS's Rules and procedures, which are discussed in 5A-2-1/7); and

ii) The performance of strength analyses and stress checks, including *finite element analyses* are to be based on reassessed net scantlings. The determination of the reassessed scantlings is given in Section 5A-2-2 and its purpose is to establish minimum renewal scantlings. The acceptance criteria for the hull structure are defined in 5A-2-1/5.

The minimum fatigue life of the hull structure is also fundamentally different for a converted vessel. For a new-build, the minimum design service life for fatigue is 20 years; for an existing vessel to be converted to FPI service, the minimum intended on-site service life for fatigue can be less than 20 years (see 5A-2-1/5.9.3).

5 Acceptance Criteria for the Hull Structure *(December 2008)*

5.1 General *(1 July 2009)*

For a vessel being converted to FPI service, the design and construction of the existing hull, superstructure and deckhouses are to meet either the applicable criteria of the *Steel Vessel Rules* at the time of original build, or as applicable, the criteria presented in 5A-2-1/7 below. In the case of the former approach in which the acceptance criteria is the *Steel Vessel Rules* at the time of original build, the hull structure is also to satisfy the hull interface structure criteria, as applicable, and the remaining fatigue life requirements in 5A-2-1/5.11. The second approach is based on criteria in 5A-2-1/7, where Environmental Severity Factors (ESFs), as described in 5A-3-2/1.1 of these Rules (which reflect expected conditions from the long-term mooring of the installation at an offshore site), are applied, and the required hull girder longitudinal strength in Section 5A-1-2 and strength assessment in Sections 5A-3-3 and 5A-3-4 are satisfied. This results in revised values of required local scantlings that reflect the site-specific nature of the structural design. In the application of these criteria, no minimum required value of any scantling is to be less than 85 percent of the value obtained with all the Beta Values set equal to 1.0.

To be eligible to apply the second approach based on criteria in 5A-2-1/7, it is to be demonstrated that the β type Environmental Severity Factors (ESFs) β_{VBM} and β_{WHT}, as defined in 5A-3-A1/3, are 1.0 or less, and the required hull girder longitudinal strength as specified in Section 5A-1-2 is satisfied.

In addition, it is expected that the applicable and most recent versions of the criteria contained in the Load Line, SOLAS, MODU Code and MARPOL Conventions issued by the International Maritime Organization are to be considered. It is further suggested that flag state and the local authorities having jurisdiction where the installation is to operate be contacted to obtain any further applicable criteria.

See also 5A-1-1/1.

Note: The ABS Eagle FPSO computer software should be used to establish the limits on permissible reductions in the scantling requirements as they are automatically accounted for in the software.

5.3 Structural Evaluation of the Hull *(1 July 2009)*

The hull structure that is to be converted is to satisfy renewal criteria that are to be established by a reassessment calculation. A reassessment calculation as described in Section 5A-2-2 is first performed to establish the minimum renewal scantlings of individual plates and structural members below which renewals are required. For the uninterrupted operation of the installation on-site without any drydocking, the anticipated corrosion predicted to occur over the proposed on-site life of the FPI is to be provided by the designer or owner and considered in the design. Estimation of anticipated corrosion rates are to be made, by taking into account any future corrosion protection measures to be used, previous service experience, the type and temperatures of stored fluids and the other variables significantly affecting the corrosion rate. In no case is this corrosion margin provided by the designer or owner for plates and structural members to be less than 0.5 mm, except for bottom, deck and side shell plating where it is not to be less than 1.0 mm.

For ABS classification of the FPI at the time of conversion, the rule required scantlings are the renewal scantlings as determined by the reassessment calculation plus the minimum corrosion margins stated above. However for surveys in service, if the gauged thickness is between the renewal thickness and the substantial corrosion thickness as defined in 5A-2-2/3.1, either the affected areas are to be renewed or repaired, or alternatively, subsequent annual surveys of these affected areas are required.

5.5 Engineering Analyses of the Hull Structure

5.5.1 General *(1 July 2009)*

This Subsection relates to the strength analyses required to verify the reassessed scantlings for the hull structure.

Depending on the specific features of the offshore installation, additional analyses to verify and to help design other portions of the hull structure will be required. Such additional analyses include those for the hull interface structure such as the deck structural components supporting deck-mounted equipment and the hull structure interface with the position mooring system. Analysis criteria for these two situations are given in Section 5A-1-4.

Provided a scantling of the existing vessel is not below its renewal limit, or if it is to be renewed at the time of conversion, then it can be modeled in the structural analyses using the "reassessed net scantling," which is the "reassessed" value minus the "nominal design corrosion values" specified in 5A-3-1/Table 1.

Documentation necessary to verify the structural adequacy of the installation is to be submitted for review.

5.5.2 Strength Analysis of the Hull Structure *(1 July 2012)*

When the design of the hull is accepted based on the criteria in 5A-2-1/7 accounting for the on-site environmental effects, finite element structural analysis using the reassessed net scantlings is to be performed. The reassessed net scantlings are obtained by deducting the nominal design corrosion values in 5A-3-1/Table 1 from the reassessed scantlings as determined in Section 5A-2-2.

A three cargo tank length model or full cargo block model as described in 5A-1-3/3.3 may be used for finite element analyses. Finite element analyses should also be performed in areas where structural configurations or novel features are present that affect the basic hull design.

The loading conditions to be analyzed for the three cargo tank length model or cargo block/full ship model are described in 5A-1-3/3.5 and 5A-2-1/5.6, respectively.

The loads from the hull mounted top side production and support systems, and other equipment are to be included in the strength analysis. The accidental load condition, where a cargo tank is flooded, is to be assessed for longitudinal strength of the hull girder consistent with load cases used in damage stability calculations.

The additional loads and load effects of 5A-1-3/1.1 are also to be considered in the strength analysis.

5.6 Alternative Structural Model – Cargo Block or Full Length Ship Model *(1 July 2012)*

5.6.1 Structural FE Model

As an alternative to the three cargo tank length model in 5A-1-3/3.5, the finite element strength assessment for FPI conversions can be based on a full length or cargo block length of the hull structure, including all cargo and ballast tanks. All main longitudinal and transverse structural elements are to be modeled. These include outer shell, floors and girders, transverse and vertical web frames, stringers and transverse and longitudinal bulkhead structures. All plates and stiffeners on the structure, including web stiffeners, are to be modeled. Topside stools should also be incorporated in the model. The modeling mesh and element types used should follow the principles that are described in 5A-3-A4/9 and 5A-3-A4/11.

An acceptable alternative to the full length hull structure model analysis is the DLA analysis in accordance with the ABS *Guide for 'Dynamic Loading Approach' for Floating Production, Storage and Offloading (FPSO) Installations* provided that the loading conditions in 5A-2-1/5.6.2 are used.

Boundary conditions should be applied at the ends of the cargo block model for dynamic equilibrium of the structure.

The strength assessment is calculated according to the loading conditions in 5A-2-1/5.6.2 associated with each load case. The plates and stiffeners in the model are to be assessed against the yielding and buckling requirements of 5A-3-4/3 and 5A-3-4/5, respectively.

Detailed local stress assessment using fine mesh models to evaluate highly stressed critical areas are to be in accordance with 5A-3-A4/21.

5.6.2 Loading Conditions

In the strength analyses of the cargo block or full ship length model, the static on site FPI operating load cases are to be established to provide the most severe loading of the hull girder and the internal tank structures. The operating load cases found in the Loading Manual and Trim & Stability Booklet provide the most representative loading conditions to be considered for analysis. The static load cases should include as a minimum tank loading patterns resulting in the following conditions:

i) Ballast or minimum draft condition after offloading

ii) Partial load condition (33% full)

iii) Partial load condition (50% full)

iv) Partial load condition (67% full)

v) Full load condition before offloading

vi) Transit load condition

vii) Inspection and repair conditions

viii) Tank testing condition – during conversion and after construction (periodic survey)

The tank testing condition is to be considered as a still water condition. The static load cases *i)* to *vii)* are to be combined with environmental loading conditions to develop static plus dynamic load cases that realistically reflect the maximum loads for each component of the structure.

5.6.3 Dynamic Loading

Hydrodynamic loading analysis of a full length model of the FPI hull in the static load conditions is to be carried out using a recognized vessel motions and loads hydrodynamic seakeeping software. In quantifying the dynamic loads, it is necessary to consider a range of wave environments and headings at the installation site, which produce the considered critical responses of the FPI structure. The maximum 100-year design response is to be determined based on the motion and structural load effects from 3-2-3/3.1. The static and dynamics of the position mooring and topside module loads contribution shall also be included.

Wave loads are to be determined based on an equivalent design wave approach where an equivalent design wave is defined as a regular wave that gives the same response level as the maximum design response for a specific response parameter. The equivalent design wave is characterized by wave amplitude, wave length, wave heading, and wave crest position referenced to amidships of the hull structure. This maximum design response parameter or Dominant Load Parameter is to be determined for the site-specific environment with a 100-year return period, transit environment with a 10-year return period, and inspection and repair condition with a 1-year return period. In selecting a specific response parameter to be maximized, all of the simultaneously occurring dynamic loads induced by the wave are also derived. These simultaneous acting dynamic load components and static loads, in addition to the quasi-static equivalent wave loads, are applied to the cargo block model. The Dominant Load Parameters essentially refer to the load effects, arising from vessel motions and wave loads, that yield the maximum structural response for critical structural members. Each set of Dominant Load Parameters with equivalent wave and wave-induced loads represents a load case for structural FE analysis.

The wave amplitude of the equivalent design wave is to be determined from the maximum design response of a Dominant Load Parameter (DLP) under consideration divided by the maximum RAO amplitude of that DLP. RAOs are to be calculated using a range of wave headings and periods. The maximum RAO occurs at a specific wave frequency and wave heading where the RAO has its own maximum value. The equivalent wave amplitude for a DLP may be expressed by the following equation:

$$a_w = \frac{R_{\max}}{RAO_{\max}}$$

where

a_w = equivalent wave amplitude of the DLP

$R_{\max}$ = maximum response of the DLP

$RAO_{\max}$ = maximum RAO amplitude of the DLP

The following DLPs are identified as necessary to develop the load cases for the hull structure:

- Vertical bending moment – sag and hog
- Vertical shear force
- Horizontal bending moment
- Horizontal shear force
- Vertical acceleration
- Lateral acceleration
- Roll angle

Vertical bending moment and shear force are to be evaluated in way of an internally mounted mooring turret. Accelerations are to be determined at a sufficient number of process equipment locations to represent accurately the load effects arising from their motion. As appropriate, roll angle calculations may include simultaneous effects of waves and winds.

Other DLPs that may be deemed critical can also be considered in the analysis. The need to consider other DLPs or additional DLPs is to be determined in consultation with ABS.

5.6.4 Load Cases

Load cases are derived based on the above static and dynamic loading conditions, and DLPs. For each load case, the applied loads to be developed for structural FE analysis are to include both the static and dynamic parts of each load component. The dynamic loads represent the combined effects of a dominant load and other accompanying loads acting simultaneously on the hull structure, including external wave pressures, internal tank pressures, deck loads and inertial loads on the structural components and equipment. For each load case, the developed loads are then used in the FE analysis to determine the resulting stresses and other load effects within the FPI hull structure.

5.7 Fatigue Analysis of the Hull Structure

Fatigue analysis is required considering the fatigue damage that has occurred during prior service as a trading vessel, during transit and during on-site operations including operational loading and unloading cycles. See 5A-1-3/3.9 and Section 5A-2-3.

5.9 Acceptance Criteria

The total assessment of the structure is to be carried out against the failure modes of material yielding, buckling and ultimate strength, and fatigue. The reference acceptance criteria of each mode are given as follows.

5.9.1 Material Yielding

See 5A-1-3/3.11.1.

5.9.2 Buckling and Ultimate Strength

See 5A-1-3/3.11.2.

5.9.3 Fatigue *(1 July 2009)*

For existing vessels that are employed in FPI service, the estimated remaining fatigue lives of the critical structural details are to be assessed and the supporting calculations submitted for review. Consideration is given to the effects of corrosion and wastage on the remaining fatigue life of existing structures by using net scantlings.

The minimum acceptable fatigue life for the FPI conversion is the greatest of: the on-site service life of the FPI, the time to the next Special Survey or five years. Whichever of these values controls, it is to be documented in accordance with 1-1-2/5.10.2 (the **FL** classification notation) and used in the *Survey Planning Document* referred to in 1-1-4/11.3.

Appendix 5A-3-A2 of these Rules is also referred to for ship-type installations with lengths less than 150 m. Application of the Appendix will result in the evaluation of members for stress ranges of an unrestricted trading service vessel. In the absence of more detailed environmental data, stress ranges are to be obtained in consideration of the unrestricted service environment.

The fatigue strength is based on a cumulative damage theory, which infers that the structure is likely to experience a fatigue failure after a finite number of stress cycles occur. This is especially important when looking at FPI conversions. The installation has already experienced cycles of stress during the "ship" phase of its life and it will experience additional cycles during the "FPI" phase of its life. The basic concept is to keep the total number of cycles below the number that results in failure.

For FPI conversions, an analysis procedure accounting for the fatigue damage of the "ship" phase and FPI phase, including transit, is acceptable. First, the historical cumulative fatigue damage up to the time of conversion is to be calculated through realistic temporal weighting of wave environments experienced along the service routes during the service life of the vessel.

Second, the expected cumulative fatigue damage is to be calculated using site-specific wave environment and operational conditions, as well as transit condition. These will provide an estimate of the remaining fatigue life of the structural members at the time of conversion. See Section 5A-2-3.

When the route and site-specific wave environments are used and they produce less severe fatigue demands than the unrestricted service environment of the *Steel Vessel Rules*, credit can be given to the less severe environment by increasing the expected fatigue life. For site-specific environmental conditions producing more severe fatigue demand than the *Steel Vessel Rule* basis, the site-specific environmental data are to be used.

Due to the structural redundancy and relative ease of inspection inherent in typical hull structures of ship-type installations, there is no further need to apply additional factors of safety above what is already built into the fatigue classification curves cited in the above reference. However, for areas of the structure which are non-inspectable or "critical", such as in way of the connections to the mooring or production systems (see 5A-2-1/5.11), additional factors of safety should be considered.

Any areas determined to be critical to the structure are to be free of cracks, and the effects of stress risers should be determined and minimized. Critical areas may require special analysis and survey.

For an existing classed vessel being converted to FPI service, the minimum fatigue lives of the structural components covered in 5A-2-1/5.11 and 5A-2-1/5.13 can be less than 20 years as mentioned above.

5.9.4 Hull Girder Ultimate Strength

See 5A-1-2/3.

5.11 Analysis and Design of Other Major Structures

See Section 5A-1-4 for required analysis of hull interface structures.

See also 5A-2-1/5.9.3 for revised target minimum fatigue life for an existing vessel being accepted as an FPI conversion.

5.13 Turret Mooring

See 6-2-1/13 for required analysis of the turret mooring system.

See also 5A-2-1/5.9.3 for revised target minimum fatigue life for as existing vessel being accepted as an FPI conversion.

7 Assessing the Design of the Hull Structure *(December 2008)*

7.1 General *(1 July 2012)*

The FPI conversion approach relies on a review of the hull's design. The review consists of an assessment of the hull girder strength and cargo region scantling review including main supporting members, local plating and stiffeners that directly contribute to the hull girder strength.

Two major purposes for this review are to assess the adequacy of the hull girder and local strength, and to "benchmark" the values upon which local scantling renewals are to be based for future in-service surveys. For this latter purpose, several approaches which can be applied are listed in 5A-2-1/7.3.

An existing vessel can be sorted into one of three basic categories, as follows.

a. Vessel satisfies ABS Rules from its original classification [✠ Maltese Cross in the classification symbol and not accepted under 1-1-4/7.5 of the ABS *Rules for Conditions of Classification (Part 1)*]. *Note:* ABS Rules also includes IACS Common Structural Rules for Double Hull Oil Tankers (ABS *Steel Vessel Rules* Part 5A)

b. Vessel currently classed by an IACS member or taken into ABS classification under 1-1-4/7.5 of the ABS *Rules for Conditions of Classification (Part 1).*

c. Vessel was never classed by an IACS member.

A vessel in category (*a*) or (*b*) can be considered for an FPI conversion. The acceptance criteria to be applied to a category (*c*) vessel will based on special consideration determined in consultation with ABS.

7.3 Hull Design Review Acceptance Criteria *(1 July 2012)*

The review of the design of an existing hull structure, which is applicable to a vessel classed for unrestricted service, does not account for the increased or reduced local structural element strength requirements that could result from the long-term, moored operation of the installation at an offshore site. The approach to the design review also allows variations in the acceptance criteria that can be based on:

i) ABS Rules from the year of build of the vessel with ABS permissible corrosion limits for renewal; or

ii) ABS current Rules with ABS permissible corrosion limits for renewal; or

iii) The prior IACS member's approved scantlings (or as-built values) using that society's permissible corrosion limits for renewal. However the permissible corrosion limits for the longitudinal members are to be based on ABS limits for the year of build of the vessel if the IACS member society's limits are greater.

When the acceptance criteria is based on *i)*, *ii)* or *iii)*, the renewal scantlings for plates and stiffeners in the deck and bottom structure, within 0.15 Depth from deck and bottom, and for plates in side shell and longitudinal bulkheads must be established at the time of conversion. The allowable material diminution of these plates and stiffeners is to be based on the smaller of:

a) The wastage allowance based on *i), ii)* or *iii)*, or

b) The allowable wastage based on buckling strength. The allowable wastage based on buckling strength is to apply to these plates and stiffeners subject to hull girder bending and shear stresses as required by Appendix 5A-2-A1. When the acceptance criteria are based on *iii)*, the IACS member's allowable wastage based on buckling considerations may be used.

The combination of the variety of ways to review local scantlings and the permissibility to account for site-dependent effects on global and local hull structural strength requirements can lead to a range of acceptable procedures.

If it is desired to account for the on-site environmental effects and how these affect the required scantlings, it will be necessary to establish the required renewal scantlings on this basis. This results in a reassessment of the hull structure design to establish the converted structure's renewal scantlings. The acceptance criteria for the hull structure are defined in 5A-2-1/5.

9 Survey Requirements for a Conversion *(2003)*

A Floating Installation is expected to remain permanently moored on site, and it is therefore without the ready access to the repair and maintenance facilities used by a vessel. Considering these conditions, the following minimum Hull survey requirements for conversion of an existing vessel to FPI service are to be followed.

9.1 Conversion Survey Requirements

9.1.1 Drydocking Survey

When the vessel is to be placed on drydock and surveyed, the requirements of Section 7-4-1 of the ABS *Rules for Survey After Construction (Part 7)* are to be followed.

9.1.2 Special Survey of Hull

A Special Periodical Survey of Hull, appropriate to the age of the installation, is to be carried out in accordance with 7-3-2/5.13 of the ABS *Rules for Survey After Construction (Part 7)* for non-Double Hull tankers and 7-3-2/5.14 of the referenced Part 7 for Double Hull tankers. All requirements for Close-up Survey and thickness measurements are to be applied.

9.1.3 Modifications

All modifications to the vessel are to be carried out in accordance with ABS-approved drawings and to the satisfaction of the attending Surveyor. In general, the IACS *Shipbuilding and Repair Quality Standard (SARQS)* requirements are to be followed unless a recognized shipyard or national standard is already established in the shipyard.

9.3 Structural Repairs/Steel Renewal

Renewed material should be replaced by steel of the same or higher grade and to the approved design scantling or greater. Workmanship is to be carried out in accordance with the IACS *SARQS* requirements.

9.5 Bottom Plate Pitting Repair

The following repair recommendations apply to pitting found in both ballast and cargo tank bottom plating.

9.5.1 Repair Recommendations

There are four main approaches used for dealing with severe bottom pitting.

9.5.1(a) Partially Crop and Renew Affected Bottom Plating. Partial cropping and renewal is primarily a matter of: proper welding technique, selection of an adequately sized plate insert and the appropriate nondestructive examination (NDE) of repaired areas.

9.5.1(b) Clean Pitted Areas and Cover with Special Coating. Cleaning out and covering with special coating without use of filler or weld build-up need only be limited by the maximum allowable depth of the pits (or allowable minimum remaining thickness of the bottom plating) permitted from a strength or pollution risk standpoint. The allowable loss of bottom cross-sectional area must also be considered.

9.5.1(c) Clean Pitted Areas and Fill with Plastic Compound. Use of plastic compound filler, such as epoxy, can be considered similar to 5A-2-1/9.5.1(b) because no strength credit is given to the filler material.

9.5.1(d) Fill by Welding. Filling with welding warrants more serious consideration. Suggested welding practices for bottom plating are noted below.

9.5.2 Pitting up to 15% of Bottom Plating Thickness (t)

No immediate remedial action is necessary. However, if the surrounding tank bottom is specially coated, corrosion progress in the pitted areas may be very rapid due to the area ratio effect of protected versus non-protected surfaces, therefore, as applicable, the coating is to be repaired.

9.5.3 Scattered Pitting Up To 33% (1/3*t*) of Bottom Plating Thickness

These pits may be filled with epoxy or other suitable protective compounds, provided the loss of area at any transverse section of the strake in question does not exceed 10%. Any areas that have been repaired by this method must be "mapped" and noted for close-up survey in the Survey and Inspection Plan required by 1-1-4/11.3 of these Rules.

9.5.4 Pitting of Any Depth may be Welded, Provided:

Pitting may be welded, provided there is at least 6 mm (0.25 in.) remaining original plating thickness at the bottom of the cavity and there is at least 75 mm (3 in.) between adjacent pit welding areas. The maximum nominal diameter of any pit repaired by welding may not exceed 300 mm (12 in.).

9.5.5 Requirements for the Welding of Pits

9.5.5(a) Pit Welding. It is recommended that pit welding in bottom plating be built up at least 3 mm (0.125 in.) above the level of the surrounding plating and then ground flush. This is mandatory for: higher-strength steels grades D and E, for very small areas (less than 75 mm (3 in.) in diameter and for such welding done afloat.

9.5.5(b) Surface Preparation. Pitted areas are to be thoroughly cleaned of rust, oil and cargo residues prior to welding.

9.5.5(c) Filler Metal. When welding, the filler metal grade appropriate to the pitted base metal and preheating, if applicable, are to be employed.

9.5.5(d) Welding While Installation is Afloat. For welding below the waterline of an installation afloat, properly dried low hydrogen electrodes are to be used. The pitted areas against water backing are to be preheated sufficiently to drive off any moisture that might be present. The preheat is to cover at least 102 mm (4 in.) of the material surrounding the welding or four times the material thickness, whichever is greater.

9.5.5(e) Layer of Welding Metal. A layer of weld metal is to be deposited along a spiral path to the bottom center of the pitted excavation. The slag is to be completely removed and the next successive layer is to be similarly deposited to build up the excavation at least 3 mm (0.125 in.) above the level of the surrounding plating.

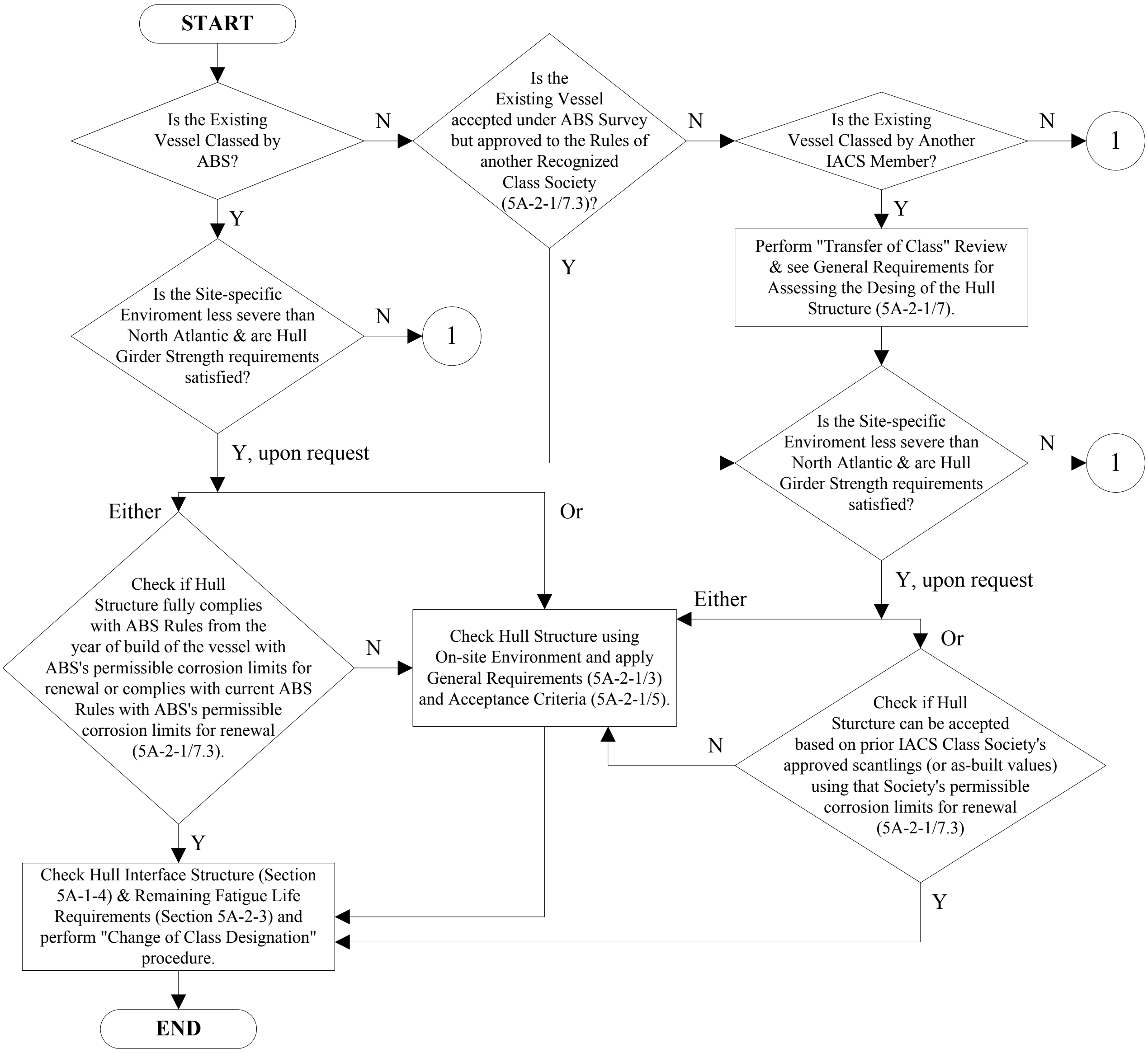
9.5.5(f) Extensive Pit Repairs. For extensive pit repairs (i.e., greater than 20% intensity) of steel grades D, E and higher strength steel, welding against water backing is not recommended.

9.5.5(g) Nondestructive Examination. All welds to pitted areas in bottom plating are to be subject to nondestructive examination with particular attention to boundaries of the welded areas and at intersections of the welded areas and existing structural welding. Also, for welds of higher-strength steels, the NDE method is to be suitable for detecting sub-surface defects.

9.5.5(h) Coating. In order to reduce the likelihood of possible galvanic attack at the boundaries of built-up areas, coating over the area with a compound such as epoxy/glass flake should be considered. Also, where the pitting is in small areas of coating breakdown, it is essential to restore the coating intact in order to avoid the possible rapid corrosion of small bare areas in large protected areas (area ratio effect).

9.5.5(i) Doublers. Fitting of a doubler over pits is not considered a satisfactory repair.

FIGURE 1
Procedure for Hull Structure Evaluation of Existing Vessel Converting to FPI *(December 2008)*



LEGEND:
1: Apply Section 3-3-1 & Part 5A, Chapter 1 OR alternative criteria determined in consultation with ABS.
Y: Yes
N: No

PART

5A

CHAPTER 2 Additional Design Considerations for Conversions to FPI

SECTION 2 Steel Renewal Assessment *(December 2008)*

1 Introduction

Major aspects associated with a conversion include an existing vessel's original design and the basis of the design such as design criteria, vessel's classification, etc., its age, condition, maintenance and operational history as well as the design, survey and maintenance requirements for the converted structure.

The relative importance of these aspects are influenced by the structure's intended service, strength and fatigue requirements, and regulatory/certification requirements.

The minimum renewal values as described in 5A-2-1/5 provide a baseline condition for the FPI installation as they are the minimum scantling requirements for classification. Also, based on the future anticipated corrosion expected to occur over the design life at the FPI site, the required minimum scantlings at the time of conversion can be determined.

3 Steel Renewal Assessment Procedure *(1 July 2009)*

The first step in determining the renewal scantlings for an FPI vessel conversion requires a reassessment of the vessel's scantlings based on the specific site of the installation. The ABS Eagle FPSO software can be used to perform the Initial Scantling Evaluation (ISE) phase of the reassessment and to calculate the renewal scantlings of an existing vessel converted to an FPI. The reassessed scantlings determined in the ISE phase, which are used to establish the renewal scantlings, must also be confirmed by finite element analysis as part of the Total Strength Assessment (TSA).

3.1 Minimum Renewal Scantlings within 0.4L *(1 July 2009)*

The Initial Scantling Evaluation assesses the strength of the longitudinal scantlings for the FPI conversion. The strength evaluation is mainly applicable for the structure within the 0.4*L* midship region and consists of performing the following steps:

1. ABS Eagle FPSO SEAS software is employed for calculation of Environmental Severity Factor (ESFs) based on the environmental conditions as specified in 3-2-3/3.
2. Determination of reassessed scantlings:
   - *a)* Assign initial input scantlings by reducing deck and bottom plating by 15%-20% of the as-built scantlings and using as-built scantlings for stiffeners.
   - *b)* Calculate the hull girder section modulus and individual stiffener section modulus.
   - *c)* Determine the hull girder and local strength requirements for the site specific offshore location.
   - *d)* Check if the input scantlings meet both hull girder and local strength requirements. If not, adjust input scantlings and go back to step 2b).
   - *e)* As an option, the input scantlings can be further adjusted provided hull girder and local strength requirements are satisfied.
   - *f)* Determine the initial reassessed scantlings as the input scantlings.

3. Establishing renewal scantlings:

   a) Determine renewal scantlings of longitudinal structural members based on Rule permissible percentage wastage allowances in 5A-2-2/Table 1.

   b) Check if renewal scantlings of longitudinal members (i.e. plating and longitudinals) satisfy local panel and stiffener buckling requirement. If not, adjust reassessed scantlings and go back to step 2(b).

   c) Calculate substantial corrosion scantlings (scantlings corroded to 75% of allowable wastage).

   d) Input anticipated corrosion wastage and then calculate yard renewal value.

4. Verification of reassessed scantlings and renewal scantlings:

   a) Check if reassessed scantlings meet hull girder bending strength requirement for inspection, repair, and transit condition.

   b) Check if reassessed scantlings meet global hull girder and local scantling requirements.

   c) Check if reassessed scantlings meet hull girder ultimate strength requirement as per 5A-3-3/3.5.

   d) Check if reassessed scantlings meet hull girder shear strength requirement.

   e) Check if reassessed scantlings meet the sloshing strength requirements for tank boundary members.

   If any one of the above requirements of the ISE phase is not met, adjust reassessed scantlings and go back to step 2(b)

5. Output renewal table, where the following information are at least included:

   a) Reassessed & renewal hull girder SM for deck and bottom

   b) Tabulate preliminary results of individual members as follows:

   Member Identification, As-built Scantlings, Reassessed Scantlings (rounded to nearest 0.5 mm), Renewal Scantlings, Substantial Corrosion Scantlings, User-defined anticipated corrosion and Yard Required Scantlings.

   c) Check reassessed scantlings by finite element analysis (TSA)

   d) Determine final results of individual members as per *b)*

The above procedure is an iterative procedure as it requires several strength and buckling requirements to be satisfied. The flow chart in 5A-2-2/Figure 1 illustrates the iterative steps necessary to determine the reassessed and renewal scantlings within 0.4*L* amidships

The procedure described above determines the reassessed and renewal scantlings within 0.4*L* amidships. The reassessed and renewal scantlings for the entire cargo block can also be determined using a similar procedure. To do so requires that the reassessed scantlings between 0.4*L* amidships and the ends of the cargo block be calculated using the same procedure as described above, except that the bending moments and local loads for scantling requirements at specific locations between 0.4*L* amidships and cargo block ends are applied in the procedure rather than the bending moments and local loads for scantling requirements required amidships. The reassessed scantlings in the cargo block region are to be verified by finite element analysis (TSA).

3.3 Minimal Renewal Scantlings at 0.125L from the Ends

If 0.125*L* from the ends is within the cargo block region, the reassessed and renewal scantlings at 0.125*L* can be determined either by taking the as-built scantlings at 0.125*L* from the ends as the reassessed scantlings at that location, or by applying the procedure described in 5A-2-2/3.1. If however 0.125*L* is outside the cargo block region, then the as-built scantlings at 0.125*L* from the ends will be the reassessed scantlings at that location. The renewal scantlings will then be determined from the reassessed scantlings

If there is an increase or decrease in vessel length due to conversion the scantlings 0.125*L* from the ends should be assessed for the new length. Where an increase in length occurs it may be necessary to either modify the structure or consider early renewal for the scantlings at the ends.

3.5 Minimum Renewal Scantlings between 0.4L Amidships and 0.125L from the Ends

If the reassessed and renewal scantlings of the cargo block have been determined by the procedure described in 5A-2-2/3.1, the reassessed and renewal scantlings have already been determined. If not, the continuous longitudinal members of the hull girder are to be maintained throughout 0.4*L* amidships, and then may be gradually tapered beyond 0.4*L* provided local strength and hull girder requirements are satisfied.

Where the scantlings are based on the still-water bending moment envelope curves, items included in the hull girder section modulus amidships are to be extended as necessary to meet the hull girder section modulus required at the location being considered.

FIGURE 1
Determination of Reassessed and Renewal Scantlings for Ship-Type FPI Conversions within 0.4L Amidships – Flow Chart (1) *(1 July 2009)*

Note 1: See 5A-2-2/Table 1 for Individual Wastage Allowances

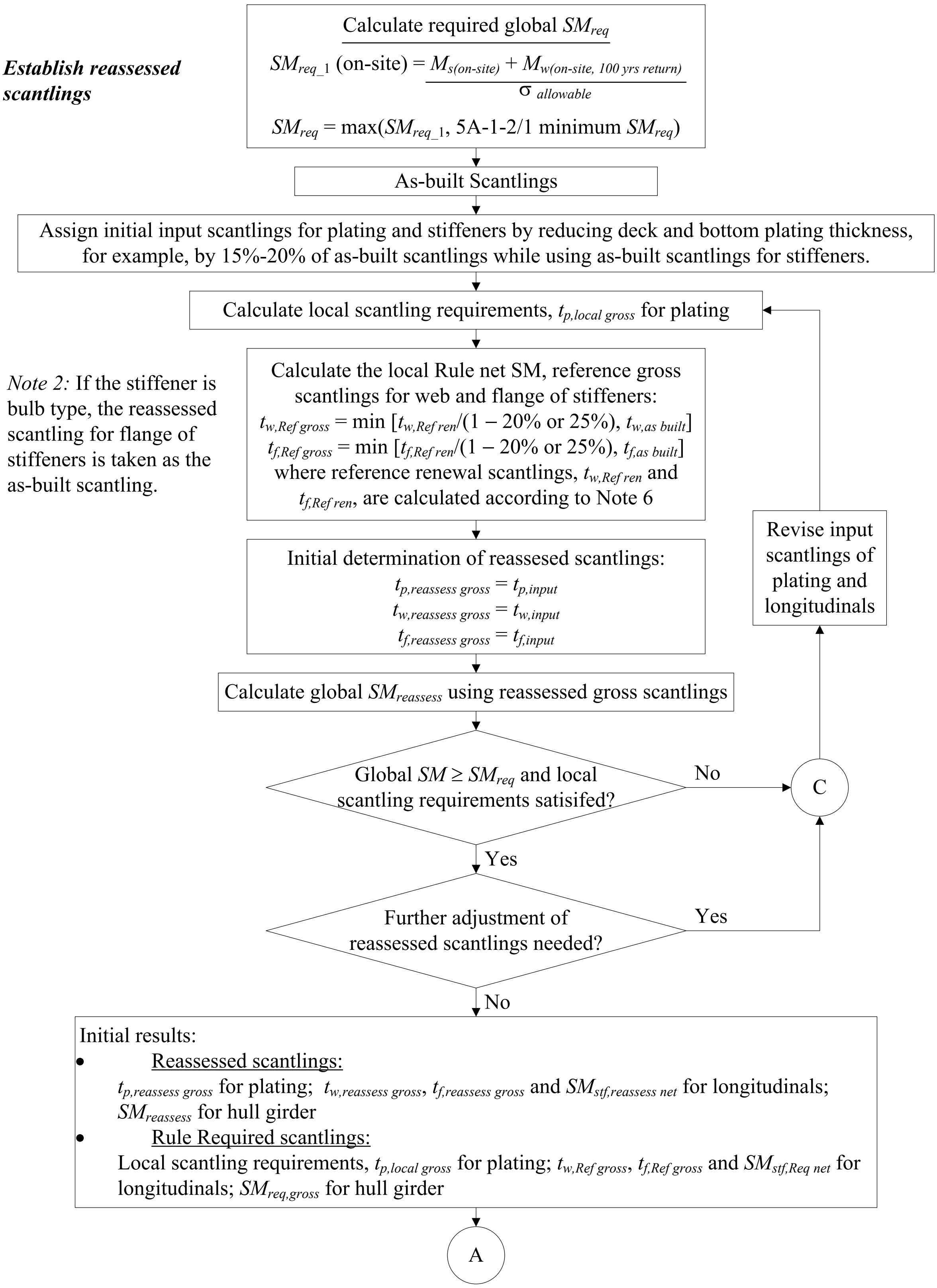


FIGURE 1 (continued)
Determination of Reassessed and Renewal Scantlings for Ship-Type FPI Conversions within 0.4L Amidships – Flow Chart *(1 July 2009)*

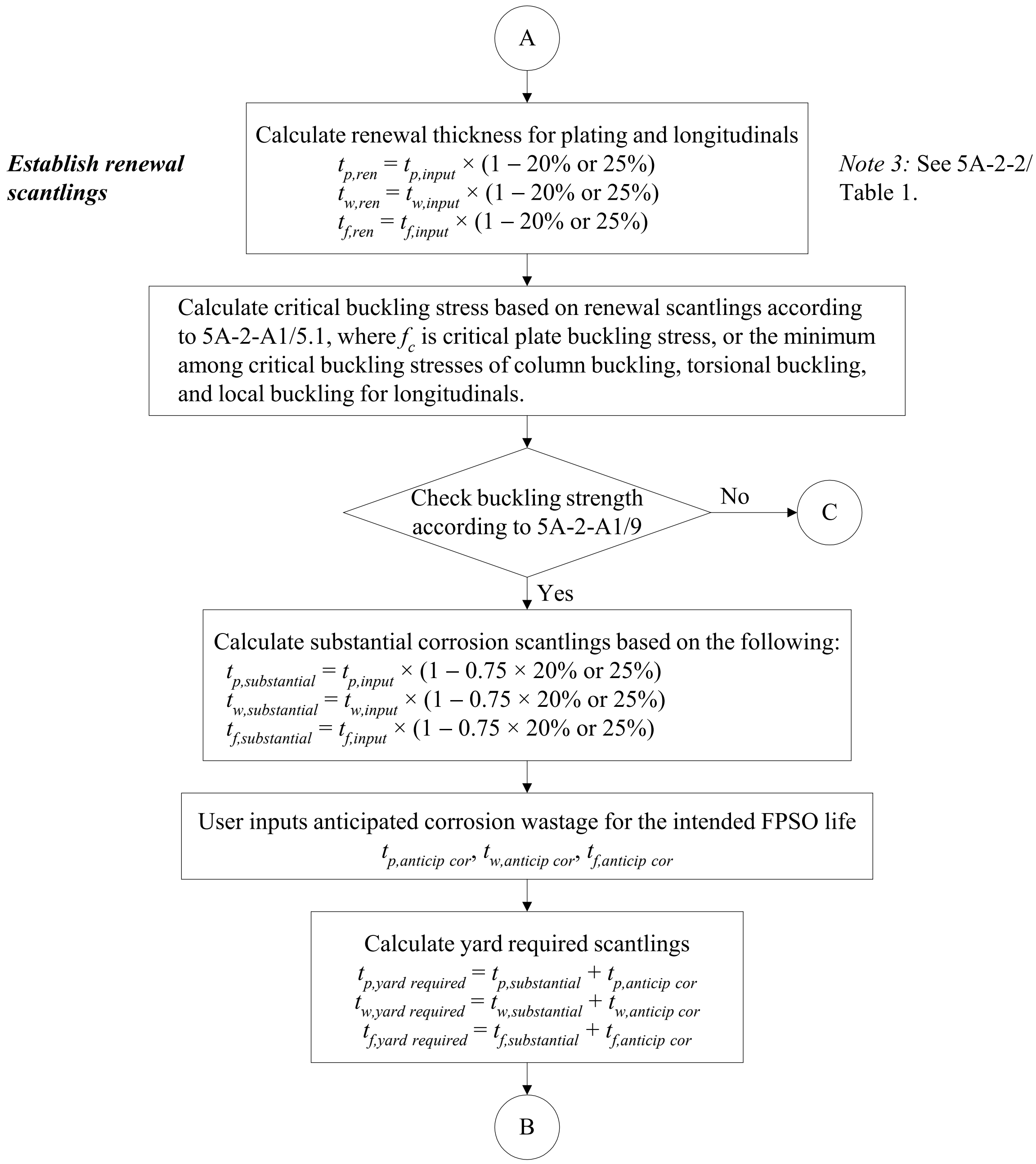
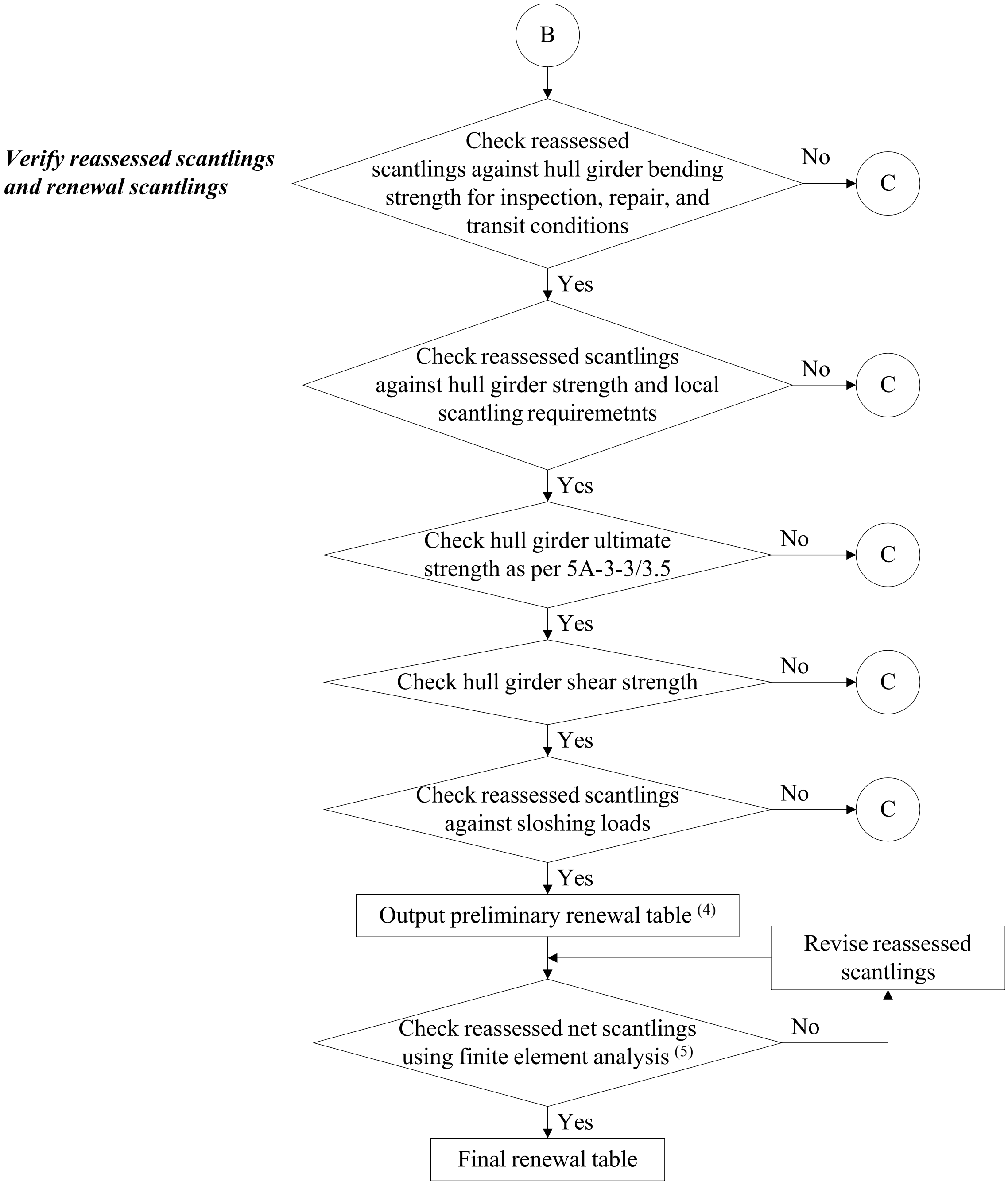


FIGURE 1 (continued)
Determination of Reassessed and Renewal Scantlings for Ship-Type FPI Conversions within 0.4L Amidships – Flow Chart *(1 July 2009)*



Notes:

4 Renewal table should include at least reassessed and renewal hull girder *SM* for deck and bottom as well as the following individual member information: Member Identification, As-built Scantlings, Reassessed Scantlings (rounded to the nearest 0.5 mm), Renewal Scantlings, Substantial Scantlings, User-defined Anticipated Corrosion, Yard Required Scantlings.

5 Reassessed net scantlings used in finite element analysis are the net scantlings of the minimum of the reassessed (round to the nearest 0.5 mm) and as-built scantlings.

FIGURE 1 (continued)
Determination of Reassessed and Renewal Scantlings for Ship-Type FPI Conversions within 0.4L Amidships – Flow Chart *(1 July 2009)*

Note 6 Buckling Check of Longitudinal Stiffeners

Stiffener Web Plate	*Material*	*Steel*			
		Mild	*HT32*	*HT36*	*HT40*
Angle and T Profile	$d_w/t_{w,Ref\ ren} \le$	70	65	60	55
Bulb Profiles	$d_w/t_{w,Ref\ ren} \le$	36	34	31	28
Flat bars	$d_w/t_{w,Ref\ ren} \le$	20	19	18	17
Stiffener Flanges	$b_{flg\text{-}out}/t_{f,Ref\ ren} \le$	15	14	13	12

where

d_w = depth of web plate, in mm

$b_{flg\text{-}out}$ = breadth of larger flange outstands, in mm

TABLE 1
Individual Wastage Allowances, Newbuilds and Vessels Converted to FPI, 90 meters and Over (1, 2, 3) *(1 July 2012)*

Ordinary and High Strength Steel	*Newbuilds or Vessels Converted 2009 or Later*		*Vessels Converted before 2009*	
	Double Bottom	*Single Bottom with Single Side or Double Side*	*Double Bottom*	*Single Bottom with Single Side or Double Side*
Strength Deck Plating	20%	20%	20%	20%
Continuous Long'l Hatch Coamings & Above Deck Box-Girders	20%	-----	20%	-----
Deck Plates within Line of Hatches and at Ends.	30%	30%	30%	30%
Forecastle, Poop and Bridge Deck Plates; Superstructure End Bulkheads	30%	30%	30%	30%
(December 2008) Tween Deck Plates	-----	-----	-----	-----
Sheer Strake Plates	20%	20%	20%	20%
Side Shell Plates	20%	25%	25%	25%
Bilge Strake Plates	20%	20%	25%	20%
Bottom Plates	20%	20%	25%	20%
Keel Plates (4)				
Outermost Strake of Inner Bottom	20%	-----	20%	-----
Other Plates of Inner Bottom	20%	-----	25%	-----
Top Strake of Longitudinal Bulkheads and Top Strake of Topside Tank Sloping Plating	20%	20%	20%	20%
Bottom Strake of Longitudinal Bulkheads	20%	20%	25%	20%
Other Plates of Longitudinal Bulkheads, Topside Tank Sloping Plating, Hopper Tank Sloping Plating and Transverse Bulkheads	20%	25%, 20% for transverse bulkheads only	25%	25%
Internals including Longitudinals, Girders, Transverses, Struts, Bulkhead Webs and Stringers, Brackets and Hatch Side Girders	20%	25%	25%	25%
Plates in way of Top of Tanks	25%	30%	30%	30%
Underdeck Box Girders (Long'l or Transverse)	20%	-----	20%	-----
Hatch Covers, Hatch coamings and brackets	30%	30%	30%	30%

TABLE 1 (continued)
Individual Wastage Allowances, Newbuilds and Vessels Converted to FPI, 90 meters and Over (1, 2, 3) *(1 July 2012)*

Notes:

1 *(1 July 2009)* The individual wastage allowances are acceptable, provided the *SM* is not less than 90% of the greater *SM* required: a) at the time of new construction or conversion or b) by 5A-1-2/1 of these Rules.

2 For tankers 130 m in length and above and over 10 years of age, sectional area calculations are to be carried out by an ABS Technical Office.

3 For vessels built to other society rules, the Technical Office carrying out the initial plan review is to be contacted for wastage allowances.

4 Keel plates are to be renewed when they reach the minimum allowed thickness for adjacent bottom plating.

PART

5A

CHAPTER 2 Additional Design Considerations for Conversions to FPI

SECTION 3 Fatigue Consideration (Remaining Fatigue Life) *(December 2008)*

1 Introduction

An existing vessel structure will have accumulated some fatigue damage due to the prior service as well as steel wastage due to corrosion and wear. In order to account for the fatigue damage that has occurred and to determine the remaining fatigue life, a fatigue assessment of structural connection details shall be performed by the following steps:

- Determine the fatigue damage that has occurred due to the prior service as a trading vessel, and at a previous installation site, if applicable.
- Determine the fatigue damage that will occur during transit to the installation site.
- Calculate the total fatigue damage exerted by the connection details during the above service.
- Calculate the remaining fatigue life in the connection details of the longitudinal stiffeners for the site specific operation of the FPI.
- Develop renewal or reinforcement requirements for any stiffener connection that does not show adequate remaining fatigue life at the installation site.

3 Remaining Fatigue Life

Based on the application of the Palmgren-Miner cumulative damage rule when the cumulative fatigue damage ratio is equal to 1.0, the connection detail is assumed to fail. Considering fatigue damage ratios for the prior service to conversion and post conversion phases, this can be expressed as:

$$S_{PriorConv}/L_{P,PriorConv} + L_{R,PostConv}/L_{P,PostConv} = 1$$

therefore

$$L_{R,PostConv} = L_{P,PostConv} \times (1 - S_{PriorConv}/L_{P,PriorConv})$$

where

$L_{R,PostConv}$ = remaining fatigue life for on-site operation, post conversion

$L_{P,PostConv}$ = predicted (design) fatigue life for on-site operation, post conversion

$S_{PriorConv}$ = service years prior to conversion

$L_{P,PriorConv}$ = predicted (design) fatigue life prior to conversion

5 Remaining Fatigue Life for Longitudinal Stiffener Connections *(1 July 2009)*

For a vessel converted to an FPI, where historical trade routes and intended site have been specified, fatigue lives of both prior and post conversion phases can be calculated using the ABS Eagle FPSO Initial Scantling Evaluation (ISE) and SEAS software. The Initial Scantling Evaluation Software is used to evaluate the fatigue response of longitudinal stiffener connections. The ABS Eagle FPSO SEAS software calculates the environmental severity factors for fatigue (α factors) for the historical routes and intended site. When the α factor is greater than 1.0, it describes an increase in fatigue life due to reduced environmental conditions when compared to the North Atlantic environment (where α equals to 1.0). Once these factors have been established, the above equation can be modified to take into account environments other than the North Atlantic environment (unrestricted service) as follows:

$$L_{R,PostConv} = (20/DM_{Comb}) \times [1 - \Sigma(S_{Route\text{-}i}/\alpha_{Route\text{-}i})/L_{P,Tanker} - \Sigma(S_{His\ Site\text{-}i}/\alpha_{His\ Site\ i})/L_{P,Site} - (S_{Transit}/\alpha_{Transit})/L_{P,Transit}]$$

where

$L_{R,PostConv}$	=	site specific post conversion remaining fatigue life of the unaltered connection
$S_{Route\text{-}i}$	=	number of service years for the *i*-th historical route
$S_{His\ Site\text{-}i}$	=	number of service years for the *i*-th historical site
$S_{Transit}$	=	number of service years for the transit phase
$L_{P,Tanker}$	=	predicted fatigue life for the tanker phase based on North Atlantic environment
$L_{P,Site}$	=	predicted fatigue life for the historical site based on North Atlantic environment
$L_{P,Transit}$	=	predicted fatigue life for the transit phase based on North Atlantic environment
$\alpha_{Route\text{-}i}$	=	environmental severity factor for the *i*-th historical route, see 5A-3-A1/5
$\alpha_{His\ Site\ i}$	=	environmental severity factor for the *i*-th historical site, see 5A-3-A1/5
$\alpha_{Transit}$	=	environmental severity factor for the transit condition, see 5A-3-A1/5
DM_{Comb}	=	combined fatigue damage post conversion, see 5A-3-A2/19

The expression $\Sigma(S_{Route\text{-}i}/\alpha_{Route\text{-}i})$ and $\Sigma(S_{His\ Site\text{-}i}/\alpha_{His\ Site\ i})$ are the weighted average for the various routes and historical sites for each longitudinal stiffener connection calculated by the ABS Eagle FPSO ISE and SEAS software.

The calculation of the remaining fatigue life is used only for the connection details that existed prior to conversion and were not modified in any way during the conversion. For connection details on new longitudinal members that are added or details that have been modified during the conversion, the predicted or design fatigue life calculated for the post conversion site specific environment will be applicable.

7 Remaining Fatigue Life for Connections of Transverses and Girders *(1 July 2009)*

Horizontal stringer or girder end connections on transverse bulkheads, bracket toes on side, bottom, deck and longitudinal bulkhead should be screened for fatigue strength using a finite element based fatigue assessment. For screening purposes the three tank length finite element model employed in the Total Strength Assessment (TSA) can be used to estimate the nominal stress in the connections. By applying the same nominal stress approach used for the fatigue evaluation of longitudinal stiffener connections, fatigue lives are estimated for transverse member connections. Where details are deemed critical as a result of this screening process, a more refined fatigue assessment based on the hot spot stress is performed using a fine mesh finite element analysis of the connection detail. The method used to account for prior service and remaining fatigue life is the same as described for longitudinal stiffener connections in 5A-2-3/3.

The remaining fatigue life is calculated as:

$$L_{R,PostConv} = (20/DM_{Comb}) \times [1 - \Sigma((S_{Route\text{-}i}/20) \times DM_{Route\text{-}i}) - \Sigma((S_{His\ Site\text{-}i}/20) \times DM_{His\ Site\text{-}i}) - (S_{Transit}/20) \times DM_{Transit}]$$

The expression $\Sigma((S_{Route\text{-}i}/20) \times DM_{Route\text{-}i})$ and $\Sigma((S_{His\ Site\text{-}i}/20) \times DM_{His\ Site\text{-}i})$ are the weighted average for the various routes and historical sites calculated based on weighted beta values from the ABS Eagle FPSO SEAS software.

PART
5A

CHAPTER 2 **Additional Design Considerations for Conversions to FPI**

APPENDIX 1 **Buckling Strength of Longitudinal Members Applied to Reassessed Scantling Determination (See 5A-2-2/Figure 1)** *(December 2008)*

1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

3 Elastic Buckling Stresses

3.1 Elastic Buckling of Plates

3.1.1 Compression

The ideal elastic buckling stress is given by:

$$\sigma_E = 0.9mE\left(\frac{t_b}{s}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = \frac{8.4}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c\left[1 + \left(\frac{s}{\ell}\right)^2\right]^2 \frac{2.1}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

where

E = 2.06×10^5 N/mm^2 (21,000 kgf/mm^2, 30×10^6 psi)

t_b = renewal thickness of plating, in mm (in.)

s = shorter side of plate panel, in mm (in.)

ℓ = longer side of plate panel, in mm (in.)

c = 1.3 when plating stiffened by floors or deep girders

= 1.21 when stiffeners are angles or T-sections

= 1.10 when stiffeners are bulb flats

= 1.05 when stiffeners are flat bars

Ψ = ratio of smallest to largest compressive stress, σ_a (see 5A-2-A1/7.1), varying linearly across panel.

3.1.2 Shear

The ideal elastic buckling stress is given by:

$$\tau_E = 0.9 k_t E \left(\frac{t_b}{s}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

$$k_t = 5.34 + 4\left(\frac{s}{\ell}\right)^2$$

E, t_b, s and ℓ are as defined in 5A-2-A1/3.1.1.

3.3 Elastic Buckling of Longitudinals

3.3.1 Column Buckling without Rotation of the Cross Section *(1 July 2009)*

For the column buckling mode (perpendicular to plane of plating), the ideal elastic buckling stress is given by:

$$\sigma_E = \frac{EI_a}{c_1 A \ell^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

I_a	=	moment of inertia, in cm^4 (in^4), of longitudinal, including plate flange and calculated with renewal thickness, as specified in 5A-2-A1/3.1.1
A	=	cross-sectional area, in cm^2 (in^2), of longitudinal, including plate flange and calculated with renewal thickness, as specified in 5A-2-A1/3.1.1
ℓ	=	unsupported span, in m (ft), of longitudinal
c_1	=	1000 (1000, 14.4)
E	=	as defined in 5A-2-A1/3.1.1

3.3.2 Torsional Buckling Mode *(1 July 2009)*

The ideal elastic buckling stress for the torsional mode is given by:

$$\sigma_E = \frac{\pi^2 EI_w}{10 c_1 I_p \ell^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385E\frac{I_t}{I_p} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

K	=	$c_2 \dfrac{C\ell^4}{\pi^4 EI_w}$	
m	=	number of half waves given by 5A-2-A1/Table 1	
E	=	as defined in 5A-2-A1/3.1.1	
c_2	=	10^6 (10^6, 20736)	
I_t	=	St. Venant's moment of inertia, in cm^4 (in^4), of profile (without plate flange)	
	=	$c_3 \dfrac{h_w t_w^3}{3}$	for flat bars (slabs)
	=	$c_3 \dfrac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0.63\dfrac{t_f}{b_f}\right)\right]$	for flanged profiles

c_3 = 10^{-4} (10^{-4}, 1.0)

I_p = polar moment of inertia, in cm^4 (in^4), of profile about connection of stiffener to plate

= $c_3 \dfrac{h_w^3 t_w}{3}$ for flat bars (slabs)

= $c_3 \left(\dfrac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right)$ for flanged profiles

I_w = warping constant, in cm^6 (in^6), of profile about connection of stiffener to plate

= $c_4 \dfrac{h_w^3 t_w^3}{36}$ for flat bars (slabs)

= $c_4 \left(\dfrac{t_f b_f^3 h_w^2}{12} \right)$ for "Tee" profiles

= $c_4 \dfrac{b_f^3 h_w^2}{12 \left(b_f + h_w\right)^2} [t_f (b_f^2 + 2 b_f h_w + 4 h_w^2) + 3 t_w b_f h_w]$ for angles and bulb profiles

c_4 = 10^{-6} (10^{-6}, 1.0)

h_w = web height, in mm (in.)

t_w = web renewal thickness, in mm (in.)

b_f = flange width, in mm (in.)

t_f = flange renewal thickness, in mm (in.). For bulb profiles the mean thickness of the bulb may be used.

ℓ = unsupported span of profile, in m (ft)

s = spacing of profiles, in mm (in.)

C = spring stiffness exerted by supporting plate panel

= $\dfrac{k_p E\, t_p^3}{3s \left(1 + \dfrac{1.33 k_p h_w t_p^3}{s t_w^3} \right)}$ N (kgf, lbf)

k_p = $1 - \eta_p$, not to be taken less than zero

t_p = plate renewal thickness, in mm (in.)

η_p = $\dfrac{\sigma_a}{\sigma_{Ep}}$

σ_a = calculated compressive stress. For longitudinals, see 5A-2-A1/7.1

σ_{Ep} = elastic buckling stress of supporting plate, as calculated in 5A-2-A1/3.1

For flanged profiles, k_p need not be taken less than 0.1.

3.3.3 Web and Flange Buckling

For web plate of longitudinals the ideal buckling stress is given by:

$$\sigma_E = 3.8CE\left(\frac{t_w}{h_w}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

C	=	1.0	for angle or tee stiffeners
	=	0.33	for bulb plates
	=	0.11	for flat bars

For flanges on angles and T-sections of longitudinals, the following requirements will apply:

$$\frac{b_f}{t_f} \leq 15$$

where

b_f = flange width, in mm (in.), for angles, half the flange width for T-sections.

t_f = flange renewal thickness, in mm (in.)

TABLE 1
Number of Half Waves *(December 2008)*

	$0 < K \leq 4$	$4 < K \leq 36$	$36 < K \leq 144$	$144 < K \leq 400$	$(m-1)^2 m^2 < K \leq m^2 (m+1)^2$
m	1	2	3	4	m

5 Critical Buckling Stresses

5.1 Compression

The critical buckling stress in compression, σ_c, is determined as follows:

$$\sigma_c = \sigma_E \qquad \text{when } \sigma_E \leq \frac{\sigma_F}{2}$$

$$= \sigma_F\left(1 - \frac{\sigma_F}{4\sigma_E}\right) \qquad \text{when } \sigma_E > \frac{\sigma_F}{2}$$

where

σ_F = yield stress of material, in N/mm^2 (kgf/mm^2, psi). σ_F may be taken as 235 N/mm^2 (24 kgf/mm^2, 34,000 psi) for mild steel.

σ_E = ideal elastic buckling stress calculated according to 5A-2-A1/3

5.3 Shear

The critical buckling stress in shear, τ_c, is determined as follows:

$$\tau_c = \tau_E \quad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \quad \text{when } \tau_E > \frac{\tau_F}{2}$$

where

τ_F = $\dfrac{\sigma_F}{\sqrt{3}}$

σ_F = as given in 5A-2-A1/5.1

τ_E = ideal elastic buckling stress in shear calculated according to 5A-2-A1/3.1.2

7 Working Stress

7.1 Longitudinal Compressive Stress *(1 July 2009)*

The compressive stresses are given in the following formula:

$$\sigma_a = c_5 \frac{\beta_{VBM} M_w + M_{sw}}{I_n} y \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

$$= \text{minimum } 30/Q \text{ N/mm}^2 \text{ (}3.1/Q \text{ kgf/mm}^2\text{, } 4400/Q \text{ psi)}$$

where

M_{sw} = maximum still water bending moment at installation site, in kN-m (tf-m, Ltf-ft)

M_w = wave bending moment, as given in 3-2-1/3.7.1(a) of the *Steel Vessel Rules*, in kN-m (tf-m, Ltf-ft)

I_n = moment of inertia of the hull girder based on the reassessed gross scantlings, in cm^4 (in^4)

y = vertical distance, in m (ft), from the neutral axis to the considered point

Q = as defined in 3-2-1/5.5 of the *Steel Vessel Rules* (1.0 for ordinary strength steel)

c_5 = 10^5 (10^5, 322,560)

β_{VBM} = ESF for vertical bending moment, as defined in 5A-3-A1/3

M_w and M_{sw} are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

7.3 Shear Stresses

7.3.1 Installations without Effective Longitudinal Bulkheads *(1 July 2009)*

The working shear stress, τ_a, in the side shell of installations without effective longitudinal bulkheads is given by the following formula:

$$\tau_a = c_6 \frac{(F_{sw} + \beta_{VSF} F_w) m_s}{2 t_s I} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

I	=	moment of inertia of the hull girder section based on the reassessed gross scantlings, in cm^4 (in^4), at the section under consideration.
m_s	=	first moment, in cm^3 (in^3), about the neutral axis of the area of the effective longitudinal material between the horizontal level at which the shear stress is being determined and the vertical extremity of effective longitudinal material, taken at the position under consideration.
t_s	=	gross thickness of the side shell plating, in cm (in.), at the position under consideration.
F_{sw}	=	hull girder shearing force in still water, in kN (tf, Ltf)
F_w	=	F_{wp} or F_{wn}, in kN (tf, Ltf), as specified by 3-2-1/3.5.3 of the *Steel Vessel Rules*, depending upon loading
c_6	=	10 (10, 2240)
β_{VSF}	=	ESF for vertical shear force, as defined in 5A-3-1/3

7.3.2 Installations with Two or More Effective Longitudinal Bulkheads

The working shear stress, τ_a, in the side shell or longitudinal bulkhead plating is to be calculated by an acceptable method and in accordance with 3-2-1/3.9.4 of the *Steel Vessel Rules*.

9 Scantling Criteria

9.1 Buckling Stress

The design buckling stress, σ_c, of plate panels and longitudinals (as calculated in 5A-2-A1/5.1) is to be such that:

$$\sigma_c \geq \beta\sigma_a$$

where

β	=	1	for plating and for web plating of stiffeners (local buckling)
	=	1.1	for stiffeners

The critical buckling stress, τ_c, of plate panels (as calculated in 5A-2-A1/5.3) is to be such that:

$$\tau_c \geq \tau_a$$

where

τ_a	=	working shear stress in the plate panel under consideration, in N/mm^2 (kgf/mm^2, lbf/in^2), as determined by 5A-2-A1/7.3

PART

5A

CHAPTER 3 Structural Design Requirements

CONTENTS

PART

5A

CHAPTER 3 Structural Design Requirements

SECTION 1 General

1 Design Considerations and General Requirements

1.1 General *(December 2008)*

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 5A-3-1/Table 1 are to be deducted.

1.3 Initial Scantling Requirements *(December 2008)*

The initial requirements for plating, the section modulus of longitudinals/stiffeners, and the scantlings of the main supporting structures are to be determined in accordance with Section 5A-3-3 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 *(December 2008)*

A total assessment of the structures, determined on the basis of the initial strength criteria in Section 5A-3-3 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 limit state given in 5A-3-4/3.1 for all load cases specified in 5A-3-2/9.

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 5A-3-4/5. In addition, the hull girder ultimate strength is to be in accordance with 5A-3-3/3.5 and Appendix 5A-3-A3.

1.5.3 Fatigue

The fatigue strength of structural details and welded joints in highly stressed regions is to be analyzed in accordance with 5A-3-4/9.

1.7 Net Scantlings and Nominal Design Corrosion Values (NDCV) *(1 July 2012)*

1.7.1 General

The "net" thickness or scantlings correspond to the minimum strength in Part 5A, Chapter 3 regardless of the design service life of the installation. 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 5A-3-1/Table 1 and 5A-3-1/Figure 1 are to be added to the net scantlings. These minimum corrosion values are intended for a design service life of 20 years. Where the design life is greater than 20 years, the minimum corrosion values of the hull structure are to be increased in accordance with 5A-3-1/1.7.2. These minimum values are introduced solely for the purpose of scantling requirements and strength criteria as indicated in 5A-3-1/1.1, and are not to be interpreted 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.

1.7.2 Nominal Design Corrosion Values for Design Life Greater than 20 Years

When the structural design life is greater than 20 years, the nominal design corrosion values (NDCV) of the hull structure are to be increased from those in 5A-3-1/Table 1 as follows:

1.7.2(a) For plating and structural members with 2.0 mm (0.08 in.) NDCV for 20-years design life, additional 0.1 mm (0.004 in.) per year for design life greater than 20-years. For example, 2.5 mm (0.1 in.) NDCV for 25-year design life.

1.7.2(b) For plating and structural members with 1.5 mm (0.06 in.) NDCV for 20-years design life, additional 0.075 mm (0.003 in.) per year for design life greater than 20-years. For example, 1.875 mm (0.075 in.) NDCV for 25-year design life.

1.7.2(c) For plating and structural members with 1.0 mm (0.04 in.) NDCV for 20-years design life, additional 0.05 mm (0.002 in) per year for design life greater than 20-years. For example, 1.25 mm (0.05 in.) NDCV for 25-year design life.

1.7.2(d) For void spaces, no change in NDCV as it is considered independent of design life.

The NDCV values are to be considered minimum nominal design corrosion values. Actual corrosion could be more or less than the NDCV values. The designer or owner may specify additional design corrosion margins based on maintenance plans.

Note: Local allowable wastage allowance of plates and stiffeners for floating installations designed for uninterrupted operation on-site without any drydocking and having a design life longer than 20 years is described in 7-2-6/3.1.10.

The rounding of the calculated thickness is to be the nearest half millimeter. For example:

- For $10.75 \le t_{calc} < 11.25$ mm, the required thickness is 11 mm
- For $11.25 \le t_{calc} < 11.75$ mm, the required thickness is 11.5 mm

When the difference between the required net thickness and the offered net thickness is less than 0.25 mm, the offered net thickness is acceptable if the rounded required gross thickness is smaller or equal to the offered gross thickness.

For US customary unit system, a similar exercise is to be carried out as described in the above for the Metric unit system.

TABLE 1
Nominal Design Corrosion Values (NDCV) *(1 July 2012)*

Structural Element/Location		*Nominal Design Corrosion Values in mm (in.)*		
		Cargo Tank	*Ballast Tank Effectively Coated*	*Void Space*
Deck Plating		1.0 (0.04)	2.0 (0.08)	1.0 (0.04)
Side Shell Plating		NA	1.5 (0.06)	1.0 (0.04)
Bottom Plating		NA	1.0 (0.04)	1.0 (0.04)
Inner Bottom Plating		1.5 (0.06)		1.0 (0.04)
Longitudinal Bulkhead Plating	Between cargo tanks	1.0 (0.04)	N.A.	1.0 (0.04)
	Other Plating	1.5 (0.06)		1.0 (0.04)
Transverse Bulkhead Plating	Between cargo tanks	1.0 (0.04)	N.A.	1.0 (0.04)
	Other Plating	1.5 (0.06)		1.0 (0.04)
Transverse & Longitudinal Deck Supporting Members		1.5 (0.06)	2.0 (0.08)	1.0 (0.04)
Double Bottom Tanks Internals (Floors and Girders)		N.A.	2.0 (0.08)	1.0 (0.04)[(5)]
Double Bottom Tanks Internals (Stiffeners)		N.A.	2.0 (0.08)	1.0 (0.06)
Vertical Stiffeners and Supporting Members Elsewhere		1.0 (0.04)	1.0 (0.04)	1.0 (0.04)
Non-vertical Longitudinals/Stiffeners and Supporting Members Elsewhere		1.5 (0.06)	2.0 (0.08)	1.0 (0.04)

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.

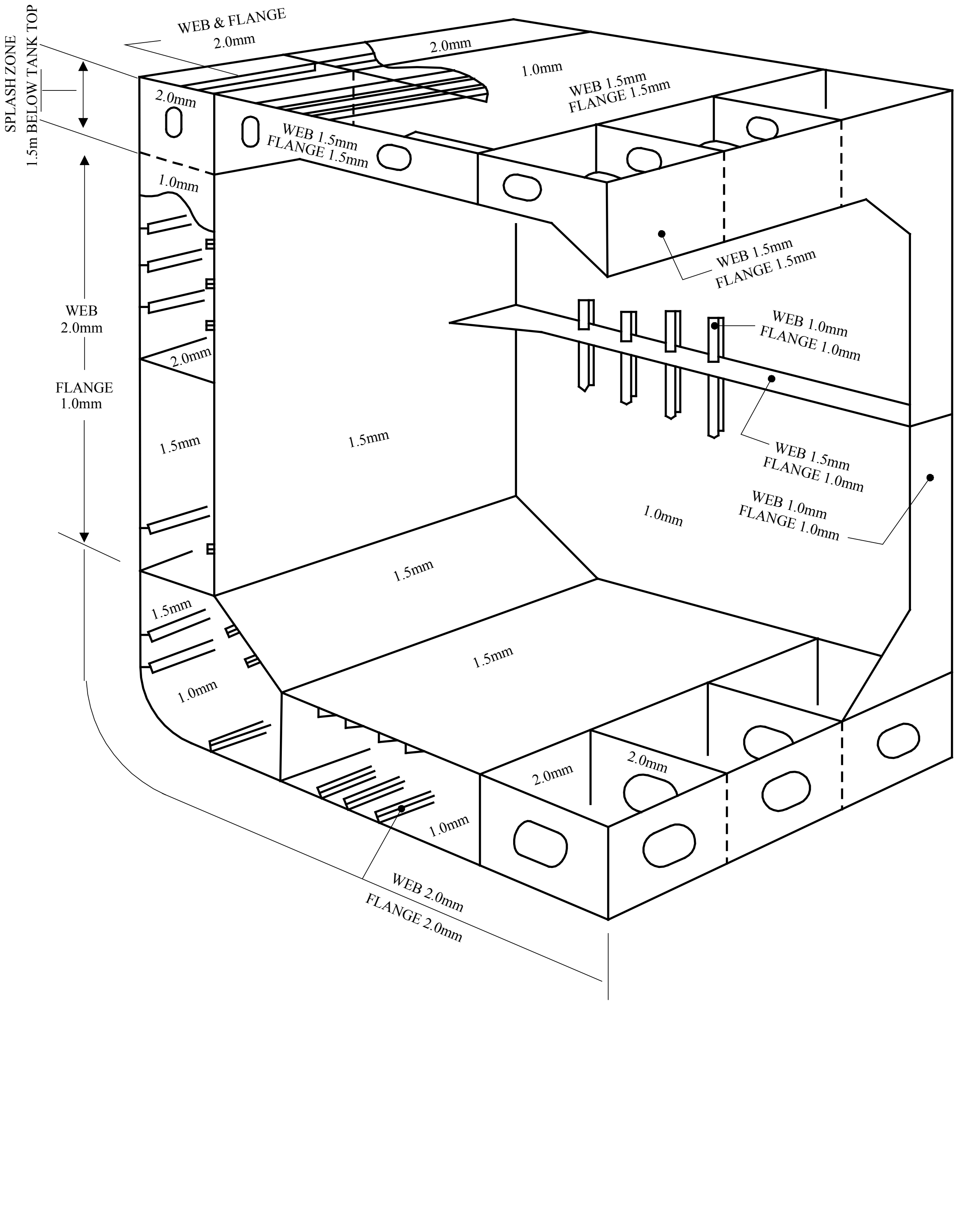
2 Pitting and grooving are regarded as localized phenomena and are not covered in this table.

3 For nominal design corrosion values for single hull ship-type installations, see Section 5A-3-6.

4 *(1 July 2012)* Side stringer plating in Void Space: Watertight adjacent to ballast tank 1.5 mm (0.06), Non-Tight: 1.0 mm (0.04).

5 *(1 July 2012)* Watertight bottom girder adjacent to ballast tank: 1.5 mm (0.06).

FIGURE 1
Nominal Design Corrosion Values (NDCV) *(December 2008)*



1.9 Application *(1 July 2012)*

1.9.1 Installation Size and Proportion *(1997)*

The requirements contained in this Chapter are applicable to double hull ship-type installations 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 of the *Steel Vessel Rules.*

1.9.2 Installation Types *(December 2008)*

The equations and formulae for determining design load and strength requirements, as specified in Sections 5A-3-2 and 5A-3-3, are applicable to double hull ship-type installations. For single hull ship-type installations, the parameters used in the equations are to be adjusted according to the structural configurations and loading patterns outlined in Section 5A-3-6. The strength assessment procedures and the failure criteria, as specified in Section 5A-3-4, are applicable to all ship-type installations.

Double hull ship-type installation is a monohull 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 grounding 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.

A Double side, single bottom ship-type installation is a monohull having full depth wing water ballast tanks or other non-cargo spaces and single bottom structure.

A Single hull ship-type installation is a monohull that does not have double side and double bottom spaces fitting the above definitions of *Double hull ship-type installation*.

1.9.3 Direct Calculations *(1 September 2007)*

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.

1.11 Internal Members *(2002)*

1.11.1 Section Properties of Structural Members *(December 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 and 3-1-2/13.5 of the *Steel Vessel Rules* or 5A-3-3/Figure 6 of these Rules, as applicable). For structural member with angle θ (see 5A-3-1/Figure 2) between web and associated plating not less than 75 degrees, the section modulus, web sectional area and moment of inertia of the "standard" (θ = 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 5A-3-1/Figure 2).

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

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

where

α_θ = $1.45 - 40.5/\theta$

SM_{90} = the section modulus at θ = 90 degrees

The effective web section area may be obtained by the following equation:

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

where

A_{90} = effective shear area at θ = 90 degrees

The effective moment of inertia may be obtained by the following equation:

$$I = \alpha_\theta I_{90}$$

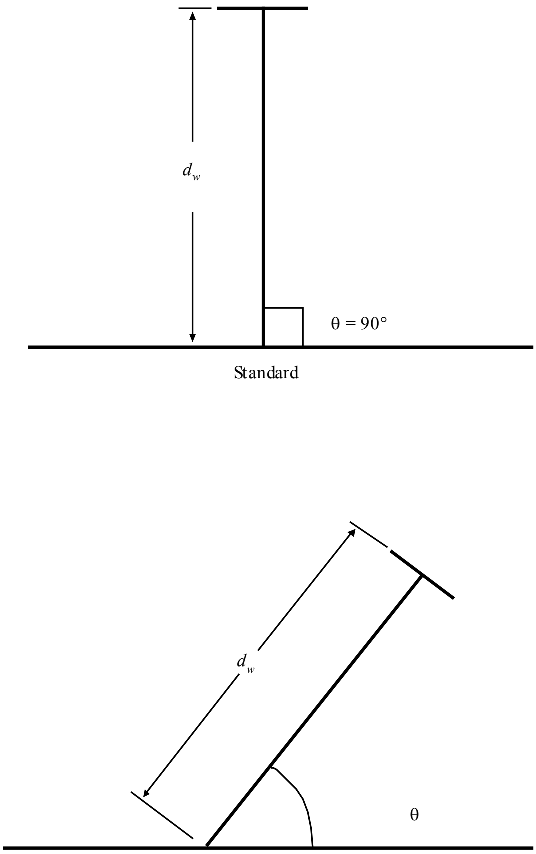
where

α_θ = $1.45 - 40.5/\theta$

I_{90} = effective moment of inertia at $\theta = 90$ degrees

In the above equation, θ is in degrees.

FIGURE 2



1.11.2 Detailed Design

The detailed design of internals is to follow the guidance given in 3-1-2/15 of the *Steel Vessel Rules* and 5A-3-3/1.5 of these Rules.

See also Appendix 5A-3-A2 "Fatigue Strength Assessment of Ship-Type Installations".

1.13 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 0.5*L*, the required shell and deck scantlings for the midship 0.4*L* may be required to be extended to introduce a gradual taper of the structure, and the deck stringer plate and sheer strake are to be increased. See 5A-3-3/9.1 and 5A-3-3/9.3. Where the breaks of the forecastle or poop are appreciably beyond the midship 0.5*L*, the requirements for the deck stringer plate and sheer strake, as specified in 5A-3-3/9.1 and 5A-3-3/9.3, may be modified.

1.15 Variations

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

1.17 Loading Guidance *(1997)*

Loading guidance is to be as required by 3-2-1/7 of the *Steel Vessel Rules*, except that 5A-3-3/5 of these Rules will apply for allowable shear stresses.

1.19 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 installation [see 5C-1-7/11.11.2 of the *Steel Vessel Rules*], 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.

1.21 Protection of Structure

For the protection of structure, see 3-2-18/5 of the *Steel Vessel Rules*.

1.23 Aluminum Paint

Paint containing 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, unless it has been shown by appropriate tests that the paint to be used does not increase the fire hazard.

3 Special Requirements for Deep Loading

3.1 General *(2003)*

Where an installation is intended to operate at the minimum freeboard allowed by the International Convention on Load Lines, 1966 for Type-A vessels, the conditions in 5A-3-1/3.3 through 5A-3-1/3.11 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 of the *Steel Vessel Rules*). 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 of the *Steel Vessel Rules* 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 of the *Steel Vessel Rules*. 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 installation. See 3-2-17/3 of the *Steel Vessel Rules*.

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

Ship-type installations 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 ship-type installations over 150 m (492 ft) in freeboard length (see 3-1-1/3.3 of the *Steel Vessel Rules*), 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 of the *Steel Vessel Rules*.

5 Arrangement *(1994)*

5.1 General

The arrangements of the installation 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 13), their protective locations (Regulation 13E – where the option in Regulation 13F (4) or (5) is exercised), collision or stranding considerations (Regulation 13F), hypothetical outflow of oil (Regulation 23), limitations of size and arrangement of cargo tanks (Regulation 24) and slop tanks [Regulation 15 (2) (c)]. A valid International Oil Pollution Prevention Certificate issued by the flag administration may be accepted as evidence of compliance with these requirements.

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 oil tight 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 of the *Steel Vessel Rules*.

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

Aluminum anodes may be used in the cargo tanks of ship-type installations, but only 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 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 non-hazardous 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 non-hazardous 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 installation, 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 5A-3-1/5.23.

5.15 Structural Fire Protection

The applicable requirements of Section 3-4-1 of the *Steel Vessel Rules* 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 installations 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 Ship-type Installations *(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 7-3-2/5.13.3 of the ABS *Rules for Survey After Construction (Part 7)*] 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 of the *Steel Vessel Rules*) 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 of the *Steel Vessel Rules* 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 installation, 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 of the *Steel Vessel Rules*.

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 of the *Steel Vessel Rules*. 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 of the *Steel Vessel Rules*.

5.27 Pumping Arrangements

See applicable requirements in Section 5C-1-7 of the *Steel Vessel Rules*.

5.29 Electrical Equipment

See 5C-1-7/31 of the *Steel Vessel Rules*.

5.31 Testing

Requirements for testing are contained in Part 3, Chapter 7 of the *Steel Vessel Rules*.

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.

PART

5A

CHAPTER 3 Structural Design Requirements

SECTION 2 Loads

1 General

1.1 The Concept and Application of Environmental Severity Factors *(December 2008)*

This Chapter referred to in Part 5A, Chapter 1 provides an explanation of the ship-type hull structural design and analysis criteria. Previously, it was customary to specify that ship-type offshore installations were to meet structural design and analysis criteria for unrestricted full ocean service conditions, i.e., a trading oil tanker. In reality, many such installations were sited at locations with dynamic components of their loading that are less than those arising from unrestricted service conditions.

At the same time, the approach to major ship design that has been developed and advocated by ABS in the last decade has relied on a two phase method. In the first phase, initial design scantlings of the installation are selected, considering nominal, maximum expected loadings that a component is likely to experience in its lifetime for the full ocean service. This step is called the Initial Scantling Evaluation (ISE) and is governed by the criteria contained in Sections 5A-3-2 through 5A-3-3. A second step requires structural analyses of major portions of the hull structure to verify the adequacy of the structural system's performance, including strength checks for failure modes associated with yielding, buckling and ultimate strength. This step is referred to as the Total Strength Assessment (TSA) and is governed by the criteria specified in Section 5A-3-4.

To adjust the loadings and load effects produced by the site-specific long-term environment at the installation site (compared to the full ocean service), a series of "Environmental Severity Factors" (ESFs) have been derived. There are two types of ESFs, which are referred to as "Alpha" type (α) and "Beta" type (β). The α factors are used to adjust fatigue strength performance expectations between the full ocean service (Rule basis) and the long-term site-specific environment. The β factors are used primarily to adjust the dynamic component of loads that are used to establish: hull girder strength (i.e., wave-induced hull girder loads), individual scantling design equations, the loads used in the strength analyses of the hull, and ancillary forces, such as those from the motion of equipment masses located on or above the main deck. In practice, the hull may be loaded over a large range of tank loading patterns and external drafts. The implied value of all ESFs of both the alpha and beta types for the full ocean service is 1.0.

The determination of the environmental severity factors is to be carried out in accordance with Appendix 5A-3-A1 using the ABS Eagle FPSO SEAS program.

1.3 Load Components *(1995)*

In the design of the hull structure of ship-type installations, all load components with respect to the hull girder and local structure as specified in this Chapter and Section 3-2-1 of the *Steel Vessel Rules* 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)*

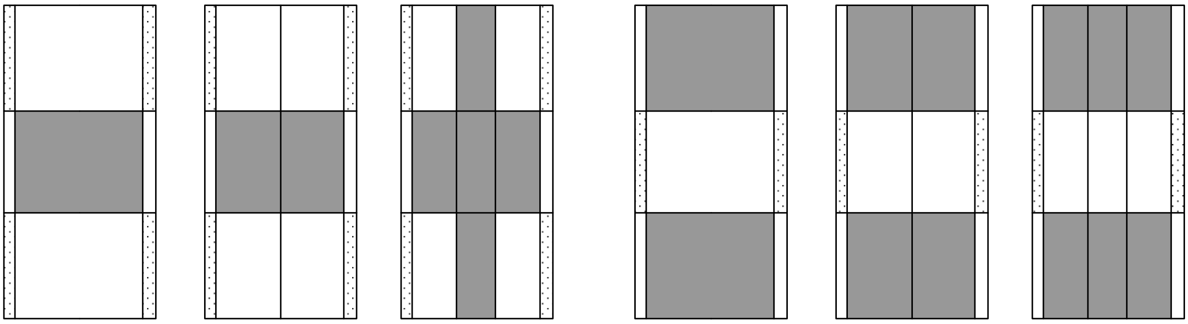
3.1 Still-water Bending Moment

For still-water bending moment calculations, see 3-2-1/3.3 of the *Steel Vessel Rules*.

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.

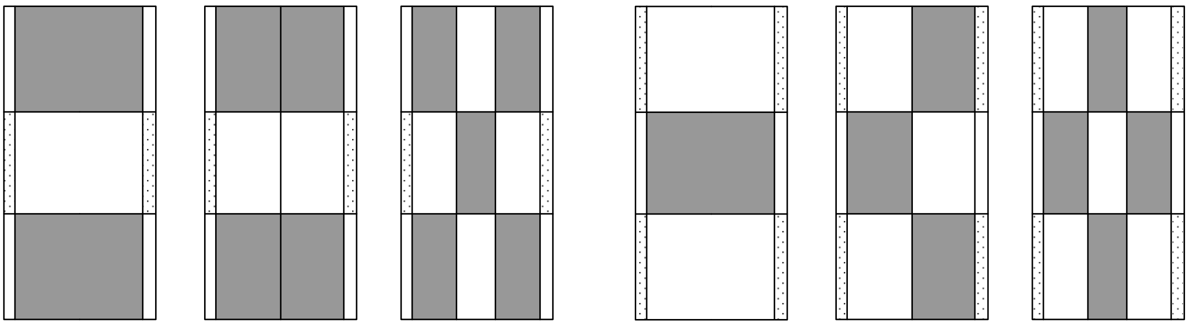
Except for special loading cases, the loading patterns shown in 5A-3-2/Figures 1A to 1C are to be considered in determining local static loads.

FIGURE 1A
Loading Pattern – Double Hull and Double Side Single Bottom FPSO/FSO
(December 2008)



a. Load Cases No. 1 and 3
2/3 Scantling Draft

b. Load Cases No. 2 and 4
0.9 Scantling Draft

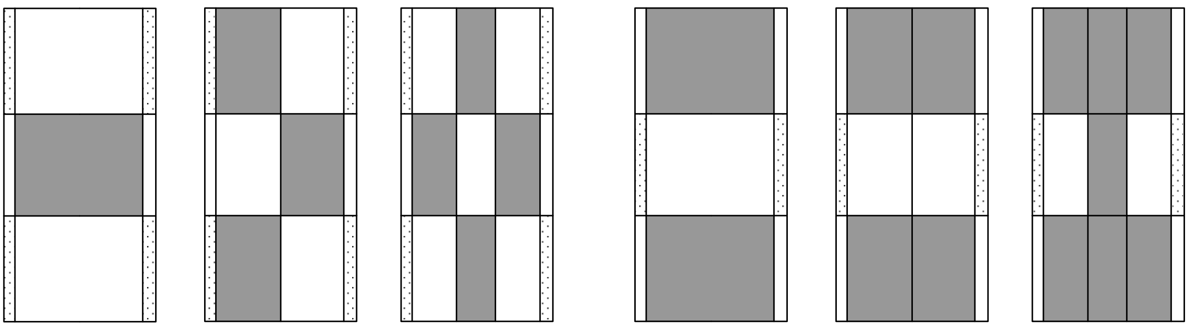


c. Load Case No. 5
2/3 Scantling Draft

g. Load Case No. 9 *
1/4 Scantling Draft

d. Load Case No. 6
2/3 Scantling Draft

h. Load Case No. 10 *
1/4 Scantling Draft



e. Load Case No. 7
2/3 Scantling Draft

f. Load Case No. 8
0.9 Scantling Draft 0.95 Scantling Draft

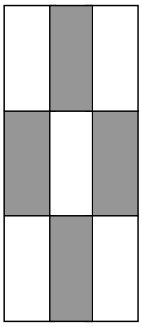
For detailed loading information see 5A-3-2/Tables 1A through 1C.

* For L.C. 9 and 10, where static conditions, such as tank testing, that have the same loading 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. 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.

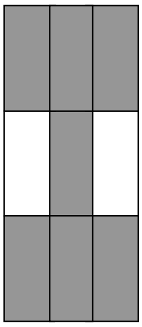
(1 July 2005) For a hull structure with the main supporting members that are asymmetric forward and aft of the mid-tank transverse bulkheads, the above load cases are to be evaluated by turning the finite element model by 180 degrees with respect to the vertical axis.

(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.

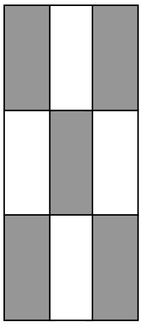
FIGURE 1B
Loading Pattern – Single Hull FPSO/FSO *(December 2008)*



a. Load Cases No. 1 and 3
2/3 Scantling Draft

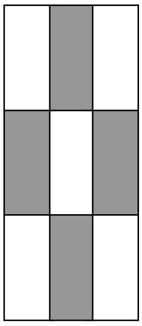


b. Load Cases No. 2 and 4
0.95 Scantling Draft



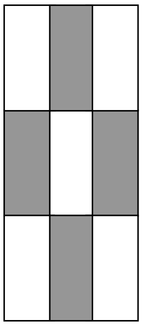
c. Load Case No. 5
2/3 Scantling Draft

g. Load Case No. 9 *
1/3 Scantling Draft

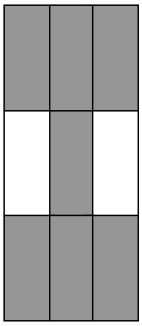


d. Load Case No. 6
2/3 Scantling Draft

h. Load Case No. 10 *
1/3 Scantling Draft



e. Load Case No. 7
2/3 Scantling Draft



f. Load Case No. 8
0.95 Scantling Draft

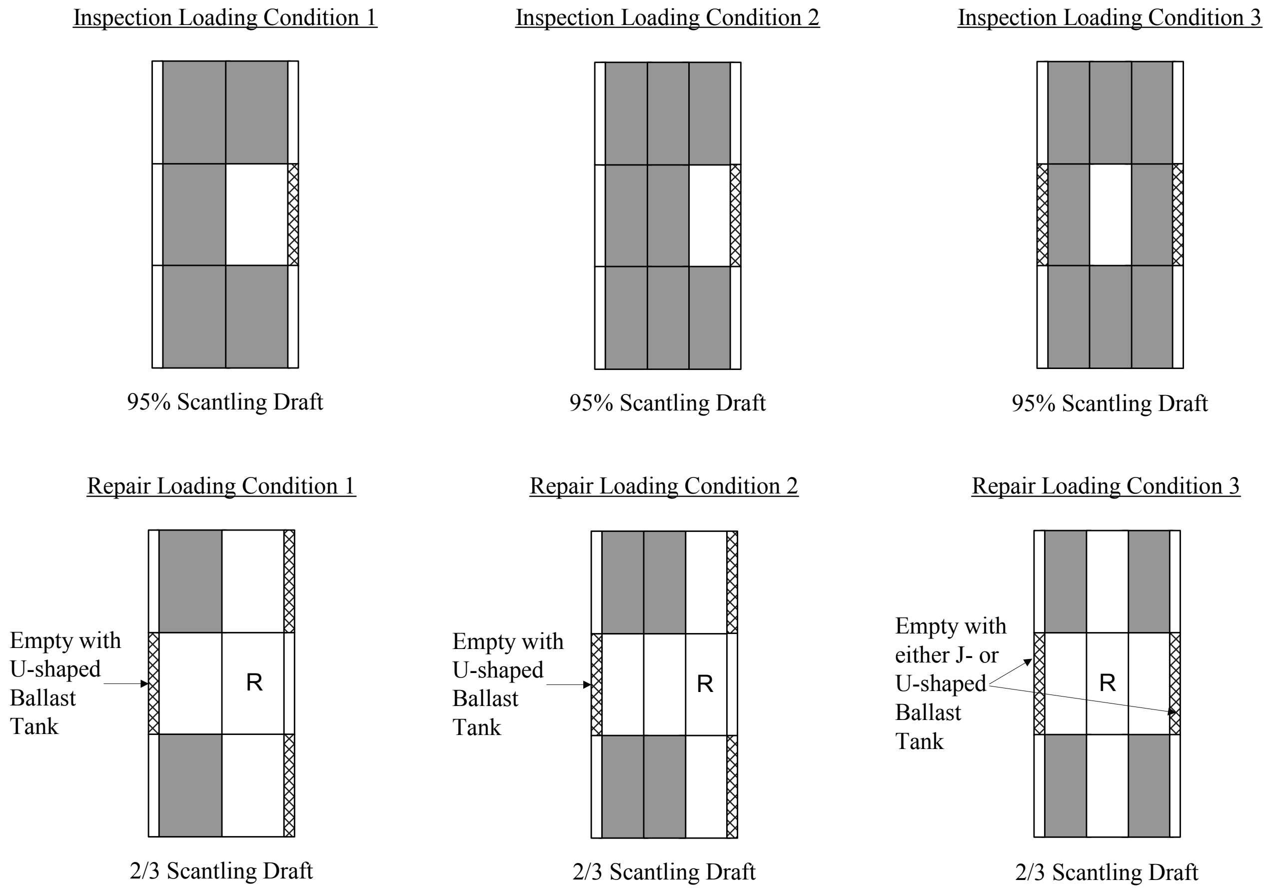
For detailed loading information see 5A-3-2/Tables 1A through 1C.

* For L.C. 9 and 10, where static conditions, such as tank testing, that have the same loading pattern as the center row of tanks resulting in a draft less than 1/3 Design Draft, the actual static condition 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.

(1 July 2005) For a hull structure with the main supporting members that are asymmetric forward and aft of 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.

FIGURE 1C
Loading Pattern – Repair and Inspection Conditions for Double Hull and Double Side Single Bottom FPSO/FSO* *(1 July 2009)*

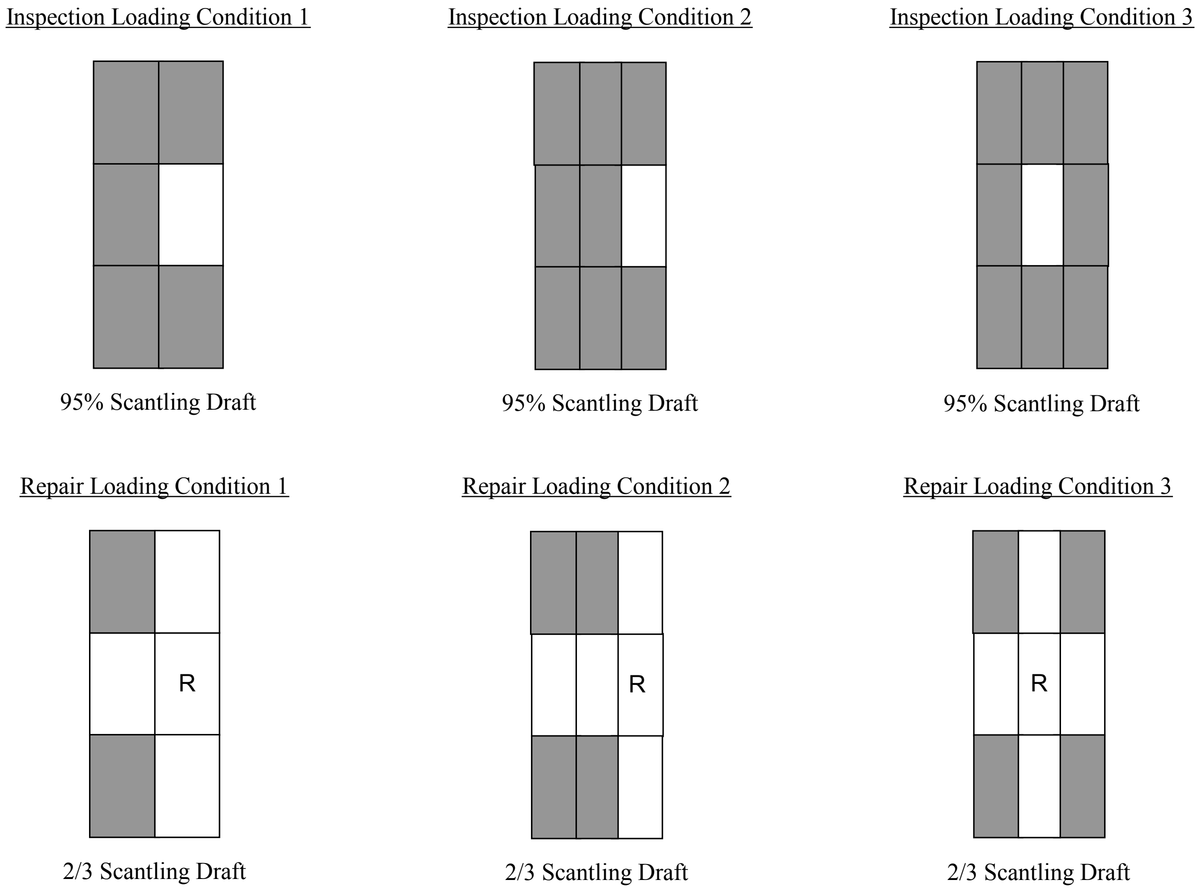
Unless more severe inspection or repair loading condition is specified by the operator, the following minimum design inspection and repair loading conditions are to be used.



* For double hull or double side structure with one cargo tank across, no loading conditions for inspection and repair are given above as they are covered under standard loading conditions shown in 5A-3-2/Figure 1A.

FIGURE 1D
Loading Pattern – Repair and Inspection Conditions for Single Hull FPSO/FSO
(December 2008)

Unless more severe inspection or repair loading condition is specified by the operator, the following minimum design inspection and repair loading conditions are to be used.



5 Wave-induced Loads *(1995)*

5.1 General *(1 July 2009)*

Where a direct calculation of the wave-induced loads is not available, the approximation equations given in the following sections and specified in 3-2-1/3.5 of the *Steel Vessel Rules* with Environmental Severity Factors (ESFs) 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.

5.2 Vertical Wave Bending Moment and Shear Force *(1 July 2012)*

5.2.1 Wave Bending Moment Amidships

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

$$M_{ws} = -\,k_1\,\beta_{VBM}\,C_1 L^2 B(C_b + 0.7) \times 10^{-3} \qquad \text{Sagging Moment}$$

$$M_{wh} = +\,k_2\,\beta_{VBM}\,C_1 L^2 B C_b \times 10^{-3} \qquad \text{Hogging Moment}$$

where

k_1 = 110 (11.22, 1.026)

k_2 = 190 (19.37, 1.772)

β_{VBM} = ESF for vertical bending moment

$C_1 = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$ $90 \le L \le 300$ m

$= 10.75$ $300 < L \le 350$ m

$= 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$ $350 \le L \le 500$ m

$C_1 = 10.75 - \left(\frac{984 - L}{328}\right)^{1.5}$ $295 \le L \le 984$ ft

$= 10.75$ $984 < L < 1148$ ft

$= 10.75 - \left(\frac{L - 1148}{492}\right)^{1.5}$ $1148 \le L \le 1640$ ft

L = length of vessel, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5 of the *Steel Vessel Rules*, in m (ft)

C_b = block coefficient, as defined in 3-1-1/11.3 of the *Steel Vessel Rules*

5.2.2 Envelope Curve of Wave Bending Moment

The wave bending moment along the length, L, of the vessel, may be obtained by multiplying the midship value by the distribution factor, M, given in 5A-3-2/Figure 3.

5.2.3 Wave Shear Force

The envelopes of maximum shearing forces induced by waves, F_w, as shown in 5A-3-2/Figure 4 and 5A-3-2/Figure 5, may be obtained from the following equations.

$F_{wp} = +k\, \beta_{VSF}\, F_1 C_1 L\, B\, (C_b + 0.7) \times 10^{-2}$ for positive shear force

$F_{wn} = -k\, \beta_{VSF}\, F_2 C_1 L\, B\, (C_b + 0.7) \times 10^{-2}$ for negative shear force

where

F_{wp}, F_{wn} = maximum shearing force induced by wave, in kN (tf, Ltf)

C_1 = as defined in 5A-3-2/5.2.1

β_{VSF} = ESF for vertical shear force

L = length of vessel, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5 of the *Steel Vessel Rules*, in m (ft)

C_b = block coefficient, as defined in 3-1-1/11.3 of the *Steel Vessel Rules*

k = 30 (3.059, 0.2797)

F_1 = distribution factor, as shown in 5A-3-2/Figure 4

F_2 = distribution factor, as shown in 5A-3-2/Figure 5

FIGURE 2
Sign Convention *(1 July 2012)*

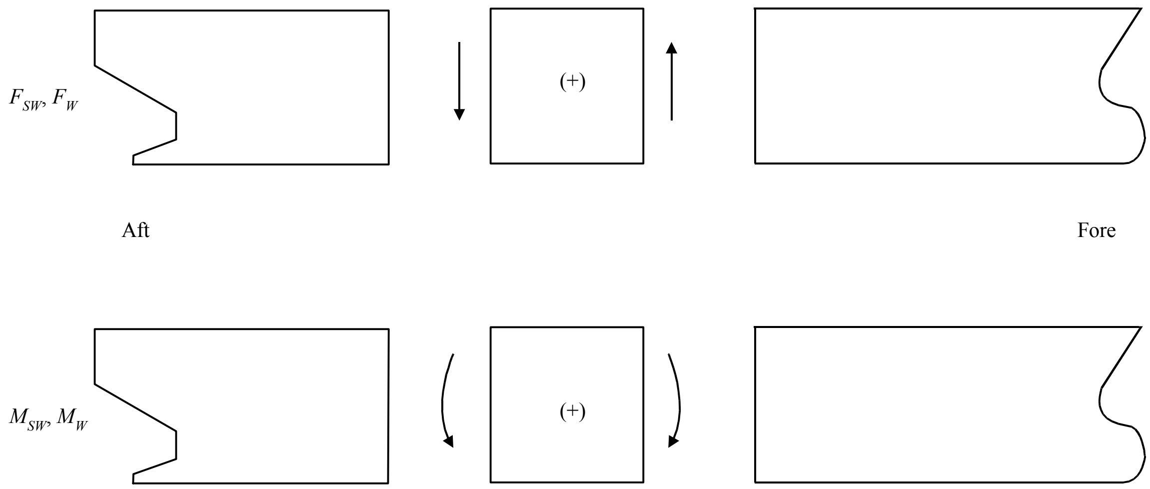


FIGURE 3
Distribution Factor M *(1 July 2012)*

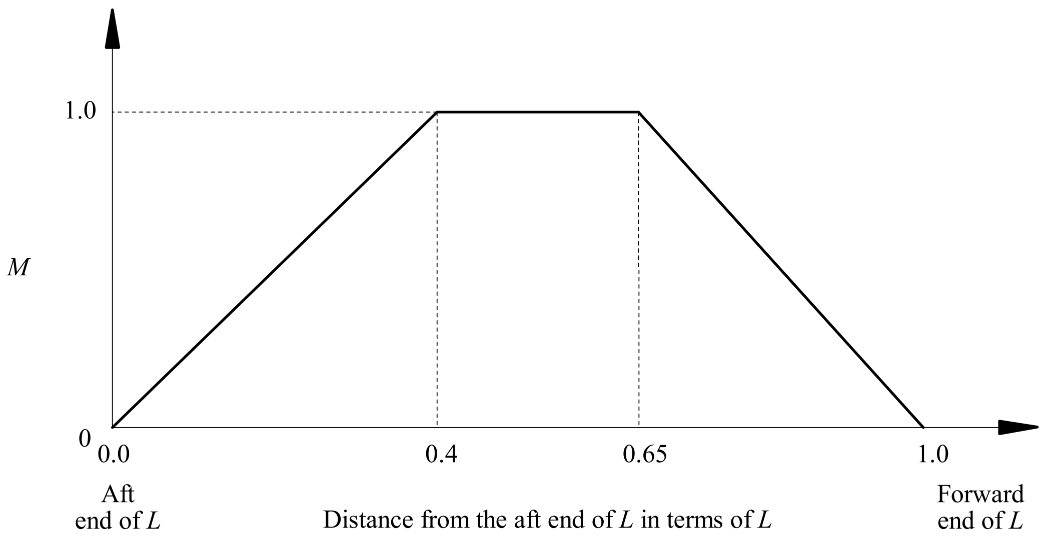


FIGURE 4
Distribution Factor F_1 *(1 July 2012)*

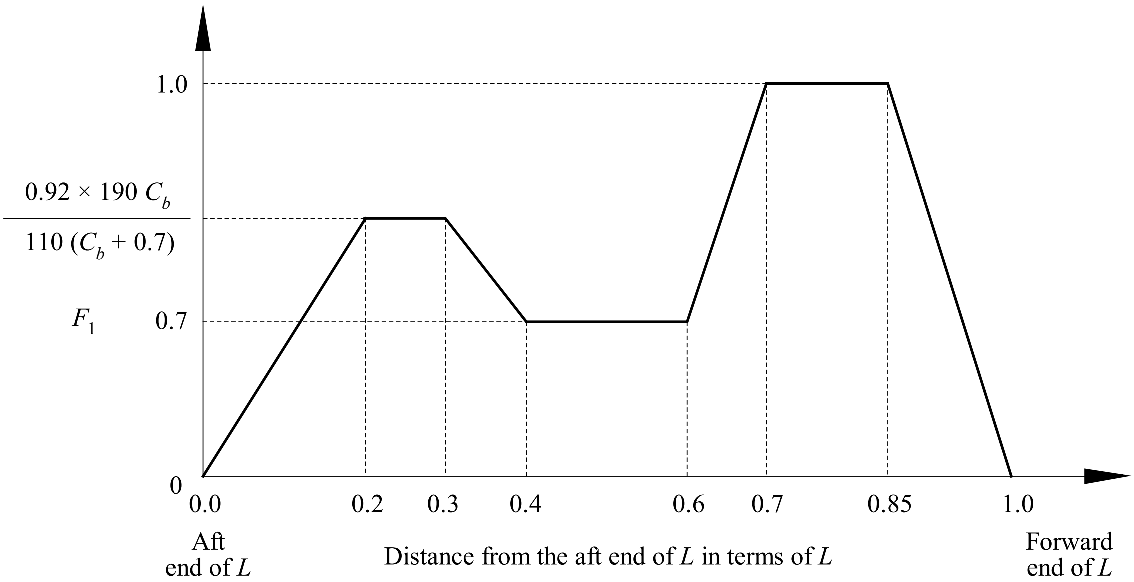
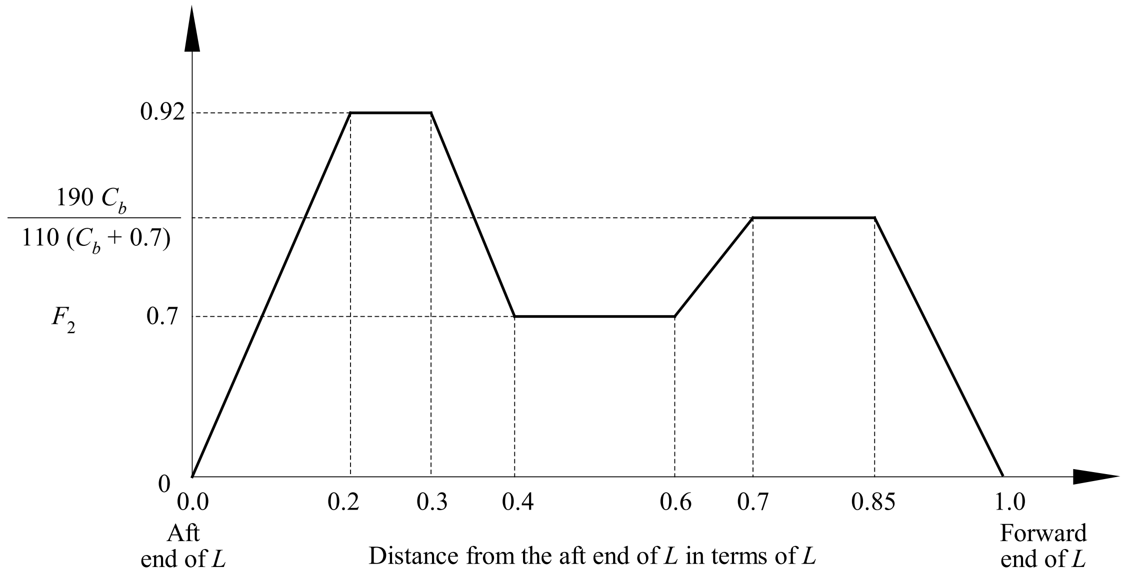


FIGURE 5
Distribution Factor F_2 *(1 July 2012)*



5.3 Horizontal Wave Bending Moment and Shear Force

5.3.1 Horizontal Wave Bending Moment *(1 September 2007)*

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

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

where

m_h = distribution factor, as given by 5A-3-2/Figure 6

β_{HBM} = ESF for horizontal bending moment, as defined in 5A-3-A1/3

K_3 = 180 (18.34, 1.68)

D = hull depth of installation, as defined in 3-1-1/7 of the *Steel Vessel Rules*, in m (ft)

C_1, L, and C_b are as given in 3-2-1/3.5 of the *Steel Vessel Rules*.

5.3.2 Horizontal Wave Shear Force *(1 September 2007)*

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:

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

where

f_h = distribution factor, as given in 5A-3-2/Figure 7

β_{HSF} = ESF for horizontal shear force, as defined in 5A-3-A1/3

k = 36 (3.67, 0.34)

C_1, L, D and C_b are as defined in 5A-3-2/5.3.1 above.

5.5 External Pressures

5.5.1 Pressure Distribution *(1 September 2007)*

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:

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

where

ρg = specific weight of sea water

= 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft)

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

$\beta_{EPS/EPP}$ = ESF for external pressure starboard/port, as defined in 5A-3-A1/3

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 5A-3-2/7.1 and 5A-3-2/9

h_{di} = hydrodynamic pressure head, in m (ft), at location i (i =1, 2, 3, 4 or 5; see 5A-3-2/Figure 8)

= $k_\ell \alpha_i h_{do}$ in m (ft)

k_ℓ = distribution factor along the length of the installation

= $1 + (k_{\ell o} - 1)\cos\mu$, $k_{\ell o}$ is as given in 5A-3-2/Figure 9

= 1.0 amidships

h_{do} = $1.36\,kC_1$ in m (ft)

C_1 = as defined in 3-2-1/3.5 of the *Steel Vessel Rules*

k = 1 (1, 3.281)

α_i = distribution factor around the girth of installation 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 5A-3-2/Figure 10.

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 5A-3-2/5.5.1 with k_u as given in 5A-3-2/7 and 5A-3-2/9.

5.5.3 Simultaneous Pressures *(1 September 2007)*

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

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

where

$\beta_{EPS/EPP}$ = ESF for external pressure starboard/port, as defined in 5A-3-A1/3

k_f is a factor denoting the phase relationship between the reference station and adjacent stations considered along the installation'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 = installation length, as defined in 3-1-1/3 of the *Steel Vessel Rules*, in m (ft)

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

k_{fo} = ±1.0, as specified in 5A-3-2/Tables 1A through 1C

* The reference station is the point along the installation'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 installation is to be determined based on the wave heading angles specified in 5A-3-2/7 and 5A-3-2/9.

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

5.7.1 Ship Motions and Accelerations *(1 September 2007)*

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 (1997). The pitch amplitude: (positive bow up)

$\phi = \beta_{PMO} k_1 (10/C_b)^{1/4}/L$, 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

β_{PMO} = ESF for pitch motion, as defined in 5A-3-A1/3

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

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

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 of the *Steel Vessel Rules (January 2005)*, respectively.

5.7.1(b) Roll. The roll amplitude: (positive starboard down)

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

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

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

where

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

k_θ = 0.005 (0.05, 0.051)

C_R = 1.05

β_{RMO} = ESF for roll motion, as defined in 5A-3-A1/3

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 of the *Steel Vessel Rules*, m (ft)

Δ = $k_d LBd_f C_b$ kN (tf, Ltf)

k_d = 10.05 (1.025, 0.0286)

L and B are as defined in Section 3-1-1 of the *Steel Vessel Rules (January 2005)*.

The roll natural motion period:

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

where

k_4 = 2 (1.104) for k_r, GM in m (ft)

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

GM = metacentric height, to be taken as:

= GM (full) for full draft

= 1.1 GM (full) for 9/10 d_f

= 1.5 GM (full) for 2/3 d_f

= 2.0 GM (full) for 1/2 d_f

GM (full) = metacentric height for fully loaded condition

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

5.7.1(c) Accelerations. 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:

$a_v = C_v \beta_{VAC} k_v a_o g$ m/sec² (ft/sec²) positive downward

$a_\ell = C_\ell \beta_{LAC} k_\ell a_o g$ m/sec² (ft/sec²) positive forward

$a_t = C_t \beta_{TAC} k_t a_o g$ m/sec² (ft/sec²) positive starboard

where

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

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

k_o = $1.34 - 0.47C_b$

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

μ = wave heading angle in degrees, 0° for head sea, and 90° for beam sea for wave coming from starboard

β_{VAC} = ESF for vertical acceleration, as defined in 5A-3-A1/3

β_{LAC} = ESF for longitudinal acceleration, as defined in 5A-3-A1/3

β_{TAC} = ESF for transverse acceleration, as defined in 5A-3-A1/3

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

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

C_ℓ = $0.35 - 0.0005(L - 200)$ for L in m

= $0.35 - 0.00015(L - 656)$ for L in ft

k_ℓ = $0.5 + 8y/L$

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 installation respectively, as defined in Section 3-1-1 of the *Steel Vessel Rules (January 2005)*, 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/sec^2 (32.2 ft/sec^2)

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:

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

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

where

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

p_n = 2.06 N/cm^2 (0.21 kgf/cm^2, 3.00 lbf/in^2)

ρg = specific weight of the liquid, not to be taken less than 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft)

η = local coordinate in vertical direction for tank boundaries measuring from the top of the tanks, as shown 5A-3-2/Figure 11, 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 = load factor – see also 5A-3-2/5.7.2(c)

= 1.0 for structural members 1 through 10 in 5A-3-2/Table 3, and for all loads from ballast tanks

= 0.878 for ρg of 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft) and 1.0 for ρg of 1.118 N/cm^2-m (0.114 kgf/cm^2-m, 0.4942 lbf/in^2-ft) and above for structural members 11 through 17 in 5A-3-2/Table 3

For cargo ρg between 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft) and 1.118 N/cm^2-m (0.114 kgf/cm^2-m, 0.4942 lbf/in^2-ft), the factor k_s may be determined by interpolation

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

h_d = wave-induced internal pressure head, including inertial force and added pressure head.

= $k_c(\eta\, a_i/g + \Delta h_i)$, in m (ft)

k_c = correlation factor and may be taken as unity unless otherwise specified

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

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

C_{dp} is as specified in 5A-3-2/5.7.2(d).

a_v, a_ℓ and a_t are as given in 5A-3-2/5.7.1(c).

w_v, w_ℓ and w_t are weighted coefficients, showing directions, as specified in 5A-3-2/Tables 1A through 1C and 5A-3-2/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 ($\phi_e < 0$, $\theta_e > 0$)

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

ζ_e = $b - \zeta$

η_e = η

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

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

ζ_e = $\zeta - \delta_b$

η_e = $\eta - \delta_h$

ξ, ζ, η are the local coordinates, in m (ft), for the point considered with respect to the origin in 5A-3-2/Figure 11.

C_{ru} is as specified in 5A-3-2/5.7.2(d).

δ_b and δ_h are local coordinates adjustments, in m (ft), for the point considered with respect to the origin shown in 5A-3-2/Figure 11.

where

θ_e = $0.71\, C_\theta\, \theta$

ϕ_e = $0.71\, C_\phi\, \phi$

ℓ = length of the tank, in m (ft)

h = depth of the tank, in m (ft)

b = breadth of the tank considered, in m (ft)

ϕ and θ are pitch and roll amplitudes, as given in 5A-3-2/5.7.1(a) and 5A-3-2/5.7.1(b).

C_ϕ and C_θ are weighted coefficients, showing directions as given in 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3.

Where pressure-vacuum valves of cargo tanks are set at greater than 2.06 N/cm^2 (0.21 kgf/cm^2, 3 lbf/in^2), 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 5A-3-2/7, 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 5A-3-2/5.7.2(a) and 5A-3-2/5.7.2(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 installation.

Note: In performing a 3D structural analysis, k_s in 5A-3-2/5.7.2(a) is to be taken as:

k_s = 1.0 for all loads from ballast tanks

= 0.878 for ρg of 1.005 N/cm²-m (0.1025 kgf/cm²-m, 0.4444 lbf/in²-ft) and 1.0 for ρg of 1.118 N/cm²-m (0.114 kgf/cm²-m, 0.4942 lbf/in²-ft) and above for all loads from cargo tanks

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.

$b/b_1 \geq 5.0$ 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 5A-3-2/Figure 11

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:

$b/b_1 \leq 3.0$ 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:

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

U-shaped Tank in non-head seas:

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

U-shaped Tank:

C_{ru} = 1.0 – 0.3 (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 6
Distribution Factor m_h (1995)

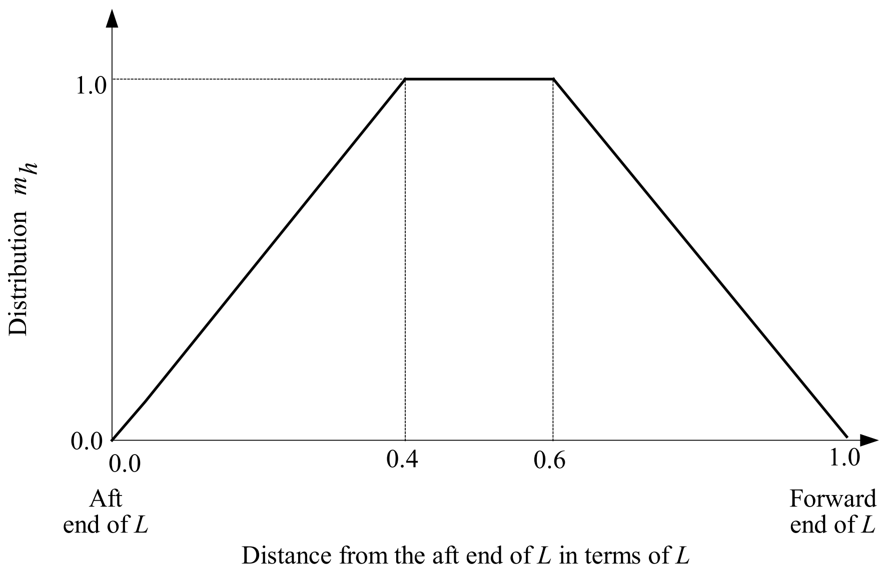


FIGURE 7
Distribution Factor f_h (1995)

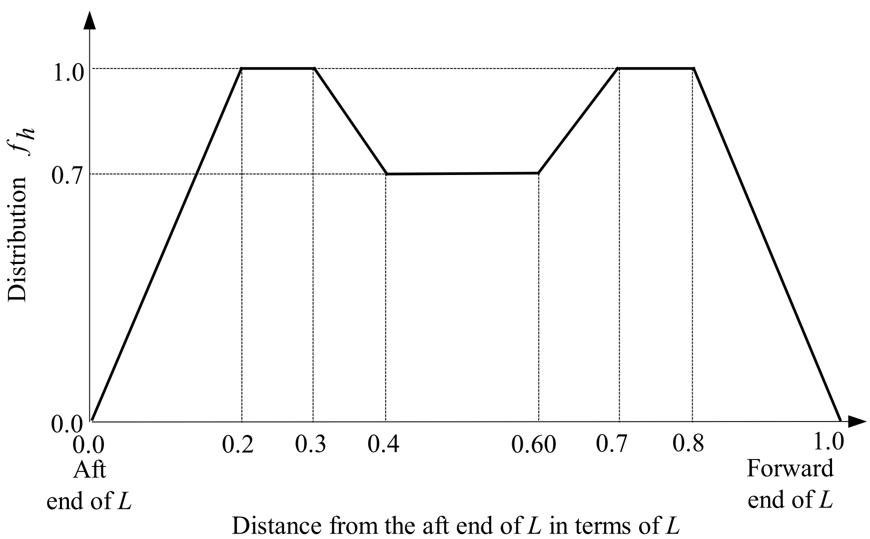
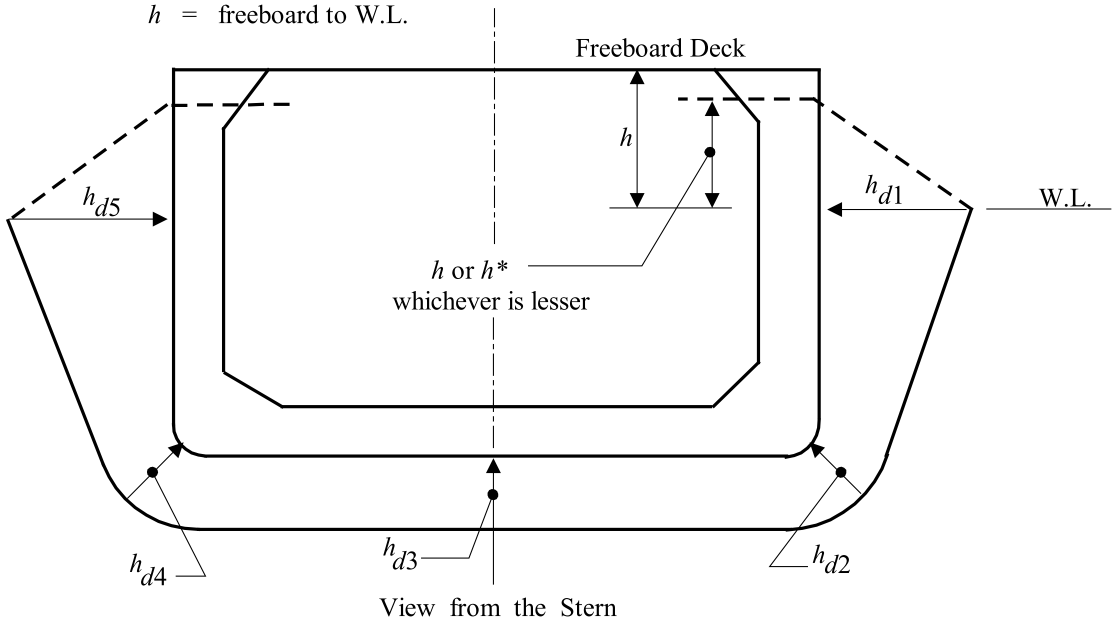


FIGURE 8
Distribution of h_{di} (1995)



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

FIGURE 9
Pressure Distribution Function $k_{\ell o}$ (1995)

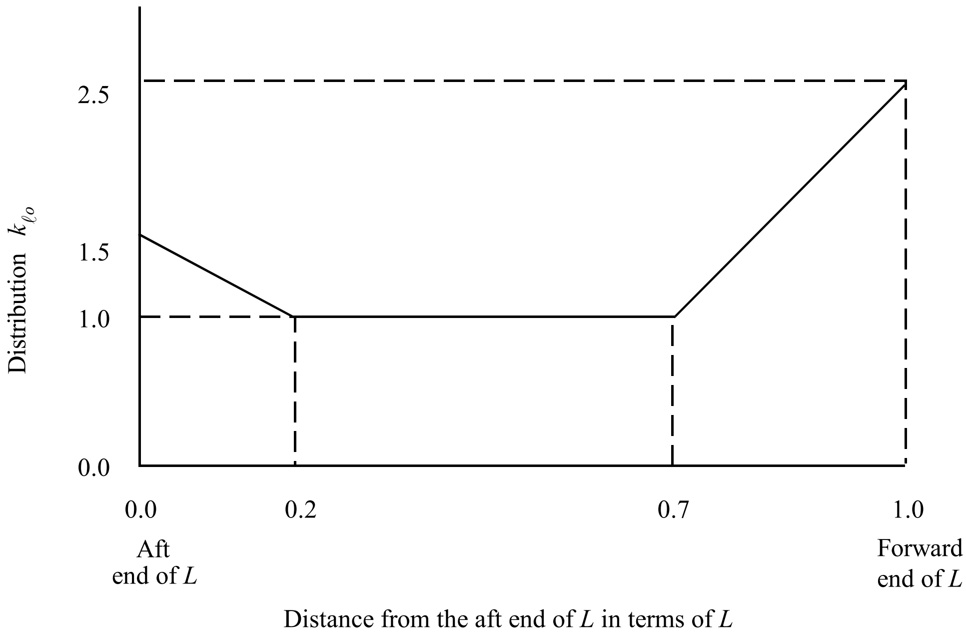
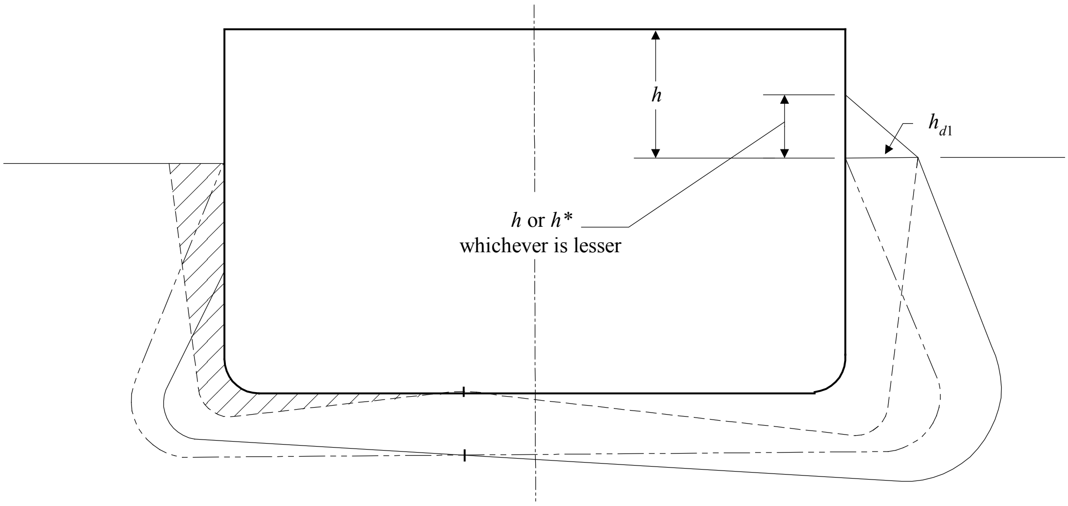


FIGURE 10
Illustration of Determining Total External Pressure *(1997)*



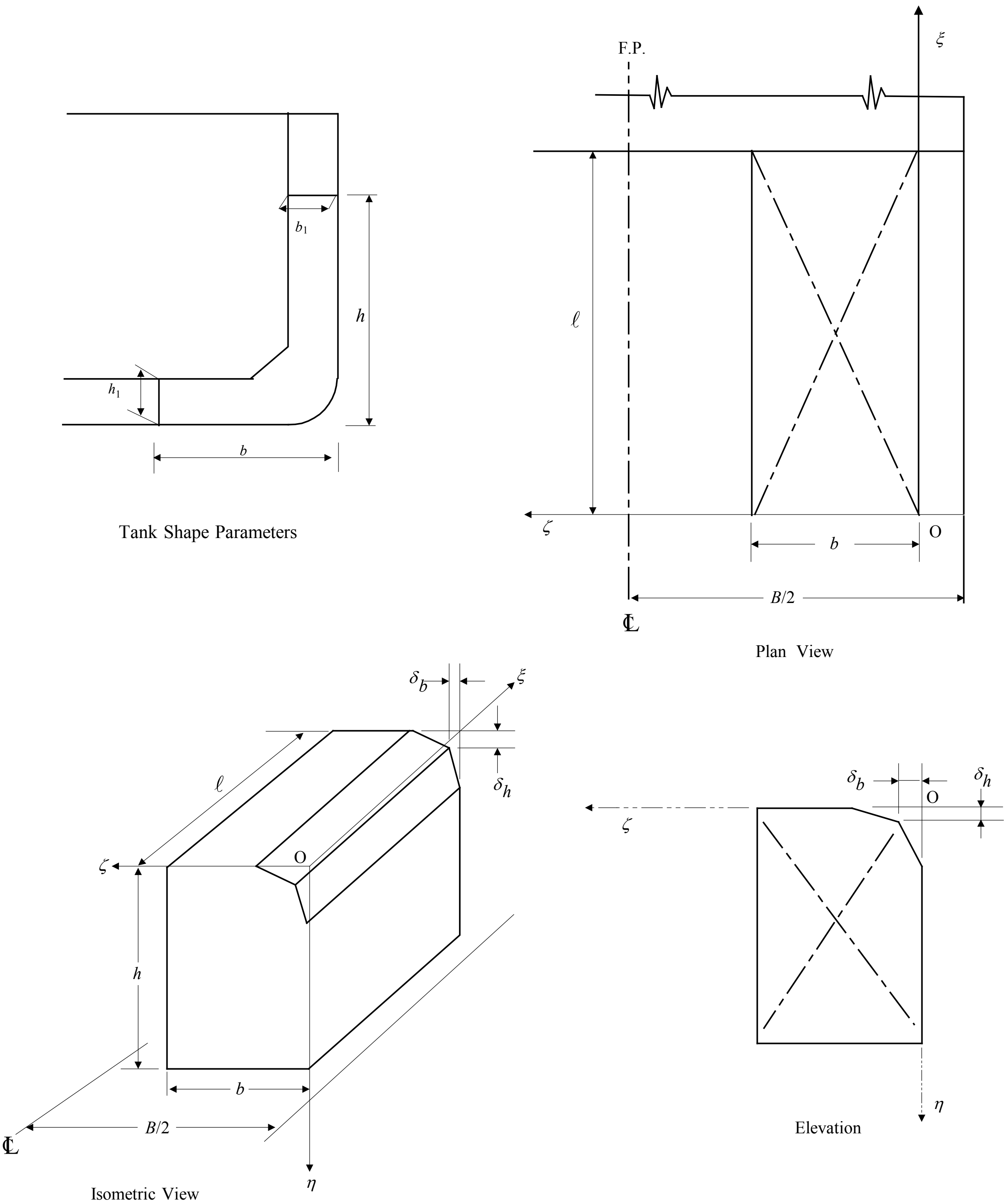
h_d : Hydrodynamic Pressure Head (indicates negative)

h_s : Hydrostatic Pressure Head in Still Water

: Total External Pressure Head

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

FIGURE 11
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).

FIGURE 12
Location of Tank for Nominal Pressure Calculation *(1997)*

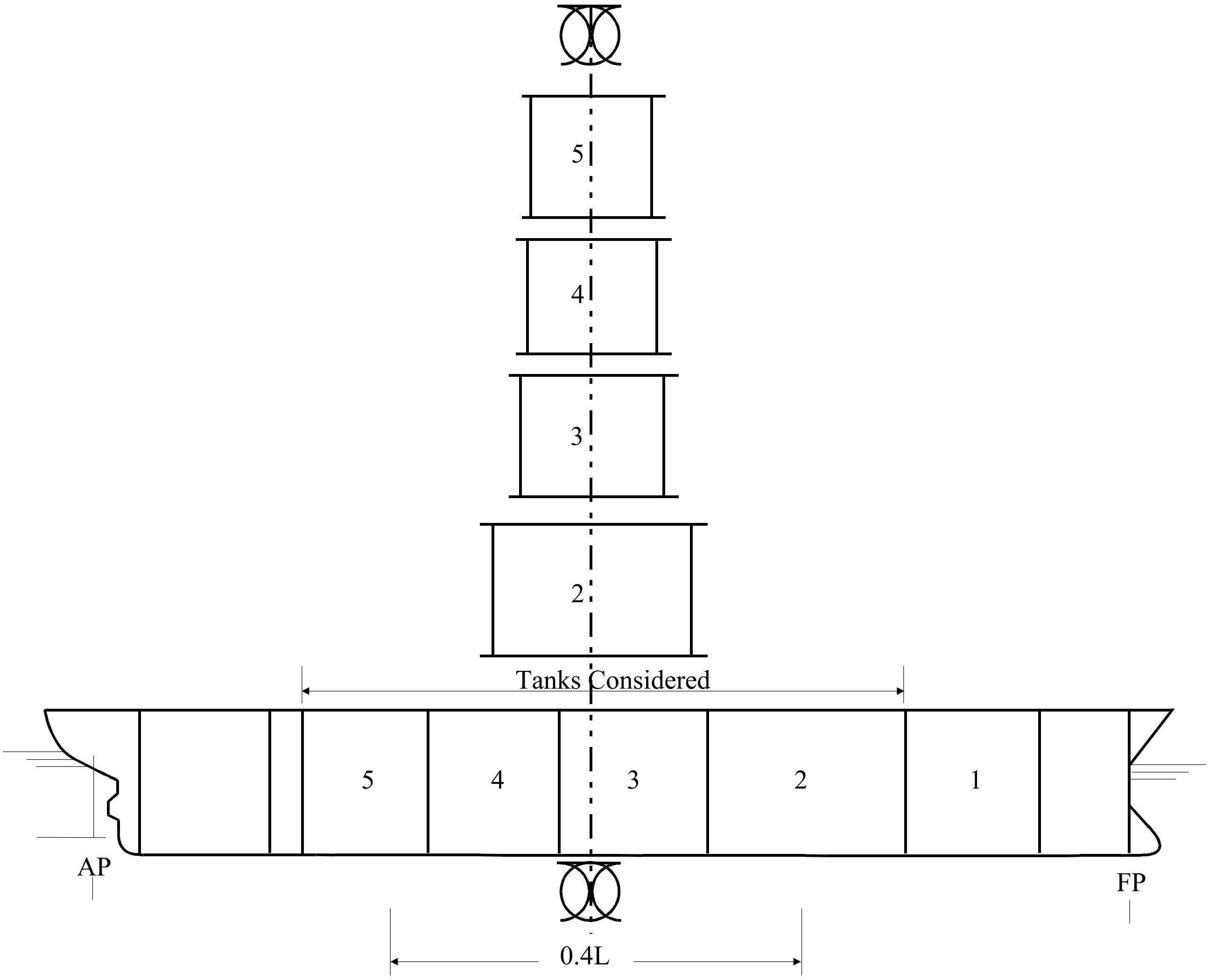


TABLE 1A
Combined Load Cases* *(2001)*

	L.C. 1	*L.C. 2*	*L.C. 3*	*L.C. 4*	*L.C. 5*	*L.C. 6*	*L.C. 7*	*L.C. 8*	*L.C. 9*	*L.C. 10*
A. Hull Girder Loads (See 5A-3-2/5)**										
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	—	—
k_c	1.0	1.0	0.7	0.7	0.3	0.3	0.4	0.4	0.0	0.0
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)	—	—
k_c	0.5	0.5	1.0	1.0	0.3	0.3	0.4	0.4	0.0	0.0
Horizontal B.M.					(–)	(+)	(–)	(+)	—	—
k_c	0.0	0.0	0.0	0.0	0.3	0.3	1.0	1.0	0.0	0.0
Horizontal S.F.					(+)	(–)	(+)	(–)	—	—
k_c	0.0	0.0	0.0	0.0	0.3	0.3	0.5	0.5	0.0	0.0
B. External Pressure (See 5A-3-2/5.5)										
k_c	0.5	0.5	0.5	1.0	0.5	1.0	0.5	1.0	0.0	0.0
k_{f0}	-1.0	1.0	-1.0	1.0	-1.0	1.0	-1.0	1.0	0.0	0.0
C. Internal Tank Pressure (See 5A-3-2/5.7)										
k_c	0.4	0.4	1.0	0.5	1.0	0.5	1.0	0.5	0.0	0.0
w_v	0.75	-0.75	0.75	-0.75	0.25	-0.25	0.4	-0.4	0.0	0.0
w_ℓ	Fwd Bhd 0.25	Fwd Bhd -0.25	Fwd Bhd 0.25	Fwd Bhd -0.25	—	—	Fwd Bhd 0.2	Fwd Bhd -0.2	—	—
	Aft Bhd -0.25	Aft Bhd 0.25	Aft Bhd -0.25	Aft Bhd 0.25	—	—	Aft Bhd -0.2	Aft Bhd 0.2	—	—
w_t	—	—	—	—	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.4	Port Bhd 0.4	—	—
	—	—	—	—	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.4	Stbd Bhd -0.4	—	—
c_ϕ, Pitch	-1.0	1.0	-1.0	1.0	0.0	0.0	-0.7	0.7	0.0	0.0
c_θ, Roll	0.0	0.0	0.0	0.0	1.0	-1.0	0.7	-0.7	0.0	0.0
D. Reference Wave Heading and Motion of Installation										
Heading Angle	0	0	0	0	90	90	60	60	—	—
Heave	Down	Up	Down	Up	Down	Up	Down	Up	—	—
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	—	—	Bow Down	Bow Up	—	—
Roll	—	—	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	—	—

* k_u = 1.0 for all load components.

** Boundary forces should be applied to produce the above specified hull girder bending moment at the middle of the structural model and the specified hull girder shear force at one end of the middle hold of the model. The sign convention for the shear force corresponds to the forward end of the middle hold.

TABLE 1B
Combined Load Cases for Inspection Condition* *(December 2008)*

	I.L.C. 1	*I.L.C. 2*	*I.L.C. 3*	*I.L.C. 4*	*I.L.C. 5*	*I.L.C. 6*	*I.L.C. 7*	*I.L.C. 8*	*I.L.C. 9*	*I.L.C. 10*
A. Hull Girder Loads (See 5A-3-2/5)**										
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.50	0.50	0.15	0.15	0.70	0.70	0.60	0.60
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.55	0.55	1.00	1.00	0.20	0.20	0.20	0.20	0.30	0.30
Horizontal B.M.					(–)	(+)	(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.00	0.00	0.25	0.25	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.00	0.00	0.25	0.25	0.85	0.85	0.80	0.80
B. External Pressure (See 5A-3-2/5.5)										
k_c	0.85	0.85	0.70	0.70	0.90	0.90	0.80	0.80	0.95	0.95
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure (See 5A-3-2/5.7)										
k_c	0.75	0.75	0.30	0.30	0.80	0.80	0.10	0.10	0.50	0.50
w_v	0.85	-0.85	0.55	-0.55	0.60	-0.60	0.10	-0.10	0.30	-0.30
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	Fwd Bhd 0.65	Fwd Bhd -0.65	—	—	Fwd Bhd 0.30	Fwd Bhd -0.30	Fwd Bhd 1.00	Fwd Bhd -1.00
	Aft Bhd -0.20	Aft Bhd 0.20	Aft Bhd -0.65	Aft Bhd 0.65	—	—	Aft Bhd -0.30	Aft Bhd 0.30	Aft Bhd -1.00	Aft Bhd 1.00
w_t	—	—	—	—	Port Bhd -1.00	Port Bhd 1.00	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.10	Port Bhd 0.10
	—	—	—	—	Stbd Bhd 1.00	Stbd Bhd -1.00	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.10	Stbd Bhd -0.10
c_ϕ, Pitch	-0.30	0.30	-0.60	0.60	-0.15	0.15	-0.10	0.10	-0.80	0.80
c_θ, Roll	0.00	0.00	0.00	0.00	1.00	-1.00	0.05	-0.05	0.15	-0.15
D. Reference Wave Heading and Motion of Installation										
Heading Angle	0	0	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

* k_u = 1.0 for all load components.

** Boundary forces should be applied to produce the above specified hull girder bending moment at the middle of the structural model and the specified hull girder shear force at one end of the middle hold of the model. The sign convention for the shear force corresponds to the forward end of the middle hold.

TABLE 1C
Combined Load Cases for Repair Condition* *(December 2008)*

	R.L.C. 1	*R.L.C. 2*	*R.L.C. 3*	*R.L.C. 4*	*R.L.C. 5*	*R.L.C. 6*	*R.L.C. 7*	*R.L.C. 8*	*R.L.C. 9*	*R.L.C. 10*
A. Hull Girder Loads (See 5A-3-2/5)**										
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.50	0.50	0.25	0.25	0.80	0.80	0.60	0.60
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.55	0.55	1.00	1.00	0.15	0.15	0.40	0.40	0.20	0.20
Horizontal B.M.					(–)	(+)	(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.00	0.00	0.15	0.15	0.80	0.80	0.80	0.80
B. External Pressure (See 5A-3-2/5.5)										
k_c	0.85	0.85	0.80	0.80	0.90	0.90	0.90	0.90	0.55	0.55
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure (See 5A-3-2/5.7)										
k_c	0.55	0.55	0.40	0.40	0.70	0.70	0.20	0.20	0.40	0.40
w_v	0.60	-0.60	0.35	-0.35	0.55	-0.55	0.15	-0.15	0.25	-0.25
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	Fwd Bhd 0.65	Fwd Bhd -0.65	—	—	Fwd Bhd 0.45	Fwd Bhd -0.45	Fwd Bhd 0.75	Fwd Bhd -0.75
	Aft Bhd -0.20	Aft Bhd 0.20	Aft Bhd -0.65	Aft Bhd 0.65	—	—	Aft Bhd -0.45	Aft Bhd 0.45	Aft Bhd -0.75	Aft Bhd 0.75
w_t	—	—	—	—	Port Bhd -0.95	Port Bhd 0.95	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.10	Port Bhd 0.10
	—	—	—	—	Stbd Bhd 0.95	Stbd Bhd -0.95	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.10	Stbd Bhd -0.10
c_ϕ, Pitch	-0.20	0.20	-0.45	0.45	-0.05	0.05	-0.10	0.10	-0.35	0.35
c_θ, Roll	0.00	0.00	0.00	0.00	1.00	-1.00	0.05	-0.05	0.05	-0.05
D. Reference Wave Heading and Motion of Installation										
Heading Angle	0	0	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

* k_u = 1.0 for all load components.

** Boundary forces should be applied to produce the above specified hull girder bending moment at the middle of the structural model and the specified hull girder shear force at one end of the middle hold of the model. The sign convention for the shear force corresponds to the forward end of the middle hold.

TABLE 2
Load Cases for Sloshing *(1997)*

Type A: For Horizontal Girder on the Aft Side of Transverse Bulkhead

	Hull Girder Loads (1)				*External Pressures*			*Sloshing Pressures* (2)		*Reference Wave Heading and Motions*			
	V.B.M. [*H.B.M.*	*V.S.F.* *H.S.F.*	k_u, k_u,	k_c k_c]	k_u	k_c	k_{fo}	k_u	k_c	*Heading Angle*	*Heave*	*Pitch*	*Roll*
LC S - 1	(–) [(–)	(+) (+)	1.0 1.0	0.4 0.7]	1.0	0.5	-1.0	1.0	1.0	60°	Down	Bow Down	Stbd Down
LC S - 2	(+) [(+)	(–) (–)	1.0 1.0	0.4 0.7]	1.0	1.0	1.0	1.0	1.0	60°	Up	Bow Up	Stbd Up

Type B: For Horizontal Girder on the Forward Side of Transverse Bulkhead

	Hull Girder Loads (1)				*External Pressures*			*Sloshing Pressures* (2)		*Reference Wave Heading and Motions*			
	V.B.M. [*H.B.M.*	*V.S.F.* *H.S.F.*	k_u, k_u,	k_c k_c]	k_u	k_c	k_{fo}	k_u	k_c	*Heading Angle*	*Heave*	*Pitch*	*Roll*
LC S - 1	(–) [(–)	(+) (+)	1.0 1.0	0.4 0.7]	1.0	0.5	1.0	1.0	1.0	60°	Up	Bow Up	Stbd Up
LC S - 2	(+) [(+)	(–) (–)	1.0 1.0	0.4 0.7]	1.0	1.0	-1.0	1.0	1.0	60°	Down	Bow Down	Stbd Down

Notes:

1 For determining the total vertical bending moment for the above two load cases, 70% of the maximum designed still water bending moment may be used at the specified wave vertical bending moment station.

where:

V.B.M. is vertical wave bending moment

V.S.F. is vertical wave shear force

H.B.M. is horizontal wave bending moment

H.S.F. is horizontal wave shear force

2 The vertical distribution of the sloshing pressure P_{is} is shown in 5A-3-2/Figure 13.

TABLE 3
Design Pressure for Local and Supporting Members

A. Plating & Longitudinals/Stiffeners

The nominal pressure, $p = |p_i - p_e|$, is to be determined from load cases "a" & "b" below, whichever is greater, with k_u = 1.10 and k_c = 1.0 unless otherwise specified in the table

	Case "a" – At fwd end of the tank				*Case "b" – At mid tank/fwd end of tank*			
Structural Members/ Components	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	*Coefficients* p_e	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	*Coefficients* p_e
1. Bottom Plating & Long'l	2/3 design draft/0°	Full ballast tank	A_i	A_e	design draft/0°	Midtank of empty ballast tanks	—	B_e
2. Inner Bottom Plating & Long'l	2/3 design draft/0°	Full ballast tank, cargo tanks empty	A_i	—	design draft/0°	Fwd end of full cargo tank, ballast tanks empty	A_i	—
3. Side Shell Plating & Long'l	2/3 design draft/60°	Starboard side of full ballast tank	B_i	A_e	design draft/60°	Midtank of empty ballast tanks	—	B_e
4. * Deck Plating & Long'l (Cargo Tank)	design draft/0°	Full cargo tank	D_i	—				
5. Deck Plating & Long'l (Ballast Tank)	2/3 design draft/0°	Full ballast tank	D_i	—				
6. * Inner Skin Long'l Bhd. Plating & Long'l	design draft/ 60°	Starboard side of full cargo tank, ballast tank empty	B_i	—	2/3 design draft/60°	Fwd. end and starboard side of full ballast tank, cargo tank empty	B_i	—
7. * Centerline Long'l Bhd. Plating & Long'l	design draft/ 60°	Full starboard cargo and ballast tanks, adjacent tank empty	E_i	—				
8. * Other Long'l Bhd. Plating & Long'l	design draft/ 60°	Starboard side of full inward cargo tanks, adjacent tank empty	B_i	—	design draft/60° *(1997)*	Fwd. end and starboard side of full outboard cargo tanks, adjacent tank empty	B_i	—
9. * Trans. Bhd. Plating & Stiffener (Cargo Tank)	design draft/0°	Fwd. bhd. of full cargo tank, adjacent tanks empty	A_i	—				
10. * Trans. Bhd. Plating & Stiffener (Ballast Tank)	2/3 design draft/0°	Fwd. bhd. of full ballast tank, adjacent tanks empty	A_i	—				

* See note 4

TABLE 3 (continued)
Design Pressure for Local and Supporting Members

B. Main Supporting Members

The nominal pressure, $p = |p_i - p_e|$, is to be determined at the mid-span of the structural member at starboard side of installation from load cases "a" & "b" below, whichever is greater, with k_u = 1.0 and k_c = 1.0 unless otherwise specified in the table

	Case "a" – Mid-tank for Transverses				*Case "b" – Mid-tank for Transverses*			
Structural Members/ Components	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	*Coefficients* p_e	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	*Coefficients* p_e
11. Double Bottom Floor & Girder	2/3 design draft/0°	Full cargo tank, ballast tanks empty	A_i	A_e	design draft/0°	Mid-tank, cargo and ballast tanks empty	—	B_e
12. Side Transverse	2/3 design draft/60°	Wing cargo tanks full	B_i	—	design draft/60°	Center cargo tank full, wing cargo tanks empty	—	B_e
13. Transverse on Long'l. Bhd.:								
Ship-type installation with C.L. Long'l, Bhd., without cross ties, (5A-3-3/ Figure 2A-b, 5A-3-3/Figure 2A-c):	2/3 design draft/60°	Starboard cargo tank full, port-empty	F_i	—				
Ship-type installation with four Long'l. Bhds. With cross ties:								
Cross Ties in wing cargo tanks (5A-3-3/ Figure 2A-d)	2/3 design draft/90°	Center cargo tank full, wing cargo tanks empty	C_i	—	2/3 design draft/90°	Center cargo tank empty, wing cargo tanks full	G_i	—
Cross Tie in center cargo tank, (5A-3-3/ Figure 2A-e)	2/3 design draft/60°	Wing cargo tanks full, center cargo tank empty	F_i	—	2/3 design draft/60°	Center cargo tank full, wing cargo tanks empty	B_i	—
Ship-type installation with four Long'l. Bhds. without cross ties, (5A-3-3/ Figure 2A-f)	2/3 design draft/60°	Wing cargo tanks full, center cargo tank empty	F_i	—	2/3 design draft/60°	Center cargo tank full, wing cargo tanks empty	C_i	—
14. Horizontal Girder and Vertical Web on Transverse Bulkhead	2/3 design draft/60°	Fwd Bhd. of full cargo tank, adjacent tanks empty	B_i	—				
15. Cross Ties: Cross Ties in wing cargo tanks 5A-3-3/Figure 2A-d)	2/3 design draft/90°	Center cargo tank full, wing cargo tanks empty	C_i	—	design draft/60°	Wing cargo tanks empty, center cargo tank full (starboard)	—	B_e
Cross tie in center cargo tank (5A-3-3/Figure 2A-e)	2/3 design draft/60°	Wing cargo tanks full, center cargo tank empty	F_i	—				

TABLE 3 (continued)
Design Pressure for Local and Supporting Members

B. Main Supporting Members

The nominal pressure, $p = |p_i - p_e|$, is to be determined at the mid-span of the structural member at starboard side of installation from load cases "a" & "b" below, whichever is greater, with k_u = 1.0 and k_c = 1.0 unless otherwise specified in the table

	Case "a" – Mid-tank for Transverses				*Case "b" – Mid-tank for Transverses*			
Structural Members/ Components	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients*		*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients*	
			p_i	p_e			p_i	p_e
16. Deck Transverses: Ship-type installation without cross ties (5A-3-3/ Figure 2A-a, 5A-3-3/Figure 2A-b, 5A-3-3/ Figure 2A-c & 5A-3-3/ Figure 2A-f) and, ship-type installations with cross tie in center cargo tanks, (5A-3-3/ Figure 2A-e)	2/3 design draft/60°	Cargo tank full, adjacent tanks empty	B_i	—				
Ship-type installation with cross ties in wing cargo tanks (5A-3-3/ Figure 2A-d)	2/3 design draft/90°	Cargo tank full, adjacent tanks empty	C_i	—				
17. Deck girders	2/3 design draft/0°	Cargo tank full, adjacent tanks empty	A_i	—	2/3 design draft/60°	Cargo tank full, adjacent tanks empty	B_i	—

TABLE 3 (continued)
Design Pressure for Local and Supporting Members *(2001)*

Notes

1 For calculating p_i and p_e, the necessary coefficients are to be determined based on the following designated groups:

a) For p_i

A_i: $w_v = 0.75$, w_ℓ(fwd bhd) $= 0.25$, w_ℓ(aft bhd) $= -0.25$, $w_t = 0.0$, $c_\phi = -1.0$, $c_\theta = 0.0$

B_i: $w_v = 0.4$, w_ℓ(fwd bhd) $= 0.2$, w_ℓ(aft bhd) $= -0.2$, w_t(starboard) $= 0.4$, w_t(port) $= -0.4$, $c_\phi = -0.7$, $c_\theta = 0.7$

C_i: $w_v = 0.25$, $w_\ell = 0$, w_t(starboard) $= 0.75$, w_t(port) $= -0.75$, $c_\phi = 0.0$, $c_\theta = 1.0$

D_i: $w_v = -0.75$, w_ℓ(fwd bhd) $= 0.25$, $w_t = 0.0$, $c_\phi = -1.0$, $c_\theta = 0.0$

E_i: $w_v = 0.4$, w_ℓ(fwd bhd) $= 0.2$, w_t(centerline) $= 0.4$, $c_\phi = -0.7$, $c_\theta = -0.7$

F_i: $w_v = 0.4$, w_ℓ(fwd bhd) $= 0.2$, w_ℓ(aft bhd) $= -0.2$, w_t(starboard) $= -0.4$, w_t(port) $= 0.4$, $c_\phi = -0.7$, $c_\theta = -0.7$

G_i: $w_v = 0.25$, $w_\ell = 0$, w_t(starboard) $= -0.75$, w_t(port) $= 0.75$, $c_\phi = 0.0$, $c_\theta = -1.0$

b) For p_e

A_e: $k_{\ell o} = 1.0$, $k_u = 1.0$, $k_c = -0.5$

B_e: $k_{\ell o} = 1.0$

2 *(1997)* For structures within $0.4L$ amidships, the nominal pressure is to be calculated for a tank located amidships. Each cargo tank or ballast tank in the region should be considered as located amidships, as shown in 5A-3-2/Figure 12.

3 *(1 July 2000)* In calculation of the nominal pressure, ρg of the fluid cargoes is not to be taken less than 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft).

4 For structural members 4 and 6 to 10, sloshing pressures are to be considered in accordance with 5A-3-2/11.3. For calculation of sloshing pressures, refer to 5A-3-2/11.5 with ρg not less than 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft).

7 Nominal Design Loads *(1995)*

7.1 General

The nominal design loads specified below are to be used for determining the required scantlings of hull structures in conjunction with the specified permissible stresses given in Section 5A-3-3.

7.3 Hull Girder Loads – Longitudinal Bending Moments and Shear Forces *(1995)*

7.3.1 Total Vertical Bending Moment and Shear Force *(1 September 2007)*

The total longitudinal vertical bending moments and shear forces may be obtained from the following equations:

$$M_t = M_{sw} + k_u\, k_c \beta_{VBM} M_w \qquad \text{kN-m (tf-m, Ltf-ft)}$$

$$F_t = F_{sw} + k_u\, k_c \beta_{VSF} F_w \qquad \text{kN (tf, Ltf)}$$

where

M_{sw} and M_w are the still-water bending moment and wave-induced bending moment, respectively, as specified in 3-2-1/3.7 of the *Steel Vessel Rules* for either hogging or sagging conditions.

F_{sw} and F_w are the still-water and wave-induced shear forces, respectively, as specified in 3-2-1/3.9 of the *Steel Vessel Rules* for either positive or negative shears.

k_u is a load factor and may be taken as unity unless otherwise specified

k_c is a correlation factor and may be taken as unity unless otherwise specified.

β_{VBM} is ESF for vertical bending moment as defined in 5A-3-A1/3.

β_{VSF} is ESF for vertical shear force as defined in 5A-3-A1/3.

For determining the hull girder section modulus for 0.4L amidships, as specified in 5A-3-3/3, the maximum still-water bending moments, either hogging or sagging, are to be added to the hogging or sagging wave bending moments, respectively. Elsewhere, the total bending moment may be directly obtained based on the envelope curves, as specified in 5A-3-2/3.1 and 5A-3-2/5.1.

For this purpose, k_u = 1.0, and k_c = 1.0

7.3.2 Horizontal Wave Bending Moment and Shear Force

For non-head sea conditions, the horizontal wave bending moment and the horizontal shear force, as specified in 5A-3-2/5.3, are to be considered as additional hull girder loads, especially for the design of the side shell and inner skin structures. The effective horizontal bending moment and shear force, M_{HE} and F_{HE}, may be determined by the following equations:

$$M_{HE} = k_u\, k_c\, M_H \qquad \text{kN-m (tf-m, Ltf-ft)}$$

$$F_{HE} = k_u\, k_c\, F_H \qquad \text{kN (tf, Ltf)}$$

where k_u and k_c are a load factor and a correlation factor, respectively, which may be taken as unity unless otherwise specified.

7.5 Local Loads for Design of Supporting Structures *(December 2008)*

In determining the required scantlings of the main supporting structures, such as girders, transverses, stringers, floors and deep webs, the nominal loads induced by the liquid pressures distributed over both sides of the structural panel within the tank boundaries should be considered for the worst possible load combinations. In general, considerations should be given to the following two load cases accounting for the worst effects of the dynamic load components.

i) Maximum internal pressures for a fully filled tank with the adjacent tanks empty and minimum external pressures, where applicable.

ii) Empty tank with the surrounding tanks full and maximum external pressures, where applicable.

Taking the side shell supporting structure as an example, the nominal loads may be determined from either:

i) $p_i = k_s \rho g (\eta + k_u h_d)$ max. and

$p_e = \rho g (h_s + \beta_{EPS/EPP} k_u h_{de})$ min.

ii) $p_i = 0$ and

$p_e = \rho g (h_s + \beta_{EPS/EPP} k_u h_{de})$ max.

where

k_u = 1.0

$\beta_{EPS/EPP}$ = ESF for external pressure starboard/port, as defined in 5A-3-A1/3

ρg, η, h_d, h_s, h_{de}, k_s are as defined in 5A-3-2/5.5 and 5A-3-2/5.7.

Specific information required for calculating the nominal loads are given in 5A-3-2/Table 3 for various structural members and configurations.

7.7 Local Pressures for Design of Plating and Longitudinals *(1995)*

In calculating the required scantlings of plating, longitudinals and stiffeners, the nominal pressures should be considered for the two load cases given in 5A-3-2/7.5, using k_u = 1.1 for p_i and p_e instead of k_u = 1.0 as shown above.

The necessary details for calculating p_i and p_e are given in 5A-3-2/Table 3.

9 Combined Load Cases

9.1 Combined Load Cases for Structural Analysis *(December 2008)*

For assessing the strength of the hull girder structure and in performing a structural analysis as outlined in Section 5A-3-4. For the three cargo tank length model structural analysis, the combined load cases specified in 5A-3-2/Tables 1A through 1C are to be considered. Additional combined load cases may be required as warranted. The loading patterns are shown in 5A-3-2/Figures 1A through 1C for three cargo tank lengths. The necessary correlation factors and relevant coefficients for the loaded tanks are also given in 5A-3-2/Tables 1A through 1C. The total external pressure distribution including static and hydrodynamic pressure is illustrated in 5A-3-2/Figure 10.

For the cargo block model structural analysis, the loading conditions in 5A-1-3/3.5.2 are to be considered.

9.3 Combined Load Cases for Failure Assessment *(December 2008)*

For assessing the failure modes with respect to material yielding and buckling, the following combined load cases shall be considered.

9.3.1 Yielding, Buckling and Ultimate Strength of Local Structures

For assessing the yielding, buckling and ultimate strength of local structures, the combined load cases as given in 5A-3-2/Tables 1A through 1C are to be considered.

9.3.2 Fatigue Strength

For assessing the fatigue strength of structural joints, the combined load cases given in 5A-3-2/9.1 are to be used for a first level fatigue strength assessment as outlined in Appendix 5A-3-A2 "Fatigue Strength Assessment of Ship-Type Installations".

11 Sloshing Loads

11.1 General *(1995)*

11.1.1 *(December 2008)*

Except for tanks that are situated wholly within the double side or double bottom, the natural periods of liquid motions and sloshing loads are to be examined in assessing the strength of boundary structures for all cargo or ballast tanks which will be partially filled between 20% and 90% of tank capacity. The sloshing pressure heads given in this Subsection may be used for determining the strength requirements for the tank structures. Alternatively, sloshing loads may be calculated either by model experiments or numerical simulation using three-dimensional flow analysis for unrestricted service conditions and for sea conditions of the specific site of operation. Methodology and procedures of tests and measurements or analysis methods are to be fully documented and submitted for review.

11.1.2

The effects of impulsive sloshing pressures on the design of the main supporting structures of tank transverse and longitudinal bulkheads are subject to special consideration.

11.3 Strength Assessment of Tank Boundary Structures

11.3.1 Tank Length and Pitch Induced Sloshing Loads *(2002)*

Tanks of length 54 m (177 ft) or greater are to satisfy requirements of either of the preventative measures given in 5A-3-2/11.3.3 or 5A-3-2/11.3.4. Where the tank has smooth surfaces, one or more swash bulkheads are to be fitted. Structural reinforcement is to be provided to the tank ends, when the calculated pressure is higher than the pressure, p_i, as specified in 5A-3-3/13.

Tanks of length 54 m (177 ft) or greater that have ring webs are to have a partial non-tight bulkhead (i.e. non-full depth swash bulkhead) to eliminate the possibility of resonance at all filling levels. The partial non-tight bulkhead may be waived if it can be demonstrated through the application of model experiments or numerical simulation using three-dimensional flow analysis that sloshing impacts do not occur. The height of the swash bulkhead is to be determined on the basis of calculation using three-dimensional flow analysis as described in 5A-3-2/11.1.1.

Where the tank length is less than 54 m (177 ft), and if either of the preventative measures given in 5A-3-2/11.3.3 or 5A-3-2/11.3.4 is not satisfied, the tank boundary structures are to be designed in accordance with 5A-3-3/13 to withstand the sloshing pressures specified in 5A-3-2/11.5.

11.3.2 Roll Induced Sloshing Loads *(2002)*

Tanks that do not satisfy either of the preventative measures given in 5A-3-2/11.3.3 or 5A-3-2/11.3.4, with respect of roll resonance, are to have their tank boundary structures designed in accordance with 5A-3-3/13 to withstand the sloshing pressures specified in 5A-3-2/11.5.

11.3.3 *(1997)*

For long or wide cargo tanks, non-tight bulkheads or ring webs or both are to be designed and fitted to eliminate the possibility of resonance at all filling levels.

Long tanks have length, ℓ, exceeding $0.1L$. Wide tanks have width, b, exceeding $0.6B$.

11.3.4

For each of the anticipated loading conditions, the "critical" filling levels of the tank should be avoided so that the natural periods of fluid motions in the longitudinal and transverse directions will not synchronize with the natural periods of the installation's pitch and roll motions, respectively. It is further recommended that the natural periods of the fluid motions in the tank, for each of the anticipated filling levels, be at least 20% greater or smaller than that of the relevant installation's motion.

The natural period of the fluid motion, in seconds, may be approximated by the following equations:

$T_x = (\beta_T \ell_e)^{1/2}/k$ in the longitudinal direction

$T_y = (\beta_L b_e)^{1/2}/k$ in the transverse direction

where

ℓ_e = effective length of the tank, as defined in 5A-3-2/11.5.1, in m (ft)

b_e = effective breadth of the tank, as defined in 5A-3-2/11.5.1 in m (ft)

k = $[(\tanh H_1)/(4\pi/g)]^{1/2}$

H_1 = $\pi d_\ell/\ell_e$ or $\pi d_b/b_e$

β_T, β_L, d_ℓ and d_b are as defined in 5A-3-2/11.5.1. The natural periods given in 5A-3-2/5.7 for pitch and roll of the installation, T_p and T_r, using the actual GM value, if available, may be used for this purpose.

11.5 Sloshing Pressures *(1995)*

11.5.1 Nominal Sloshing Pressure *(1 July 2009)*

For cargo tanks with filling levels within the critical range specified in 5A-3-2/11.3.2, the internal pressures p_{is}, including static and sloshing pressures, positive toward tank boundaries, may be expressed in terms of equivalent liquid pressure head, h_e, as given below:

$p_{is} = k_s \rho g h_e \geq 0$ in N/cm² (kgf/cm², lbf/in²)

where

k_s = load factor as defined in 5A-3-2/5.7.2(a)

h_e = $k_u[h_c + (h_t - h_c)(y - d_m)/(h - d_m)]$ for $y > d_m$

= $c_m h_m + k_u h_c$ for $0.15h \leq y \leq d_m$ ($c_m h_m$ need not exceed h)

h_e calculated at $y = 0.15h$ for $y < 0.15h$, but h_e should not be smaller than $c_m h_m$.

c_m = coefficient in accordance with 5A-3-2/Figure 14

h_m = static pressure head, taken as the vertical distance, in m (ft), measured from the filling level, d_m, down to the point considered. d_m, the filling level for maximum h_c calculated with $C_{\phi s}$ and $C_{\theta s}$ equal to 1.0, should not be taken less than $0.55h$.

d_m = filling level, in m (ft), as shown in 5A-3-2/Figure 13

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

h_c = maximum average sloshing pressure heads, in m (ft), to be obtained from calculations as specified below for at least two filling levels, $0.55h$ and the one closest to the resonant period of ship's motions, between $0.2h$ and $0.9h$. h_c may be taken as constant over the tank depth, h (See 5A-3-2/Figure 13)

h_t = sloshing pressure heads for upper bulkhead, in m (ft), to be obtained from calculation below

h = depth of tank, in m (ft)

y = vertical distance, in m (ft), measured from the tank bottom to the point considered

ρg is as defined in 5A-3-2/5.7.2.

The values of h_c and h_t may be obtained from the following equations:

$$h_c = k_c\,(C_{\phi s}\, h_\ell^2 + C_{\theta s}\, h_b^2)^{1/2} \qquad \text{in m (ft)}$$

$$h_t = k_c\,(C_{\phi s}\, h_{t\ell}^2 + C_{\theta s}\, h_{tb}^2)^{1/2} \qquad \text{in m (ft)}$$

where

k_c = correlation factor for combined load cases, and may be taken as unity unless otherwise specified.

h_ℓ = $\phi_{es}\ell_e C_{t\ell}\beta_T[0.018 + C_{f\ell}(1.0 - d_\ell/H_\ell)/\phi_{es}]d_\ell/H_\ell$ m (ft) for ϕ_{es}

h_b = $\theta_{es}b_e C_{tb}\beta_L[0.016 + C_{fb}(1.0 - d_b/H_b)/\theta_{es}]d_b/H_b$ m (ft) for θ_{es}

$C_{\phi s}$ and $C_{\theta s}$ are the weighted coefficients as given in 5A-3-2/Figure 14.

where

β_T represents β for transverse bulkheads and β_L represents β for the longitudinal bulkheads.

$\phi_{es} = 0.71\phi$

$\theta_{es} = 0.71\theta$

The pitch amplitude ϕ and roll amplitude θ are as defined in 5A-3-2/5.7.1 with d_i = $2/3d_f$ and V = 10 knots

ℓ_e = effective tank length that accounts for the effect of deep ring-web frames, in m (ft)

= $\beta_T^{*2}\,\ell$

b_e = effective tank width that accounts for the effect of deep ring-web frames, in m (ft)

= $\beta_L^{*2}\,b$

β^* = 1.0 for tanks without deep ring webs,

= $0.25[4.0 - (1 - \alpha^*) - (1 - \alpha^*)^2]$ for α^* to be determined at d_o,

β_T^* represents β^* for transverse bulkheads.

β_L^* represents β^* for longitudinal bulkheads.

β = $(\beta_o)(\beta_u)(\beta_s)$

β_T represents β for transverse bulkheads.

β_L represents β for longitudinal bulkheads.

β_o	=	1.0	for tanks without a swash bulkhead
	=	$0.25[4.0 - (1 - \alpha_o) - (1 - \alpha_o)^2]$	for tanks with a swash bulkhead
β_u	=	1.0	for tanks without any deep bottom transverse and deep bottom longitudinal girder
	=	$0.25[4.0 - d_{\ell 1}/h - (d_{\ell 1}/h)^2]$	for tanks with deep bottom transverses
	=	$0.25[4.0 - d_{b1}/h - (d_{b1}/h)^2]$	for tanks with deep bottom longitudinal girders

β_s = 1.0 for boundary bulkheads that:

i) do not contain any deep horizontal girder; or

ii) do contain deep horizontal girders but with an opening ratio, α_s, less than 0.2 or greater than 0.4

= $0.25[4.0 - (1 - \alpha_s) - (1 - \alpha_s)^2]$ for bulkheads with deep horizontal girders having an opening ratio, α_s, between 0.2 and 0.4

α = opening ratio (see 5A-3-2/Figure 15)

For α_o 5A-3-2/Figure 16(1), opening ratios of swash bulkheads, shall be used for all filling levels considered. Also, 5A-3-2/Figure 16(2), local opening ratio for $d_o = 0.7h$, bounded by the range between $0.6h$ and $0.9h$, shall be considered for openings within the range. The smaller of the two opening ratios calculated, based on 5A-3-2/Figure 16(1) and 5A-3-2/Figure 16(2) for this filling level, shall be used as the opening ratio.

For α^*, 5A-3-2/Figure 16(3), opening ratio of deep ring-webs, filling level d_o shall be used.

For α_s, 5A-3-2/Figure 16(4), opening ratio of a deep horizontal girder on a boundary bulkhead, is applicable to a filling level just above the horizontal girder in the zones illustrated in the figure. Not to be considered for $d_o = 0.7h$, unless a sizable girder is installed between $0.7h$ and h. Also not to be considered if opening area in the girder is less than 20% or greater than 40% of the area of the girder (i.e., $\alpha_s = 1$)

$C_{f\ell}$ = $0.792[d_\ell/(\beta_T \ell_e)]^{1/2} + 1.98$

C_{fb} = $0.704[d_b/(\beta_L b_e)]^{1/2} + 1.76$

$C_{t\ell}$ = $0.9\, x_{o1}/[1 + 9(1 - x_o)^2] \geq 0.25$

x_o = T_x/T_p

x_{o1} = x_o if $x_o \leq 1.0$

= $1/x_o$ if $x_o > 1.0$

C_{tb} = $0.9\, y_{o1}/[1 + 9(1 - y_o)^2] \geq 0.25$

y_o = T_y/T_r. If roll radius of gyration is not known, $0.39B$ may be used in the calculation of T_r

y_{o1} = y_o if $y_o \leq 1.0$

= $1/y_o$ if $y_o > 1.0$

T_x and T_y are as defined in 5A-3-2/11.3.4.

T_p and T_r are as defined in 5A-3-2/5.7.

d_o = filling depth, in m (ft)

d_ℓ = $d_o - d_{\ell 1}[1 - \sigma_n^2(n + 1)/2]^{1/2}\, k_{\ell 1} - 0.45 d_{\ell 2}\, k_{\ell 2}$ and ≥ 0.0

d_b = $d_o - d_{b1}[1 - \sigma_m^2(m + 1)/2]^{1/2}\, k_{b1} - 0.45 d_{b2}\, k_{b2}$ and ≥ 0.0

H_ℓ = $h - d_{\ell 1}[1 - \sigma_n^2(n + 1)/2]^{1/2}\, k_{\ell 1} - 0.45 d_{\ell 2}\, k_{\ell 2}$

H_b = $h - d_{b1}[1 - \sigma_m^2(m + 1)/2]^{1/2}\, k_{b1} - 0.45 d_{b2}\, k_{b2}$

$d_{\ell 1}$ = height of deep bottom transverses measured from the tank bottom, (5A-3-2/Figure 17), in m (ft)

$d_{\ell 2}$ = bottom height of the lowest openings in non-tight transverse bulkhead measured above the tank bottom or top of bottom transverses (5A-3-2/Figure 17), in m (ft)

n = number of deep bottom transverses in the tank

d_{b1} = height of deep bottom longitudinal girders measured from the tank bottom (5A-3-2/Figure 17), in m (ft)

d_{b2} = bottom height of the lowest openings in non-tight longitudinal bulkhead measured above the tank bottom, or top of bottom longitudinal girders (5A-3-2/Figure 17), in m (ft)

m = number of deep bottom longitudinal girders in the tank

$k_{\ell 1}$ = -1 if $d_o \le d_{\ell 1}$

= 1 if $d_o > d_{\ell 1}$

$k_{\ell 2}$ = -1 if $d_o \le d_{\ell 2}$

= 1 if $d_o > d_{\ell 2}$

k_{b1} = -1 if $d_o \le d_{b1}$

= 1 if $d_o > d_{b1}$

k_{b2} = -1 if $d_o \le d_{b2}$

= 1 if $d_o > d_{b2}$

σ_n = $(4/\pi)(n + 1)/[n(n + 2)]\cos[\pi/\{2(n + 1)\}]$

σ_m = $(4/\pi)(m + 1)/[m(m + 2)]\cos[\pi/\{2(m + 1)\}]$

ℓ_s (b_s) shall be used in place of ℓ_e (b_e) for a filling level below the completely solid portion of the nontight bulkhead, i.e., the region below the lowest opening, (5A-3-2/Figure 17), where ℓ_s (b_s) is taken as the distance bounded by the solid portion of the nontight bulkhead below the lowest opening and the tight bulkhead. d_ℓ, H_ℓ and d_b, H_b need not consider the effect of $d_{\ell 2}$ and d_{b2}, respectively.

$h_{tl} = 0.0068\,\beta'_T\,\ell_e\,C'_{t\ell}\,(\phi_{es} + 40)\,(\phi_{es})^{1/2}$ m (ft)

$h_{tb} = 0.0055\,\beta'_L\,b_e\,C'_{tb}\,(\theta_{es} + 35)\,(\theta_{es})^{1/2}$ m (ft)

where

$C'_{t\ell}$ and C'_{tb} are $C_{t\ell}$ and C_{tb} for $h_m = 0.70h$; β'_T and β'_L correspond to β for $d_o = 0.7h$; ϕ_{es} and θ_{es} are as defined previously.

$C_{\phi s}$ and $C_{\theta s}$ are weighted coefficients, as given in 5A-3-2/Figure 14.

h_{tl} shall not be less than h_p; h_{tb} shall not be less than h_r

h_p = $\ell \sin(\phi_{es})$

h_r = $b \sin(\theta_{es})$

11.5.2 Sloshing Loads for Assessing Strength of Structures at Tank Boundaries

11.5.2(a) In assessing the strength of tank boundary supporting structures, the two combined load cases with loading pattern shown in 5A-3-2/Figure 18, with the specified sloshing loads shown in 5A-3-2/Table 2 for the respective side on which the horizontal girder is located, are to be considered when performing a 3D structural analysis.

11.5.2(b) In assessing the strength of plating and stiffeners at tank boundaries, local bending of the plating and stiffeners with respect to the local sloshing pressures for structural members/elements is to be considered in addition to the nominal loadings specified for the 3D analysis in 5A-3-2/11.5.2(a) above. In this regard, k_u should be taken as 1.15 instead of 1.0, shown in 5A-3-2/11.5.2(a) above for the combined load cases, to account for the maximum pressures due to possible non-uniform distribution.

11.5.3 Sloshing Loads Normal to the Web Plates of Horizontal and Vertical Girders

In addition to the sloshing loads acting on the bulkhead plating, the sloshing loads normal to the web plates of horizontal and vertical girders are to be also considered for assessing the strength of the girders. The magnitude of the normal sloshing loads may be approximated by taking 25% of h_c or h_t for $k_u = 1.0$, whichever is greater, at the location considered.

FIGURE 13
Vertical Distribution of Equivalent Slosh Pressure Head, h_e (1995)

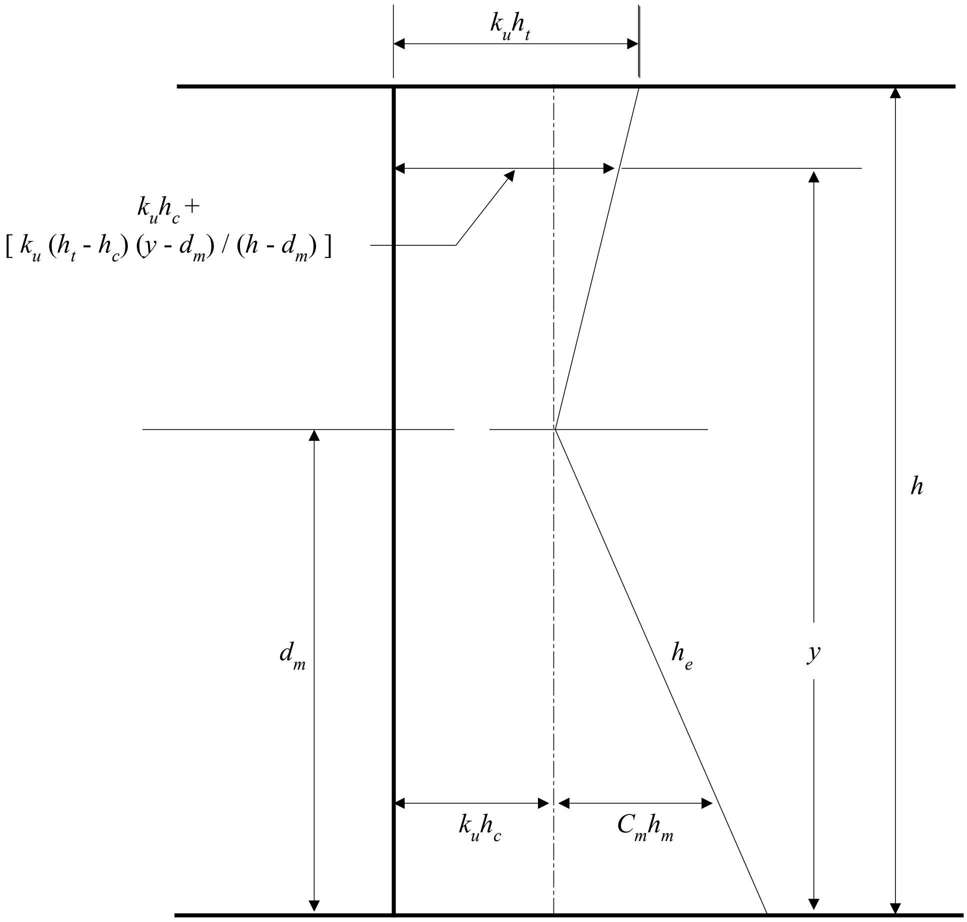
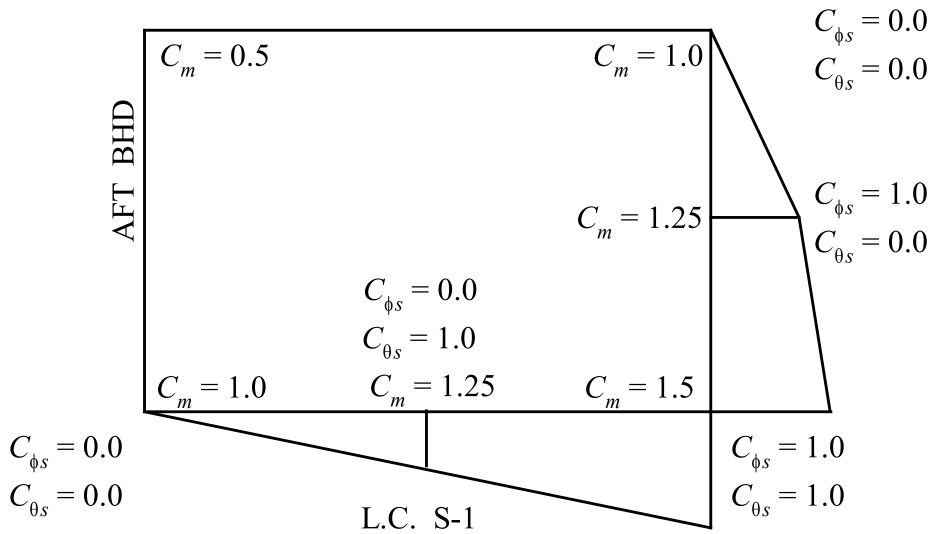
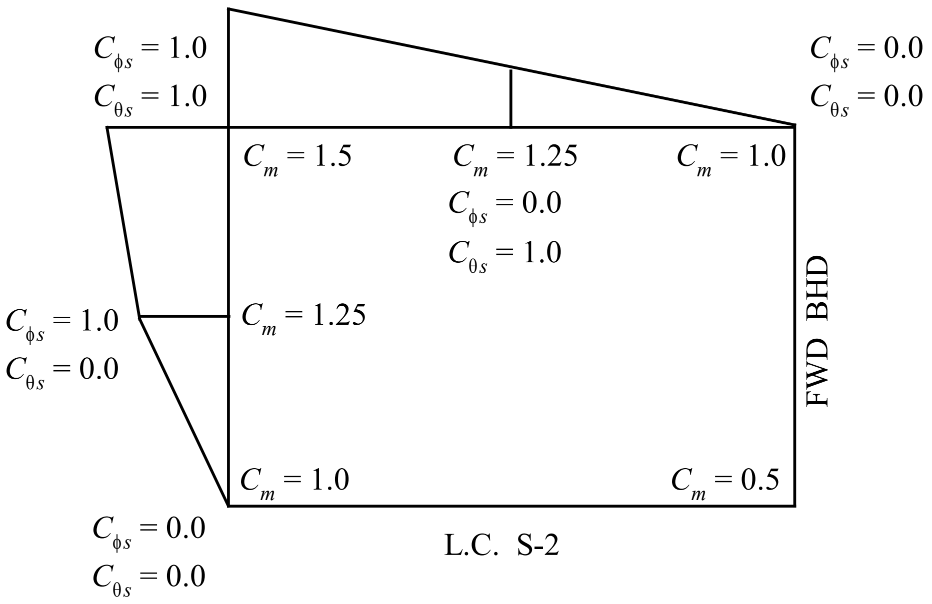


FIGURE 14
Horizontal Distribution of Simultaneous Slosh Pressure Heads, h_c (ϕ_s θ_s) or h_t (ϕ_s θ_s) *(1995)*



L.C. S-1



L.C. S-2

Note: h_c may be taken as zero for the deck and inner bottom

FIGURE 15
Definitions for Opening Ratio, α *(1995)*

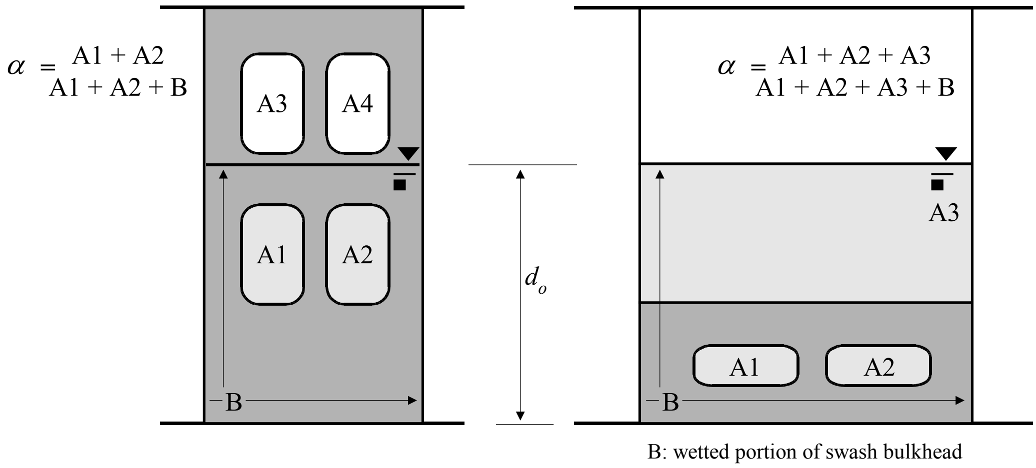
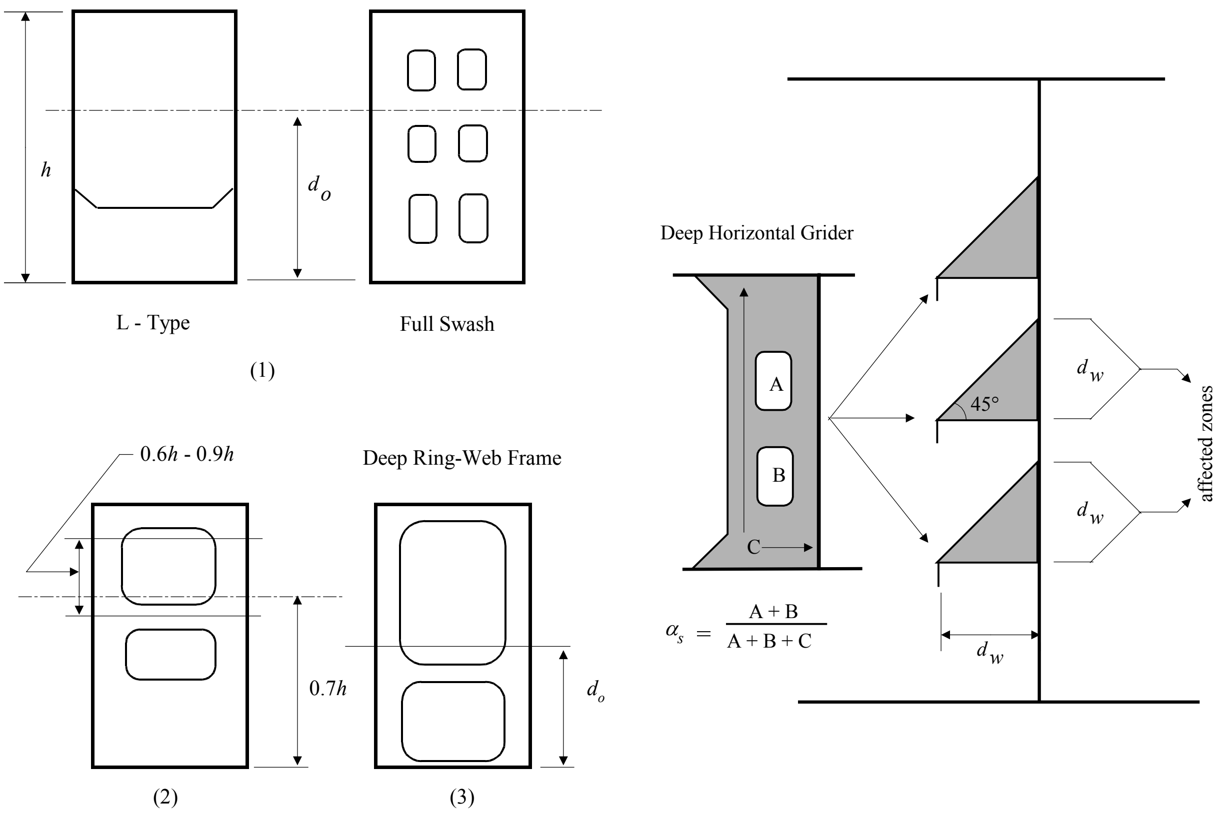


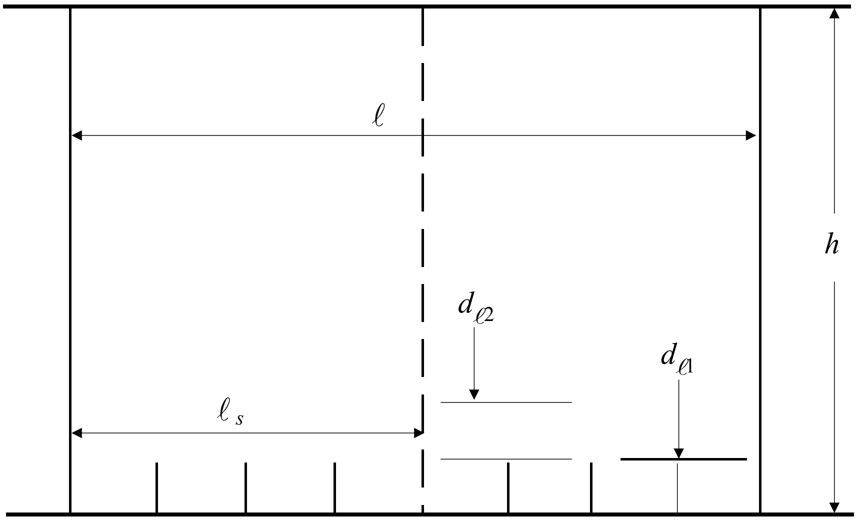
FIGURE 16
Opening Ratios *(1995)*



(1) – (3) Opening Ratios of Nontight Bulkheads and Deep Ring-Webs

(4) Opening Ratio of Deep Horizontal Girders Boundary Bulkheads

FIGURE 17
Dimensions of Internal Structures *(1995)*



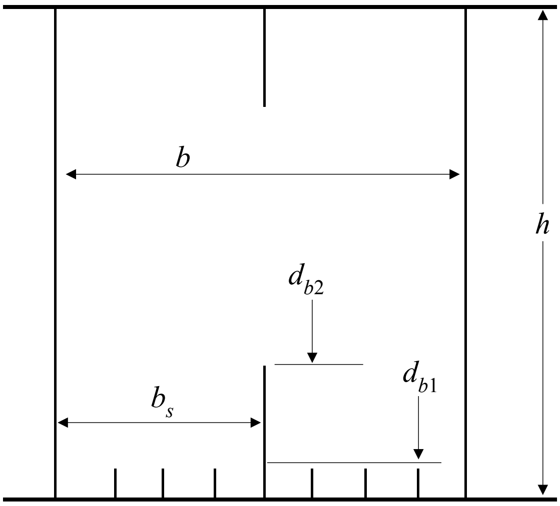
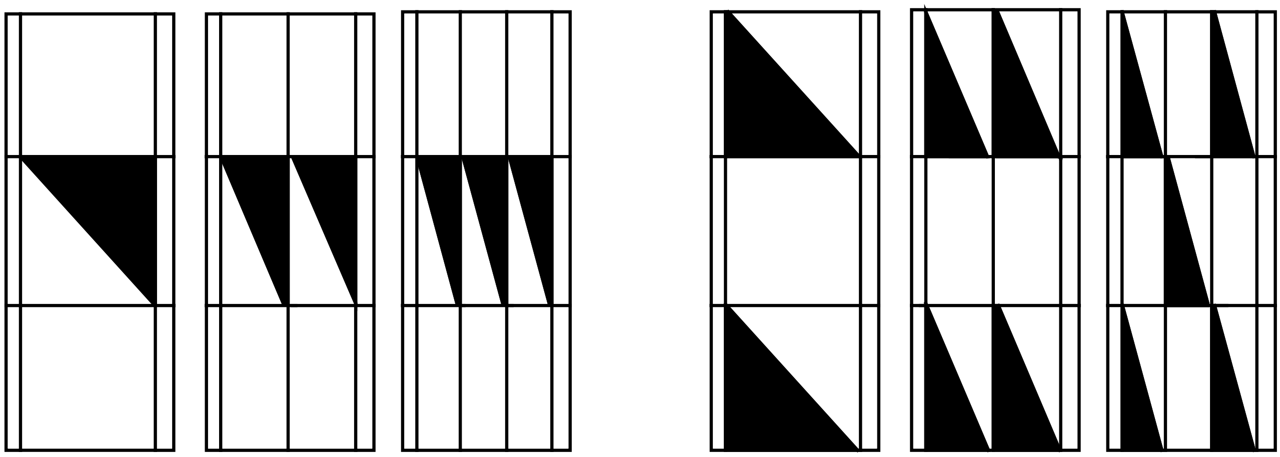


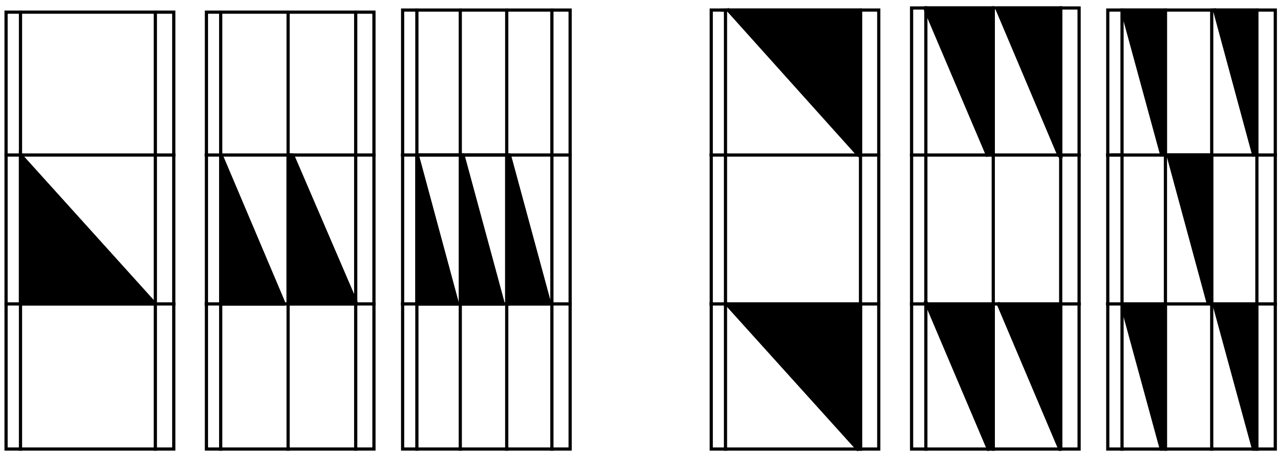
FIGURE 18
Loading Patterns for Sloshing Load Cases *(1 July 2009)*

Type A: Where the Horizontal Girder is on the Aft Side of Transverse Bulkhead



a. Load Case S-1; 2/3 Design Draft b. Load Case S-2; 2/3 Design Draft

Type B: Where the Horizontal Girder is on the Forward Side of Transverse Bulkhead



a. Load Case S-1; 2/3 Design Draft b. Load Case S-2; 2/3 Design Draft

13 Impact Loads

13.1 Impact Loads on Bow *(2000)*

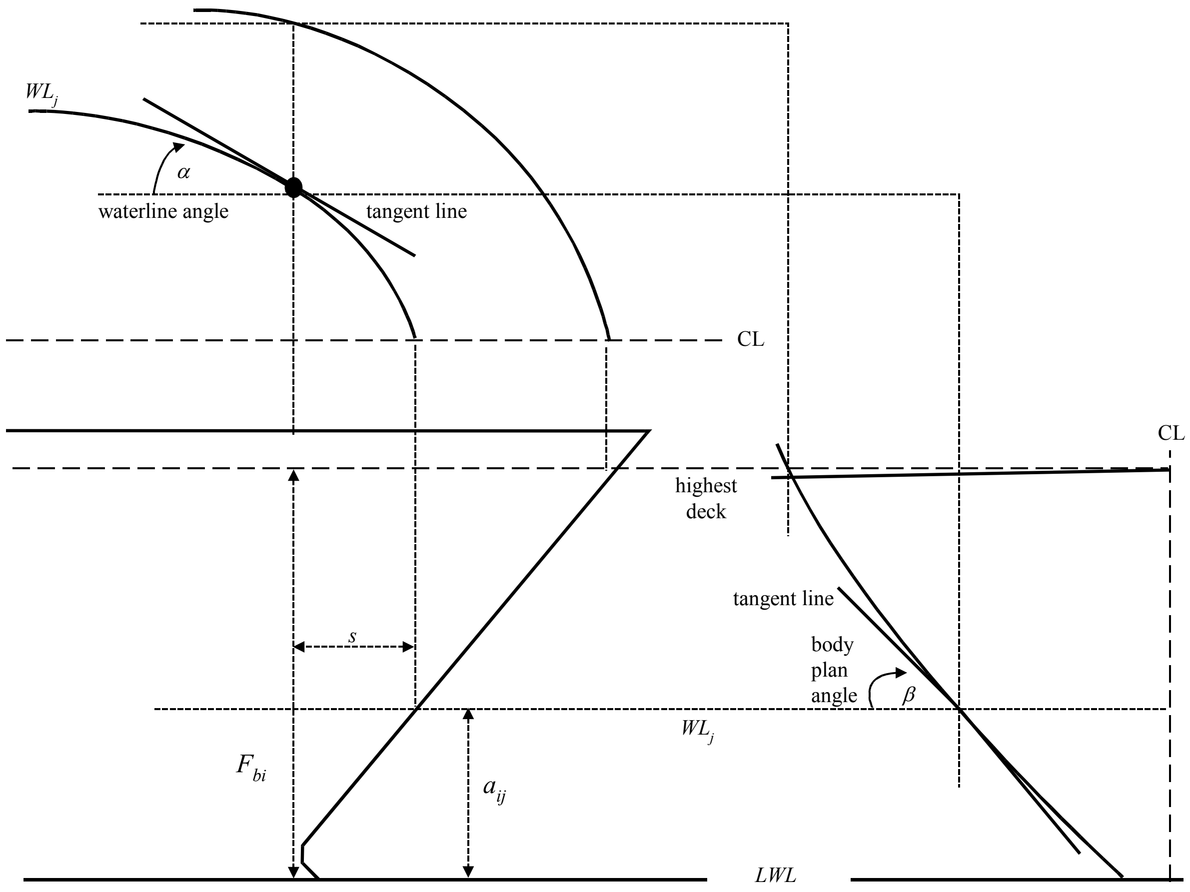
When experimental data or direct calculations are not available, nominal bow impact pressures due to wave celerity above the load waterline (LWL) in the region from the forward end to the collision bulkhead may be obtained from the following equation:

$P_{bij} = k\, C_k\, C_{ij}\, V_{ij}^2 \sin \gamma_{ij}$ kN/m^2 (tf/m^2, Lt/ft^2)

where:

k	=	1.025 (0.1045, 0.000888)	
C_{ij}	=	$\{1 + \cos^2[90(F_{bi} - 2a_j)/F_{bi}]\}^{1/2}$	
V_{ij}	=	$\omega_1 \sin \alpha_{ij} + \omega_2 (\beta_{WHT} L)^{1/2}$	
ω_1	=	3.09 (10.14) for m (ft)	
ω_2	=	1.0 (1.8) for m (ft)	
β_{WHT}	=	ESF for Wave Height as defined in 5A-3-A1/3	
γ_{ij}	=	$\tan^{-1}(\tan \beta_{ij}/\cos \alpha_{ij})$ not to be taken less than 50 degrees	
α_{ij}	=	local waterline angle measured from the centerline, see 5A-3-2/Figure 19	
β_{ij}	=	local body plan angle measured from the horizontal, see 5A-3-2/Figure 19	
F_{bi}	=	freeboard from the highest deck at side to the load waterline (LWL) at station *i,* see 5A-3-2/Figure 19	
a_j	=	vertical distance from LWL to WL-*j*, see 5A-3-2/Figure 19	
i, j	=	station and waterline to be taken to correspond to the locations under consideration, as required by 5A-3-5/3.1.1	
C_k	=	0.7	at collision bulkhead and 0.9 at 0.0125L, linear interpolation for in between
	=	0.9	between 0.0125L and FP
	=	1.0	at and forward of FP.

FIGURE 19
Definition of Bow Geometry *(2000)*



13.3 Bottom Slamming *(1 July 2012)*

For ship-type installations with heavy weather ballast draft forward less than $0.04L$, bottom slamming loads are to be considered for assessing strength of the flat of bottom plating forward and the associated stiffening system in the fore body region.

13.3.1 Bottom Slamming Pressure

The equivalent bottom slamming pressure for strength formulation and assessment should be determined based on well-documented experimental data or analytical studies. When these direct calculations are not available, nominal bottom slamming pressures may be determined by the following equations:

$$P_{si} = kk_i [\, v_o^2 + M_{Vi} E_{ni}] E_f \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

where

P_{si}	=	equivalent bottom slamming pressure for section i
k	=	1.025 (0.1045, 0.000888)
k_i	=	$2.2\, b^*/d_o + \alpha \le 40$
b^*	=	half width of flat of bottom at the i-th ship station, see 5A-3-2/Figure 20
d_o	=	$^1/_{10}$ of the section draft at the heavy ballast condition, see 5A-3-2/Figure 20
α	=	a constant as given in 5A-3-2/Table 4

E_f = $f_1\ \omega_1\ (L)^{1/2}$

f_1 = 0.004 (0.0022) for m (ft)

where b represents the half breadth at the $^1/_{10}$ draft of the section, see 5A-3-2/Figure 20. Linear interpolation may be used for intermediate values.

v_o = $c_o(L)^{1/2}$, in m/s (ft/s)

c_o = 0.29 (0.525) for m (ft)

M_{Ri} = 1.391 $A_i\ \beta_{vm}\ (L/C_b)^{1/2}$ for L in meters

= 8.266 $A_i\ \beta_{vm}\ (L/C_b)^{1/2}$ for L in feet

β_{vm} = ESF for vertical relative motion as defined in 5A-3-A1/3

C_b = as defined in 3-2-1/3.5 of the *Steel Vessel Rules*

M_{Vi} = B_iM_{Ri}

A_i and B_i are as given in 5A-3-2/Table 5.

G_{ei} = $e^{[-(v_o^2/M_{Vi}+d_i^2/M_{Ri})]}$

d_i = local section draft, in m (ft)

E_{ni} = natural log of n_i

n_i = $5730(M_{Vi}/M_{Ri})^{1/2}\ G_{ei}$, if $n_i < 1$ then $P_{si} = 0$

ω_1 = natural angular frequency of the hull girder 2-node vertical vibration of the installation in the wet mode and the heavy weather ballast draft condition, in rad/second. If not known, the following equation may be used:

= $\mu[B\ D^3/(\Delta_S\ C_b^3\ L^3)]^{1/2} + c_o \geq 3.7$

where

μ = 23400 (7475, 4094)

Δ_S = $\Delta_b[1.2 + B/(3d_b)]$

Δ_b = installation displacement at the heavy ballast condition, in kN (tf, Ltf)

d_b = mean draft of installation at the heavy ballast condition, in m (ft)

c_o = 1.0 for heavy ballast draft

L, B and D are as defined in Section 3-1-1 of the *Steel Vessel Rules*.

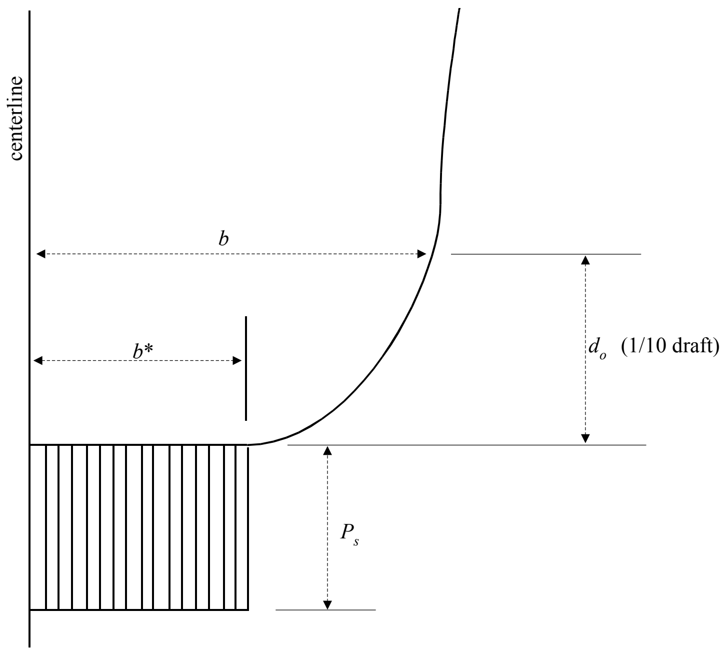
TABLE 4
Values of α *(2000)*

b/d_o	α	b/d_o	α
1.00	0.00	4.00	20.25
1.50	9.00	5.00	22.00
2.00	11.75	6.00	23.75
2.50	14.25	7.00	24.50
3.00	16.50	7.50	24.75
3.50	18.50	25.0	24.75

TABLE 5
Values of A_i and B_i

Section i from F.P.	A_i	B_i
-0.05*L*	1.25	0.3600
0	1.00	0.4000
0.05*L*	0.80	0.4375
0.10*L*	0.62	0.4838
0.15*L*	0.47	0.5532
0.20*L*	0.33	0.6666
0.25*L*	0.22	0.8182
0.30*L*	0.22	0.8182

FIGURE 20
Distribution of Bottom Slamming Pressure Along the Section Girth *(2000)*



13.5 Bowflare Slamming

For installations possessing bowflare and having a shape parameter A_r greater than 21 m (68.9 ft), in the forebody region, bowflare slamming loads are to be considered for assessing the strength of the side plating and the associated stiffening system in the forebody region of the installation at its scantling draft.

A_r = the maximum value of A_{ri} in the forebody region

A_{ri} = bowflare shape parameter at a station *i* forward of the quarter length, up to the FP of the installation, to be determined between the *LWL* and the upper deck/forecastle, as follows:

= $(b_T/H)^2 \ \sum b_j[1 + (s_j/b_j)^2]^{1/2}, \ \ j = 1, n; \ n \geq 3$

where

n = number of segments

b_T = $\sum b_j$

H = $\sum s_j$

b_j = local change (increase) in beam for the j-th segment at station i (see 5A-3-2/Figure 21)

s_j = local change (increase) in freeboard up to the highest deck for the j-th segment at station i forward (see 5A-3-2/Figure 21)

13.5.1 Nominal Bowflare Slamming

When experimental data or direct calculation is not available, nominal bowflare slamming pressures may be determined by the following equations:

$P_{ij} = P_{oij}$ or P_{bij} as defined below, whichever is greater

$P_{oij} = k_1(9M_{Ri} - h_{ij}^2)^{2/3}$ kN/m^2 (tf/m^2, Ltf/ft^2)

$P_{bij} = k_2[C_2 + K_{ij}M_{Vi}(1 + E_{ni})]$ kN/m^2 (tf/m^2, Ltf/ft^2)

where

k_1 = 9.807 (1, 0.0278)

k_2 = 1.025 (0.1045, 0.000888)

C_2 = 39.2 (422.46) for m (ft)

n_{ij} = $5730(M_{Vi}/M_{Ri})^{1/2}\ G_{ij} \geq 1.0$

E_{ni} = natural log of n_{ij}

G_{ij} = $e^{\left(-h_{ij}^2 / M_{Ri}\right)}$

M_{Ri} = $1.391\ A_i\ \beta_{RVM}\ (L/C_b)^{1/2}$ for L in meters

= $8.266\ A_i\ \beta_{RVM}\ (L/C_b)^{1/2}$ for L in feet

A_i = as shown in 5A-3-2/Table 6

β_{RVM} = ESF for relative vertical motion as defined in 5A-5-A1/3

C_b = as defined in 3-2-1/3.5 of the *Steel Vessel Rules*

L = length of installation as defined in 3-1-1/3.1 of *Steel Vessel Rules*

M_{Vi} = B_iM_{Ri}, where B_i is given in 5A-3-2/Table 6

h_{ij} = vertical distance measured from the load waterline (LWL) at station i to WL_j on the bowflare. The value of h_{ij} is not to be taken less than 2.0 m (6.56 ft)

K_{ij} = $f_{ij}[r_j/(b_{ij} + 0.5h_{ij})]^{3/2}\ [\ell_{ij}/r_j]$

r_j = $(M_{Ri})^{1/2}$

b_{ij} = local half beam of WL_j at station i. The value of b_{ij} is not to be taken less than 2.0 m (6.56 ft)

ℓ_{ij} = longitudinal distance of WL_j at station i measured from amidships

f_{ij} = $[90/\beta_{ij} - 1]^2 [\tan(\beta_{ij})/3.14]^2 \cos\gamma$

β_{ij} = local body plan angle measured from the horizontal, in degrees, need not be taken less than 35 degrees, see 5A-3-2/Figure 21

γ = installation stem angle at the centerline measured from the horizontal, 5A-3-2/Figure 22, in degrees, not to be taken greater than 75 degrees

TABLE 6
Values of A_i and B_i * *(2000)*

	A_i	B_i
-0.05L	1.25	0.3600
FP	1.00	0.4000
0.05L	0.80	0.4375
0.10L	0.62	0.4838
0.15L	0.47	0.5532
0.20L	0.33	0.6666
0.25L	0.22	0.8182
0.30L	0.22	0.8182

* Linear interpolation may be used for intermediate values.

FIGURE 21
Definition of Bowflare Geometry for Bowflare Shape Parameter *(2000)*

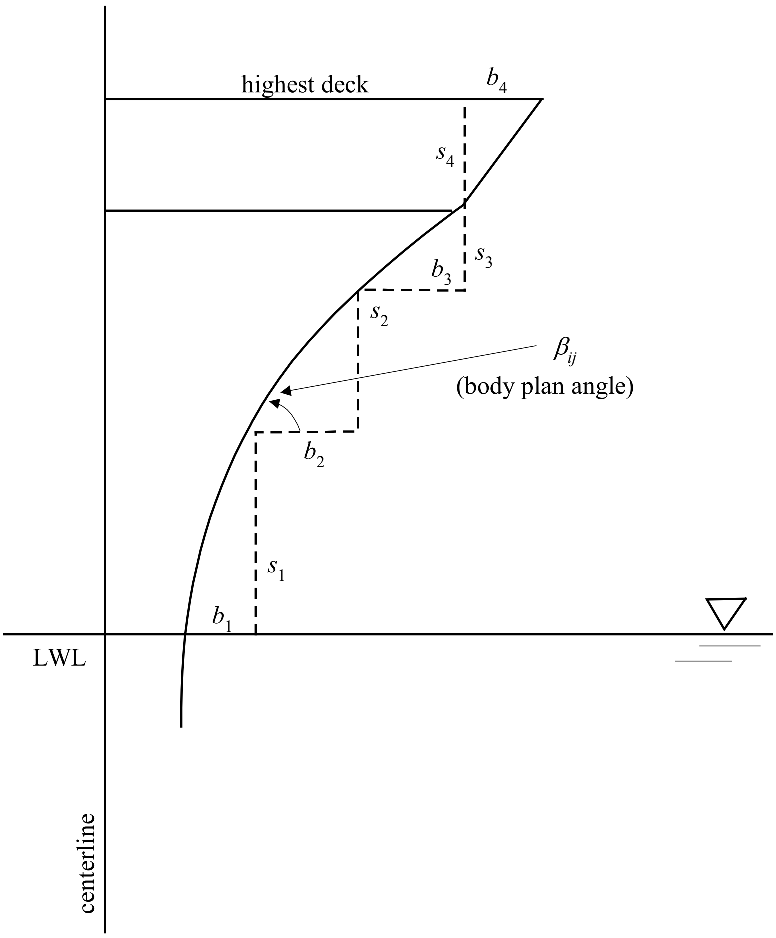
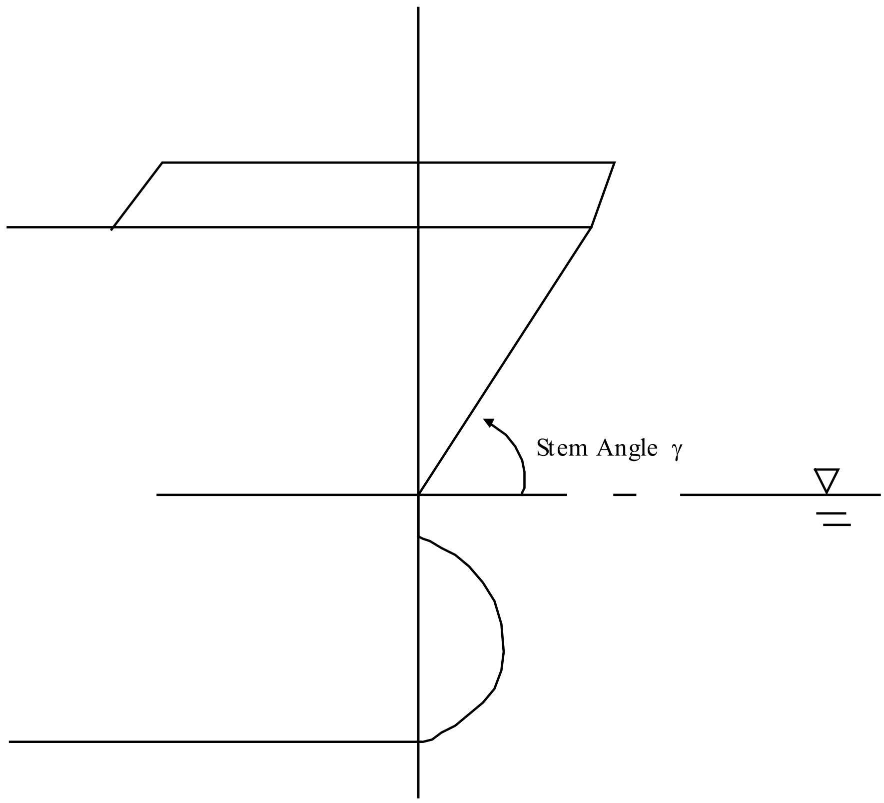


FIGURE 22
Ship-Type Installation Stem Angle, γ



13.5.2 Simultaneous Bowflare Slamming Pressure

For performing structural analyses to determine overall responses of the hull structures, the spatial distribution of instantaneous bowflare slamming pressures on the forebody region of the hull may be expressed by multiplying the calculated maximum bowflare slamming pressures, P_{ij}, at forward ship stations by a factor of 0.71 for the region between the stem and 0.3L from the FP.

13.7 Green Water on Deck *(31 March 2007)*

When experimental data or direct calculations are not available, nominal green water pressure imposed on deck along the installation length, including the extension beyond the FP, may be obtained from the following equations.

$$P_{gi} = K\{[\beta_{RVM}A_i(B/L)^{1/4}/C_b] - k_1F_{bi}\} \qquad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

where

P_{gi}	=	Green water pressure, uniformly distributed across the deck at specified longitudinal section i along the installation length under consideration (see 5A-3-2/Table 7 below). Pressure in between is obtained by linear interpolation. P_{gi} is not to be taken less than 20.6 kN/m^2 (2.1 tf/m^2, 0.192 Lt/ft^2).
K	=	10.052 (1.025, 0.09372)
k_1	=	1.0 (3.28) for m (ft)
A_i	=	as shown in 5A-3-2/Table 7
β_{RVM}	=	ESF factor of relative vertical motion, as defined in 5A-3-A1/3

C_b = as defined in 3-2-1/3.5 of the *Steel Vessel Rules*

L = scantling length of installation, in m (ft), as defined in 3-1-1/3.1 of the *Steel Vessel Rules*

B = greatest molded breath of installation, in m (ft), as defined in 3-1-1/5 of the *Steel Vessel Rules*

F_{bi} = freeboard from the highest deck at side to the load waterline (LWL) at station i, in m (ft), see 5A-3-2/Figure 19

TABLE 7
Values of A_i *(1 March 2006)*

Section i from F.P.	A_i
-0.05L	23.3
0	20.7
0.05L	18.2
0.10L	16.1
0.15L	14.7
0.20L	14.3
0.25L	14.2
0.30L	14.1
0.35L	14
0.40L	14
0.45L	14
0.50L	14
0.55L	14
0.60L	14
0.65L	14
0.70L	14
0.75L	14.2
0.80L	14.2
0.85L	14.2
0.90L	14.7
0.95L	17.1
1.00L	19.9

15 Deck Loads *(2000)*

15.1 General

For the design and evaluation of deck structures, the following loads due to on deck production facilities are to be considered:

i) Static weight of on deck production facilities in upright condition.

ii) Dynamic loads due to ship motions.

iii) Wind load.

15.3 Loads for On-Site Operation *(December 2008)*

The nominal forces from each individual deck production module at the center of gravity of the module can be obtained from the following equations:

$$F_v = W\,[\cos(0.71C_\phi\phi)\cos(0.71C_\theta\theta) + 0.71c_v a_v/g]$$

$$F_t = W\,[\sin(0.71C_\theta\theta) + 0.71c_T a_t/g] + k_t F_{wind}$$

$$F_\ell = W\,[-\sin(0.71C_\phi\phi) + 0.71c_L a_\ell/g] + k_\ell F_{wind}$$

where

ϕ and θ are the pitch and roll amplitudes defined in 5A-3-2/5.7.1.

ϕ, in degrees, need not to be taken more than 10 degrees.

θ, in degrees, need not to be taken more than 30 degrees.

a_v, a_t and a_ℓ are the vertical, transverse and longitudinal accelerations, as specified in 5A-3-2/5.7.1 for heading angles μ in 5A-3-2/Table 8

Note: The accelerations specified in 5A-3-2/5.7.1 are to be considered preliminary values and may be used only when values from model tests or ship motion calculations are not yet available. The final design forces from deck production modules are to be calculated using acceleration values obtained from model test data or ship motions calculations for the site location.

F_v = vertical load from each production module, positive downward

F_t = transverse load from each production module, positive starboard

F_ℓ = longitudinal load from each production module, positive forward

W = weight of the production module, in kN (tf, Ltf)

F_{wind} = $k\,A_{wind}C_s\,C_h\,V_{wind}^2$ = wind force, in kN (tf, Ltf)

Two combinations of wave-induced and wind forces are to be considered:

F_v, F_t with factor $k_t = 1$ and F_ℓ with factor $k_\ell = 0$

F_v, F_t with factor $k_t = 0$ and F_ℓ with factor $k_\ell = 1$

The deck load is to be obtained for the maximum weight of on deck production facilities for head sea (Load Case A), beam sea (Load Case B) and oblique sea (Load Case C) listed in 5A-3-2/Table 8, where the correlation factors c_v, c_T, c_L, C_ϕ and C_θ for each load case are also shown.

TABLE 8
Correlation Factors c_v, c_T, c_L, C_ϕ and C_θ

Load Case	*LC A (head sea)*	*LC B (beam sea)*	*LC C (oblique)*
c_v	0.8	0.4	0.7
c_L	0.6	0	0.7
c_T	0	0.9	0.7
C_ϕ	-1	0	-0.7
C_θ	0	1	0.7
Wave heading angle μ in deg.	0	90	60

where

V_{wind} = wind velocity based on 1-hour average speed

A_{wind} = projected area of windage on a plane normal to the direction of the wind, in m^2 (ft^2)

C_s = shape coefficient, defined in Section 3-2-4 of these Rules

C_h = height coefficient, defined in Section 3-2-4 of these Rules for 1-hour average wind

The forces from each deck production module can be obtained based on long-term prediction for the realistic sea states of the specific site of operation. In no case are the forces F_v, F_t and F_ℓ to be less than those obtained using the values of Environmental Severity Factors (ESFs) established from 5A-3-A1/3.

15.5 Loads in Transit Condition

Nominal loads of the production facility modules on deck during transit condition can be obtained from the equations in item 5A-3-2/15.3, above. Alternatively, corresponding forces can be calculated based on the sea condition for the specific voyage. Also see Part 3, Chapter 2 of these Rules.

PART
5A

CHAPTER 3 **Structural Design Requirements**

SECTION 3 **Initial Scantling Evaluation**

1 General

1.1 Strength Requirement *(1995)*

This Section specifies the minimum strength requirements for hull structure with respect to the determination of initial scantlings, including the hull girder, shell and bulkhead plating, longitudinals/ stiffeners and main supporting members. Once the minimum scantlings are determined, the strength of the resulting design is to be assessed in accordance with Section 5A-3-4. The assessment is to be carried out by means of an appropriate structural analysis as per 5A-3-4/11, in order to establish compliance with the failure criteria in 5A-3-4/3. Structural details are to comply with 5A-3-3/1.5.

The requirements for hull girder strength are specified in 5A-3-3/3. The required scantlings of double bottom structures, side shell and deck, and longitudinal and transverse bulkheads are specified in 5A-3-3/7 through 5A-3-3/17 below. 5A-3-3/Figure 1 shows the appropriate Subsections giving scantling requirements for the various structural components of typical double hull ship-type installations. For hull structures beyond 0.4*L* amidships, the initial scantlings are determined in accordance with Section 5A-3-5.

1.3 Calculation of Load Effects *(1995)*

Equations giving approximate requirements are given in 5A-3-3/7 through 5A-3-3/13 for calculating the maximum bending moments and shear forces for main supporting members clear of the end brackets, and axial loads for cross ties for typical structural arrangements and configurations (5A-5-3/Figures 2A and 2B). For designs with different structural configurations, these local load effects may be determined from a 3D structural analysis at the early design stages, as outlined in 5A-3-4/11, for the combined load cases specified in 5A-3-2/9, excluding the hull girder load components. In this regard, the detailed analysis results are to be submitted for review.

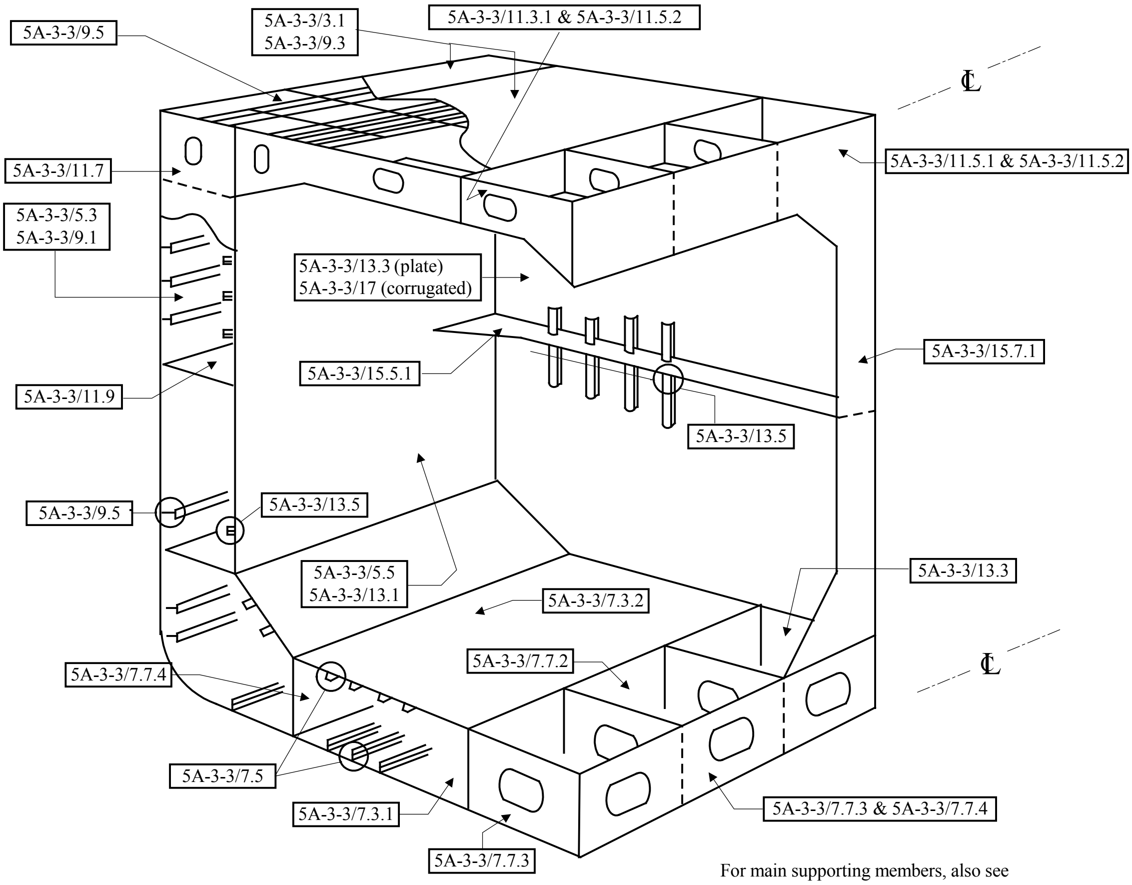
1.5 Structural Details *(1995)*

The strength criteria specified in this Section and Section 5A-3-5 are based on assumptions that all structural joints and welded details are properly designed and fabricated and are compatible with the anticipated working stress levels at the locations considered. It is critical to closely examine the loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions. In this exercise, failure criteria specified in 5A-3-4/3 may be used to assess the adequacy of structural details.

1.7 Evaluation of Grouped Stiffeners *(1 July 2008)*

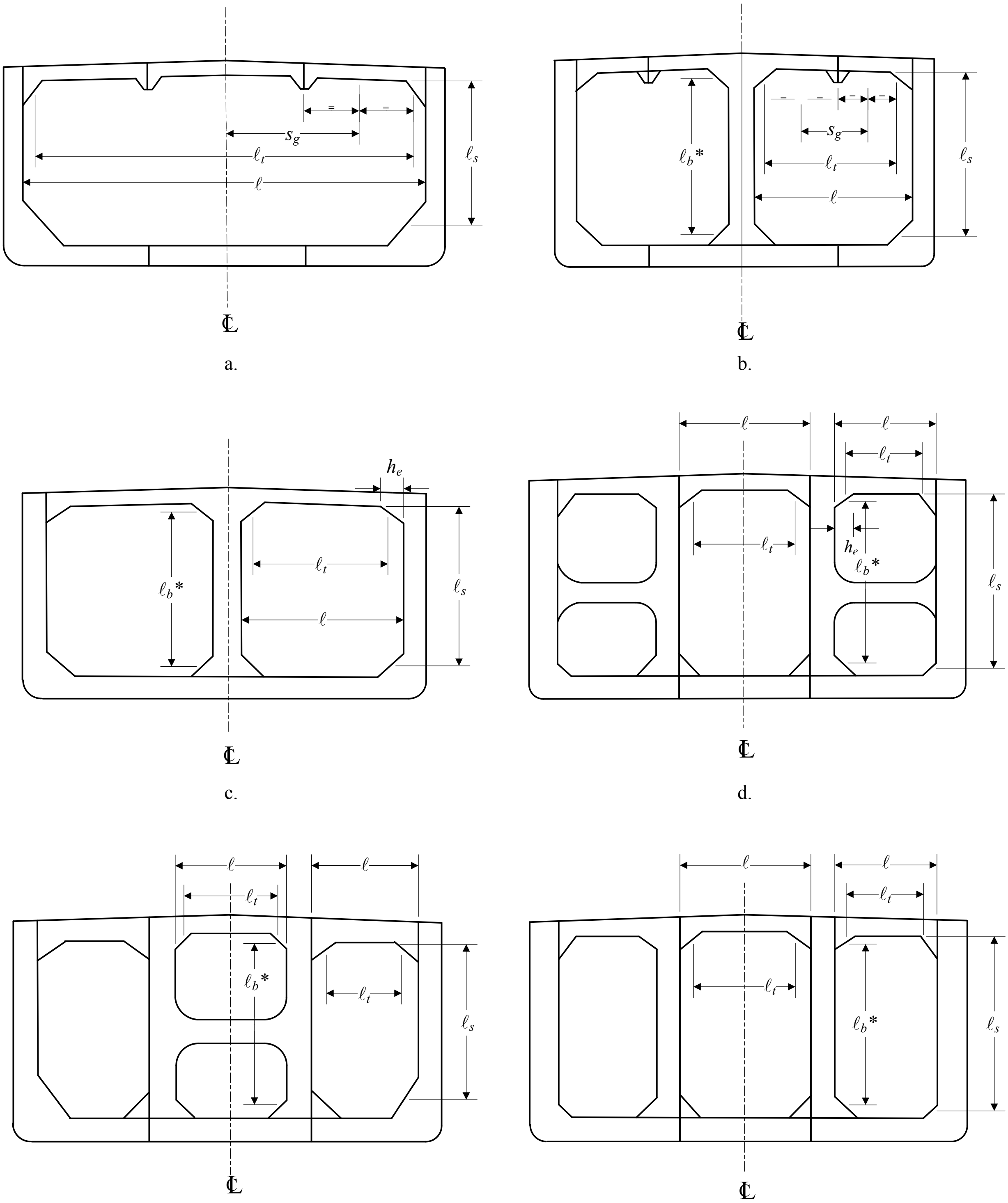
Where several members in a group with some variation in requirement are selected as equal, the section modulus requirement may be taken as the average of each individual requirement in the group. However, the section modulus requirement for the group is not to be taken less than 90% of the largest section modulus required for individual stiffeners within the group. Sequentially positioned stiffeners of equal scantlings may be considered a group.

FIGURE 1
Scantling Requirement Reference by Subsection *(1 September 2007)*



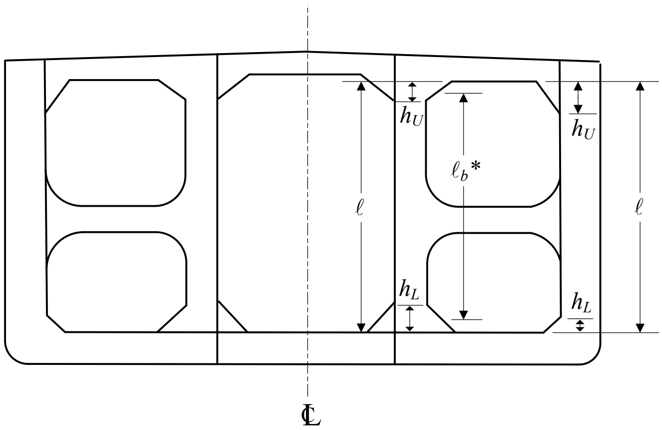
For main supporting members, also see 5A-3-3/11.9 & 5A-3-3/11.11 for minimum web depth and thickness requirements.

FIGURE 2A
Definitions of Spans (A) *(1 July 2012)*

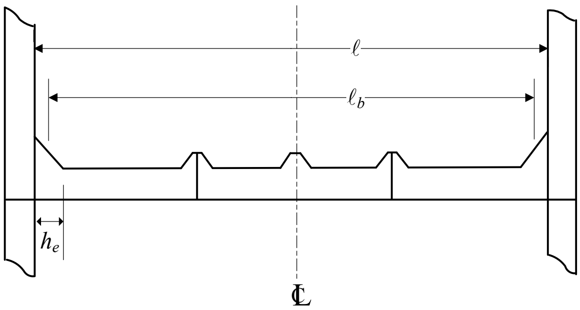


* Where both lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b may be taken between the toes of the effective lower and upper brackets.

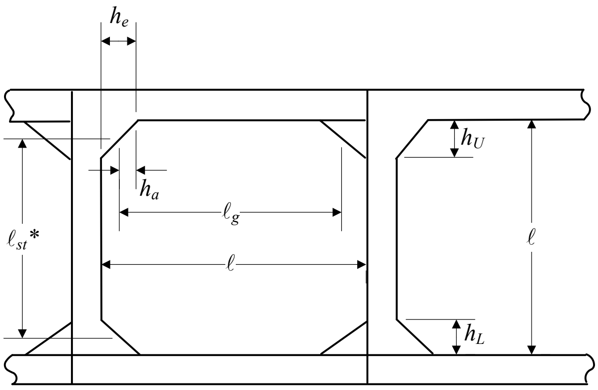
FIGURE 2B
Definitions of Spans (B) *(1 July 2012)*



a. Side Transverse and Vertical Web on Longitudinal Bulkhead



b. Horizontal Girder on Transverse Bulkhead



c. Deck Girder and Vertical Web on Transverse Bulkhead

* Where both lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b or ℓ_{st} may be taken between the toes of the effective lower and upper brackets.

3 Hull Girder Strength

3.1 Hull Girder Section Modulus *(1 July 2012)*

3.1.1 Hull Girder Section Modulus Amidships

The required hull girder section modulus amidships is to be calculated in accordance with 5A-1-2/1 of these Rules and 3-2-1/3.7, 3-2-1/5 and 3-2-1/9 of the *Steel Vessel Rules*. For the assessment of ultimate strength as specified in 5A-3-3/3.5 and the determination of initial net structural scantlings, the net hull girder section modulus amidships, SM_n, is to be calculated in accordance with 5A-3-3/3.1.2 below.

3.1.2 Effective Longitudinal Members

The hull girder section modulus calculation is to be carried out in accordance with 3-2-1/9 of the *Steel Vessel Rules*, as modified below. To suit the strength criteria based on a "net" ship concept, the nominal design corrosion values specified in 5A-3-1/Table 1 are to be deducted in calculating the net section modulus, SM_n.

3.1.3 Extent of Midship Scantlings

The items included in the hull girder section modulus amidships are to be extended as necessary to meet the hull girder section modulus required at the location being considered. The required hull girder section modulus can be obtained as M_t/f_p at the location being considered except if $(M_t)_{\max}/f_p$ is less than $SM_{\min}$ in 5A-1-2/1. In this case, the required section modulus is to be obtained by multiplying $SM_{\min}$ by the ratio of $M_{ti}/(M_t)_{\max}$ where M_{ti} is the total bending moment at the location under consideration and $(M_t)_{\max}$ is the maximum total bending moment amidships.

3.3 Hull Girder Moment of Inertia *(1 July 2012)*

The hull girder moment of inertia, I, amidships, is to be not less than:

$$I = L \cdot SM/33.3 \quad \text{cm}^2\text{-m}^2 \ (\text{in}^2\text{-ft}^2)$$

where

L = length of installation, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)

SM = required hull girder section modulus, in cm^2-m (in^2-ft). See 5A-1-2/1.

3.5 Hull Girder Ultimate Strength *(December 2008)*

In addition to the strength requirements specified in 5A-3-3/3.1, the vertical hull girder ultimate strength for either hogging or sagging conditions for the FPI design environmental condition (DEC) is to satisfy the limit state as specified below. It need only be applied within the 0.4L amidship region.

$$\gamma_s M_s + \gamma_w \beta_{VBM} M_w \le M_u/\gamma_u$$

where

M_s = permissible still-water bending moment, in kN-m (tf-m, Ltf-ft)

M_w = vertical wave-induced bending moment in accordance with 3-2-1/3.5.1 of the *Steel Vessel Rules*, in kN-m (tf-m, Ltf-ft)

M_u = hull girder ultimate strength, which may be determined from the equations as given in Appendix 5A-3-A3, in kN-m (tf-m, Ltf-ft)

β_{VBM} = ESF for vertical wave-induced bending moment for DEC

γ_s = load factor for the maximum permissible still-water bending moment, but not to be taken as less than 1.0

γ_w = load factor for the wave-induced bending moment, but not to be taken as less than below for the given limits

= 1.3 for $M_s < 0.2\,M_t$ or $M_s > 0.5\,M_t$

= 1.2 for $0.2M_t \leq M_s \leq 0.5\,M_t$

M_t = total bending moment, in kN-m (tf-m, Ltf-ft)

= $M_s + \beta_{VBM}\,M_w$

γ_u = safety factor for the vertical hull girder bending capacity, but not to be taken as less than 1.15

5 Shearing Strength *(1997)*

5.1 General *(December 2008)*

The net thickness of the side shell and longitudinal bulkhead plating is to be determined based on the total vertical shear force, F_t, and the permissible shear stress, f_s, given below, where the outer longitudinal bulkheads (inner skin) are located no further than $0.075B$ from the side shell.

The nominal design corrosion values as given in 5A-3-1/Table 1 for the side shell and longitudinal bulkhead plating are to be added to the "net" thickness thus obtained.

$F_t = F_S + \beta_{VSF}\,F_W$ kN (tf, Ltf)

$t = Fm/I\,f_s$ cm (in.)

where

F_S = still-water shear force based on the still-water shear force envelope curve for all anticipated loading conditions in accordance with 3-2-1/3.3 of the *Steel Vessel Rules*, at location considered, in kN (tf, Ltf).

β_{VSF} = ESF for vertical shear force, as defined in 5A-3-A1/3

F_W = vertical wave shear force, as given in 3-2-1/3.5.3 of the *Steel Vessel Rules*, in kN (tf, Ltf). F_W for in-port condition may be taken as zero.

t = t_s or t_i (see 5A-3-3/5.3 and 5A-3-3/5.5)

F = F_tD_s or $(F_t + R_i)D_i$ (see 5A-3-3/5.3 and 5A-3-3/5.5 below)

m = first moment of the "net" hull girder section, in cm^3 (in^3), about the neutral axis, of the area between the vertical level at which the shear stress is being determined and the vertical extremity of the section under consideration

I = moment of inertia of the "net" hull girder section at the position considered, in cm^4 (in^4)

f_s = $11.96/Q$ kN/cm^2 ($1.220/Q$ tf/cm^2, $7.741/Q$ Ltf/in^2) at sea

= $10.87/Q$ kN/cm^2 ($1.114/Q$ tf/cm^2, $7.065/Q$ Ltf/in^2) in port

Q = material conversion factor

= 1.0 for ordinary strength steel

= 0.78 for Grade H32 steel

= 0.72 for Grade H36 steel

= 0.68 for Grade H40 steel

For the purpose of calculating required thickness for hull girder shear, the sign of F_t may be disregarded unless algebraic sum with other shear forces, such as local load components, is appropriate.

5.3 Net Thickness of Side Shell Plating

$t_s \geq F_t D_s m/I f_s$ cm (in.)

where

D_s = shear distribution factor for side shell, as defined in 5A-3-3/5.3.1, 5A-3-3/5.3.2 or 5A-3-3/5.3.3 below.

F_t, m, I and f_s are as defined in 5A-3-3/5.1 above.

5.3.1 Shear Distribution Factor for Ship-type Installations with Two Outer Longitudinal Bulkheads (inner skin only)

$D_s = 0.384 - 0.167A_{ob}/A_s - 0.190\ b_s/B$

where

A_{ob} = total projected area of the net outer longitudinal bulkhead (inner skin) plating above inner bottom (one side), in cm^2 (in^2)

A_s = total projected area of the net side shell plating (one side), in cm^2 (in^2)

b_s = distance between outer side longitudinal bulkhead (inner skin) and side shell, in m (ft)

B = breadth of the installation, in m (ft), as defined in 3-1-1/5 of the *Steel Vessel Rules*.

5.3.2 Shear Distribution Factor for Ship-type Installations with Two Outer Longitudinal Bulkheads and a Centerline Swash or Oil-tight Longitudinal Bulkhead

$D_s = 0.347 - 0.057A_{cb}/A_s - 0.137\ A_{ob}/A_s - 0.070b_s/B$

where

A_{cb} = total area of the net centerline longitudinal bulkhead plating above inner bottom, in cm^2 (in^2)

A_s, A_{ob}, b_s and B are as defined in 5A-3-3/5.3.1 above.

5.3.3 Shear Distribution Factor for Ship-type Installations with Two Outer and Two Inner Longitudinal Bulkheads

$D_s = 0.330 - 0.218A_{ob}/A_s - 0.043b_s/B$

where A_s, A_{ob} ,b_s and B are as defined in 5A-3-3/5.3.1 above.

5.5 Thickness of Longitudinal Bulkheads

$t_i \geq (F_t + R_i)D_i m/I f_s$ cm (in.)

where

D_i = shear distribution factor

R_i = local load correction

i = *ob* for outer longitudinal bulkhead (inner skin)

= *ib* for inner longitudinal bulkhead

= *cb* for centerline longitudinal bulkhead

F_t, I, m and f_s are as defined above.

The other parameters, depending on the configuration of the ship-type installation, are defined in 5A-3-3/5.5.1, 5A-3-3/5.5.2 and 5A-5-3/5.5.3 below.

5.5.1 Ship-type Installations with Two Outer Longitudinal Bulkheads (Inner Skin Only)

The net thickness of the outer longitudinal bulkhead plating at the position considered:

$t_{ob} \geq F_t D_{ob} m/I f_s$ cm (in.)

where

D_{ob} = $0.105 + 0.156A_{ob}/A_s + 0.190b_s/B$

A_s, A_{ob}, b_s, B, F_t, I, m and f_s are defined above.

5.5.2 Ship-type Installations with Two Outer Longitudinal Bulkheads and a Centerline Swash or Oil-tight Longitudinal Bulkhead

5.5.2(a) (1999) The net thickness of the centerline longitudinal bulkhead plating at the position considered:

$t_{cb} \geq (F_t + R_{cb})D_{cb} m/I f_s$ cm (in.)

where

R_{cb} = $W_c[(2N_{wcb}\, k_{cb} I/3H_{cb}\, D_{cb} m) - 1] \geq 0$

k_{cb} = $1 + A^*_{cb}/A_{cb} \leq 1.9$

D_{cb} = $0.229 + 0.152A_{cb}/A_s - 0.10A_{ob}/A_s - 0.198\, b_s/B$

W_c = local load, in kN (tf, Ltf), calculated according to 5A-3-3/5.7 and 5A-3-3/Figure 3a

N_{wcb} = local load distribution factor for the centerline longitudinal bulkhead

= $(0.66D_{cb} + 0.25)\,(n - 1)/n$

n = total number of transverse frame spaces in the center tank

H_{cb} = depth of the centerline longitudinal bulkhead above inner bottom, in cm (in.)

A^*_{cb} = total area of the net centerline longitudinal bulkhead plating above the lower edge of the strake under consideration, in cm^2 (in^2)

All other parameters are as defined in 5A-3-3/5.3.

5.5.2(b) The net thickness of the outer longitudinal bulkhead plating at the position considered:

$t_{ob} \geq F_t D_{ob} m/I f_s$ cm (in.)

where

D_{ob} = $0.106 - 0.093A_{cb}/A_s + 0.164A_{ob}/A_s + 0.202b_s/B$

All other parameters are as defined in 5A-3-3/5.3 and 5A-3-3/5.5.

5.5.3 Ship-type Installations with Two Outer and Two Inner Longitudinal Bulkheads

5.5.3(a) The net thickness of the inner longitudinal bulkhead plating at the position considered:

$t_{ib} \geq (F_t + R_{ib})D_{ib} m/I f_s$ cm (in.)

where

R_{ib} = $W_{c1}[(2N_{wib1} k_{ib} I/3H_{ib} D_{ib} m) - 1] + W_{c2}[(2N_{wib2} k_{ib} I/3H_{ib} D_{ib} m) - 1] \geq 0$

k_{ib} = $1 + A^*_{ib}/A_{ib} \leq 1.9$

D_{ib} = $0.058 + 0.173A_{ib}/A_s - 0.043b_s/B$

W_{c1}, W_{c2} = local load, in kN (tf, Ltf), calculated according to 5A-3-3/5.7 and 5A-3-3/Figure 3b

A_{ib} = total area of the net inner longitudinal bulkhead plating above inner bottom, in cm^2 (in^2)

A^*_{ib} = total area of the net inner longitudinal bulkhead plating above the lower edge of the strake under consideration, in cm^2 (in^2)

N_{wib1}, N_{wib2} = local load distribution factor for inner longitudinal bulkhead

N_{wib1} = $(0.49D_{ib} + 0.18)(n - 1)/n$ for local load W_{c1}

N_{wib2} = $(0.60D_{ib} + 0.10)(n - 1)/n$ for local load W_{c2}

H_{ib} = depth of the inner longitudinal bulkhead above inner bottom, in cm (in.)

All other parameters are as defined above.

5.5.3(b) The net thickness of the outer longitudinal bulkhead plating at the position considered:

$t_{ob} \geq F_t D_{ob} m/I f_s$ cm (in.)

where

D_{ob} = $0.013 + 0.153A_{ob}/A_s + 0.172\, b_s/B$

All other parameters are as defined above.

5.7 Calculation of Local Loads *(1995)*

In determining the shear forces at the ends of cargo tanks, the local loads are to be calculated as shown in the following example. The tank arrangement for this example is as shown in 5A-3-3/Figure 3. The ballast tanks within double bottom and double side are to be considered as being empty in calculating excess liquid head.

5.7.1 Ship-type Installations with Two Outer Longitudinal Bulkheads and a Centerline Swash or Oil-tight Longitudinal Bulkhead *(1 July 2000)*

Local load W_c may be denoted by $W_c(f)$ and $W_c(a)$ at the fore and aft ends of the center tank, respectively, in kN (tf, Ltf).

$$W_c(f) = W_c(a) = 0.5\rho g b_c \ell_c[k_s H_c + 0.71k_s(a_v/g)H_c + 0.47k_s\ell_c \sin\phi - 0.55(\rho_o/\rho)d_f + 0.2(\rho_o/\rho)C_1] \geq 0$$

but need not be taken greater than $0.5k_s\rho g b_c \ell_c H_c$

where

k_s = load factor

= 1.0 for all loads from ballast tanks

= 0.878 for ρg of 10.05 kN/m^3 (1.025 tf/m^3, 0.0286 Ltf/ft^3) and 1.0 for ρg of 11.18 kN/m^3 (1.14 tf/m^3, 0.0318 Ltf/ft^3) and above for all loads from cargo tanks.

For cargo ρg between 10.05 kN/m^3 (1.025 tf/m^3, 0.0286 Ltf/ft^3) and 11.18 kN/m^3 (1.14 tf/m^3, 0.0318 Ltf/ft^3), the factor k_s may be determined by interpolation

ρg = specific weight of the liquid, not to be taken less than 10.05 kN/m^3 (1.025 tf/m^3, 0.0286 Ltf/ft^3)

$\rho_o g$ = specific weight of sea water, 10.05 kN/m^3 (1.025 tf/m^3, 0.0286 Ltf/ft^3)

ℓ_c, b_c = length and breadth, respectively, of the center tanks, in m (ft), as shown in 5A-3-3/Figure 3a

H_c = liquid head in the center tank, in m (ft)

a_v = vertical acceleration amidships with a wave heading angle of 0 degrees, in m/sec^2 (ft/sec^2), as defined in 5A-3-2/5.7.1(c)

g = acceleration of gravity = 9.8 m/sec^2 (32.2 ft/sec^2)

ϕ = pitch amplitude in degrees, as defined in 5A-3-2/5.7.1(a)

d_f = draft, as defined in 3-1-1/9 of the *Steel Vessel Rules*, in m (ft)

C_1 = as defined in 3-2-1/3.5 of the *Steel Vessel Rules*

5.7.2 Ship-type Installations with Two Outer and Two Inner Longitudinal Bulkheads *(1 July 2000)*

Local loads W_{c1}, W_{c2} may be denoted by $W_{c1}(f)$, $W_{c2}(f)$ and $W_{c1}(a)$, $W_{c2}(a)$ at the fore and aft ends of the center tank, respectively, in kN (tf, Ltf).

$$W_{c1}(f) = \frac{k_s \rho g b_{c1}}{\ell_c} \left[h_{c1}\ell_1 \left(\ell_2 + \frac{\ell_1}{2}\right) + h_{c2} \frac{\ell_2^2}{2}\right]$$

$$W_{c1}(a) = \frac{k_s \rho g b_{c1}}{\ell_c} \left[h_{c1} \frac{\ell_1^2}{2} + h_{c2}\ell_2 \left(\ell_1 + \frac{\ell_2}{2}\right)\right]$$

$$W_{c2}(f) = \frac{k_s \rho g b_{c2}}{\ell_c} \left[h_{c3}\ell_1 \left(\ell_2 + \frac{\ell_1}{2}\right) + h_{c4} \frac{\ell_2^2}{2}\right]$$

$$W_{c2}(a) = \frac{k_s \rho g b_{c2}}{\ell_c} \left[h_{c3} \frac{\ell_1^2}{2} + h_{c4}\ell_2 \left(\ell_1 + \frac{\ell_2}{2}\right)\right]$$

where

k_s = load factor, as defined in 5A-3-3/5.7.1

ρg = specific weight of the liquid, not to be taken less than 10.05 kN/m^3 (1.025 tf/m^3, 0.0286 Ltf/ft^3)

ℓ_c = length of the center tank, in m (ft), as shown in 5A-3-3/Figure 3b

ℓ_1, ℓ_2 = longitudinal distances from the respective center tank ends to the intermediate wing tank transverse bulkheads, in m (ft), as shown in 5A-3-3/Figure 3b

b_{c1} = breadth of the center tank, in m (ft), as shown in 5A-3-3/Figure 3b

b_{c2} = breadth of the center and wing tanks, in m (ft), as shown in 5A-3-3/Figure 3b

H_1, H_2 = liquid heads in the wing tanks, in m (ft), as shown in 5A-3-3/Figure 3b

h_{c1} = $H_c - H_1$, but not to be taken less than zero

h_{c2} = $H_c - H_2$, but not to be taken less than zero

h_{c3} = H_c or H_1, whichever is lesser

h_{c4} = H_c or H_2, whichever is lesser

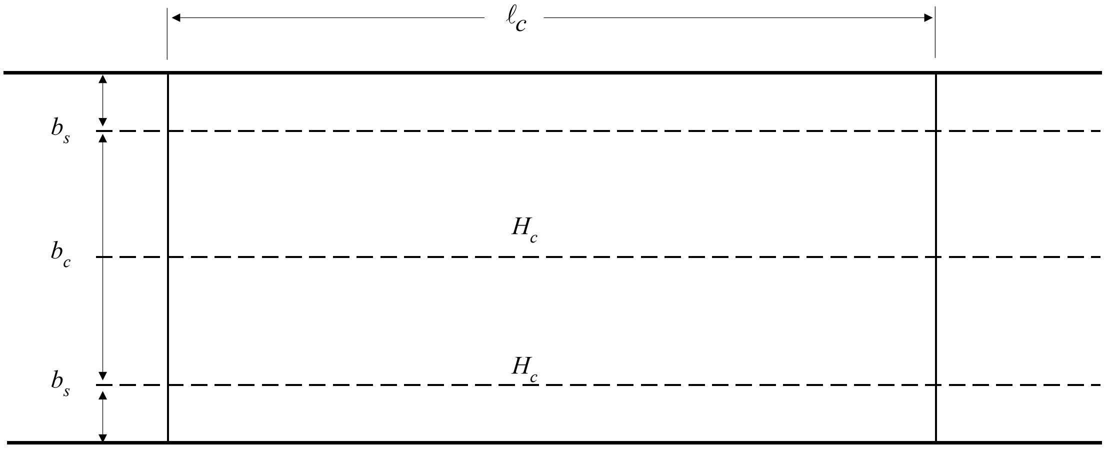
Where adjacent tanks are loaded with cargoes of different densities, the heads are to be adjusted to account for the difference in density. For locations away from the ends of the tanks, R_{cb} and R_{ib} may be determined using the calculated values of W_c at the locations considered.

5.9 Three Dimensional Analysis *(1995)*

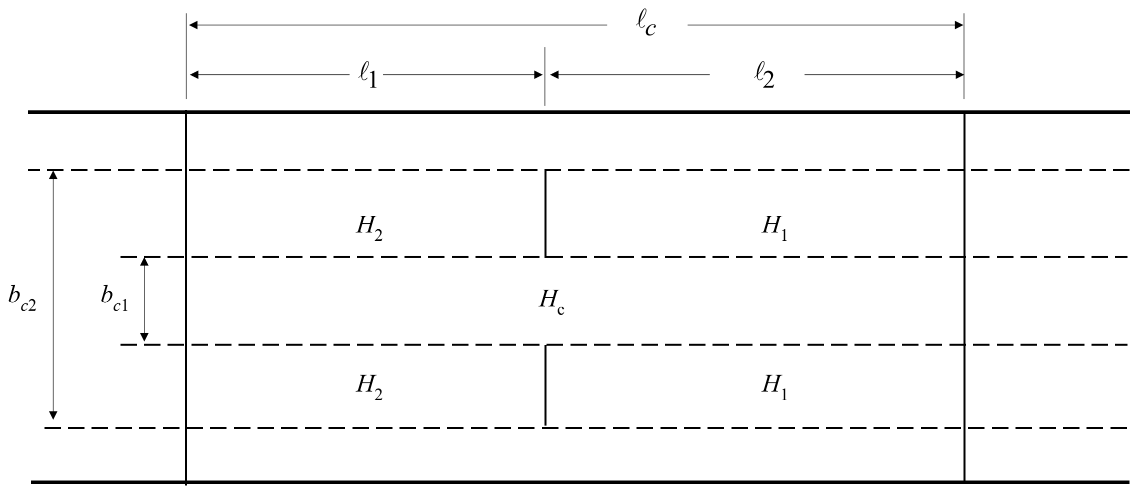
The total shear stresses in the side shell and longitudinal bulkhead plating (net thickness) may be calculated using a 3D structural analysis to determine the general shear distribution and local load effects for the critical shear strength conditions among all of the anticipated loading conditions.

FIGURE 3
Center Tank Region *(1995)*

a Tankers with Double Hull and Centerlilne Swash or Oil-tight Longitudinal Bulkhead.



b Tankers with Four Longitudinal Bulkheads



7 Double Bottom Structures

7.1 General *(1995)*

7.1.1 Arrangement

The depth of the double bottom and arrangement of access openings are to be in compliance with 5A-3-1/5. Centerline and side girders are to be fitted, as necessary, to provide sufficient stiffness and strength for docking loads as well as those specified in Section 5A-3-2.

Struts connecting the bottom and inner bottom longitudinals are not to be fitted.

7.1.2 Keel Plate

The net thickness of the flat plate keel is to be not less than that required for the bottom shell plating at that location by 5A-3-3/7.3.1 increased by 1.5 mm (0.06 in.), except where the submitted docking plan (see 3-1-2/11 of the *Steel Vessel Rules*) specifies all docking blocks be arranged away from the keel.

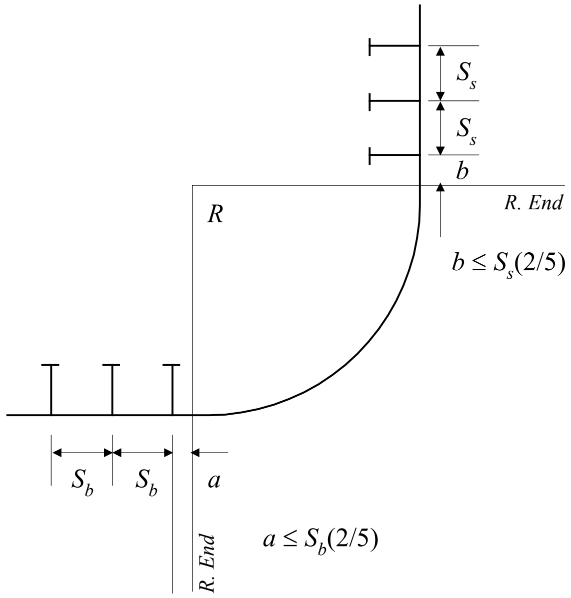
7.1.3 Bottom Shell Plating – Definition

The term "bottom shell plating" refers to the plating from the keel to the upper turn of the bilge for 0.4L amidships.

7.1.4 Bilge Longitudinals *(2004)*

Longitudinals around the bilge are to be graded in size from that required for the lowest side longitudinal to that required for the bottom longitudinals. Where longitudinals are omitted in way of the bilge, the bottom and side longitudinals are to be arranged so that the distance between the nearest longitudinal and the turn of the bilge is not more than 0.4s (s is the spacing of bottom (S_b) or side (S_s) longitudinals), as applicable (see 5A-3-3/Figure 4).

FIGURE 4



7.3 Bottom Shell and Inner Bottom Plating *(1997)*

The thickness of the bottom shell and inner bottom plating over the midship 0.4L is to satisfy the hull girder section modulus requirements in 3-2-1/3.7 of the *Steel Vessel Rules*. The buckling and ultimate strength are to be in accordance with the requirements in 5A-3-4/5. In addition, the net thickness of the bottom shell and inner bottom plating is to be not less than the following.

7.3.1 Bottom Shell Plating *(1999)*

The net thickness of the bottom shell plating, t_n, is to be not less than t_1, t_2 and t_3, specified as follows:

$t_1 = 0.73s(k_1 p/f_1)^{1/2}$ mm (in.)

$t_2 = 0.73s(k_2\, p/f_2)^{1/2}$ mm (in.)

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

where

s = spacing of bottom longitudinals, in mm (in.)

k_1 = 0.342

k_2 = 0.500

p = $p_a - p_{uh}$ or p_b, whichever is greater, in N/cm^2 (kgf/cm^2, lbf/in^2)

p_{uh}	=	$0.12\gamma(h\ell_{wt}\tan\phi_e)^{1/2}$	where $\ell_{wt} \geq 0.20L$
	=	0	where $\ell_{wt} \leq 0.15L$

Linear interpolation is to be used for intermediate values of ℓ_{wt}.

p_a and p_b are nominal pressures, in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in load case "a" and "b" in 5A-3-2/Table 3 for bottom plating, respectively.

γ	=	specific weight of the ballast water, 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft)
h	=	height of double side ballast tank at installation's side, in m (ft)
ℓ_{wt}	=	length at tank top of double side ballast tank, in m (ft)
L	=	installation length, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)
ϕ_e	=	effective pitch amplitude, as defined in 5A-3-2/5.7.2 with $C_\phi = 1.0$
f_1	=	permissible bending stress in the longitudinal direction, in N/cm^2 (kgf/cm^2, lbf/in^2)
	=	$(1 - 0.70\alpha_1 SM_{RB}/SM_B)S_m f_y \leq 0.40 S_m f_y$
f_1	=	$(1 - 0.70\alpha_1 SM_{RB}/SM_B)S_m f_y \leq (0.40 + 0.1(190 - L)/40)\, S_m f_y$ for $L < 190$ m
α_1	=	$S_{m1} f_{y1}/S_m f_y$
SM_{RB}	=	reference net hull girder section modulus based on the material factor of the bottom flange of the hull girder, in cm^2-m (in^2-ft)
	=	$0.92SM$
SM	=	required gross hull girder section modulus at the location under consideration, in accordance with 3-2-1/3.7 and 3-2-1/5.5 of the *Steel Vessel Rules*, based on the material factor of the bottom flange of the hull girder, in cm^2-m (in^2-ft)
SM_B	=	design (actual) net hull girder section modulus to the bottom, in cm^2-m (in^2-ft), at the location under consideration
f_2	=	permissible bending stress in the transverse direction, in N/cm^2 (kgf/cm^2, lbf/in^2)
	=	$0.80\, S_m f_y$
S_m	=	strength reduction factor
	=	1 — for Ordinary Strength Steel, as specified in 2-1-2/Table 2 of the ABS *Rules for Materials and Welding (Part 2)*
	=	0.95 — for Grade H32, as specified in 2-1-3/Table 2 of the ABS *Rules for Materials and Welding (Part 2)*
	=	0.908 — for Grade H36, as specified in 2-1-3/Table 2 of the ABS *Rules for Materials and Welding (Part 2)*
	=	0.875 — for Grade H40, as specified in 2-1-3/Table 2 of the ABS *Rules for Materials and Welding (Part 2)*
S_{m1}	=	strength reduction factor for the bottom flange of the hull girder
f_y	=	minimum specified yield point of the material, 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)

E = modulus of elasticity of the material, may be taken as 2.06×10^7 N/cm^2 (2.1×10^6 kgf/cm^2, 30×10^6 lbf/in^2) for steel

c = $0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$

N = $R_b(Q/Q_b)^{1/2}$

R_b = $(SM_{RBH}/SM_B)^{1/2}$

SM_{RBH} = reference net hull girder section modulus for hogging bending moment based on the material factor of the bottom flange of the hull girder, in cm^2-m (in^2-ft)

= $0.92SM_H$

SM_H = required gross hull girder section modulus, in accordance with 3-2-1/3.7.1 and 3-2-1/5.5 of the *Steel Vessel Rules*, for hogging total bending moment at the location under consideration, based on the material factor of the bottom flange of the hull girder, in cm^2-m (in^2-ft)

Q, Q_b = material conversion factor in 5A-3-3/5.1 for the bottom shell plating under consideration and the bottom flange of the hull girder, respectively.

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.

In addition to the foregoing, the net thickness of the bottom shell plating, outboard of $0.3B$ from the centerline of the installation, is to be not less than that of the lowest side shell plating required by 5A-3-3/9.1 adjusted for the spacing of the longitudinals and the material factors.

7.3.2 Inner Bottom Plating *(1999)*

The net thickness of the inner bottom plating, t_n, is to be not less than t_1, t_2 and t_3, specified as follows:

$t_1 = 0.73s(k_1\, p/f_1)^{1/2}$ mm (in.)

$t_2 = 0.73s(k_2\, p/f_2)^{1/2}$ mm (in.)

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

where

s = spacing of inner bottom longitudinals, in mm (in.)

k_1 = 0.342

k_2 = 0.50

p = $p_a - p_{uh}$ or p_b, whichever is greater, in N/cm^2 (kgf/cm^2, lbf/in^2)

p_a and p_b are nominal pressures, in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in load case "a" and "b" in 5A-3-2/Table 3 for inner bottom plating, respectively.

p_{uh} is defined in 5A-3-3/7.3.1.

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.

f_1 = permissible bending stress in the longitudinal direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $(1 - 0.52\alpha_1 SM_{RB}/SM_B)S_m f_y \le 0.57S_m f_y$, where SM_B/SM_{RB} is not to be taken more than 1.4

f_2 = permissible bending stress in the transverse direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.85\, S_m f_y$

α_1 = $S_{m1} f_{y1} / S_m f_y$

S_m = strength reduction factor obtained from 5A-3-3/7.3.1 for the steel grade of inner bottom material

S_{m1} = strength reduction factor obtained from 5A-3-3/7.3.1 for the steel grade of bottom flange material.

f_y = minimum specified yield point of the inner bottom material, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{y1} = minimum specified yield point of the bottom flange material, in N/cm^2 (kgf/cm^2, lbf/in^2)

c = $0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$

N = $R_b\ [(Q/Q_b)(y/y_n)]^{1/2}$

Q = material conversion factor in 5A-3-3/5.1 for the inner bottom plating

y = vertical distance, in m (ft), measured from the inner bottom to the neutral axis of the hull girder section

y_n = vertical distance, in m (ft), measured from the bottom to the neutral axis of the hull girder section

SM_{RB}, SM_B, R_b, Q_b and E are as defined in 5A-3-3/7.3.1.

Where the breadth of the center tank exceeds $0.6B$, or the wing ballast tanks are U-shaped, the net thickness of the inner bottom plating in the center tank, outboard of $0.3B$ from the centerline of the tank, is also to be not less than that of the adjacent strake on the outer longitudinal bulkhead (inner skin) required by 5A-3-3/13.1, adjusted for the spacing of the longitudinals and the material factors.

7.5 Bottom and Inner Bottom Longitudinals *(1 July 2005)*

The net section modulus of each bottom or inner bottom longitudinal, in association with the effective plating to which it is attached, is to be not less than obtained from the following equations:

$SM = M/f_b$ cm^3 (in^3)

where

M = $1000ps\ell^2/k$ N-cm (kgf-cm, lbf-in.)

k = 12 (12, 83.33)

s = spacing of longitudinals, in mm (in.)

ℓ = span of the longitudinal between effective supports, as shown in 5A-3-3/Figure 5, in m (ft)

p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified in 5A-3-3/7.3.1 and 5A-3-3/7.3.2 for bottom and inner bottom longitudinals, respectively

f_b = permissible bending stresses, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $(1.0 - 0.65\alpha_1 SM_{RB}/SM_B)S_m f_y \leq 0.55 S_m f_y$ for bottom longitudinals

= $(1.0 - 0.50\alpha_1 SM_{RB}/SM_B)S_m f_y \leq 0.65 S_m f_y$ for inner bottom longitudinals

α_1 = $S_{m1} f_{y1} / S_m f_y$

S_m = strength reduction factor, as defined in 5A-3-3/7.3.1, for the material of longitudinals considered

S_{m1} = strength reduction factor, as defined in 5A-3-3/7.3.1, for the bottom flange material

f_y = minimum specified yield point for the material of longitudinals considered, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{y1} = minimum specified yield point of the bottom flange material, in N/cm^2 (kgf/cm^2, lbf/in^2)

SM_{RB} and SM_B are as defined in 5A-3-3/7.3.1.

The net section modulus of the bottom longitudinals, outboard of 0.3B from the centerline of the installation, is also to be not less than that of the lowest side longitudinal required by 5A-3-3/9.5, adjusted for the span and spacing of the longitudinals and the material factors.

Where the breadth of center tank exceeds 0.6B, or the wing ballast tanks are U-shaped, the net section modulus of the inner bottom longitudinals in the center tank, outboard of 0.3B from the centerline of the tank, is also to be not less than that of the lowest outer longitudinal bulkhead longitudinal required by 5A-3-3/13.5, adjusted for the span and spacing of the longitudinals and the material factors.

In determining compliance with the foregoing, an effective breadth, b_e, of attached plating is to be used in calculation of the section modulus of the design longitudinal. b_e is to be obtained from line a) of 5A-3-3/Figure 6.

7.7 Bottom Girders/Floors *(1997)*

The minimum scantlings for bottom girders/floors are to be determined from 5A-3-3/7.7.1, 5A-3-3/7.7.2, 5A-3-3/7.7.3 and 5A-3-3/7.7.4, as follows:

7.7.1 Bottom Centerline Girder *(1999)*

The net thickness of the centerline girder amidships, where no centerline bulkhead is fitted, is to be not less than t_1 and t_2, as defined below:

$t_1 = (0.045L + 4.5)R$ mm

$= (0.00054L + 0.177)R$ in.

$t_2 = 10F_1/(d_b f_s)$ mm

$= F_1/(d_b f_s)$ in.

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.

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

where F_1 is the maximum shear force in the center girder, as obtained from the equations given below (see also 5A-3-3/1.3). Alternatively, F_1 may be determined from finite element analyses, as specified in 5A-3-4/11, with the combined load cases in 5A-3-4/11.9. However, in no case should F_1 be taken less than 85% of that determined from the equations below:

$F_1 = 1000k\alpha_1\gamma n_1 n_2 p\ell_s s_1$ N (kgf, lbf), for $\lambda \le 1.5$

$F_1 = 414k\gamma n_1 n_2 p b_s s_1$ N (kgf, lbf), for $\lambda > 1.5$

where

k = 1.0 (1.0, 2.24)

α_1 = $0.606 - 0.22\lambda$

λ = ℓ_s/b_s

γ = $2x/(\ell_s - s_3)$, ≤ 1.0

n_1 = $0.0374(s_1/s_3)^2 - 0.326(s_1/s_3) + 1.289$

n_2 = $1.3 - (s_3/12)$ for SI or MKS Units

= $1.3 - (s_3/39.37)$ for U.S. Units

ℓ_s = unsupported length of the double bottom structures under consideration, in m (ft), as shown in 5A-3-3/Figure 7

b_s = unsupported width of the double bottom structures under consideration, in m (ft), as shown in 5A-3-3/Figure 7

s_1 = sum of one-half of girder spacing on each side of the center girder, in m (ft)

s_3 = spacing of floors, in m (ft)

x = longitudinal distance from the mid-span of unsupported length (ℓ_s) of the double bottom to the section of the girder under consideration, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), as specified in 5A-3-2/Table 3

d_b = depth of double bottom, in cm (in.)

f_s = permissible shear stresses, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

c = $0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$ but need not be greater than $0.45(Q/Q_b)^{1/2}$

N = $R_b\,(Q/Q_b)^{1/2}$

Q = material conversion factor in 5A-3-3/5 for the bottom girder

s = spacing of longitudinal stiffeners on the girder, in mm (in.)

R = 1.0 for ordinary mild steel

= $f_{ym}/S_m f_{yh}$ for higher strength material

f_{ym} = specified minimum yield point for ordinary strength steel, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{yh} = specified minimum yield point for higher tensile steel, in N/cm^2 (kgf/cm^2, lbf/in^2)

L = length of installation, in m (ft), as defined in 3-1-1/3.1 of the *Steel Vessel Rules*.

S_m, E, R_b, Q_b and f_y are as defined in 5A-3-3/7.3.1.

7.7.2 Bottom Side Girder *(1999)*

The net thickness of the bottom side girders is to be not less than t_1 and t_2, as defined below:

$t_1 = (0.026L + 4.5)R$ mm

$= (0.00031L + 0.177)R$ in.

$t_2 = 10\, F_2/(d_b f_s)$ mm

$= F_2/(d_b f_s)$ in.

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.

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

where F_2 is the maximum shear force in the side girders under consideration, as obtained from the equations given below (see also 5A-3-3/1.3). Alternatively, F_2 may be determined from finite element analyses, as specified in 5A-3-4/11, with the combined load cases in 5A-3-4/11.9. However, in no case should F_2 be taken less than 85% of that determined from the equations below:

$F_2 = 1000\, k\alpha_2\beta_1\gamma n_3 n_4\, p\ell_s s_2$ N (kgf, lbf), for λ ≤ 1.5

$F_2 = 285k\beta_1\gamma n_3 n_4\, pb_s s_2$ N (kgf, lbf), for λ > 1.5

where

k	=	1.0 (1.0, 2.24)	
α_2	=	$0.445 - 0.17\lambda$	
β_1	=	$1.25 - (2z_1/b_s)$	for ship-type installations with inner skin only [5A-3-3/Figure 7(d)]
	=	1.0	for all other ship-type installations
n_3	=	$1.072 - 0.0715(s_2/s_3)$	
n_4	=	$1.2 - (s_3/18)$	for SI or MKS Units
	=	$1.2 - (s_3/59.1)$	for U.S. Units
s_2	=	sum of one-half of girder spacings on both sides of the side girders, in m (ft)	
z_1	=	transverse distance from the centerline of the unsupported width b_s of the double bottom to the girder under consideration, in m (ft)	
c	=	$0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$, but need not be greater than $0.45(Q/Q_b)^{1/2}$	
N	=	$R_b\,(Q/Q_b)^{1/2}$	
Q	=	material conversion factor in 5A-3-3/5 for the bottom girder	
s	=	spacing of longitudinal stiffeners on the girder, in mm (in.)	

γ, ℓ_s, b_s, λ, s_3, p, d_b, f_s, L, R, S_m and f_y are as defined above.

7.7.3 Floors *(1997)*

The net thickness of the floors is to be not less than t_1 and t_2, as specified below:

$t_1 = (0.026L + 4.50)R$ mm

$= (0.00031L + 0.177)R$ in.

$t_2 = 10F_3/(d_b f_s)$ mm

$= F_3/(d_b f_s)$ in.

where F_3 is the maximum shear force in the floors under consideration, as obtained from the equation given below (see also 5A-3-3/1.3). Alternatively, F_3 may be determined from finite element analyses, as specified in 5A-3-4/11 with the combined load cases in 5A-3-4/11.9. However, in no case should F_3 be taken less than 85% of that determined from the equation below.

$F_3 = 1000k\alpha_3\beta_2\, pb_s s_3$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

α_3 as shown in 5A-3-3/Figure 7.

ρ_0	=	$\eta(0.66 - 0.08\eta)$,	for $\eta \le 2.0$
	=	1.0,	for $\eta > 2.0$, or for structures without longitudinal girders

β_2 = $1.05(2z_2/b_s)^2 \leq 1.0$ for ship-type installations with inner skin only [5A-3-3/Figure 7(d)]

= $2z_2/b_s$ for all other ship-type installations

η = $(\ell_s/b_s)(s_0/s_3)^{1/4}$

s_0 = average spacing of girders, in m (ft)

z_2 = transverse distance from the centerline of the unsupported width b_s of the double bottom to the section of the floor under consideration, in m (ft)

f_s = $0.45\ S_m f_y$ in N/cm^2 (kgf/cm^2, lbf/in^2)

ℓ_s, b_s, s_3, R, p, d_b, L, S_m and f_y are as defined above.

7.7.4 Bottom Girders under Longitudinal Bulkhead *(1999)*

The net thickness of the bottom centerline and side girders under longitudinal bulkheads is to be not less than t_1 and t_2, as defined below:

$t_1 = (0.045L + 4.5)R$ mm

$= (0.00054L + 0.177)R$ in.

The net thickness, t_2, may be determined based on S_m and f_y of the hull girder strength material required at the location under consideration.

$t_2 = cs(S_m f_y/E)^{1/2}$ mm (in.)

where

c = $0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$

N = $R_b\ (Q/Q_b)^{1/2}$

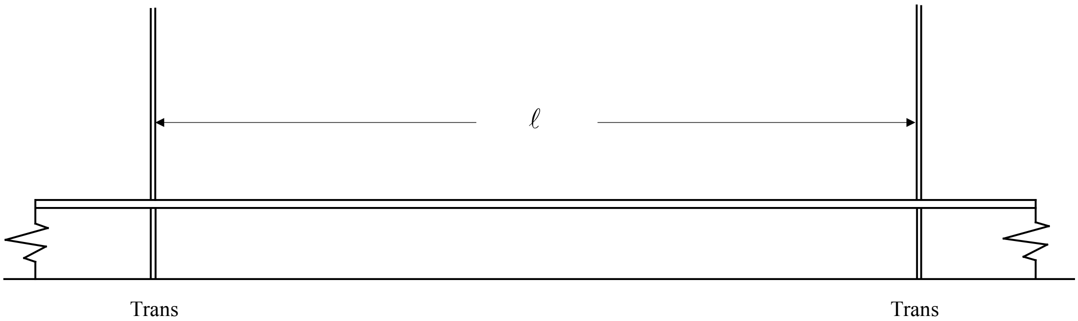
Q = material conversion factor in 5A-3-3/5 for the bottom girder

s = spacing of longitudinal stiffeners on the girder, in mm (in.)

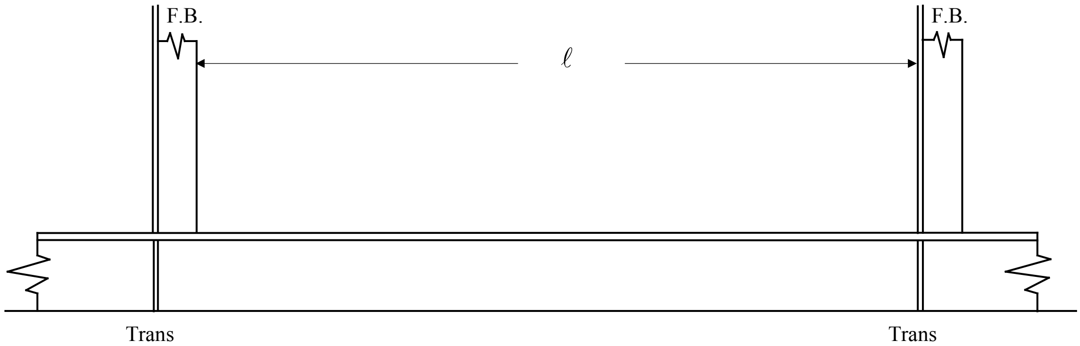
L, R, S_m and f_y are as defined above.

E, R_b and Q_b are as defined in 5A-3-3/7.3.1.

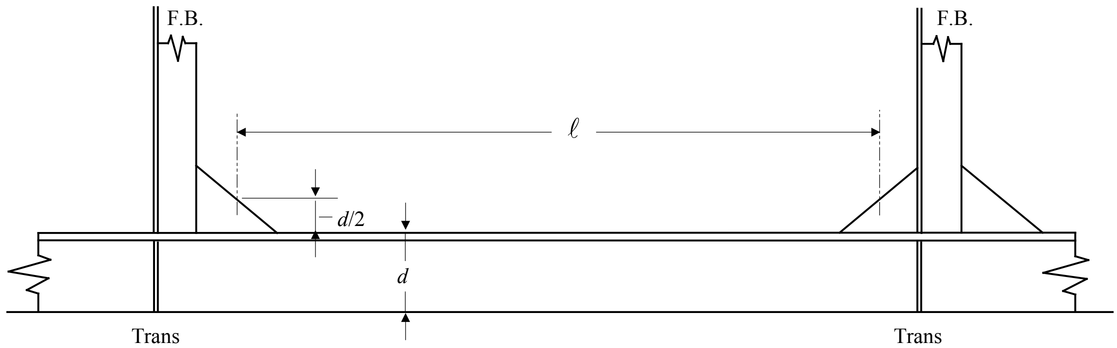
FIGURE 5
Unsupported Span of Longitudinal *(1995)*



a) Supported by transverses

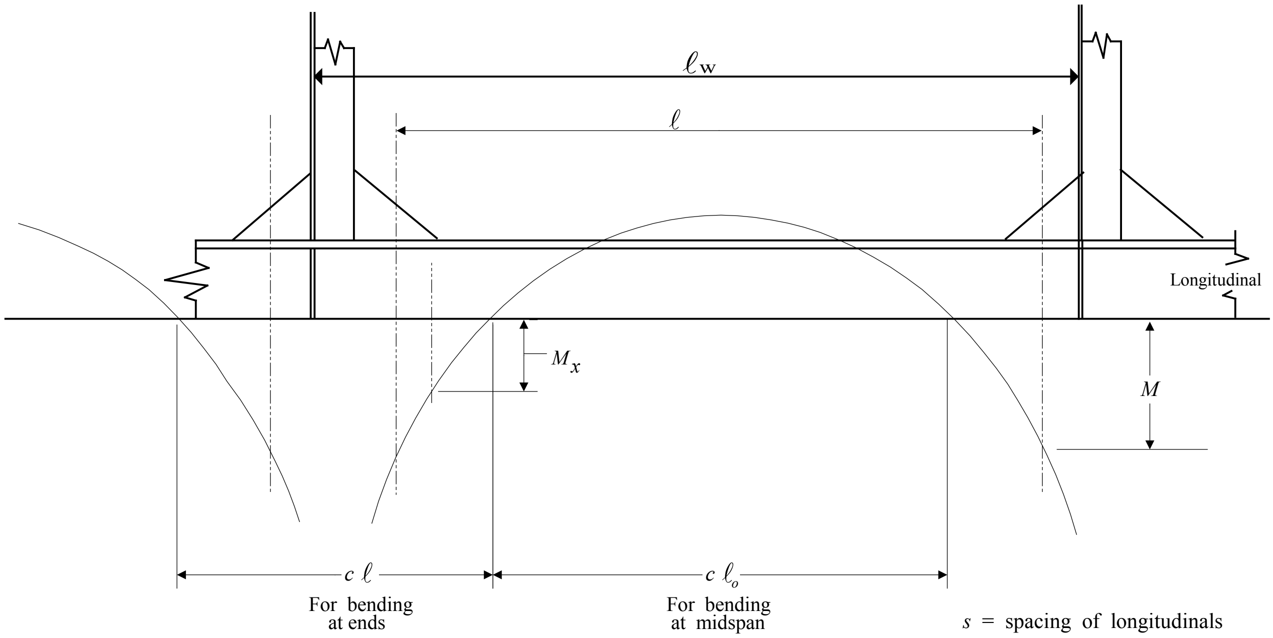


b) Supported by transverses and flat bar stiffeners



c) Supported by transverses, flat bar stiffeners and brackets

FIGURE 6
Effective Breadth of Plating b_e *(1 July 2009)*



a) For bending at midspan

$b_e/s = 1.219 - 0.965/(c\ell_0/s)$, when $c\ell_0/s < 4.5$

otherwise

$b_e/s = 1.0$

$c\ell_o/s$	1.5	2	2.5	3	3.5	4	4.5 and greater
b_e/s	0.58	0.73	0.83	0.90	0.95	0.98	1.0

b) For bending at ends

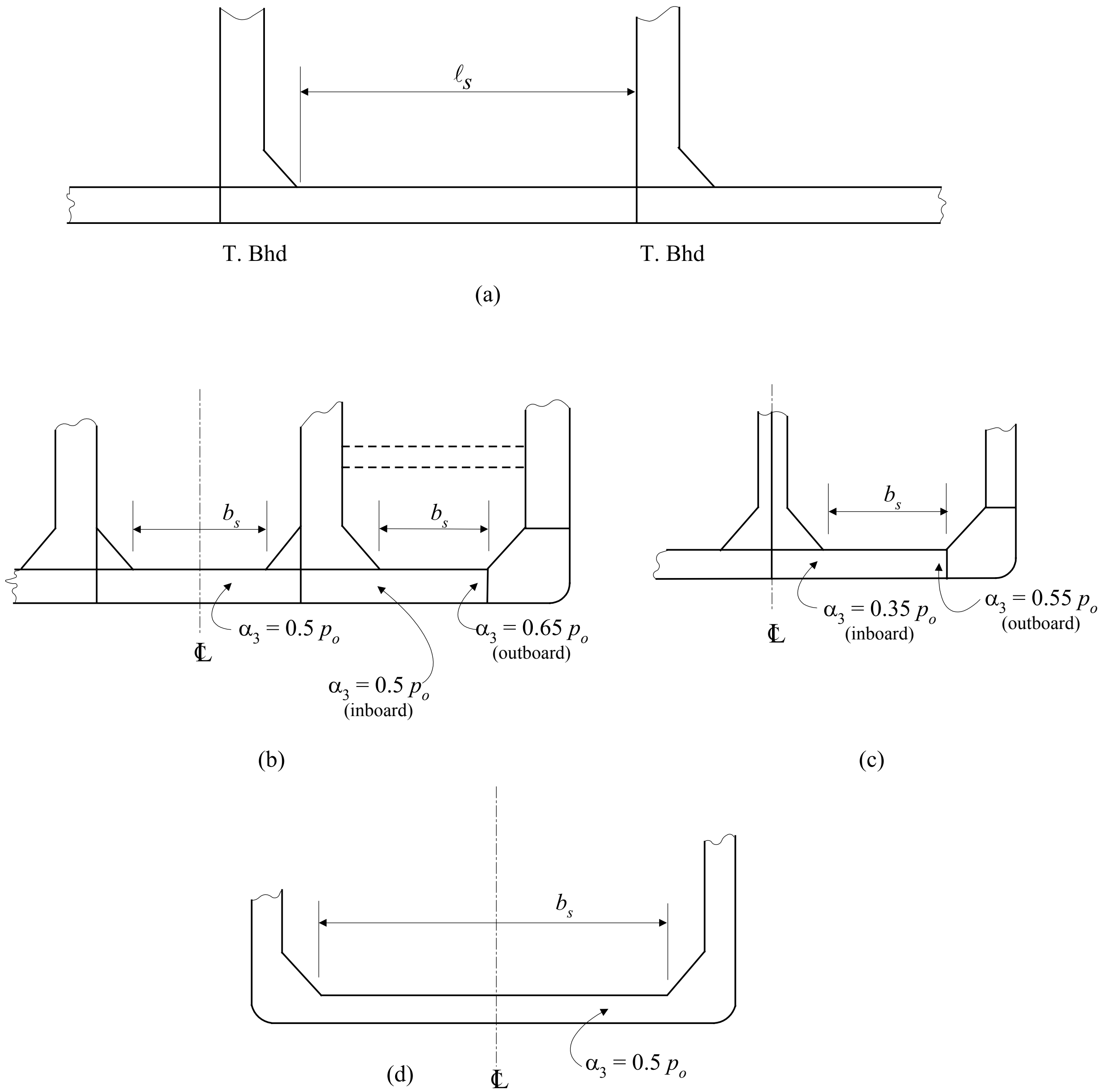
$b_e/s = (0.124c\ell/s - 0.062)^{1/2}$, when $c\ell_0/s < 8.5$

otherwise

$b_e/s = 1.0$

$c\ell/s$	1	1.5	2	2.5	3	3.5	4.0
b_e/s	0.25	0.35	0.43	0.5	0.55	0.6	0.67

FIGURE 7
Definitions of α_3, ℓ_s and b_s (1 July 2009)



9 Side Shell and Deck – Plating and Longitudinals

9.1 Side Shell Plating *(2014)*

The net thickness of the side shell plating, in addition to compliance with 5A-3-3/5.3, is to be not less than t_1, t_2 and t_3, as specified below for the midship 0.4L:

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

$t_2 = 0.73s(k_2\, p/f_2)^{1/2}$ mm (in.)

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

where

s = spacing of side longitudinals, in mm (in.)

k_1 = 0.342

k_2 = 0.50

p = $p_a - p_{uo}$ or p_b, whichever is greater, in N/cm² (kgf/cm², lbf/in²)

p_{uo} = $0.24\gamma(h\ell_{wt}b_{wt} \tan \phi_e \tan \theta_e)^{1/3}$ where $\ell_{wt} \geq 0.20L$

= 0 where $\ell_{wt} \leq 0.15L$

Linear interpolation is to be used for intermediate values of ℓ_{wt}.

p_a and p_b are nominal pressures at the lower edge of each plate strake, in N/cm² (kgf/cm², lbf/in²), as defined in load case "a" and "b" 5A-3-2/Table 3 for side shell plating, respectively. Where the wing ballast tanks are U-shaped, the nominal pressure may be taken at the lower edge of each plate, but is not to be less than that calculated at upper turn of bilge for J-shaped ballast tanks.

b_{wt} = breadth at tank top of double side ballast tank, in m (ft)

ϕ_e = effective pitch amplitude, as defined in 5A-3-2/5.7.2, with $C_\phi = 0.7$

θ_e = effective roll amplitude, as defined in 5A-3-2/5.7.2, with $C_\theta = 0.7$

L is installation length, as defined in 3-1-1/3.1 of the *Steel Vessel Rules (January 2005)*, in m (ft).

γ, h and ℓ_{wt} are also defined in 5A-3-3/7.3.1.

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.

f_1 = permissible bending stress, in the longitudinal direction, in N/cm² (kgf/cm², lbf/in²)

= $[0.86 - 0.50\alpha_1(SM_{RB}/SM_B)(y/y_b)]S_m f_y$

$\leq 0.43\, S_m f_y$, for $L \geq 190$ m (623 ft), below neutral axis

$\leq [0.43 + 0.17(190 - L)/40]S_m f_y$, for $L < 190$ m (623 ft), below neutral axis

SM_B/SM_{RB} is not to be taken more than 1.4.

= $0.43\, S_m f_y$, for $L \geq 190$ m (623 ft), above neutral axis

= $[0.43 + 0.17\,(190 - L)/40]S_m f_y$ for $L < 190$ m (623 ft), above neutral axis

f_2 = permissible bending stress in the vertical direction, in N/cm² (kgf/cm², lbf/in²)

= $0.80\, S_m f_y$

α_1 = $S_{m1} f_{y1} / S_m f_y$

S_m = strength reduction factor obtained from 5A-3-3/7.3.1 for the steel grade of side shell plating material

S_{m1} = strength reduction factor obtained from 5A-3-3/7.3.1 for the steel grade of bottom flange material

f_y = minimum specified yield point of the side shell material, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{y1} = minimum specified yield point of the bottom flange material, in N/cm^2 (kgf/cm^2, lbf/in^2)

y_b = vertical distance, in m (ft), measured from the upper turn of bilge to the neutral axis of the section

c = $0.7N^2 - 0.2$, not to be less than $0.4Q^{1/2}$

N = $R_d (Q/Q_d)^{1/2}$ for the sheer strake

= $R_d [(Q/Q_d)(y/y_n)]^{1/2}$ for other locations above neutral axis

= $R_b [(Q/Q_b)(y/y_n)]^{1/2}$ for locations below neutral axis

R_d = $(SM_{RDS}/SM_D)^{1/2}$

y = 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 for *N*.

= 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 under consideration for f_1.

SM_{RDS} = reference net hull girder section modulus for sagging bending moment, based on the material factor of the deck flange of the hull girder, in cm^2-m (in^2-ft)

= $0.92SM_S$

SM_S = required gross hull girder section modulus, in accordance with 3-2-1/3.7.1and 3-2-1/5.5 of the *Steel Vessel Rules*, for sagging total bending moment at the location under consideration, based on the material factor of the deck flange of the hull girder, in cm^2-m (in^2-ft)

Q, Q_d = material conversion factor in 5A-3-3/5 for the side shell plating under consideration and the deck flange of the hull girder, respectively.

y_n = vertical distance, in m (ft), measured from the bottom (deck) to the neutral axis of the section, when the strake under consideration is below (above) the neutral axis.

SM_{RB}, SM_B, R_b, Q_b and E are as defined in 5A-3-3/7.3.1. SM_D is as defined in 5A-3-3/9.5.

The minimum width of the sheer strake for the midship 0.4L is to be in accordance with 3-2-2/3.11 of the *Steel Vessel Rules (January 2005)*.

The thickness of the sheer strake is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.26 in.).

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

$$t_4 = 90(s/1000 + 0.7)\,[B\,d/(S_m f_y)^2]^{1/4} + 0.5 \text{ mm}$$

where

s = spacing of side longitudinal stiffeners, in mm

B = breadth of installation, as defined in 3-1-1/5 of the *Steel Vessel Rules*, in m

d = molded draft, as defined in 3-1-1/9 of the *Steel Vessel Rules*, in m

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 exceed 0.9B, and a section forward of amidships where the breadth at the waterline exceeds 0.6B.
- *Vertical extent.* Between 300 mm below the lowest ballast waterline to 0.25d or 2.2 m, whichever is greater, above the summer load line.

Alternatively, in lieu of the t_4 requirements above, side shell strength calculations may be submitted to demonstrate the structural adequacy of the side shell to the impact absorbing characteristics of fenders or equivalent, and their arrangement.

9.3 Deck Plating *(1 July 2012)*

The thickness of the strength deck plating is to be not less than that needed to meet the hull girder section modulus requirement in 3-2-1/3.7 of the *Steel Vessel Rules (January 2005)*. The buckling and ultimate strength are to be in accordance with the requirements in 5A-3-4/5. In addition, the net thickness of deck plating is to be not less than t_1, t_2 and t_3, as specified below for the midship 0.4L:

$t_1 = 0.73s(k_1 p/f_1)^{1/2}$ mm (in.)

$t_2 = 0.73s(k_2\,p/f_2)^{1/2}$ mm (in.)

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

where

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

k_1 = 0.342

k_2 = 0.50

p = p_n in cargo tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $p_n - p_{uh}$ in ballast tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

In no case is p to be taken less than 2.06 N/cm^2 (0.21 kgf/cm^2, 2.987 lbf/in^2).

p_n is nominal pressure, in N/cm^2 (kgf/cm^2 lbf/in^2), as defined in 5A-3-2/Table 3 for deck plating.

p_{uh} is defined in 5A-3-3/7.3.1.

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.

f_1 = permissible bending stress in the longitudinal direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.15\,S_m f_y$

f_2 = permissible bending stress in the transverse direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.80\,S_m f_y$

c = $0.5\,(0.6 + 0.0015L)$ for SI or MKS Units

= $0.5\,(0.6 + 0.00046L)$ for U.S. Units

c is not to be taken less than $(0.7N^2 - 0.2)$ for installations having length less than 267 m (876 ft)

L = length of installation, in m (ft), as defined in 3-1-1/3.1 of the *Steel Vessel Rules (January 2005)*

N = $R_d\,(Q/Q_d)^{1/2}$

R_d = $(SM_{RDS}/SM_D)^{1/2}$

Q = material conversion factor in 5A-3-3/5 for the deck plating

S_m, f_y and E are as defined in 5A-3-3/7.3.1.

SM_{RDS} and Q_d are as defined in 5A-3-3/9.1.

SM_D is as defined in 5A-3-3/9.5.

The t_3 requirement for a converted ship-type FPI may be adjusted based on the ratio M_r, where M_r = total maximum sagging bending moment as a ship-type FPI/total maximum sagging bending moment as a trading vessel. The total sagging bending moment as a ship-type FPI is the sum of the maximum sagging still water and wave bending moments for the onsite condition. The sagging wave bending moment may be obtained from 5A-3-2/5.2.1.

The t_3 requirement for a new build ship-type FPI may be adjusted based on the ratio M_r, where M_r = (maximum sagging still water bending moment + sagging wave bending moment for the on-site DEC)/ (maximum sagging still water bending moment + wave sagging bending moment for North Atlantic environment).

M_r	*Adjusted* t_3
$M_r < 0.7$	$0.85 * t_3$
$0.7 \le M_r \le 1.0$	Varies linearly between $0.85 * t_3$ and t_3
$M_r > 1.0$	$1.0 * t_3$

The thickness of the stringer plate is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). The required deck area is to be maintained throughout the midship 0.4L of the installation or beyond the end of a superstructure at or near the midship 0.4L point. From these locations to the ends of the installation, the deck area may be gradually reduced in accordance with 3-2-1/11.3 of the *Steel Vessel Rules (January 2005)*. Where bending moment envelope curves are used to determine the required hull girder section modulus, the foregoing requirements for strength deck area may be modified in accordance with 3-2-1/11.3 of the *Steel Vessel Rules (January 2005)*. Where so modified, the strength deck area is to be maintained a suitable distance from superstructure breaks and is to be extended into the superstructure to provide adequate structural continuity.

9.5 Deck and Side Longitudinals *(1 July 2005)*

The net section modulus of each individual side or deck longitudinal, in association with the effective plating to which it is attached, is to be not less than obtained from the following equation:

$SM = M/f_b$ cm^3 (in^3)

$M = 1000ps\ell^2/k$ N-cm (kgf-cm, lbf-in)

where

k = 12 (12, 83.33)

p = $p_{ai} - p_{uo}$ or p_b, whichever is greater, for side longitudinals, in N/cm^2 (kgf/cm^2, lbf/in^2)

= p_n for deck longitudinals in cargo tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $p_n - p_{uh}$ for deck longitudinals in ballast tank, N/cm^2 (kgf/cm^2, lbf/in^2)

In no case is p to be taken less than 2.06 N/cm^2 (0.21 kgf/cm^2, 2.987 lbf/in^2).

p_a and p_b are nominal pressures, in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in load case "a" and "b", at the side longitudinal considered, in 5A-3-2/Table 3 for side longitudinals, respectively.

p_n is nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in 5A-3-2/Table 3 for deck longitudinals.

p_{uo} and p_{uh} are defined in 5A-3-3/9.1 and 5A-3-3/7.3.1, respectively.

s and ℓ are as defined in 5A-3-3/7.5.

f_b = permissible bending stresses, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $(1.0 - 0.60\alpha_2 SM_{RD}/SM_D)S_m f_y$ for deck longitudinals

= $1.0[0.86 - 0.52\alpha_1(SM_{RB}/SM_B)(y/y_n)]\ S_m f_y \le 0.75 S_m f_y$

for side longitudinals below neutral axis

$= 2.0[0.86 - 0.52\alpha_2(SM_{RD}/SM_D)(y/y_n)]\ S_m f_y \leq 0.75 S_m f_y$

for side longitudinals above neutral axis

$\alpha_2 = S_{m2} f_{y2}/S_m f_y$

S_m, f_y and α_1 are as defined in 5A-3-3/7.5.

S_{m2} = strength reduction factor, as obtained from 5A-3-3/7.3.1, for the steel grade of top flange material of the hull girder.

f_{y2} = minimum specified yield point of the top flange material of the hull girder, in N/cm^2 (kgf/cm^2, lbf/in^2)

SM_{RD} = reference net hull girder section modulus based on the material factor of the top flange of the hull girder, in cm^2-m (in^2-ft)

= 0.92 SM

SM = required gross hull girder section modulus at the location under consideration, in accordance with 3-2-1/3.7 and 3-2-1/5.5 of the *Steel Vessel Rules (January 2005)*, based on the material factor of the top flange of the hull girder, in cm^2-m (in^2-ft)

SM_D = design (actual) net hull girder section modulus at the deck, in cm^2-m (in^2-ft), at the location under consideration

SM_{RB} and SM_B are as defined in 5A-3-3/7.3.1.

y = vertical distance in m (ft) measured from the neutral axis of the section to the longitudinal under consideration at its connection to the associated plate

y_n = vertical distance, in m (ft), measured from the deck (bottom) to the neutral axis of the section, when the longitudinal under consideration is above (below) the neutral axis.

Where the wing ballast tanks are U-shaped, the net section modulus of deck longitudinals in the wing ballast tanks is to be not less than that of the uppermost side longitudinal, adjusted for the span and spacing of the longitudinal and the material factors.

Where the breadth of center tank exceeds 0.6B, the net section modulus of deck longitudinals in the center tank, located outboard of 0.3B from the centerline of the tank, is also to be not less than that of the uppermost boundary longitudinal bulkhead longitudinal required by 5A-3-3/13.5, adjusted for the span and spacing of the longitudinal and the material factors.

In determining compliance with the foregoing, an effective breadth, b_e, of attached plating is to be used in the calculation of the section modulus of the design longitudinal. b_e is to be obtained from line a) of 5A-3-3/Figure 6.

The net moment of inertia about the neutral axis of deck longitudinals and side longitudinals within the region of 0.1D from the deck, in association with the effective plating ($b_{wL} t_n$), is to be not less than obtained from the following equation:

$i_o = k A_e \ell^2 f_y / E$ cm^4 (in^4)

where

k = 1220 (1220, 17.57)

A_e = net sectional area of the longitudinal with the associated effective plating $b_{wL} t_n$, in cm^2 (in^2)

$b_{wL} = cs$

$c = 2.25/\beta - 1.25/\beta^2$ for $\beta \geq 1.25$

$= 1.0$ for $\beta < 1.25$

$\beta = (f_y/E)^{1/2}\ s/t_n$

t_n = net thickness of the plate, in mm (in.)

D = depth of installation, in m (ft), as defined in 3-1-1/7 of the *Steel Vessel Rules (January 2005)*.

ℓ, s and f_y are as defined in 5A-3-3/7.5.

E is as defined in 5A-3-3/7.3.1.

11 Side Shell and Deck – Main Supporting Members

11.1 General *(1 July 2012)*

The main supporting members, such as transverses and girders, are to be arranged and designed with sufficient stiffness to provide support to the installation's hull structures. In general, the deck transverses, side transverses and bottom floors are to be arranged in one plane to form continuous transverse rings. Deck girders, where fitted, are to extend throughout the cargo tank spaces and are to be effectively supported at the transverse bulkheads.

Generous transitions are to be provided at the intersections of main supporting members to provide smooth transmission of loads and to minimize the stress concentrations. Abrupt changes in sectional properties and sharp re-entrant corners are to be avoided. It is recommended that the intersection of the inner skin and inner bottom be accomplished by using generous sloping or large radiused bulkheads. Stool structures, where fitted, are to have sloping bulkheads on both sides.

The net section modulus and sectional area of the main supporting members required by Part 5A, Chapter 3 apply to those portions of the member clear of the end brackets. They are considered as the requirements of initial scantlings for deck transverses, side transverses, vertical webs on longitudinal bulkheads and horizontal girders and vertical webs on transverse bulkheads, and may be reduced, provided that the strength of the resultant design is verified with the subsequent total strength assessment in Section 5A-3-4. However, in no case should they be taken less than 85% of those determined from 5A-3-3/11 or 5A-3-3/15. (See also 5A-3-4/11.1.) The structural properties of the main supporting members and end brackets are to comply with the failure criteria specified in 5A-3-4/3.

The section modulus of the main supporting members is to be determined in association with the effective plating to which they are attached, as specified in 3-1-2/13 of the *Steel Vessel Rules*.

In the calculation of the nominal pressure, ρg of the liquid cargoes is not to be taken less than 0.1025 kgf/cm^2-m (0.4444 lbf/in^2-ft) for main supporting members.

Section modulus and web sectional area of the deck transverses and deck girders may be obtained in accordance with the procedure given below or other recognized design procedures.

The section modulus and web sectional area of the deck transverse and deck girders are not to be less than loading pattern 1 as specified in 5A-3-3/11.3.

For a deck transverse and/or deck girder that is subjected to reactions (forces and moments) from the topside structure, the section modulus and web sectional area of the deck transverse and/or deck girders are also not to be less than for loading pattern 1 as specified in 5A-3-3/11.3 and for loading pattern 2 as specified in 5A-3-3/11.5.

11.3 Deck Transverses and Deck Girders – Loading Pattern 1 *(1 July 2012)*

11.3.1 Section Modulus of Deck Transverses

The net section modulus of deck transverses is to be not less than obtained from the following equation (see also 5A-3-3/1.3 of these Rules):

$$SM = M/f_b \qquad \text{cm}^3\ (\text{in}^3)$$

For deck transverses in wing cargo tanks (See 5A-3-3/Figure 2A-a, b, c, d, e, and f):

$$M = k(10{,}000\, c_1 \varphi\, p s \ell_t^2 + \beta_s M_s) \geq M_o \qquad \text{N-cm (kgf-cm, lbf-in)}$$

For deck transverses in center cargo tanks (see 5A-3-3/Figure 2A-d, e and f)

$$M = k(10{,}000\, c_1 \varphi\, ps\, \ell_t^2 + \beta_b M_b) \geq M_o \qquad \text{N-cm (kgf-cm, lbf-in)}$$

where

M_s = $10{,}000 c_2\, p_s\, s\, \ell_s^2$

M_b = $10{,}000 c_2\, p_b\, s\, \ell_b^2$

M_o = $10{,}000 k c_3\, ps\, \ell_t^2$

k = 1.0 (1.0, 0.269)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid span of the deck transverse under consideration, as specified in 5A-3-2/Table 3, item 16. In no case is p to be taken less than 2.06 N/cm^2 (0.21 kgf/cm^2, 2.987 lbf/in^2).

p_s = corresponding nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the side transverse (5A-3-2/Table 3, item 12)

p_b = corresponding nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web on longitudinal bulkhead (5A-3-2/Table 3, item 13)

c_1 for tanks without deck girders:

= 0.30 for 5A-3-3/Figure 2A-c with non-tight centerline bulkhead

= 0.42 for all other cases

c_1 for tanks with deck girders:

= $0.30\alpha^2$ for 5A-3-3/Figure 2A-b with a non-tight centerline bulkhead, 0.05 min. and 0.30 max.

= $0.42\alpha^2$ for 5A-3-3/Figure 2A-a or 5A-3-3/Figure 2A-b with an oil-tight centerline bulkhead, 0.05 min. and 0.42 max.

α = $(\ell_g/\ell_t)[(s_g/s)(I_t/I_g)]^{1/4}$

ℓ_g = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c

ℓ_t = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A, but is not to be taken as less than 60% of the breadth of the tank, except for ship-type vessels with a non-tight centerline bulkhead (5A-3-3/Figure 2A-b), for which the span is not to be taken as less than 30% of the breadth of the tank.

I_g, I_t = moments of inertia, in cm^4 (in^4), of the deck girder and deck transverse, clear of the brackets, respectively

s_g = spacing of the deck girder, in m (ft)

s = spacing of the deck transverses, in m (ft)

When calculating α, if more than one deck girder is fitted, average values of s_g, ℓ_g and I_g are to be used when the girders are not identical.

φ = $1 - [5(h_a/\alpha\ell_t)]$, for cargo tanks with deck girders, 0.6 minimum

= $1 - 5(h_a/\ell_t)$, for cargo tanks without deck girders, 0.6 minimum

h_a = distance, in m (ft), from the end of the span to the toe of the end bracket of the deck transverse, as indicated in 5A-3-3/Figure 8

β_s = $0.9[(\ell_s/\ell_t)(I_t/I_s)]$, 0.10 min. and 0.65 max.

β_b = $0.9[(\ell_b/\ell_t)(I_t/I_b)]$, 0.10 min. and 0.50 max.

ℓ_s, ℓ_b = spans, in m (ft), of side transverse and vertical web on longitudinal bulkhead, respectively, as indicated in 5A-3-3/Figure 2A. Where a cross tie is fitted and is located at a distance greater than $0.7\ell_s$ or $0.7\ell_b$ from the deck transverse, the effective span of the side transverse or the vertical web may be taken as that measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross tie.

I_s, I_b = moments of inertia, in cm^4 (in^4), clear of the brackets, of side transverse and vertical web on longitudinal bulkhead, respectively

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\, S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1.

c_2 is given in 5A-3-3/Table 1.

c_3 = $2.0c_1$ for ship-type vessels with oil-tight longitudinal bulkheads and without deck girders (5A-3-3/Figure 2A-c, d, e and f)

= $1.6c_1$ for ship-type vessels with non-tight centerline longitudinal bulkhead and without deck girders (5A-3-3/Figure 2A-c)

= $1.1c_1$ for cargo tanks with deck girders

The section modulus of the deck transverse in the wing cargo tank is to be not less than that of the deck transverse in the center tank.

11.3.2 Sectional Area of Deck Transverses

The net sectional area of the web portion of deck transverses is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

$F = 1000k[c_1 ps(0.50\ell - h_e) + c_2 DB_c s]$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

c_2 = 0.05 for wing cargo tanks of ship-type vessels with four longitudinal bulkheads (5A-3-3/Figure 2A-d, e and f)

= 0 for other tanks (5A-3-3/Figure 2A-a, b, c, d, e and f)

c_1 for tanks with deck girders:

= $0.90\alpha^{1/2}$ for 5A-3-3/Figure 2A-a without longitudinal bulkhead and for 5A-3-3/Figure 2A-b with an oil-tight centerline bulkhead, 0.50 min. and 1.0 max.

= $0.60\alpha^{1/2}$ for 5A-3-3/Figure 2A-b with a non-tight centerline bulkhead, 0.45 min. and 0.85 max.

c_1 for tanks without deck girders:

= 1.10 for 5A-3-3/Figure 2A-c, with a nontight centerline longitudinal bulkhead

= 1.30 for all other cases (5A-3-3/Figure 2A-c, d, e and f)

ℓ = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A

h_e = length of the bracket, in m (ft), as indicated in 5A-3-3/Figure 2A-c and 5A-3-3/Figure 2A-d and 5A-3-3/Figure 8

D = depth of the vessel, in m (ft), as defined in 3-1-1/7 of the *Steel Vessel Rules*

B_c = breadth of the center tank, in m (ft)

P, s and α are as defined in 5A-3-3/11.3.1 of these Rules.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1 of these Rules.

11.3.3 Section Modulus of Deck Girders

The net section modulus of deck girders is to be not less than obtained from the following equation (see also 5A-3-3/1.3):

$SM = M/f_b$ cm^3 (in^3)

M equals M_1 or M_2, whichever is greater, as given below:

$M_1 = 4200 k p s_g \ell_g^2$ N-cm (kgf-cm, lbf-in)

$M_2 = k(3000 \varphi p s_g \ell_g^2 + 0.15 M_b)$ N-cm (kgf-cm, lbf-in)

$M_b = 10{,}000 p_{st} s_g \ell_{st}^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

ℓ_g = span, in m (ft), of the deck girder, as indicated in 5A-3-3/Figure 2B-c

ℓ_{st} = span, in m (ft), of the vertical web on transverse bulkhead, as indicated in 5A-3-3/Figure 2B-c

s_g = spacing, in m (ft), of the deck girder considered, as indicated in 5A-3-3/Figure 2A

φ = $1 - 5(h_a/\ell_g)$, 0.6 min.

h_a = distance, in m (ft), from the end of the span to the toe of the end bracket of the deck girder, as indicated in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), as specified in 5A-3-2/Table 3, item 17 for the girder considered. Where three or more deck girders are fitted in the cargo tank, p is to be not less than its value determined for the outermost girder clear of the end bracket of the deck transverse. In no case is p to be taken less than 2.06 N/cm^2 (0.21 kgf/cm^2, 2.987 lbf/in^2).

p_{st} = corresponding nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web on the forward transverse bulkhead of cargo tank under consideration (5A-3-2/Table 3, item 17)

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

= $(1.0 - 0.55\alpha_2 SM_{RD}/SM_D) S_m f_y \le 0.52 S_m f_y$ for $L < 190$ m

S_m and f_y, as defined in 5A-3-3/7.3.1 of these Rules.

11.3.4 Sectional Area of Deck Girders

The net sectional area of the web portion of deck girders is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

$F = 1000kcps_g(0.5\ell - h_e)$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

c = 0.55 for one or two girders in the tank

= 0.67 for three or more girders in the tank

ℓ = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c

h_e = length of the bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9.

p and s_g are defined in 5A-3-3/11.3.3.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.30\, S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1 of these Rules.

11.5 Deck Transverses and Deck Girders – Loading Pattern 2 *(1 July 2012)*

11.5.1 Section Modulus of Deck Transverses

The net section modulus of deck transverses, in association with the effective deck plating, is to be obtained from the following equation:

$SM = M/f_b$ cm^3 (in^3)

11.5.1(a) For deck transverses in wing tanks

$M = 10^5\, k\, (M_p + M_g + M_s)$ N-cm (kgf-cm, lbf-in)

11.5.1(b) For deck transverses in center tanks

$M = 10^5\, k\, (M_p + M_g + M_b)$ N-cm (kgf-cm, lbf-in)

where

K = 1.0 (1.0, 0.269)

M_p = bending moment due to reactions from topside structure

= $\left|(M_v + M_m) f_t\right|$

M_v = $\ell_t \sum_n P_n (k_{1n} + k_{2n})$

M_m = $\sum_n M_n (k_{3n} + k_{4n})$

P_n = reaction deck force number n, in kN (tf, Ltf), applied to the deck transverse in tank under consideration, see 5A-3-3/Figure 8

M_n = reaction deck moment number n, in kN-m (tf-m, Ltf-ft), applied to the deck transverse in tank under consideration, see 5A-3-3/Figure 8

n = 1, 2,….., N_v to obtain bending moment M_v

n = 1, 2,….., N_m to obtain bending moment M_m

N_v = total number of reaction forces at deck transverse under consideration, (in tank under consideration)

N_m = total number of reaction moments at deck transverse under consideration, (in tank under consideration)

ℓ_t = span of the deck transverse under consideration, in m (ft), as defined in 5A-3-3/Figure 2A

k_{1n} = $(1 - \overline{a}_n)^2 [\overline{a}_n - \overline{z} (1 + 2\overline{a}_n)]$

k_{2n} = 0 if $\overline{z} \le \overline{a}_n$

= $(\overline{z} - \overline{a}_n)$ if $\overline{z} > \overline{a}_n$

k_{3n} = $(1 - \overline{a}_n)(3\overline{a}_n - 1 - 6\overline{a}_n \overline{z})$

k_{4n} = 0 if $\overline{z} \le \overline{a}_n$

= 1 if $\overline{z} > \overline{a}_n$

$\overline{a}_n$ = a_n/ℓ_t

$\overline{z}$ = z/ℓ_t, $(0 \le \overline{z} \le 1)$

a_n = distance, in m (ft), from a point of application of reaction (force P_n or moment M_n) to the end of the deck transverse span ℓ_t, in m (ft), as shown in 5A-3-3/Figure 8

z = coordinate (measured from the end of the span ℓ_t) of the section of the deck transverse under consideration, in m (ft), as shown in 5A-3-3/Figure 8

For the toe of the deck transverse end brackets, $\overline{z} = h_a/\ell_t$ and $\overline{z} = 1 - h_a/\ell_t$.

h_a = distance, in m(ft), from the end of the span to the toe of the end bracket of the deck transverse, as shown in 5A-3-3/Figure 9 of these Rules.

Note: For a wide topside bracket, the vertical load on a deck transverse can be considered uniformly distributed with pressure $q_n = P_n/c$, and the concentrated bending moment can be substituted by force couples.

$P_m = M_n/(k\,c)$

where

P_n, M_n = concentrated force and moment obtained from FE analysis of topside structure

c = width of the topside bracket

k = shape bracket factor, and may be taken as 0.8, unless otherwise specified

Bending moment at the toe of the end brackets due to green water pressure, M_g:

$M_g = 0.1\, c_3\, \varphi\, P_{gi}\, s\, \ell_t^2$

where

P_{gi} = nominal green water pressure imposed on the deck, in kN/m^2 (tf/m^2, Ltf/ft^2), as defined in 5A-3-2/13.7 of these Rules

s = spacing, in m (ft), of the deck transverses

c_3 = $2.0c_1$ for ship-type vessels with oil-tight longitudinal bulkheads and without deck girders (5A-3-3/Figure 2A-c, d, e and f)

= $1.6c_1$ for ship-type vessels with non-tight centerline longitudinal bulkhead and without deck girders (5A-3-3/Figure 2A-c)

= $1.1c_1$ for cargo tanks with deck girders

φ = $1 - [5(h_a/\alpha\ell_t)]$, for cargo tanks with deck girders, 0.6 minimum

= $1 - 5(h_a/\ell_t)$, for cargo tanks without deck girders, 0.6 minimum

h_a = distance, in m (ft), from the end of the span to the toe of the end bracket of the deck transverse, as indicated in 5A-3-3/Figure 9

ℓ_t = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A, but is not to be taken as less than 60% of the breadth of the tank, except for ship-type vessels with a non-tight centerline bulkhead (5A-3-3/Figure 2A-b), for which the span is not to be taken as less than 30% of the breadth of the tank.

c_1 for tanks without deck girders:

= 0.30 for 5A-3-3/Figure 2A-c with non-tight centerline bulkhead

= 0.42 for all other cases

c_1 for tanks with deck girders:

= $0.30\alpha^2$ for 5A-3-3/Figure 2A-b with a non-tight centerline bulkhead, 0.05 min. and 0.30 max.

= $0.42\alpha^2$ for 5A-3-3/Figure 2A-a or 5A-3-3/Figure 2A-b with an oil-tight centerline bulkhead, 0.05 min. and 0.42 max.

α = $(\ell_g/\ell_t)[(s_g/s)(I_t/I_g)]^{1/4}$

ℓ_g = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c of these Rules

I_g, I_t = moments of inertia, in cm^4 (in^4), of the deck girder and deck transverse with effective deck plating, clear of the end brackets, respectively

s_g = spacing of the deck girder, in m (ft) as shown in 5A-3-3/Figure 2A

s = spacing of the deck transverses, in m (ft)

When calculating α, if more than one deck girder is fitted, average values of s_g, ℓ_g and I_g are to be used when the girders are not identical.

Bending moments due to pressure on side transverse and vertical web of longitudinal bulkhead:

$$M_s = k_s \beta_s c_2 p_s s \ell_s^2$$

$$M_b = k_b \beta_b c_2 p_b s \ell_b^2$$

where $k_s = 0.1$, and $k_b = 0.1$, unless otherwise specified.

ℓ_s, ℓ_b = spans, in m (ft), of side transverse and vertical web on longitudinal bulkhead, respectively, as indicated in 5A-3-3/Figure 2A. Where a cross tie is fitted and is located at a distance greater than $0.7\ell_s$ or $0.7\ell_b$ from the deck transverse, the effective span of the side transverse or the vertical web may be taken as that measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross tie.

p_s = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of side transverse when wing tank is empty, adjacent tanks full (5A-3-2/Table 3, item 12)

p_b = nominal internal cargo pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web on longitudinal bulkhead when center tank is empty, adjacent tanks full (5A-3-2/Table 3, item 13)

β_s = $0.9[(\ell_s/\ell_t)(I_t/I_s)]$, 0.10 min. and 0.65 max.

β_b = $0.9[(\ell_b/\ell_t)(I_t/I_b)]$, 0.10 min. and 0.50 max.

I_s, I_b = moments of inertia, in cm^4 (in^4), clear of the brackets, of side transverse and vertical web on longitudinal bulkhead, respectively

c_2 are given in 5A-3-3/Table 1 of these Rules.

f_t = 1 for tanks without deck girders

f_t = $1 - [0.67/(1 + 2\delta)]$ is not to be taken less than 0.70 for tanks with deck girders

δ = $(\ell_g/\ell_t)^3\ (I_t/I_g)$

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\ S_m f_y$

S_m and f_y as defined in 5A-3-3/7.3.1 of these Rules.

11.5.2 Section Modulus of Deck Girders

The net section modulus of deck girder with effective deck plating is to be not less than that obtained from the following equation:

$SM = M/f_b$ cm^3 (in^3)

$M = k\ 10^5\ (M_p + M_g)$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

11.5.2(a) Bending moment due to reactions from topside structure, M_p

$$M_p = \left|(M_v + M_m) f_g\right|$$

$$M_v = \ell_g \sum_n P_n (k_{1n} + k_{2n})$$

$$M_m = \sum_n M_n (k_{3n} + k_{4n})$$

where

P_n = reaction force number n, in kN (tf, Lt-ft), applied to the deck girder under consideration

M_n = reaction moment number n, in kN-m (tf-m, Lt-ft), applied to the deck girder under consideration

N = 1, 2,….., N_v to obtain bending moment M_v

N = 1, 2,….., N_m to obtain bending moment M_m

N_v = total number of reaction forces at the deck girder between transverse bulkheads in the tank under consideration

N_m = total number of reaction moments at the deck girder between transverse bulkheads in the tank under consideration

k_{1n} = $(1 - \bar{b}_n)^2 [\bar{b}_n - \bar{x}(1 + 2\bar{b}_n)]$

k_{2n} = 0 if $\bar{x} \le \bar{b}_n$

= $(\bar{x} - \bar{b}_n)$ if $\bar{x} > \bar{b}_n$

k_{3n} = $(1 - \bar{b}_n)(3\bar{b}_n - 1 - 6\bar{b}_n\bar{x})$

k_{4n} = 0 if $\bar{x} \le \bar{b}_n$

= 1 if $\bar{x} > \bar{b}_n$

$\bar{b}_n$ = b_n/ℓ_g

$\bar{x}$ = x/ℓ_g

b_n = distance, in m (ft), from reaction force P_n to the end of the deck girder span ℓ_g

x = coordinate, in m (ft), of the section of the deck girder under consideration, measured from the end of span ℓ_g

For the toe of the brackets, $\bar{x} = h_a/\ell_g$ and $\bar{x} = 1 - h_a/\ell_g$.

h_a = distance, in m (ft), from the end of the deck girder span to the toe of the end of the bracket, as shown in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9 of these Rules

f_g = $1 - 0.13[(\ell_g/\ell_t)^3 (\ell_g/s)(I_t/I_g)]^{0.25}$ is not to be taken less than 0.65

I_t, I_g, s, ℓ_g, ℓ_t are as defined in 5A-3-3/11.5.1, above.

11.5.2(b) Bending moment at the toe of the end brackets due to green water pressure, M_g

$$M_g = 0.083\,\varphi\,p_{gi}\,s_g\,\ell_g^2$$

where p_{gi} and s_g are as defined in 5A-3-3/11.5.1, above.

φ = $1 - 5(h_a/\ell_g)$, 0.6 min.

f_b = permissible bending stress, in N/cm² (kgf/cm², lbf/in²)

= $0.45\,S_m f_y$

= $(1.0 - 0.55\alpha_2 SM_{RD}/SM_D)S_m f_y \le 0.52 S_m f_y$ for $L < 190$ m

α_2, SM_{RD} and SM_D are as defined in 5A-3-3/9.5. S_m and f_y, are as defined in 5A-3-3/7.3.1.

11.5.3 Web Sectional Area of Deck Transverses

The net sectional area of the web portion of deck transverse is to be obtained from the following equation:

$A = F/f_s$ cm² (in²)

where

F = $1000\,k\,(F_p + F_g + c_2\,s\,D\,B_c)$, in N (kgf, lbf)

F_p = $|(F_v + F_m) f_1|$

F_v = $\sum_n \left[P_n(1-\overline{a}_n)^2(2\overline{a}_n+1)+\Delta F\right]$

F_m = $6\sum_n \overline{a}_n(1-\overline{a}_n)M_n/\ell_t$

F_g = $c_1\, p_{gi}\, s\, (0.50\ell - h_e)$

k = 1.0 (1.0, 2.24)

ΔF = 0 if $\overline{z} \le \overline{a}_n$

= $-P_n$ if $\overline{z} > \overline{a}_n$

f_1 = $1 - [0.5/(1 + 4\delta)]$

c_2 = 0.05 for wing cargo tanks of ship-type vessels with four longitudinal bulkheads (5A-3-3/Figure 2A-d, e and f of these Rules)

= 0 for other tanks (5A-3-3/Figure 2A-a, b, c, d, e and f of these Rules)

c_1 for tanks with deck girders:

= $0.90\alpha^{1/2}$ for 5A-3-3/Figure 2A-a without longitudinal bulkhead and for 5A-3-3/Figure 2A-b with an oil-tight centerline bulkhead, 0.50 min. and 1.0 max.

= $0.60\alpha^{1/2}$ for 5A-3-3/Figure 2A-b with a non-tight centerline bulkhead, 0.45 min. and 0.85 max.

c_1 for tanks without deck girders:

= 1.10 for 5A-3-3/Figure 2A-c, with a nontight centerline longitudinal bulkhead

= 1.30 for all other cases (5A-3-3/Figure 2A-c, d, e and f)

ℓ = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A of these Rules

h_e = length of the bracket, in m(ft), as indicated in 5A-3-3/Figures 2A and 2B and 5A-3-3/Figure 9 of these Rules

D = depth of a vessel, in m (ft), as defined in 3-1-1/7 of the *Steel Vessel Rules*

B_c = breadth of the center tank, in m (ft)

f_s = permissible shear stress

= $0.45\, S_m f_y$, in N/cm² (kgf/cm², lbf/in²)

P_n, M_n, p_{gi}, ℓ_t, s, $\overline{a}_n$, $\overline{z}$, α and δ are as defined in 5A-3-3/11.5.1, above.

11.5.4 Web Sectional Area of Deck Girders

The net sectional area of the web portion of deck girders is to be not less than that obtained from the following equation:

$A = F/f_s$ cm² (in²)

where

F = $1000\, k\,(F_p + F_g)$, in N (kgf, lbf)

F_p = $|(F_v + F_m)\, f_g|$

$F_v = \sum_n P_n\left(1-\bar{b}_n\right)^2\left(2\bar{b}_n+1\right)\left(1+2\bar{b}_n\right)+\Delta F$

$F_m = 6\sum_n \bar{b}_n\left(1-\bar{b}_n\right)M_n/\ell_{tg}$

$\Delta F_n = 0$ if $\bar{x} \le \bar{b}_n$

$= -P_n$ if $\bar{x} > \bar{b}_n$

$F_g = c\,p_{gi}\,(0.5\ell - h_e)\,s_g$

k = 1.0 (1.0, 2.24)

c = 0.55 for one or two girders in the tank

= 0.67 for three or more girders in the tank

ℓ = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c

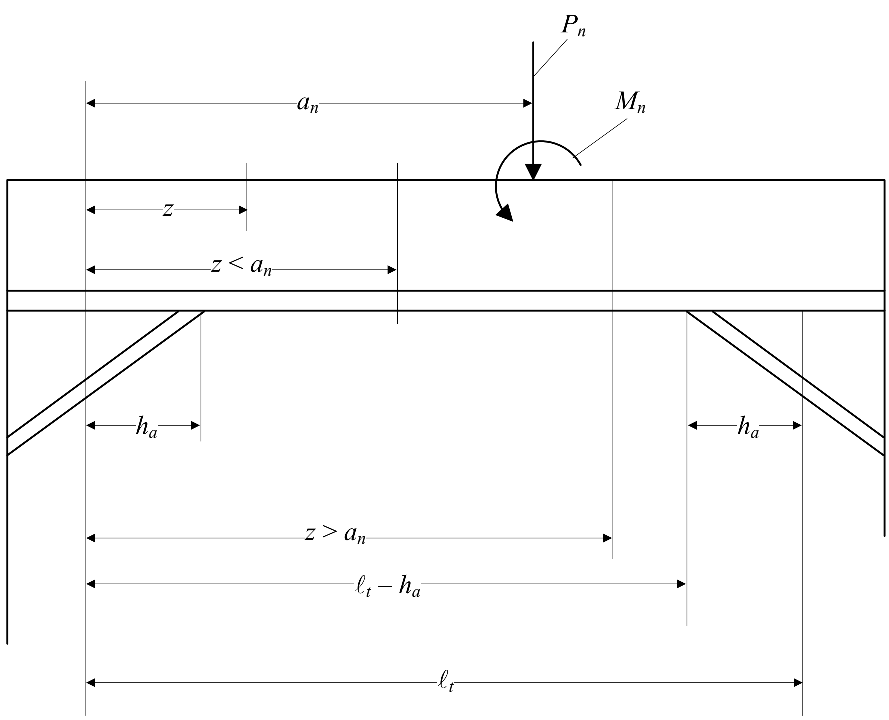
h_e = length of the bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.30\,S_m f_y$

P_n, M_n, ℓ_g, s_g, $\bar{b}_n$, $\bar{x}$, p_{gi}, f_g, S_m, f_y are as defined in 5A-3-3/11.5.2, above.

FIGURE 8
Deck Transverse – Definition of Parameters *(1 July 2012)*



11.7 Web Sectional Area of Side Transverses

The net sectional area of the web portion of side transverses is to be not less than obtained from the following equation:

$$A = F/f_s \qquad \text{cm}^2 \text{ (in}^2\text{)}$$

The shear force F, in N (kgf, lbf), for the side transverse can be obtained from the following equations (see also 5A-3-3/1.3):

$$F = 1000ks[K_U \ell(P_U + P_L) - h_U P_U] \qquad \text{for upper part of transverse}$$

$$F = 1000ks[K_L \ell(P_U + P_L) - h_L P_L] \quad \text{or} \quad 350ksK_L \ell(P_U + P_L) \qquad \text{whichever is greater for lower part of transverse}$$

In no case is the shear force for the lower part of the transverse to be less than 120% of that for the upper part of the transverse.

where

k = 1.0 (1.0, 2.24)

ℓ = span, in m (ft), of the side transverse, as indicated in 5A-3-3/Figure 2B-a. Where one cross tie is fitted in the wing tank and is located at a distance of more than 0.7ℓ from the deck transverse, the effective span of the side transverse may be measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross tie.

s = spacing, in m (ft), of the side transverses

P_U = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of upper bracket, as specified in 5A-3-2/Table 3

P_L = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of lower bracket, as specified in 5A-3-2/Table 3.

h_U = length of the upper bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-a

h_L = length of the lower bracket, in m (ft), as indicated in 5A-5-3/Figure 2B-a

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

K_U and K_L are given in 5A-5-3/Table 2.

S_m and f_y, as defined in 5A-3-3/7.3.1.

For ship-type installations without cross ties in the wing cargo tank, the required sectional area of the lower side transverse is to extend to 0.15ℓ from the toe of the lower bracket or 0.33ℓ from the lower end of the span, whichever is greater.

For ship-type installations with one cross tie, the sectional area required for the lower portion of the transverse is to be maintained up to the cross tie.

11.9 Minimum Thickness for Web Portion of Main Supporting Members *(1997)*

In general, the net thickness of the web plate of the main supporting members, except stringers in double side structures, is to be not less than t, as obtained below:

$$t = 0.012L + 7.7 \qquad \text{mm}$$

$$= 0.144L \times 10^{-3} + 0.303 \qquad \text{in.}$$

but t need not be taken greater than 11.0 mm (0.433 in.)

The net thickness of side stringers in double side structures is not to be less than t_1 and t_2, as specified below:

$t_1 = 0.012L + 6.7$ mm

$= 0.144L \times 10^{-3} + 0.264$ in.

but t_1 need not be taken greater than 10.0 mm (0.394 in.)

$t_2 = cs(S_m f_y/E)^{1/2}$ mm (in.)

where

L = length of the installation, in m (ft), as defined in 3-1-1/3.1 of the *Steel Vessel Rules*

c = $0.7N^2 - 0.2$, not to be less than 0.33

s = spacing of longitudinals, in mm (in.)

S_m = strength reduction factor, obtained from 5A-3-3/7.3.1 for the steel grade of the side stringer

f_y = minimum specified yield point of the side stringer material, in N/cm² (kgf/cm², lbf/in²)

N = $R_d\,[(Q/Q_d)(y/y_n)]^{1/2}$ for side stringers above neutral axis

= $R_b\,[(Q/Q_b)(y/y_n)]^{1/2}$ for side stringers below neutral axis

Q = material conversion factor 5A-3-3/5 for the side stringer under consideration

y = vertical distance, in m (ft), measured from the neutral axis of the hull girder transverse section to the side stringer under consideration

E, R_b and Q_b are as defined in 5A-3-3/7.3.1. R_d, Q_d and y_n are as defined in 5A-3-3/9.1.

11.11 Proportions

In general, webs, girders and transverses are not to be less in depth than specified below, as a percentage of the span, ℓ_t, ℓ_b or ℓ_g, where applicable (see 5A-3-3/Figures 2A and 2B). Alternative designs with stiffness equivalent to the specified depth/length ratio and the required section modulus may be considered, provided that the calculated results are submitted for review.

11.11.1 Deck Transverse

23% for deck transverses in wing cargo tanks of ship-type installations with four side longitudinal bulkheads where no deck girders are fitted (see 5A-3-3/Figure 2A-d, e and f).

12.5% for deck transverses in center cargo tanks of ship-type installations with four side longitudinal bulkheads where no deck girders are fitted (see 5A-3-3/Figure 2A-d, e and f). In this case, the depth is also to be not less than that of the transverse in the wing tank.

12.5% for deck transverses without deck girders for ship-type installations with centerline longitudinal bulkhead (See 5A-3-3/Figure 2A-c).

8.5% for deck transverses in cargo tanks with one deck girder.

5.5% for deck transverses in cargo tanks with two deck girders.

3.5% for deck transverse in cargo tanks with three or more deck girders.

11.11.2 Deck Girder

20% for deck girders where only one is fitted in a tank.

12.5% for deck girders where two are fitted in a tank.

9.0% for deck girders where three or more are fitted in a tank.

11.11.3 Longitudinal Bulkhead Webs/Girders *(2005)*

14% for vertical webs of longitudinal bulkheads without strut and horizontal girders of longitudinal bulkheads.

9.0% for vertical webs of longitudinal bulkheads with one or more struts

11.11.4 Transverse Bulkhead Webs/Girders

20.0% for vertical webs of transverse bulkheads where only one is fitted in a tank.

12.5% for vertical webs of transverse bulkheads where two are fitted in a tank.

9.0% for vertical webs of transverse bulkheads where three or more are fitted in a tank.

28% for horizontal girders of transverse bulkheads in wing tanks for ship-type installations with four side longitudinal bulkheads (See 5A-3-3/Figure 2A-d, e and f).

20% for horizontal girders of transverse bulkheads in center tanks for ship-type installations with four side longitudinal bulkheads (See 5A-3-3/Figure 2A-d, e and f), but not less in depth than horizontal girders in wing tanks

20% for horizontal girders of transverse bulkheads without vertical webs for ship-type installations with centerline longitudinal bulkhead (See 5A-3-3/Figure 2A-c)

10% for horizontal girders of transverse bulkhead with one vertical web in the cargo tank

7% for horizontal girders of transverse bulkhead with two or more vertical webs in the cargo tank, except in the case where more than two vertical webs are fitted for ship-type installations with centerline longitudinal bulkheads (See 5A-3-3/Figure 2A-b), or more than five vertical webs are fitted for ship-type installations with outer longitudinal bulkheads only (See 5A-3-3/Figure 2A-a). In that case, horizontal girders are not to be less in depth than 15% of the maximum distance between two adjacent vertical webs or the end of span ℓ_b of the horizontal girder and next vertical web.

In no case are the depths of supporting members to be less than three times the depth of the slots for longitudinals. The thickness of the webs is to be not less than required by 5A-3-3/11.9.

11.13 Brackets

Generally, brackets are to have a thickness not less than that of the member supported, are to have flanges or face plates at their edges and are to be suitably stiffened.

11.15 Web Stiffeners and Tripping Brackets

11.15.1 Web Stiffeners

Stiffeners are to be fitted for the full depth of the webs of the main supporting member at the following intervals:

Floor	every longitudinal
Side	every longitudinal
Bulkhead	every second stiffener
Deck	every third longitudinal

Special attention is to be given to the stiffening of web plate panels close to change in contour of the web or where higher strength steel is used.

Web stiffener attachment to the deep webs, longitudinals and stiffeners is to be effected by continuous welds.

Where depth/thickness ratio of the web plating exceeds 200, a stiffener is to be fitted parallel to the flange or face plate at approximately one-quarter depth of the web from the flange or face plate.

Alternative system of web-stiffening of the main supporting members may be considered based on the structural stability of the web and satisfactory levels of the shear stresses in the welds of the longitudinals to the web plates.

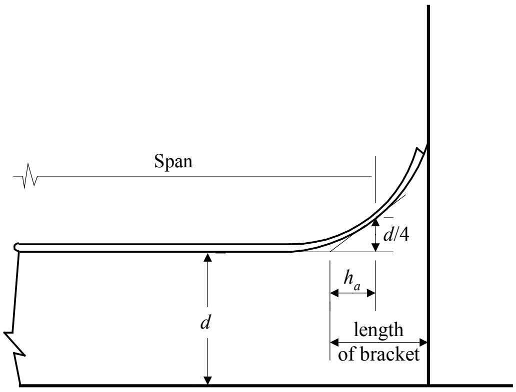
11.15.2 Tripping Bracket

Tripping brackets, arranged to support the flanges, are to be fitted at intervals of about 3 m (9.84 ft), close to any changes of section, and in line with the flanges of struts.

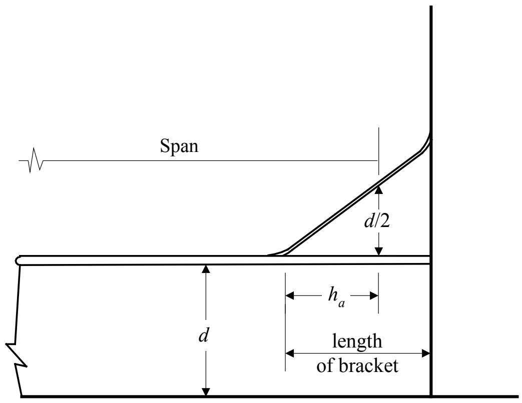
11.17 Slots and Lightening Holes

When slots and lightening holes are cut in transverses, webs, floors, stringers and girders, they are to be kept well clear of other openings. The slots are to be neatly cut and well rounded. Lightening holes are to be located midway between the slots and at about one-third of the depth of the web from the shell, deck or bulkhead. Their diameters are not to exceed one-third the depth of the web. In general, lightening holes are not to be cut in those areas of webs, floors, stringers, girders and transverses where the shear stresses are high. Similarly, slots for longitudinals are to be provided with filler plates or other reinforcement in these same areas. Where it is necessary to cut openings in highly stressed areas, they are to be effectively compensated. Continuous fillet welds are to be provided at the connection of the filler plates to the web and at the connection of the filler plate to the longitudinals.

FIGURE 9
Effectiveness of Brackets *(1 September 2007)*



Where face plate on the member is carried along the face of the bracket.



Where face plate on the member is not carried along the face of the bracket, and where the face plate area on the bracket is at least one-half the face plate area on the member.

Brackets are not to be considered effective beyond the point where the arm of the girder or web is 1.5 times the arm on the bulkhead or base.

TABLE 1
Coefficient c_2 For Deck Transverses *(1995)*

Structural Arrangement	*No cross ties (5A-3-3/Figure 2A-a, b, c and f)*	*Cross ties in wing cargo tank (5A-3-3/Figure 2A-d)*		*Cross ties in center cargo tank (5A-3-3/Figure 2A-e)*	
Location of Deck Transverse	All cargo tanks	Wing tank	Center tank	Wing tank	Center tank
c_2	0.40 (1)	0.37	0.13	0.40	0.14

Note

1 c_2 = 0.50 for ship-type installations with an oil-tight centerline bulkhead which will be loaded from one side only.

TABLE 2
Coefficients K_U and K_L for Side Transverses *(1995)*

Arrangement of Cross Ties	K_U (1)	K_L (1)
No cross ties (5A-3-3/Figure 2A-a, b, c and f)	0.13	0.30
One cross tie in center cargo tank (5A-3-3/Figure 2A-e)		
One cross tie in wing cargo tank (5A-3-3/Figure 2A-d)	0.09	0.21

Note:

1 For ship-type installations without cross ties in wing cargo tank (5A-3-3/Figure 2A-a, b, c, e and f) and having three or more side stringers, $K_U = 0.10$ and $K_L = 0.22$

13 Longitudinal and Transverse Bulkheads

13.1 Longitudinal Bulkhead Plating *(December 2008)*

The net thickness of the longitudinal bulkhead plating, in addition to complying with 5A-3-3/5.5, is to be not less than t_1, t_2 and t_3, as specified below:

$t_1 = 0.73s(k_1 p/f_1)^{1/2}$ mm (in.)

$t_2 = 0.73s(k_2 p/f_2)^{1/2}$ mm (in.)

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

but not less than 9.5 mm (0.37 in.) where

s = spacing of longitudinal bulkhead longitudinals, in mm (in.)

k_1 = 0.342

k_2 = 0.5

p = pressure at the lower edge of each plate, p_i, or maximum slosh pressure, p_s, whichever is greater, in N/cm^2 (kgf/cm^2, lbf/in^2).

In no case is p to be taken less than 2.06 N/cm^2 (0.21kgf/cm^2, 2.987 lbf/in^2).

p_i = p_n in cargo tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $p_n - p_{uo}$ in ballast tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

p_n is nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), at the lower edge of each plate, as defined in 5A-3-2/Table 3 for longitudinal bulkhead plating.

p_{uo} is also defined in 5A-3-3/9.1.

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.

p_s = $k_s p_{is}$, not to be taken less than $k_s p_{is(mid)}$

p_{is} = nominal slosh pressure, as specified in 5A-3-2/11.5.1

$p_{is(mid)}$ = nominal slosh pressure at the mid-tank of the bulkhead at the same height as the point under consideration

k_s = b_t/ℓ_t, $0.9 \geq k_s \geq 0.65$ ($k_s = 0.9$ for $p_{is(mid)}$)

f_1 = permissible bending stress, in the longitudinal direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $[1 - 0.28z/B - 0.52\alpha_1(SM_{RB}/SM_B)(y/y_n)]S_m f_y$, below neutral axis

= $[1 - 0.28z/B - 0.52\alpha_2(SM_{RD}/SM_D)(y/y_n)]S_m f_y$, above neutral axis

b_t and ℓ_t are the width and length, respectively, of the cargo tank being considered.

SM_B/SM_{RB} is not to be taken more than $1.2\alpha_1$ or 1.4, whichever is lesser.

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 steel grade for the longitudinal bulkhead plating obtained from 5A-3-3/7.3.1

f_y = minimum specified yield point of the longitudinal bulkhead plating, in N/cm^2 (kgf/cm^2, lbf/in^2)

z = transverse distance, in m (ft), measured from the centerline of the section to the bulkhead strake under consideration

y_n = vertical distance, in m (ft), measured from the deck (bottom) to the neutral axis of the section, when the strake under consideration is above (below) the neutral axis

f_2 = permissible bending stress, in the vertical direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $S_m f_y$

c = $0.7N^2 - 0.2$

c for the top strake is not to be taken less than $0.4Q^{1/2}$, but need not be greater than 0.45.

c for other strakes is not to be taken less than 0.33, but need not be greater than $0.45(Q/Q_d)^{1/2}$ for strakes above the neutral axis nor greater than $0.45(Q/Q_b)^{1/2}$ for strakes below the neutral axis.

N = $R_d[(Q/Q_d)(y/y_n)]^{1/2}$, for strake above the neutral axis

= $R_b[(Q/Q_b)(y/y_n)]^{1/2}$, for strake below the neutral axis

y = vertical distance, in m (ft), measured from the neutral axis of the hull girder transverse section to the upper edge (lower edge) of the bulkhead strake, when the strake under consideration is above (below) the neutral axis for N

= vertical distance, in m (ft), measured from the neutral axis of the hull girder transverse section to the lower edge of the bulkhead strake under consideration for f_1

Q = material conversion factor in 5A-3-3/5.1 for the longitudinal bulkhead plating

B = installation's breadth, in m (ft), as defined in 3-1-1/5 of the *Steel Vessel Rules (January 2005)*

SM_{RB}, SM_B, R_b, Q_b and E are as defined in 5A-3-3/7.3.1.

S_{m1} and f_{y1} are as defined in 5A-3-3/7.5.

R_d and Q_d are as defined in 5A-3-3/9.1.

SM_{RD}, SM_D, S_{m2} and f_{y2} are as defined in 5A-3-3/9.5.

The minimum width of the top strake for the midship $0.4L$ is to be obtained from the following equation:

b = $5L + 800$ mm for $L \leq 200$ m

= 1800 mm for $200 < L \leq 500$ m

b	=	$0.06L + 31.5$ in.	for $L \leq 656$ ft
	=	70.87 in.	for $656 < L \leq 1640$ ft

L = length of installation, as defined in 3-1-1/3.1 of the *Steel Vessel Rules (January 2005)*, in m (ft)

b = width of top strake, in mm (in.)

13.3 Transverse Bulkhead Plating *(1999)*

The net thickness of transverse bulkhead plating is to be not less than t, as specified below:

$$t = 0.73s(k_2\, p/f_2)^{1/2} \qquad \text{mm (in.)}$$

but not less than 9.5 mm (0.37 in.)

where

s = spacing of transverse bulkhead stiffeners, in mm (in.)

k_2 = 0.50

p = p_i or maximum slosh pressure, p_s, whichever is greater, in N/cm^2 (kgf/cm^2, lbf/in^2)

In no case is p to be taken less than 2.06 N/cm^2 (0.21 kgf/cm^2, 2.987 lbf/in^2).

p_i	=	p_n	in cargo tank, in N/cm^2 (kgf/cm^2, lbf/in^2)
	=	$p_n - p_{uh}$	in ballast tank, in N/cm^2 (kgf/cm^2, lbf/in^2)

p_n is nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), at the lower edge of each plate, as defined in 5A-3-2/Table 3 for transverse bulkhead plating.

p_{uh} is also defined in 5A-3-3/7.3.1.

p_s = $k_s p_{is}$, not to be taken less than $k_s p_{is(mid)}$

p_{is} = nominal slosh pressure, as specified in 5A-3-3/11.5.1

$p_{is(mid)}$ = nominal slosh pressure at the mid-tank of the bulkhead at the same height as the point under consideration.

k_s = ℓ_t/b_t, $0.9 \geq k_s \geq 0.65$ ($k_s = 0.9$ for $p_{is(mid)}$)

f_2 = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.85\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

ℓ_t, b_t are defined in 5A-3-3/13.1.

Where the wing ballast tanks are U-shaped, the net thickness of transverse bulkhead plating in the wing ballast tanks is also to be not less than as obtained from the above equation with the following substituted for p and f_2.

where

p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified for side shell structure (item 3 case a) in 5A-3-2/Table 3, at the lower edge level of each transverse bulkhead plate

f_2 = $S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

where the breadth of center tank exceeds $0.6B$, the net thickness of transverse bulkhead plating in the center tank ,outboard of $0.3B$ from the centerline of the tank, is also to be not less than as obtained from the above equation with the following substituted for p and f_2:

p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified for inner skin longitudinal bulkhead structure (item 6 case a) in 5A-3-2/Table 3, at the lower edge level of each transverse bulkhead plate

f_2 = $S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

13.5 Longitudinals and Vertical/Horizontal Stiffeners *(1 July 2005)*

The net section modulus of each individual longitudinal or vertical/horizontal stiffener on longitudinal and transverse bulkheads, in association with the effective plating to which it is attached, is to be not less than obtained from the following equation:

$SM = M/f_b$ cm^3 (in^3)

$M = 1000 c_1 ps\ell^2/k$ N-cm (kgf-cm, lbf-in.)

where

k = 12 (12, 83.33)

c_1 = 1.0 for longitudinals and horizontal stiffeners

= $1 + \gamma\ell/10p$ for vertical stiffeners

γ = specific weight of the liquid, ≥ 1.005 N/cm^2-m (0.1025 kgf/cm^2-m, 0.4444 lbf/in^2-ft)

s = spacing of longitudinals or vertical/horizontal stiffeners, in mm (in.)

ℓ = span of longitudinals or stiffeners between effective supports, in m (ft)

p = pressure, p_i, in N/cm^2 (kgf/cm^2, lbf/in^2), at the longitudinal or stiffener considered, as specified in 5A-3-3/13.1 and 5A-3-3/13.3, or maximum slosh pressure, p_s, whichever is greater. For vertical stiffeners, pressure is to be taken at the middle of span of each stiffener.

p_s = $c_3 p_{is}$, not to be taken less than $c_3 p_{is(mid)}$

$p_{is(mid)}$ = nominal slosh pressure at the mid-tank of the bulkhead at the same height as the point under consideration

p_{is} = nominal slosh pressure, as specified in 5A-3-2/11.5.1

c_3 = as specified below:

for transverse bulkheads

0.60 for angle or T-bar, 0.68 for bulb plate or flat bar, and 0.73 for corrugation, if tank length ℓ_t is greater than 1.4 times tank width b_t and no transverse swash bulkheads in the tank.

Otherwise, $c_3 = c_{st}$ (c_{st} = 1.0 for $p_{is(mid)}$)

c_{st} = ℓ_t/b_t, $1.0 \geq c_{st} \geq 0.71$

for longitudinal bulkheads

0.60 for angle or T-bar, 0.68 for bulb plate or flat bar and 0.73 for corrugation, if tank width b_t is greater than 1.4 times tank length ℓ_t and no longitudinal swash bulkheads in the tank.

Otherwise $c_3 = c_{s\ell}$ ($c_{s\ell}$ = 1.0 for $p_{is(mid)}$)

$c_{s\ell}$ = b_t/ℓ_t, $1.0 \geq c_{s\ell} \geq 0.71$

f_b = permissible bending stresses, in N/cm^2 (kgf/cm^2, lbf/in^2).

= $0.70\, S_m f_y$ for transverse bulkhead stiffeners

= $1.4[1.0 - 0.28(z/B) - 0.52\alpha_1(SM_{RB}/SM_B)(y/y_n)]S_m f_y \leq 0.90 S_m f_y$ for longitudinal bulkhead longitudinals below neutral axis

= $2.2[1.0 - 0.28(z/B) - 0.52\alpha_2(SM_{RD}/SM_D)(y/y_n)]S_m f_b \leq 0.90 S_m f_y$ for longitudinal bulkhead longitudinals above neutral axis

z = transverse distance, in m (ft), measured from the centerline of the installation to the longitudinal under consideration at its connection to the associated plate

h = vertical distance, in m (ft), measured from the tank bottom to the longitudinal under consideration

H = depth of the tank, in m (ft)

B = installation's breadth, in m (ft), as defined in 3-1-1/5 of the *Steel Vessel Rules (January 2005)*

S_m, f_y and α_1 are as defined in 5A-3-3/7.5.

α_2, y, y_n, SM_{RD} and SM_D are as defined in 5A-3-3/9.5.

SM_{RB} and SM_B are as defined in 5A-3-3/7.3.1.

The effective breadth of plating, b_e, is as defined in line a) of 5A-3-3/Figure 6.

Where the wing ballast tanks are U-shaped, the net section modulus of transverse bulkhead stiffeners in the wing ballast tanks is also to be not less than as obtained from the above equation with the following substituted for p and f_b:

p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified for side shell structure (item 3 case a) in 5A-3-2/Table 3 at each transverse bulkhead stiffener level.

f_b = $S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

Where the breadth of center tank exceeds $0.6B$, the net section modulus of transverse bulkhead stiffeners in the center tank, located outboard of $0.3B$ from the centerline of the tank, is also to be not less than as obtained from the above equation with the following substituted for p and f_b:

p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified for inner skin longitudinal bulkhead structure (item 6 case a) in 5A-3-2/Table 3 at each transverse bulkhead stiffener level.

f_b = $S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

The net moment of inertia of longitudinals on the longitudinal bulkhead, with the associated effective plating, within the region of $0.1D$ from the deck is to be not less than i_o, as specified in 5A-3-3/9.5.

15 Bulkheads – Main Supporting Members *(1995)*

15.1 General

The main supporting members of longitudinal and transverse bulkheads are to be arranged and designed, as indicated in 5A-3-3/11.1.

15.3 Vertical Web on Longitudinal Bulkhead

15.3.1 Section Modulus of Vertical Web on Longitudinal Bulkhead *(1997)*

The net section modulus of the vertical web is to be not less than obtained from the following equation (see also 5A-3-3/1.3).

$$SM = M/f_b \qquad \text{cm}^3\ (\text{in}^3)$$

$$M = 10{,}000kcps\,\ell_b^2 \qquad \text{N-cm (kgf-m, lbf-in.)}$$

where

k = 1.0 (1.0, 0.269)

ℓ_b = span of member, in m (ft), as indicated in 5A-3-3/Figure 2B-a. Where a cross tie (in wing or center tank) is fitted and is located at a distance greater than $0.7\ell_b$ from the deck transverse, the effective span of the vertical web may be measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross ties. Where both the lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b may be taken between the toes of the effective lower and upper brackets.

s = spacing of vertical webs, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web, as specified in 5A-3-2/Table 3

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2 lbf/in^2)

= $0.70\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

c is given in 5A-3-3/Table 3.

For ship-type installations without cross ties, and fitted with an oil-tight centerline bulkhead, the required section modulus of the web is to be maintained for $0.6\ell_b$, measured from the lower end of the web. The value of the bending moment, M, used for calculation of the required section modulus of the remainder of the web may be appropriately reduced, but by not more than 20%. Where the centerline bulkhead is non-tight, the required section modulus is to be maintained throughout.

15.3.2 Web Sectional Area of Vertical Webs on Longitudinal Bulkheads

The net sectional area of the web portion of vertical members is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force F, in N (kgf, lbf), may be obtained from the following equations (see also 5A-3-3/1.3).

$F = 1000ks[K_U \ell(P_U + P_L) - h_U P_U]$ for upper part of vertical web

$= 1000ks[K_L \ell(P_U + P_L) - h_L P_L]$ for lower part of vertical web

but F for lower part of vertical web is not to be less than

$= 1000\gamma ks K_L \ell(P_U + P_L)$

where

k = 1.0 (1.0, 2.24)

P_U = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of upper bracket, as specified in 5A-3-2/Table 3

P_L = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of lower bracket, as specified in 5A-3-2/Table 3

ℓ = span of the vertical web, in m (ft), as indicated in 5A-3-3/Figure 2B-a. Where a cross tie (in wing or center tank) is fitted and is located at a distance greater than 0.7ℓ from the deck transverse, the effective span of the vertical web may be measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross ties.

s = spacing of the vertical webs, in m (ft)

h_U = length, in m (ft), of the upper bracket of the vertical web, as indicated in 5A-3-3/Figure 2B-a and 5A-3-3/Figure 9

h_L = length, in m (ft), of the lower bracket of the vertical web, as indicated in 5A-3-3/Figure 2B-a and 5A-3-3/Figure 9

γ = 0.57 for ship-type installations without cross ties, (5A-3-3/Figure 2A-b, c and f)

= 0.50 for ship-type installations with one cross tie, (5A-3-3/Figure 2A-d and e)

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\ S_m f_y$

S_m and f_y are as defined in 5A-5-3/7.3.1.

Coefficients K_U and K_L are given in 5A-5-3/Table 4.

For ship-type installations without cross ties, the required sectional area of the lower part of the web is to be maintained for 0.6ℓ measured from the lower end of the web.

For ship-type installations with one cross tie, the required sectional area of the lower part of the web is to be maintained up to the cross tie.

In no case is the shear force for the lower part of the vertical web to be taken less than 120% of that for the upper part of the vertical web.

TABLE 3
Coefficient c for Vertical Web on Longitudinal Bulkheads *(2001)*

Arrangement of Cross Ties	*For Upper Part*	*For Lower Part*
No Cross Ties (5A-3-3/Figure 2A-b, c & f) 1) Tight Bhd	0.80	
2) Non-tight Centerline Bhd	0.28	
One Cross Tie in Center Tank, (5A-3-3/Figure 2A-e)	0.14	0.31
One Cross Tie in Wing Cargo Tank, (5A-3-3/Figure 2A-d)	0.18	0.36

TABLE 4
Coefficients K_U and K_L for Vertical Web on Longitudinal Bulkhead *(2001)*

Arrangement of Cross Ties	K_U	K_L
No Cross Ties (5A-3-3/Figure 2A-b, c & f) 1) Tight Bhd	0.18	0.28
2) Non-tight Centerline Bhd.	0.09	0.14
One Cross Tie in Center or Wing Cargo Tank, (5A-3-3/Figure 2A-d & e)	0.08	0.18

15.5 Horizontal Girder on Transverse Bulkhead

15.5.1 Section Modulus of Horizontal Girder on Transverse Bulkhead

The net section modulus of the horizontal girder is to be not less than obtained from the following equation (see also 5A-3-3/1.3).

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps\,\ell_b^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

ℓ_b = span of the horizontal girders, in m (ft), as indicated in 5A-3-3/Figure 2B-b

For ship-type installations with four longitudinal bulkheads, (5A-3-3/Figure 2A-d, e and f), ℓ_b is to be taken not less than 60% of the breadth of the wing cargo tanks.

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

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), calculated at the mid-span of the horizontal girder under consideration, as specified in 5A-3-2/Table 3

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\,S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1.

c for transverse bulkheads without vertical webs

= 0.73 for ship-type installations with an oil-tight centerline bulkhead (5A-3-3/Figure 2A-c)

= 0.55 for ship-type installations with a non-tight centerline bulkhead (5A-3-3/Figure 2A-c)

= 0.83 in wing cargo tanks of installations with four longitudinal bulkheads (5A-3-3/Figure 2A-d, e and f)

= 0.63 in the center tanks of installations with four longitudinal bulkheads (5A-3-3/Figure 2A-d, e and f)

c for transverse bulkheads with vertical webs

For 5A-3-3/Figure 2A-b, ship-type installations with oil-tight centerline bulkhead and 5A-3-3/Figure 2A-a:

= $0.73\alpha^2$ for $\alpha < 0.5$

= $0.467\alpha^2 + 0.0657$ for $0.5 \le \alpha \le 1.0$

= $0.1973\alpha + 0.3354$ for $\alpha > 1.0$

c is not to be taken less than 0.013 and need not be greater than 0.73.

For 5A-3-3/Figure 2A-b, ship-type installations with a non-tight centerline bulkhead:

= $0.55\alpha^2$ for $\alpha < 0.5$

= $0.35\alpha^2 + 0.05$ for $0.5 \le \alpha \le 1.0$

= $0.15\alpha + 0.25$ for $\alpha > 1.0$

c is not to be taken less than 0.013 and need not to be greater than 0.55.

α = $0.9(\ell_{st}/\ell_b)[(I/I_v)(s_v/s)]^{1/4}$

if more than one vertical web is fitted on the bulkhead, average values of ℓ_{st}, s_v and I_v are to be used when these values are not the same for each web.

ℓ_{st} = span of the vertical web, in m (ft) (5A-3-3/Figure 2B-b)

s_v = spacing of the vertical webs, in m (ft)

I, I_v = moments of inertia, in cm^4 (in^4), of the horizontal girder and the vertical web clear of the end brackets

15.5.2 Web Sectional Area of the Horizontal Girder on Transverse Bulkhead

The net sectional area of the web portion of the horizontal girder is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

$F = 1000\, kscp(0.5\ell - h_e)$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

c = 0.80 for transverse bulkheads without vertical webs

= $0.72\alpha^{1/2}$ for transverse bulkheads with vertical webs for $\alpha \geq 0.70$

= $0.887\alpha - 0.02$ for transverse bulkheads with vertical webs for $\alpha < 0.7$, 0.1 min. and 0.8 max.

ℓ = distance, in m (ft), between longitudinal bulkheads, as indicated in 5A-3-3/Figure 2B-b

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

h_e = length of the bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-b

p and α are as defined in 5A-3-3/15.5.1.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

15.7 Vertical Web on Transverse Bulkhead

15.7.1 Section Modulus of Vertical Web on Transverse Bulkhead

The net section modulus of the vertical web is to be not less than obtained from the following equation (see also 5A-3-3/1.3):

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000 kcps\, \ell_{st}^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

c = 0.83 for bulkheads without horizontal girders

= $0.83 - 0.52\alpha$ (but not less than 0.3) for transverse bulkheads with horizontal girders.

ℓ_{st} = span of the vertical web, in m (ft), (5A-3-3/Figure 2B-c). Where both lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_{st} may be taken between the toes of the upper and lower brackets

s = spacing of vertical webs, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web, as specified in 5A-3-2/Table 3

α = as defined in 5A-3-3/15.5.1, except that the values of s, ℓ_b and I are to be averaged in the case that more than one horizontal girder is fitted on the bulkhead

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\ S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1.

The required section modulus for the web is to be maintained for a distance of $0.60\ell_{st}$ from the lower end of the span. Above that point, the value of the bending moment, M, used for the calculation of the required section modulus may be reduced by not more than 20%.

15.7.2 Web Sectional Area of Vertical Web on Transverse Bulkheads

The net sectional area of the web portion of vertical members is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force F in N (kgf, lbf) may be obtained from the following equations (see also 5A-3-3/1.3).

$F = 1000ks[0.18c\ell(P_U + P_L) - h_U P_U]$ for upper part of vertical web

$F = 1000ks[0.30c\ell(P_U + P_L) - h_L P_L]$ or $120ksc\ell(P_U + P_L)$ whichever is greater, for lower part of vertical web

where

k = 1.0 (1.0, 2.24)

c = 1.0 for transverse bulkheads without horizontal girders

= $1.13 - 0.6\alpha$ for transverse bulkheads with horizontal girders, 0.6 min. and 1.0 max.

P_U = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of upper bracket, as specified in 5A-3-2/Table 3

P_L = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of lower bracket, as specified in 5A-3-2/Table 3

ℓ = span of the vertical web, in m (ft), as indicated in 5A-3-3/Figure 2B-c

s = spacing of the vertical webs, in m (ft)

h_U = length, in m (ft), of the upper bracket, as indicated in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9

h_L = length, in m (ft), of the lower bracket, as indicated in 5A-3-3/Figure 2B-c and 5A-3-3/Figure 9

α is as defined in 5A-3-3/15.7.1.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\ S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

The required sectional area of the lower portion of the web is to be maintained for a distance of 0.15ℓ from the toe of the lower bracket or 0.33ℓ measured from the lower end of the span, whichever is greater.

In no case is the shear force for the lower part of the vertical web to be taken less than 120% of that for the upper part of the vertical web.

15.9 Minimum Web Thickness, Proportions, Brackets, Stiffeners, Tripping Brackets, Slots and Lightening Holes

Requirements for these items are given in 5A-3-3/11.9, 5A-3-3/11.11, 5A-3-3/11.13, 5A-3-3/11.15 and 5A-3-3/11.17.

15.11 Cross Ties *(1997)*

Where cross ties are fitted as effective supports for the tank structural members, they are to be spaced so as to divide the supported members into spans of approximately equal length. The axial load imposed on cross ties, W, is to be not greater than the permissible load, W_a, both are as specified below (see also 5A-3-3/1.3). Alternatively, W may be determined from finite element analyses, as specified in 5A-3-4/11, with the combined load cases in 5A-3-2/9. However, in no case should W be taken less than 85% of that determined from the approximate equation below. For this purpose, an additional load case is also to be investigated, modifying load case 5 (of 5A-3-2/Table 1A) with a full design draft and K_{f0} = 1.0 for external pressure where cross ties are located in wing cargo tanks. (See also 5A-3-4/11.1).

$W = pbs$ kN (tf, Ltf)

$W_a = 0.45 f_y [1 - 0.0254 (f_y/E)(\ell/r)^2] A_s$ kN (tf, Ltf), when $(r/\ell)^2 (E/f_y) > 0.0507$

$W_a = 4.44 E (r/\ell)^2 A_s$ kN (tf, Ltf) when $(r/\ell)^2 (E/f_y) \le 0.0507$

where

b = mean breadth of the area supported, in m (ft)

s = spacing of transverses, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the center of the area supported by the cross tie, as specified in 5A-3-2/Table 3, item 15

ℓ = unsupported span of the cross tie, in cm (in.)

r = least radius of gyration of the cross tie, in cm (in.)

A_s = net cross section area of the cross tie, in cm^2 (in^2)

f_y = minimum specified yield point of the material, in kN/cm^2 (tf/cm^2, Ltf/in^2)

E = 2.06×10^4 kN/cm^2 (2.1×10^3 tf/cm^2, 13.4×10^3 Ltf/in^2)

Special attention is to be paid to the adequacy of the welded connections for transmission of the tensile forces and also to the stiffening arrangements at the ends, in order to provide effective means for transmission of the compressive forces into the webs. In addition, horizontal stiffeners are to be located in line with and attached to the first longitudinal above and below the ends of the cross ties.

15.13 Nontight Bulkheads *(1 July 2012)*

Nontight bulkheads referred to in 5A-3-2/11.3.1 are to be fitted in line with transverse webs, bulkheads or other structures with equivalent rigidity. They are to be suitably stiffened. Openings in the nontight bulkhead are to have generous radii and their aggregate area is not to exceed 33%, nor to be less than 10% of the area of the nontight bulkhead, but it is recommended to be as close to 33% as practicable. The opening area is to be evenly distributed between 0.1 and 0.9 of the bulkhead depth. The net thickness of nontight bulkheads is to be not less than 11.0 mm (0.433 in.). Section moduli of stiffeners and webs may be half of those required for watertight bulkheads in 5A-3-3/13.5, 5A-3-3/15.3.1, 5A-3-3/15.5.1, 5A-3-3/15.7.1 and 5A-3-3/15.9.

Alternatively, the opening ratio and scantlings may be determined by an acceptable method of engineering analysis.

17 Corrugated Bulkheads *(1997)*

17.1 General

All vertically corrugated transverse and longitudinal bulkheads in cargo tanks are to be designed in compliance with the requirements specified in this Subsection and the strength assessment criteria with respect to yielding, buckling and ultimate strength, and fatigue, as specified in Section 5A-3-4.

In general, the approximation equations given below are applicable to vertical corrugations with corrugation angles, ϕ (5A-3-3/Figure 11 or 5A-3-3/Figure 10), within the range between 60 and 90 degrees. For corrugation angles less than 60 degrees and corrugation in the horizontal direction, direct calculations may be required.

17.3 Plating *(1999)*

The net thickness of the vertically corrugated plating is not to be less than t_1, t_2, t_3 and t_4, obtained from the following equations:

$t_1 = 0.516k_1a(p_\ell/f_1)^{1/2}$ in mm (in.) for flange and web plating

$t_2 = 0.42k_2a(f_y/E)^{1/2}$ in mm (in.) for flange plating

$t_3 = k(a/k_3)(f_3)^{1/2}\,10^{-3}$ in mm (in.) for flange plating

$t_4 = 100F/(df_4)$ in mm (in.) for web plating

but not less than 9.5 mm (0.37 in.)

where

k = 0.728 (2.28, 0.605)

a = width of flange plating, in mm (in.) (5A-3-3/Figure 10 or 5A-3-3/Figure 11)

c = width of web plating, in mm (in.) (5A-3-3/Figure 10 or 5A-3-3/Figure 11)

d = depth of corrugation, in mm (in.) (5A-3-3/Figure 10 or 5A-3-3/Figure 11)

ϕ = corrugation angle, (5A-3-3/Figure 10 or 5A-3-3/Figure 11)

k_1 = $(1 - c/a + c^2/a^2)^{1/2}$

k_2 = $f_2/(0.73f_y)$

k_3 = $7.65 - 0.26(c/a)^2$

F = shear force, in N (kgf, lbf), imposed on the web plating at the lower end of corrugation span

= $k_4s\ell(0.375p_\ell + 0.125p_u)$

k_4 = 10 (10, 12)

s = spacing of corrugation, in mm (in.), i.e., $a + c\cos\phi$, (5A-3-3/Figure 10 or 5A-3-3/Figure 11)

ℓ = span of corrugation, in m (ft), taken as the distance between lower and upper stools at centerline

p_ℓ, p_u = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), at the lower and upper ends of span, respectively, as specified in 5A-3-2/Table 3

f_1 = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.90\,S_mf_y$

f_2 = maximum vertical bending stress in the flange at the mid-depth of corrugation span to be calculated from 5A-3-3/17.5 below, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_3 = maximum vertical bending stress in the flange at the lower end of corrugation span to be calculated from 5A-3-3/17.5 below, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_4 = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.40\, S_m f_y$

E, S_m and f_y are as defined in 5A-3-3/7.3.1.

The plate thickness, as determined above based on the maximum anticipated pressures, is to be generally maintained throughout the entire corrugated bulkhead, except that the net thickness of plating above $^2/_3$ of span, ℓ, from the top of the lower stool may be reduced by 20%.

17.5 Stiffness of Corrugation *(1999)*

17.5.1 Depth/Length Ratio

The depth/length ratio (d/ℓ) of the corrugation is not to be less than $^1/_{15}$, where d and ℓ are as defined in 5A-3-3/17.3 above.

17.5.2 Section Modulus

The net section modulus for any unit corrugation is not to be less than obtained from the following equation for all anticipated service loading conditions.

$SM = M/f_b$ cm^3 (in^3)

$M = 1000(C_i/C_j)ps\,\ell_o^2/k$ N-cm (kgf-cm, lbf-in)

where

k = 12 (12, 83.33)

ℓ_o = nominal length of the corrugation, in m (ft), measured from the mid-depth of the lower stool to the mid-depth of the upper stool

p = $(p_u + p_\ell)/2$, N/cm^2 (kgf/cm^2, lbf/in^2)

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.90\, S_m f_y$, for lower end of corrugation span ℓ

= $c_e f_y \le 0.90 S_m f_y$, for the mid $\ell/3$ region of the corrugation

c_e = $2.25/\beta - 1.25/\beta^2$ for $\beta \ge 1.25$

= 1.0 for $\beta < 1.25$

β = $(f_y/E)^{1/2}\, a/t_f$

t_f = net thickness of the corrugation flange, in mm (in.)

C_i = bending moment coefficients, as given below

Values of C_i (All Bulkheads with Lower and Upper Stools)

Bulkhead	*Lower End of Span ℓ*	*Mid-depth*	*Upper End of Span ℓ*
Trans. Bhd:			
(w/Long'l Bhd)	C_1	C_{m1}	$0.80C_{m1}$
(w/out Long'l Bhd)	C_2	C_{m2}	$0.65C_{m2}$
Long'l. Bhd.	C_3	C_{m3}	$0.65C_{m3}$

$C_1 \quad = \quad a_1 + b_1(kA_{dt}/B_d)^{1/2} \geq 0.6$

where $a_1 = 0.95 - 0.26/R_b$, $b_1 = -0.20 + 0.05/R_b$

$C_{m1} \quad = \quad a_{m1} + b_{m1}(kA_{dt}/B_d)^{1/2} \geq 0.55$

where $a_{m1} = 0.63 + 0.16/R_b$, $b_{m1} = -0.25 - 0.07/R_b$

$C_2 \quad = \quad a_2 + b_2(kA_{dt}/B_d)^{1/2} \geq 0.6$

where $a_2 = 0.84 - 0.07/R_b$, $b_2 = -0.24 + 0.02/R_b$

$C_{m2} \quad = \quad a_{m2} + b_{m2}(kA_{dt}/B_d)^{1/2} \geq 0.55$

where $a_{m2} = 0.56 + 0.05/R_b$, $b_{m2} = -0.34 - 0.03/R_b$

$C_3 \quad = \quad a_3 + b_3(kA_{d\ell}/L_d)^{1/2} \geq 0.6$

where $a_3 = 1.07 - 0.21/R_b$, $b_3 = -0.21 + 0.04/R_b$

$C_{m3} \quad = \quad a_{m3} + b_{m3}(kA_{d\ell}/L_d)^{1/2} \geq 0.55$

where $a_{m3} = 0.30 + 0.07/R_b$, $b_{m3} = -0.12 - 0.03/R_b$

C_j = bending moment factors due to sloshing effect

Values of C_j (All Bulkheads with Lower and Upper Stools)

Bulkhead	*Mid-depth*	*Upper End of Span ℓ*
Trans. Bhd:	C_{mj1}	C_{mj2}
Long'l. Bhd.	C_{mj3}	C_{mj4}

$$C_{mj1} = 1.83\frac{P}{P_s} - 0.74 \geq 0.40 \qquad \text{if } \frac{P}{P_s} < 0.95$$

$$= 1.0 \qquad \text{if } \frac{P}{P_s} \geq 0.95$$

$$C_{mj2} = 3.73\frac{P}{P_s} - 2.36 \geq 0.62 \qquad \text{if } \frac{P_n}{P_s} < 0.90$$

$$= 1.0 \qquad \text{if } \frac{P}{P_s} \geq 0.90$$

$$C_{mj3} = 4.14\frac{P}{P_s} - 3.14 \geq 0.75 \qquad \text{if } \frac{P}{P_s} < 1.00$$

$$= 1.0 \qquad \text{if } \frac{P}{P_s} \geq 1.00$$

$$C_{mj4} = 2.36\frac{P}{P_s} - 1.71 \geq 0.72 \qquad \text{if } \frac{P}{P_s} < 1.15$$

$$= 1.0 \qquad \text{if } \frac{P}{P_s} \geq 1.15$$

P_s = $(p_{su} + p_{s\ell})/2$ N/cm^2 (kgf/cm^2, lbf/in^2)

P = $(p_u + p_\ell)/2$ N/cm^2 (kgf/cm^2, lbf/in^2)

$p_{s\ell}, p_{su}$	=	sloshing pressure, in N/cm² (kgf/cm², lbf/in²), at the lower and upper ends of span, respectively, as specified in 5A-3-2/11.5, calculated at the same locations indicated for p_ℓ and p_u.
p_ℓ, p_u	=	nominal pressure, in N/cm² (kgf/cm², lbf/in²), at the lower and upper ends of span, respectively, as specified in 5A-3-2/Table 3, to be calculated at a section located B/4 from the C.L. when the installation has one or no longitudinal bulkheads. For installations with two longitudinal bulkheads, the nominal pressure is to be calculated at a section located b/4 from the outboard boundary of the center or the wing tank.
R_b	=	$kH_{st}(B_{ct} + B_{st})(1 + L_b/B_b + 0.5H_b/L_b)/(2B_b)$ for transverse bulkheads
	=	$H_{s\ell}\,(B_{c\ell} + B_{s\ell})(1 + B_b/L_b + 0.5H_b/B_b)/(2L_b)$ for longitudinal bulkheads
A_{dt}	=	cross sectional area, in m² (ft²), enclosed by the outside lines of upper stool of transverse bulkhead
$A_{d\ell}$	=	cross sectional area, in m² (ft²), enclosed by the outside lines of upper stool of longitudinal bulkheads
B_{ct}	=	width of the bottom stool of transverse bulkhead, in m (ft), at the top (5A-3-3/Figure 11 or 5A-3-3/Figure 10)
$B_{c\ell}$	=	width of the bottom stool of longitudinal bulkhead, in m (ft), at the top (5A-3-3/Figure 11)
B_{st}	=	width of the bottom stool of transverse bulkhead, in m (ft), at the inner bottom level (5A-3-3/Figure 11)
$B_{s\ell}$	=	width of the bottom stool of longitudinal bulkhead, in m (ft), at the inner bottom level (5A-3-3/Figure 11)
H_b	=	double bottom height, in m (ft)
H_{st}	=	height of the bottom stool of transverse bulkhead, in m (ft), from the inner bottom to the top (5A-3-3/Figure 11 or 5A-3-3/Figure 10)
$H_{s\ell}$	=	height of the bottom stool of longitudinal bulkhead, in m (ft), from the inner bottom to the top (5A-3-3/Figure 11)
B_b	=	transverse distance, in m (ft), between hopper tanks at the inner bottom level (5A-3-3/Figure 11 or 5A-3-3/Figure 10)
B_d	=	transverse distance, in m (ft), between upper wing tanks or between upper wing tank and centerline deck structure, at the deck level (5A-3-3/Figure 11 or 5A-3-3/Figure 10)
L_b	=	longitudinal distance, in m (ft), between bottom stools in the loaded tanks at the inner bottom level (5A-3-3/Figure 11 or 5A-3-3/Figure 10)
L_d	=	longitudinal distance, in m (ft), between upper stools in the loaded tanks at the deck level (5A-3-3/Figure 11)
k	=	1 (1, 3.2808)
B	=	breadth of installation, as defined in 3-1-1/5 of the *Steel Vessel Rules*, in m (ft)
b	=	width of tank under consideration, in m (ft)

a, ℓ, s, p_u and p_ℓ are as defined in 5A-3-3/17.3 above.

E is as defined in 5A-3-3/7.3.

S_m and f_y are as defined in 5A-3-3/7.5.

The developed net section modulus *SM* may be obtained from the following equation, where a, c, d, t_f(net), and t_w(net), all in cm (in.), are as indicated in 5A-3-3/Figure 10.

$$SM = d(3at_f + ct_w)/6 \qquad \text{cm}^3 \text{ (in}^3\text{)}$$

17.7 Bulkhead Stools

17.7.1 Lower Stool *(2004)*

The height of the lower stool is to be not less than three times the minimum depth of corrugation required by 5A-3-3/17.5.1 above. The net thickness and material of the stool top plate is not to be less than that required for the bulkhead plating in 5A-3-3/17.3 above. The net thickness and material of the upper portion of vertical or sloping stool side plate within the region of one meter from the stool top is not to be less than the required flange plate thickness to meet the bulkhead stiffness requirement at the lower end of the corrugation in 5A-3-3/17.5 above. The net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than those required for plane transverse or longitudinal bulkhead plating and stiffeners in 5A-3-3/13.1, 5A-3-3/13.3 and 5A-3-3/13.5, with the corresponding tank pressure specified in 5A-3-2/Table 3. The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool.

The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation. The stool bottom is to be installed in line with double bottom floors or girders, fitted with proper brackets, and diaphragms are to be provided in the stool to effectively support the panels of the corrugated bulkhead. The width of the stool at the inner bottom is to be not less than 2.5 times the mean depth of the corrugation. Scallops in the brackets and diaphragms in way of the top and bottom connections to the plates and in the double bottom floors or girders are to be avoided.

17.7.2 Upper Stool

The upper stool is to have a depth generally not less than twice the minimum depth of corrugation, as specified in 5A-3-3/17.5, and is to be properly supported by girders or deep brackets.

The width of the stool bottom plate should generally be the same as that of the lower stool top plate. The net thickness of the stool bottom plate should generally be the same as that of the bulkhead plating, and the net thickness of the lower portion of the stool side plate is not to be less than 80% of that required for the bulkhead plating in 5A-3-3/17.3 above for the upper one-third portion of the bulkhead. The net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than those required for plane transverse bulkhead plating and stiffeners in 5A-3-3/13.1, 5A-3-3/13.3 and 5A-3-3/13.5, with the corresponding tank pressure specified in 5A-3-2/Table 3. The ends of stool side stiffeners are to be attached to brackets at the upper and lower ends of the stool. Brackets or diaphragms are to be fitted to effectively support the web panels of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

17.7.3 Alignment *(2001)*

Stool side vertical stiffeners and their brackets in the lower stool of the transverse bulkhead should align with the inner bottom longitudinal to provide appropriate load transmission between the stiffening members.

17.9 End Connections *(1 July 2001)*

The structural arrangements and size of the welding at the ends of corrugations are to be designed to develop the required strength of the corrugated bulkhead. Where shedder plates (slanting plates) are fitted at the end connection of the corrugation to the lower stool, appropriate means are to be provided to prevent the possibility of gas pockets being formed in way of these plates within the cargo tanks.

Welding for all connections and joints is to be in compliance with the Rules. The welded connection of the bulkhead to the stools within 10% of the depth of the corrugation from the outer surface of the corrugation, d_1, is to be double continuous with fillet size not less than 0.7 times the thickness of bulkhead plating or penetration welds of equal strength (see 5A-3-3/Figure 12).

FIGURE 10
Definition of Parameters for Corrugated Bulkhead (Ship-type Installations without Longitudinal Bulkhead at Centerline) *(1 September 2007)*

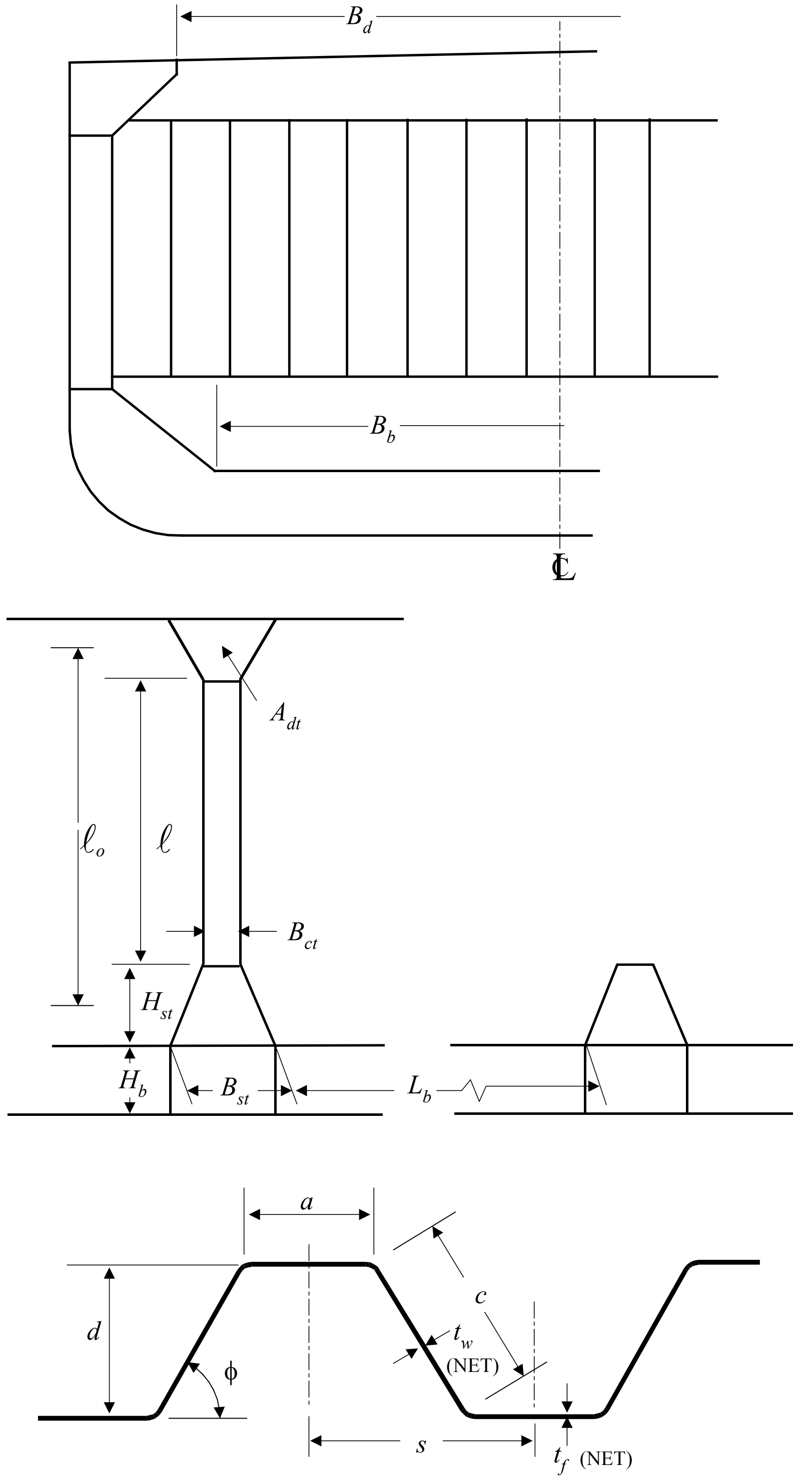


FIGURE 11
Definition of Parameters for Corrugated Bulkhead (Ship-type Installations with Longitudinal Bulkhead at Centerline) *(1 September 2007)*

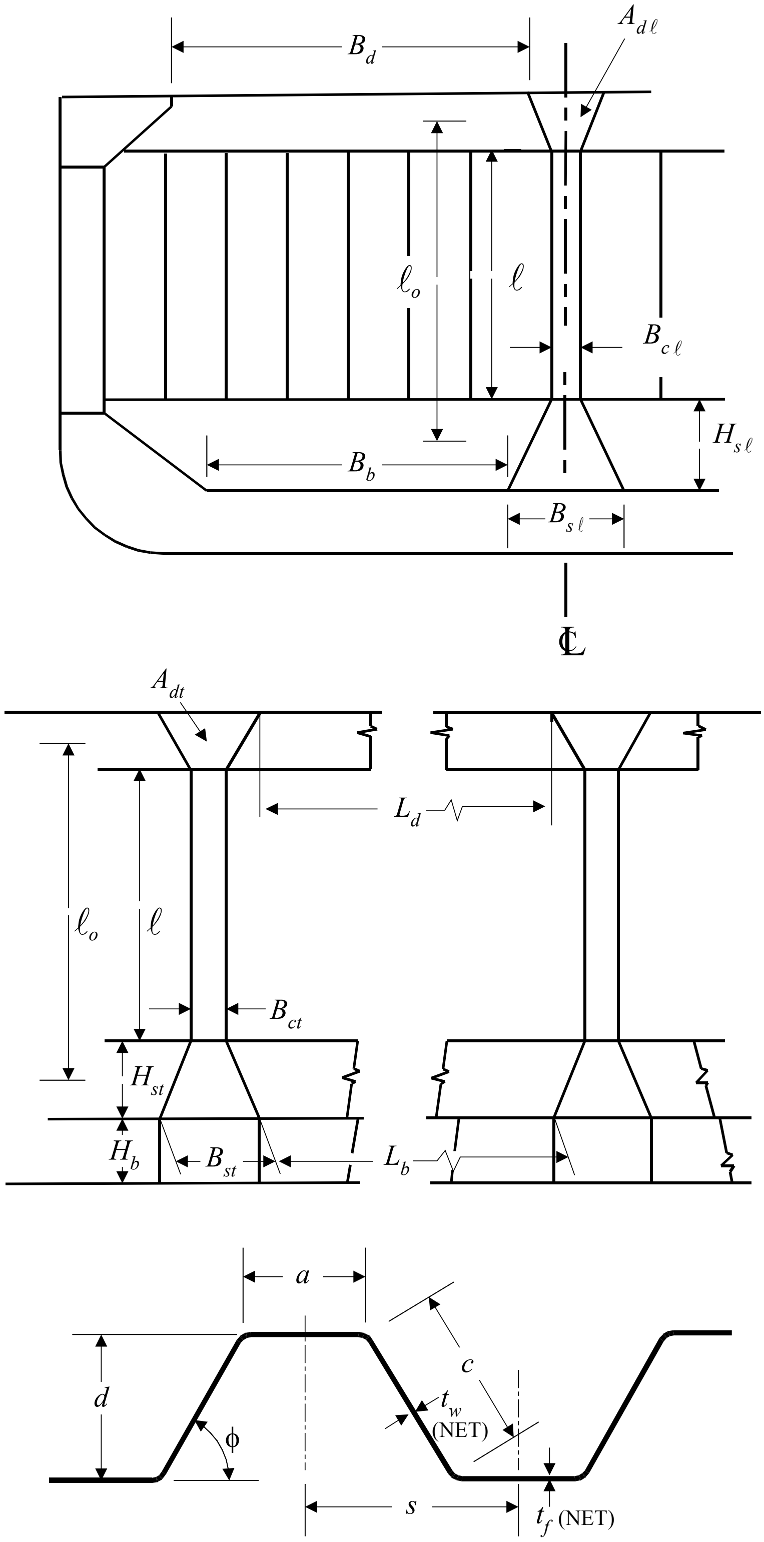
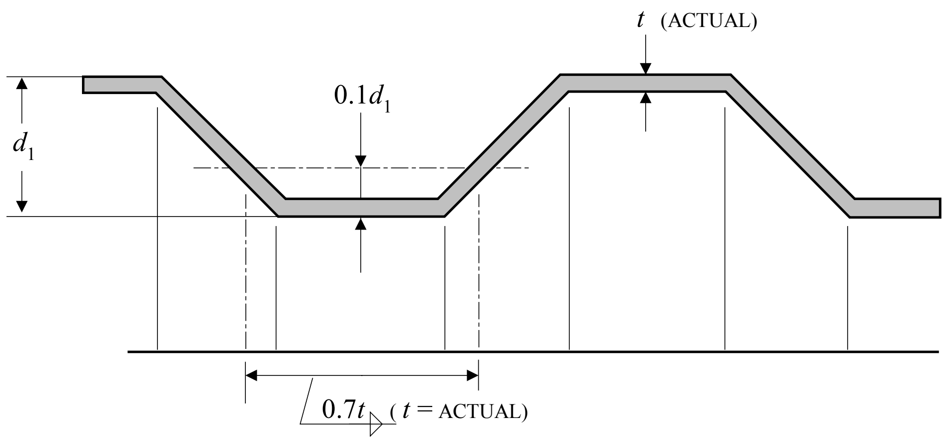


FIGURE 12
Corrugated Bulkhead End Connections



PART

5A

CHAPTER 3 Structural Design Requirements

SECTION 4 Total Strength Assessment

1 General Requirements

1.1 General *(1995)*

In assessing the adequacy of the structural configuration and the initially selected scantlings, the strength of the hull girder and the individual structural member or element is to be in compliance with the failure criteria specified in 5A-3-4/3 below. In this regard, the structural response is to be calculated by performing a structural analysis, as specified in 5A-3-4/11, or by other equivalent and effective means. Due consideration is to be given to structural details, as specified in 5A-3-3/1.5.

1.3 Loads and Load Cases *(December 2008)*

In determination of the structural response, the combined load cases given in 5A-3-2/9.3 are to be considered together with sloshing loads specified in 5A-3-2/11. Deck loads as specified in Sections 5A-1-4 and 5A-1-5 are also to be considered. If this information is not yet available, the deck loads as indicated in 5A-3-2/15 are to be used. Bowflare/bottom slamming and other loads, as specified in 5A-3-2/13, are also to be considered as necessary.

1.5 Stress Components *(1995)*

The total stress in stiffened plate panels are divided into the following three categories:

1.5.1 Primary

Primary stresses are those resulting from hull girder bending. The primary bending stresses may be determined by simple beam method using the specified total vertical and horizontal bending moments and the effective net hull girder section modulus at the section considered. These primary stresses, designated by f_{L1} (f_{L1V}, f_{L1H} for vertical and horizontal bending, respectively), may be regarded as uniformly distributed across the thickness of plate elements, at the same level measuring from the relevant neutral axis of the hull girder.

1.5.2 Secondary

Secondary stresses are those resulting from bending of large stiffened panels between longitudinal and transverse bulkheads, due to local loads in an individual cargo or ballast tank.

The secondary bending stresses, designated by f_{L2} or f_{T2}, are to be determined by performing a 3D FEM analysis, as outlined in this Section.

For stiffened hull structures, there is another secondary stress due to the bending of longitudinals or stiffeners with the associated plating between deep supporting members or floors. The latter secondary stresses are designated by f_{L2}^* or f_{T2}^*, and may be approximated by simple beam theory.

The secondary stresses, f_{L2}, f_{T2}, f_{L2}^* or f_{T2}^*, may be regarded as uniformly distributed in the flange plating and face plates.

1.5.3 Tertiary

Tertiary stresses are those resulting from the local bending of plate panels between stiffeners. The tertiary stresses, designated by f_{L3} or f_{T3}, can be calculated from classic plate theory. These stresses are referred to as point stresses at the surface of the plate.

3 Failure Criteria – Yielding

3.1 General

The calculated stresses in the hull structure are to be within the limits given below for the entire combined load cases specified in 5A-3-2/9.3.

3.3 Structural Members and Elements *(1999)*

For all structural members and elements, such as longitudinals/stiffeners, web plates and flanges, the combined effects of all of the calculated stress components are to satisfy the following limits:

$$f_i \leq S_m f_y$$

where

f_i = stress intensity

= $(f_L^2 + f_T^2 - f_L f_T + 3 f_{LT}^2)^{1/2}$ N/cm² (kgf/cm², lbf/in²)

f_L = calculated total in-plane stress in the longitudinal direction including primary and secondary stresses

= $f_{L1} + f_{L2} + f_{L2}^*$ N/cm² (kgf/cm², lbf/in²)

f_{L1} = direct stress due to the primary (hull girder) bending, N/cm² (kgf/cm², lbf/in²)

f_{L2} = direct stress due to the secondary bending between bulkheads in the longitudinal direction, N/cm² (kgf/cm², lbf/in²)

f_{L2}^* = direct stress due to local bending of longitudinal between transverses in the longitudinal direction, N/cm² (kgf/cm², lbf/in²)

f_T = calculated total direct stress in the transverse/vertical direction, including secondary stresses

= $f_{T1} + f_{T2} + f_{T2}^*$ N/cm² (kgf/cm², lbf/in²)

f_{LT} = calculated total in-plane shear stress, N/cm² (kgf/cm², lbf/in²)

f_{T1} = direct stress due to sea and cargo load in the transverse/vertical direction, N/cm² (kgf/cm², lbf/in²)

f_{T2} = direct stress due to the secondary bending between bulkheads in the transverse/vertical direction, N/cm² (kgf/cm², lbf/in²)

f_{T2}^* = direct stress due to local bending of stiffeners in the transverse/vertical direction, N/cm² (kgf/cm², lbf/in²)

f_y = specified minimum yield point, N/cm² (kgf/cm², lbf/in²)

S_m = strength reduction factor, as defined in 5A-3-3/7.3.1

For this purpose, f_{L2}^* and f_{T2}^* in the flanges of longitudinal and stiffener at the ends of span may be obtained from the following equation:

$$f_{L2}^*(f_{T2}^*) = 0.071 s p \ell^2 / SM_L(SM_T) \quad \text{N/cm}^2 \text{ (kgf/cm}^2\text{, lbf/in}^2\text{)}$$

where

s = spacing of longitudinals (stiffeners), in cm (in.)

ℓ = unsupported span of the longitudinal (stiffener), in cm (in.)

p = net pressure load, in N/cm² (kgf/cm², lbf/in²), for the longitudinal (stiffener)

SM_L (SM_T) = net section modulus, in cm³ (in³), of the longitudinal (stiffener)

3.5 Plating *(1 July 2012)*

For plating away from knuckle, horizontal girder or stringer or cruciform connections of high stress concentrations and subject to both in-plane and lateral loads, the combined effects of all of the calculated stress components are to satisfy the limits specified in 5A-3-4/3.3 with f_L and f_T modified as follows:

$$f_L = f_{L1} + f_{L2} + f^*_{L2} + f_{L3} \qquad \text{N/cm}^2\ (\text{kgf/cm}^2,\ \text{lbf/in}^2)$$

$$f_T = f_{T1} + f_{T2} + f^*_{T2} + f_{T3} \qquad \text{N/cm}^2\ (\text{kgf/cm}^2,\ \text{lbf/in}^2)$$

where

f_{L3}, f_{T3} = plate bending stresses between stiffeners in the longitudinal and transverse directions, respectively, and may be approximated as follows.

f_{L3} = $0.182p(s/t_n)^2$ N/cm^2 (kgf/cm^2, lbf/in^2)

f_{T3} = $0.266p(s/t_n)^2$ N/cm^2 (kgf/cm^2, lbf/in^2)

p = lateral pressures for the combined load case considered (see 5A-3-2/9), in N/cm^2 (kgf/cm^2, lbf/in^2)

s = spacing of longitudinals or stiffeners, in mm (in.)

t_n = net plate thickness, in mm (in.)

$f_{L1}, f_{L2}, f^*_{L2}, f_{T1}, f_{T2}$ and f^*_{T2} are as defined in 5A-3-4/3.3.

For plating within two longitudinals or stiffeners from knuckle or cruciform connections of high stress concentrations, the combined effects of the calculated stress components are to satisfy the following stress limit:

$$f_i \leq 0.80\ S_m f_y$$

where

f_i = stress intensity

= $(f_L^2 + f_T^2 - f_L f_T + 3 f_{LT}^2)^{1/2}$ N/cm^2 (kgf/cm^2, lbf/in^2)

f_L = calculated total in-plane stress in the longitudinal direction including primary and secondary stresses

= $f_{L1} + f_{L2}$ N/cm^2 (kgf/cm^2, lbf/in^2)

f_T = calculated total direct stress in the transverse/vertical direction, including secondary stresses

= $f_{T1} + f_{T2}$ N/cm^2 (kgf/cm^2, lbf/in^2)

In addition, the failure criteria for knuckle or cruciform connections in 5A-3-4/13 are to be complied with.

5 Failure Criteria – Buckling and Ultimate Strength *(1995)*

5.1 General

5.1.1 Approach

The strength criteria given here correspond to either serviceability (buckling) limit states or ultimate limit states for structural members and panels, according to the intended functions and buckling resistance capability of the structure. For plate panels between stiffeners, buckling in the elastic range is acceptable, provided that the ultimate strength of the structure satisfies the specified design limits. The critical buckling stresses and ultimate strength of structures may be determined based on either well-documented experimental data or a calibrated analytical approach. When a detailed analysis is not available, the equations given in 5A-3-4/7.1 may be used to assess the buckling strength.

5.1.2 Buckling Control Concepts

The strength criteria in 5A-3-4/5.3 through 5A-3-4/5.11 are based on the following assumptions and limitations with respect to buckling control in design.

5.1.2(a) The buckling strength of longitudinals and stiffeners is generally greater than that of the plate panels they support.

5.1.2(b) All longitudinals with their associated effective plating are to have moments of inertia not less than i_o given in 5A-3-4/7.9.1.

5.1.2(c) The main supporting members, including transverses, girders and floors, with their associated effective plating are to have the moments of inertia not less than I_s given in 5A-3-4/7.9.3.

5.1.2(d) Face plates and flanges of girders, longitudinals and stiffeners are proportioned such that local instability is prevented. (See 5A-3-4/7.9.4)

5.1.2(e) Webs of longitudinals and stiffeners are proportioned such that local instability is prevented. (See 5A-3-4/7.9.5).

5.1.2(f) Webs of girders, floors and transverses are designed with proper proportions and stiffening systems to prevent local instability. Critical buckling stresses of the webs may be calculated from equations given in 5A-3-4/7.3.

For structures which do not satisfy these assumptions, a detailed analysis of buckling strength using an acceptable method is to be submitted for review.

5.3 Plate Panels

5.3.1 Buckling Limit State *(December 2008)*

The buckling limit state for plate panels between stiffeners is defined by the following equation:

$$(f_{Lb}/f_{cL})^2 + (f_{Tb}/f_{cT})^2 + (f_{LT}/f_{cLT})^2 \leq 1.0$$

where

$f_{Lb} = f_{L1} + f_{L2}$ = calculated total compressive stress in the longitudinal direction for the plate, in N/cm^2 (kgf/cm^2, lbf/in^2), induced by bending of the hull girder and large stiffened panels between bulkheads

$f_{Tb} = f_{T1} + f_{T2}$ = calculated total compressive stress in the transverse/vertical direction, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{LT} = calculated total in-plane shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{cL}, f_{cT} and f_{cLT} are the critical buckling stresses corresponding to uniaxial compression in the longitudinal, transverse/vertical directions and edge shear, respectively, in N/cm^2 (kgf/cm^2, lbf/in^2), and may be determined from the equations given in 5A-3-4/7.3.

f_L, f_T and f_{LT} are to be determined for the panel in question under the load cases specified in 5A-3-2/9.3.2 including the primary and secondary stresses, as defined in 5A-3-4/3.1.

5.3.2 Effective Width

When the buckling limit state specified in 5A-3-4/5.3.1 above is not satisfied, the effective width b_{wL} or b_{wT} of the plating given below is to be used instead of the full width between longitudinals, s, for verifying the ultimate strength, as specified in 5A-3-4/5.3.3 below. When the buckling limit state in 5A-3-4/5.3.1 above is satisfied, the full width between longitudinals, s, may be used as the effective width, b_{wL}, for verifying the ultimate strength of longitudinals and stiffeners specified in 5A-3-4/5.5.

5.3.2(a) For long plate:

$b_{wL}/s = C$

$C = 2.25/\beta - 1.25/\beta^2$ for $\beta \geq 1.25$

$= 1.0$ for $\beta < 1.25$

$\beta = (f_y/E)^{1/2}s/t_n$

s = longitudinal spacing, in mm (in.)

t_n = net thickness of the plate, in mm (in.)

E = Young's modulus, 2.06×10^7 N/cm² (2.1×10^6 kgf/cm², 30×10^6 lbf/in²) for steel

f_y = specified minimum yield point of the material, in N/cm² (kgf/cm², lbf/in²)

5.3.2(b) (1999) For wide plate (compression in transverse direction):

$$b_{wT}/\ell = Cs/\ell + 0.115(1 - s/\ell)(1 + 1/\beta^2)^2 \leq 1.0$$

where

ℓ = spacing of transverses, in cm (in.)

s = longitudinal spacing, in cm (in.)

C, β are as defined in 5A-3-4/5.3.2(a) above.

5.3.3 Ultimate Strength *(December 2008)*

The ultimate strength of a plate panel between stiffeners is to satisfy all of the following equations:

$$(f_{Lb}/f_{uL})^2 + (f_{LT}/f_{uLT})^2 \leq S_m$$

$$(f_{Tb}/f_{uT})^2 + (f_{LT}/f_{uLT})^2 \leq S_m$$

$$(f_{Lb}/f_{uL})^2 + (f_{Tb}/f_{uT})^2 - \eta(f_{Lb}/f_{uL})(f_{Tb}/f_{uT}) + (f_{LT}/f_{uLT})^2 \leq S_m$$

where

f_{Lb}, f_{Tb} and f_{LT} are as defined in 5A-3-4/5.3.1 above.

S_m is as defined in 5A-3-3/7.3.1.

$\eta = 1.5 - \beta/2 \geq 0$

β is as defined in 5A-3-4/5.3.2 above.

f_{uL}, f_{uT} and f_{uLT} are the ultimate strengths with respect to uniaxial compression and edge shear, respectively, and may be obtained from the following equations, except that they need not be taken less than the corresponding critical buckling stresses specified in 5A-3-4/5.3.1 above.

$$f_{uL} = f_y b_{wL}/s$$

$$f_{uT} = f_y b_{wT}/\ell$$

$$f_{uLT} = f_{cLT} + 0.5(f_y - \sqrt{3}\, f_{cLT})/(1 + \alpha + \alpha^2)^{1/2}$$

where

$\alpha = \ell/s$

f_y, b_{wL}, b_{wT}, s, ℓ and f_{cLT} are as defined above.

For assessing the ultimate strength of plate panels between stiffeners, special attention is to be paid to the longitudinal bulkhead plating in the regions of high hull girder shear forces and the bottom and inner bottom plating in the mid portion of cargo tanks subject to bi-axial compression.

5.5 Longitudinals and Stiffeners

5.5.1 Beam-Column Buckling Limit States and Ultimate Strength *(2002)*

The buckling limit states for longitudinals and stiffeners are considered as the ultimate limit states for these members and are to be determined as follows:

$$f_a/(f_{ca}A_e/A) + mf_b/f_y \leq S_m$$

where

f_a	=	nominal calculated compressive stress
	=	P/A, N/cm^2 (kgf/cm^2, lbf/in^2)
P	=	total compressive load, N (kgf, lbf)
f_{ca}	=	critical buckling stress, as given in 5A-3-4/7.5.1, N/cm^2 (kgf/cm^2, lbf/in^2)
A	=	total net sectional area, cm^2 (in^2)
	=	$A_s + st_n$
A_s	=	net sectional area of the longitudinal, excluding the associated plating, cm^2 (in^2)
A_e	=	effective net sectional area, cm^2 (in^2)
	=	$A_s + b_{wL}t_n$
b_{wL}	=	effective width, as specified in 5A-3-4/5.3.2 above
E	=	Young's modulus, 2.06×10^7 N/cm^2 (2.1×10^6 kgf/cm^2, 30×10^6 lbf/in^2) for steel
f_y	=	minimum specified yield point of the longitudinal or stiffener under consideration, N/cm^2 (kgf/cm^2, lbf/in^2)
f_b	=	bending stress, N/cm^2 (kgf/cm^2, lbf/in^2)
	=	M/SM_e
M	=	maximum bending moment induced by lateral loads
	=	$c_m ps\ell^2/12$ N-cm (kgf-cm, lbf-in)
c_m	=	moment adjustment coefficient, and may be taken as 0.75
p	=	lateral pressure for the region considered, N/cm^2 (kgf/cm^2, lbf/in^2)
s	=	spacing of the longitudinals, cm (in.)
SM_e	=	effective section modulus of the longitudinal at flange, accounting for the effective breadth, b_e, cm^3 (in^3)
b_e	=	effective breadth, as specified in 5A-3-3/Figure 6, line b
m	=	amplification factor
	=	$1/[1 - f_a/\pi^2E(r/\ell)^2] \geq 1.0$

S_m is as defined in 5A-3-3/7.3.1.

r and ℓ are as defined in 5A-3-4/7.5.1.

5.5.2 Torsional-Flexural Buckling Limit State *(2002)*

In general, the torsional-flexural buckling limit state of longitudinals and stiffeners is to satisfy the ultimate limit states given below:

$$f_a/(f_{ct}A_e/A) \leq S_m$$

where

f_a = nominal calculated compressive stress in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in 5A-3-4/5.5.1 above

f_{ct} = critical torsional-flexural buckling stress in N/cm^2 (kgf/cm^2, lbf/in^2), and may be determined by equations given in 5A-3-4/7.5.2.

A_e and A are as defined in 5A-3-4/5.5.1 above and S_m is as defined in 5A-3-3/7.3.1.

5.7 Stiffened Panels

5.7.1 Large Stiffened Panels between Bulkheads

For a double hull ship-type installation, assessment of buckling limit state is not required for the large stiffened panels of the bottom and inner bottom structures, side shell and inner skin. Assessments of the buckling limit states are to be performed for large stiffened panels of the deck structure and other longitudinal bulkheads. In this regard, the buckling strength is to satisfy the following condition for uniaxially or orthogonally stiffened panels.

$$(f_{L1}/f_{cL})^2 + (f_{T1}/f_{cT})^2 \le S_m$$

where

f_{L1}, f_{T1} = calculated average compressive stresses in the longitudinal and transverse/vertical directions, respectively, as defined in 5A-3-4/3.3 above

f_{cL}, f_{cT} = critical buckling stresses for uniaxial compression in the longitudinal and transverse direction, respectively, and may be determined in accordance with 5A-3-4/7.7, in N/cm^2 (kgf/cm^2, lbf/in^2)

S_m = strength reduction factor, as defined in 5A-3-3/7.3.1

5.7.2 Uniaxially Stiffened Panels between Transverses and Girders

The bucking strength of uniaxially stiffened panels between deep transverses and girders is also to be examined in accordance with the specifications given in 5A-3-4/5.7.1 above by replacing f_{L1} and f_{T1} with f_{Lb} and f_{Tb}, respectively. f_{Lb} and f_{Tb} are as defined in 5A-3-4/5.3.1 above.

5.9 Deep Girders and Webs

5.9.1 Buckling Criteria *(December 2008)*

In general, the stiffness of the web stiffeners along the depth of the web plating is to be in compliance with the requirements of 5A-3-4/7.9.2. Web stiffeners which are oriented parallel to and near the face plate, and thus subject to axial compression, are also to satisfy the limits specified in 5A-3-4/5.5, considering the combined effect of the compressive and bending stresses in the web. In this case, the unsupported span of these parallel stiffeners may be taken between tripping brackets, as applicable.

The buckling strength of the web plate between stiffeners and flange/face plate is to satisfy the limits specified below.

5.9.1(a) For web plate:

$$(f_{Lb}/f_{cL})^2 + (f_b/f_{cb})^2 + (f_{LT}/f_{cLT})^2 \le S_m$$

where

f_{Lb} = calculated uniform compressive stress along the length of the girder, N/cm^2 (kgf/cm^2, lbf/in^2)

f_b = calculated ideal bending stresses, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_{LT} = calculated total in-plane shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

S_m = strength reduction factor, as defined in 5A-3-3/7.3.1

f_{Lb}, f_b and f_{LT} are to be calculated for the panel in question under the combined load cases specified in 5A-3-2/9.3 and these stresses may be calculated from the relative displacements of four corner nodes. This method is useful when the meshing within the panel is irregular. However, care should be taken when one corner of the panel is located in an area of high stress concentration or the panel shape is significantly different from a rectangular shape. The calculated stresses from the above mentioned method tend to be on the conservative side. If one corner of the panel is highly stressed and if the mesh is sufficiently refined, the plate panel stresses may be calculated from the displacements slightly away from the corner point of the high stress concentration area. For a regularly meshed plate panel, f_L, f_b and f_{LT} may also be calculated directly from the components stresses for the elements in the panel.

f_{cL}, f_{cb} and f_{cLT} are critical buckling stresses with respect to uniform compression, ideal bending and shear, respectively, and may be determined in accordance with 5A-3-4/7.

In the determination of f_{cL} and f_{cLT}, the effects of openings are to be considered.

For deck transverse web plating of existing vessels converted to FPIs, when the buckling limit state specified above is not satisfied and the Survey Record Review does not indicate any buckling problems for the deck transverse plating panels, it may be acceptable to apply the criteria specified in 5A-3-4/5.3.2 and 5A-3-4/5.3.3..

5.9.1(b) For face plate and flange. The breadth to thickness ratio of face plate and flange is to satisfy the limits given in 5A-3-4/7.9.

5.9.1(c) For large brackets and sloping webs. The buckling strength is to satisfy the limits specified in 5A-3-4/5.9.1(a) above for web plate.

5.11 Corrugated Bulkheads *(1997)*

5.11.1 Local Plate Panels *(December 2008)*

5.11.1(a) Buckling criteria. The buckling strength of the flange and web plate panels is not to be less than that specified below.

$$(f_{Lb}/R_\ell f_{cL})^2 + (f_{Tb}/R_t f_{cT})^2 + (f_{LT}/f_{cLT})^2 \le S_m \qquad \text{for flange panels}$$

$$(f_{Lb}/R_\ell f_{cL})^2 + (f_b/f_{cb})^2 + (f_{LT}/f_{cLT})^2 \le S_m \qquad \text{for web panels}$$

where

R_t = reduction factor accounting for lateral load effects, and may be approximated by:

= $1.0 - 0.45(q - 0.5)$

q = lateral load parameter

= $p_n(s/t_n)^4/\pi^2E$, 0.5 minimum

p_n = lateral pressure for the combined load case considered (see 5A-3-2/9), in N/cm² (kgf/cm², lbf/in²)

s = longitudinal spacing, in mm (in.)

t_n = net thickness of the plate, in mm (in.)

E = Young's modulus, in N/cm² (kgf/cm², lbf/in²), for steel 2.06×10^7 (2.10×10^6, 30×10^6)

All of the parameter definitions and calculations are as specified in 5A-3-4/5.3.1 and 5A-3-4/5.9.1(a), except that f_{Lb} is the average compressive stress at the upper and lower ends of the corrugation, and an average value of f_{Tb}, f_{LT} and f_b, calculated along the entire length of the panel, should be used in the above equation.

5.11.1(b) Ultimate strength. The ultimate strength of flange panels in the middle one-third of the depth are to satisfy the following criteria, considering a portion of flange panel having a length of three times the panel width, *a*, with the worst bending moments in the mid-depth region for all load cases.

$$(f_{Lb}/f_{uL})^2 + (f_{Tb}/f_{uT})^2 \le S_m$$

where

f_{Lb} = the calculated average compressive bending stress in the region within 3a in length, N/cm^2 (kgf/cm^2, lbf/in^2)

f_{Tb} = horizontal compressive stresses, as specified in 5A-3-4/5.11.1(a) above

f_{uL} and f_{uT} may be calculated in accordance with 5A-3-4/5.3.3 above.

5.11.2 Unit Corrugation

Any unit corrugation of the bulkhead may be treated as a beam column and is to satisfy the buckling criteria (same as the ultimate strength) specified in 5A-3-4/5.5.1. The ultimate bending stress is to be determined in accordance with 5A-3-4/7.5.3.

5.11.3 Overall Buckling

The buckling strength of the entire corrugation is to satisfy the equation given in 5A-3-4/5.7.1 with respect to the biaxial compression by replacing the subscripts "*L*" and "*T*" with "*V*" and "*H*" for the vertical and horizontal directions, respectively.

7 Calculation of Critical Buckling Stresses *(December 2008)*

7.1 General

The critical buckling stresses for various structural elements and members may be determined in accordance with this Subsection or other recognized design practices. Critical buckling stresses derived from experimental data or analytical studies may be considered, provided that well-documented supporting data are submitted for review.

7.3 Rectangular Plates

The critical buckling stresses for rectangular plate elements, such as plate panels between stiffeners; web plates of longitudinals, girders, floors and transverses; flanges and face plates, may be obtained from the following equations, with respect to uniaxial compression, bending and edge shear, respectively.

$$f_{ci} = f_{Ei} \qquad \text{for } f_{Ei} \le P_r f_{yi}$$

$$f_{ci} = f_{yi}[1 - P_r(1 - P_r)f_{yi}/f_{Ei}] \qquad \text{for } f_{Ei} > P_r f_{yi}$$

where

f_{ci} = critical buckling stress with respect to uniaxial compression, bending or edge shear, separately, N/cm^2 (kgf/cm^2, lbf/in^2)

f_{Ei} = $K_i\,[\pi^2 E/12(1 - \nu^2)](t_n/s)^2$, N/cm^2 (kgf/cm^2, lbf/in^2)

K_i = buckling coefficient, as given in 5A-3-4/Table 1

E = modulus of elasticity of the material, may be taken as 2.06×10^7 N/cm^2 (2.1×10^6 kgf/cm^2, 30×10^6 lbf/in^2) for steel

ν = Poisson's ratio, may be taken as 0.3 for steel

t_n = net thickness of the plate, in cm (in.)

s = spacing of longitudinals/stiffeners, in cm (in.)

P_r = proportional linear elastic limit of the structure, may be taken as 0.6 for steel

f_{yi} = f_y, for uniaxial compression and bending

= $f_y/\sqrt{3}$, for edge shear

f_y = specified minimum yield point of the material, in N/cm^2 (kgf/cm^2, lbf/in^2)

TABLE 1
Buckling Coefficient, K_i *(December 2008)*

For Critical Buckling Stress Corresponding to f_L, f_T, f_b or f_{LT}

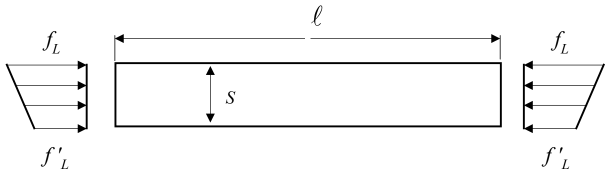
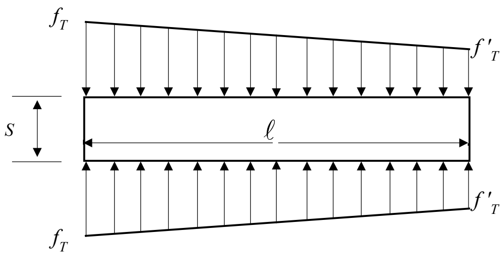
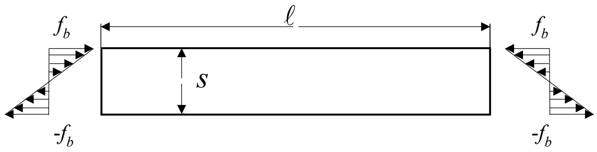
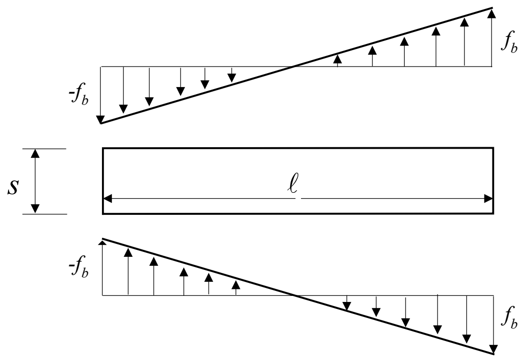
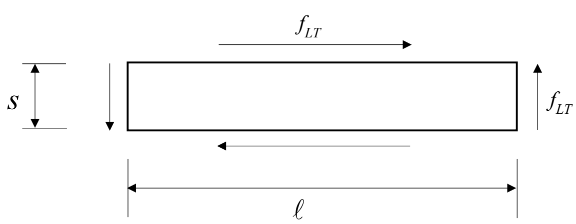
I. Plate panel between stiffeners			K_i
A Uniaxial compression 1. Long plate $\ell \geq s$	 	a. For f'_L, $= f_L$: b. For f'_L, $= f_L/3$: (see note)	$4C_1$, $5.8C_1$,
2. Wide plate $\ell \geq s$	 	a. For f'_T, $= f_T$: b. For f'_T, $= f_T/3$: (see note)	$[1 + (s/\ell)^2]^2 C_2$ $1.45[1 + (s/\ell)^2]^2 C_2$
B Ideal Bending 1. Long plate $\ell \geq s$	 		$24C_1$
2. Wide plate $\ell \geq s$	 	a. For $1.0 \leq \ell/s \leq 2.0$: b. For $2.0 < \ell/s$:	$24\ (s/\ell)^2 C_2$ $12\ (s/\ell) C_2$
C Edge Shear	 		K_i $[5.34 + 4\ (s/\ell)^2] C_1$

TABLE 1 (continued)
Buckling Coefficient, K_i *(December 2008)*

D Values of C_1 and C_2

1. For plate panels between angles or tee stiffeners

C_1 = 1.1

C_2 = 1.3 within the double bottom or double side*

C_2 = 1.2 elsewhere

2. For plate panels between flat bars or bulb plates

C_1 = 1.0

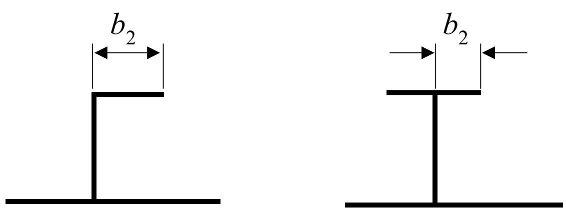
C_2 = 1.2 within the double bottom or double side*

C_2 = 1.1 elsewhere

* applicable where shorter edges of a panel are supported by rigid structural members, such as bottom, inner bottom, side shell, inner skin bulkhead, double bottom floor/girder and double side web stringer.

II. Web of Longitudinal or Stiffener	K_i
A Axial compression	
Same as I.A.1 by replacing s with depth of the web and ℓ with unsupported span	
a. For $f'_L = f_L$:	$4C$
b. For $f'_L = f_L/2$: (see note)	$5.2C$
where	
C = 1.0 for angle or tee stiffeners	
C = 0.33 for bulb plates	
C = 0.11 for flat bars	
B Ideal Bending	
Same as I.B.1 by replacing s with depth of the web and ℓ with unsupported span	$24C$

III. Flange and Face Plate	K_i
Axial Compression	0.44



$s = b_2$

ℓ = unsupported span

Note:

In I.A. (II.A), K_i for intermediate values of f'_L/f_L (f'_T/f_T) may be obtained by interpolation between a and b.

7.5 Longitudinals and Stiffeners

7.5.1 Axial Compression

The critical buckling stress, f_{ca}, of a beam-column, i.e., the longitudinal and the associated effective plating, with respect to axial compression may be obtained from the following equations:

$$f_{ca} = f_E \qquad \text{for } f_E \le P_r f_y$$

$$f_{ca} = f_y[1 - P_r(1 - P_r)f_y/f_E] \qquad \text{for } f_E > P_r f_y$$

where

f_E = $\pi^2 E/(\ell/r)^2$, N/cm² (kgf/cm², lbf/in²)

ℓ = unsupported span of the longitudinal or stiffener, in cm (in.), as defined in 5A-3-3/Figure 5

r = radius of gyration of area A_e, in cm (in.)

A_e = $A_s + b_{wL}\, t_n$

A_s = net sectional area of the longitudinals or stiffeners, excluding the associated plating, cm² (in²)

b_{wL} = effective width of the plating as given in 5A-3-4/5.3.2, in cm (in.)

t_n = net thickness of the plating, in cm (in.)

f_y = minimum specified yield point of the longitudinal or stiffener under consideration, N/cm² (kgf/cm², lbf/in²)

P_r and E are as defined in 5A-3-4/7.3.

7.5.2 Torsional/Flexural Buckling

The critical torsional/flexural buckling stress with respect to axial compression of a longitudinal, including its associated plating (effective width, b_{wL}), may be obtained from the following equations:

$$f_{ct} = f_{ET} \qquad \text{for } f_{ET} \le P_r f_y$$

$$f_{ct} = f_y[1 - P_r(1 - P_r)f_y/f_{ET}] \qquad \text{for } f_{ET} > P_r f_y$$

where

f_{ct} = critical torsional/flexural buckling stress with respect to axial compression, N/cm² (kgf/cm², lbf/in²)

f_{ET} = $E[K/2.6 + (n\pi/\ell)^2\Gamma + C_o(\ell/n\pi)^2/E]/I_o[1 + C_o(\ell/n\pi)^2/I_o f_{cL}]$, N/cm² (kgf/cm², lbf/in²)

K = St. Venant torsion constant for the longitudinal's cross section, excluding the associated plating.

= $[b_f\, t_f^3 + d_w\, t_w^3]/3$

I_o = polar moment of inertia of the longitudinal, excluding the associated plating, about the toe (intersection of web and plating), in cm⁴ (in⁴)

= $I_x + mI_y + A_s(x_o^2 + y_o^2)$

I_x, I_y = moment of inertia of the longitudinal about the x-and y-axis, respectively, through the centroid of the longitudinal, excluding the plating (x-axis perpendicular to the web), in cm⁴ (in⁴)

m = $1.0 - u(0.7 - 0.1d_w/b_f)$

u = unsymmetry factor

= $1 - 2b_1/b_f$

x_o = horizontal distance between centroid of stiffener, A_s, and centerline of the web plate, cm (in.)

y_o = vertical distance between the centroid of the longitudinal's cross section and its toe, cm (in.)

d_w = depth of the web, cm (in.)

t_w = net thickness of the web, cm (in.)

b_f = total width of the flange/face plate, cm (in.)

b_1 = smaller outstanding dimension of flange with respect to centerline of web (see 5A-3-4/Figure 1), cm (in.)

t_f = net thickness of the flange/face plate, cm (in.)

C_o = $Et_n^3/3s$

Γ = warping constant

$\cong$ $mI_{yf}\, d_w^2 + d_w^3\, t_w^3/36$

I_{yf} = $t_f\, b_f^3\,(1.0 + 3.0\, u^2 d_w t_w/A_s)/12$, cm^4 (in^4)

f_{cL} = critical buckling stress for the associated plating, corresponding to n-half waves, N/cm^2 (kgf/cm^2, lbf/in^2)

= $\pi^2 E(n/\alpha + \alpha/n)^2(t_n/s)^2/12(1 - \nu^2)$

α = ℓ/s

n = number of half-wave which yield a smallest f_{ET}

f_y = minimum specified yield point of the longitudinal or stiffener under consideration, N/cm^2 (kgf/cm^2, lbf/in^2)

P_r, E, s and ν are as defined in 5A-3-4/7.3.

A_s, t_n and ℓ are as defined in 5A-3-4/7.5.1.

7.5.3 Buckling Criteria for Unit Corrugation of Transverse Bulkhead

The critical buckling stress, which is also the ultimate bending stress, f_{cb}, for a unit corrugation, may be determined from the following equation (See 5A-3-4/5.11.2).

$f_{cb} = f_{Ec}$ for $f_{Ec} \le P_r f_y$

$f_{cb} = [1 - P_r(1 - P_r)f_y/f_{Ec}]f_y$ for $f_{Ec} > P_r f_y$

where

f_{Ec} = $k_c E(t/a)^2$

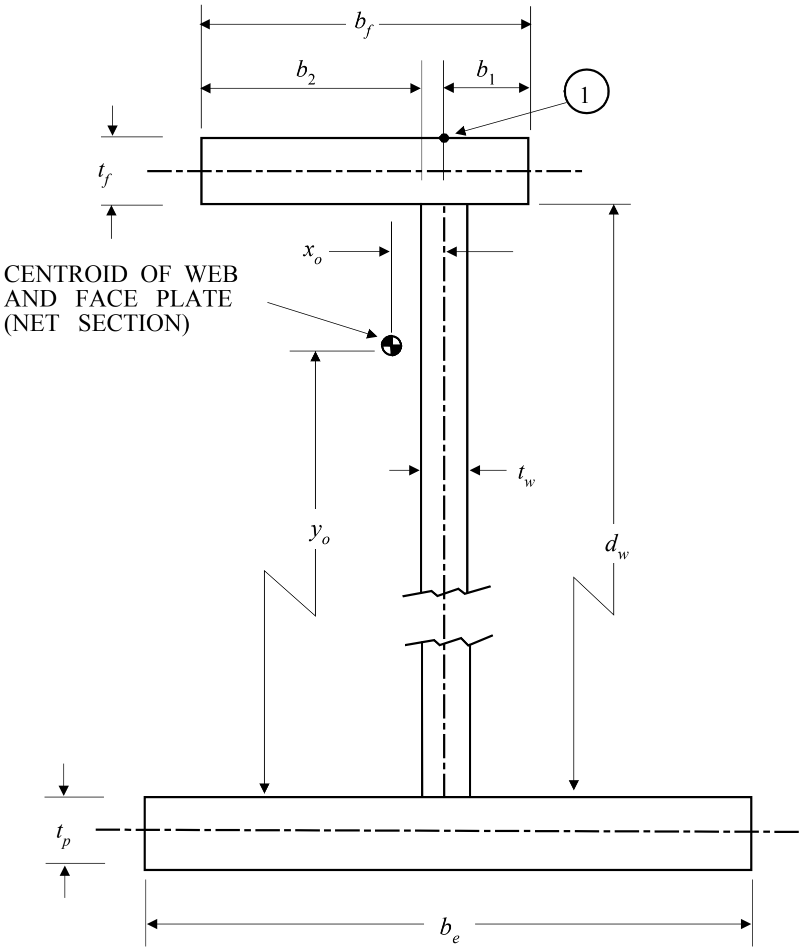
k_c = $0.09[7.65 - 0.26\,(c/a)^2]^2$

c and a are widths of the web and flange panels, respectively, in cm^2 (in^2)

t = net thickness of the flange panel, in cm (in.)

P_r, f_y and E are as defined in 5A-3-4/7.3.

FIGURE 1
Net Dimensions and Properties of Stiffeners *(December 2008)*



7.7 Stiffened Panels

7.7.1 Large Stiffened Panels

For large stiffened panels between bulkheads or panels stiffened in one direction between transverses and girders, the critical buckling stresses with respect to uniaxial compression may be determined from the following equations:

$$f_{ci} = f_{Ei} \qquad \text{for } f_{Ei} \leq P_r f_y$$

$$f_{ci} = f_y[1 - P_r(1 - P_r) f_y / f_{Ei}] \qquad \text{for } f_{Ei} > P_r f_y$$

where

f_{Ei} = $k_L \pi^2 (D_L D_T)^{1/2} / t_L b^2$ in the longitudinal direction, N/cm² (kgf/cm², lbf/in²)

f_{Ei} = $k_T \pi^2 (D_L D_T)^{1/2} / t_T \ell^2$ in the transverse direction, N/cm² (kgf/cm², lbf/in²)

k_L = 4 for $\ell/b \geq 1$

= $[1/\phi_L^2 + 2\eta + \phi_L^2]$ for $\ell/b < 1$

k_T	=	4	for $b/\ell \geq 1$
	=	$[1/\phi_T^2 + 2\eta + \phi_T^2]$	for $b/\ell < 1$
D_L	=	$EI_L/s_L(1 - \nu^2)$	
D_T	=	$EI_T/s_T(1 - \nu^2)$	
D_T	=	$Et_n^3/12(1 - \nu^2)$	if no stiffener in the transverse direction
ℓ, b	=	length and width between transverse and longitudinal bulkheads, respectively, in cm (in.) (See 5A-3-4/Figure 2)	
t_L, t_T	=	net equivalent thickness of the plating and stiffener in the longitudinal and transverse direction, respectively, cm (in.)	
	=	$(s_Lt_n + A_{sL})/s_L$ or $(s_Tt_n + A_{sT})/s_T$	
s_L, s_T	=	spacing of longitudinals and transverses, respectively, cm (in.) (See 5A-3-4/Figure 2)	
ϕ_L	=	$(\ell/b)\ (D_T/D_L)^{1/4}$	
ϕ_T	=	$(b/\ell)\ (D_L/D_T)^{1/4}$	
η	=	$[(I_{pL}I_{pT})/(I_LI_T)]^{1/2}$	
A_{sL}, A_{sT}	=	net sectional area of the longitudinal and transverse, excluding the associated plating, respectively, cm^2 (in^2)	
I_{pL}, I_{pT}	=	net moment of inertia of the effective plating alone (effective breadth due to shear lag) about the neutral axis of the combined cross section, including stiffener and plating, cm^4 (in^4)	
I_L, I_T	=	net moment of inertia of the stiffener (one) with effective plating in the longitudinal or transverse direction, respectively, cm^4 (in^4). If no stiffener, the moment of inertia is calculated for the plating only.	

f_y, P_r, E and ν are as defined in 5A-3-4/7.3. t_n is as defined in 5A-3-4/7.5.1.

With the exception of deck panels, when the lateral load parameter, q_o, defined below, is greater than 5, reduction of the critical buckling stresses given below is to be considered.

$$q_o = p_nb^4/(\pi^4t_TD_T)$$

$$q_o = p_n\ell^4/(\pi^4t_LD_L)$$

where

p_n = average net lateral pressure, N/cm^2 (kgf/cm^2, lbf/in^2)

D_T, D_L, b, ℓ, t_T, t_L and s_T are as defined above.

In this regard, the critical buckling stress may be approximated by:

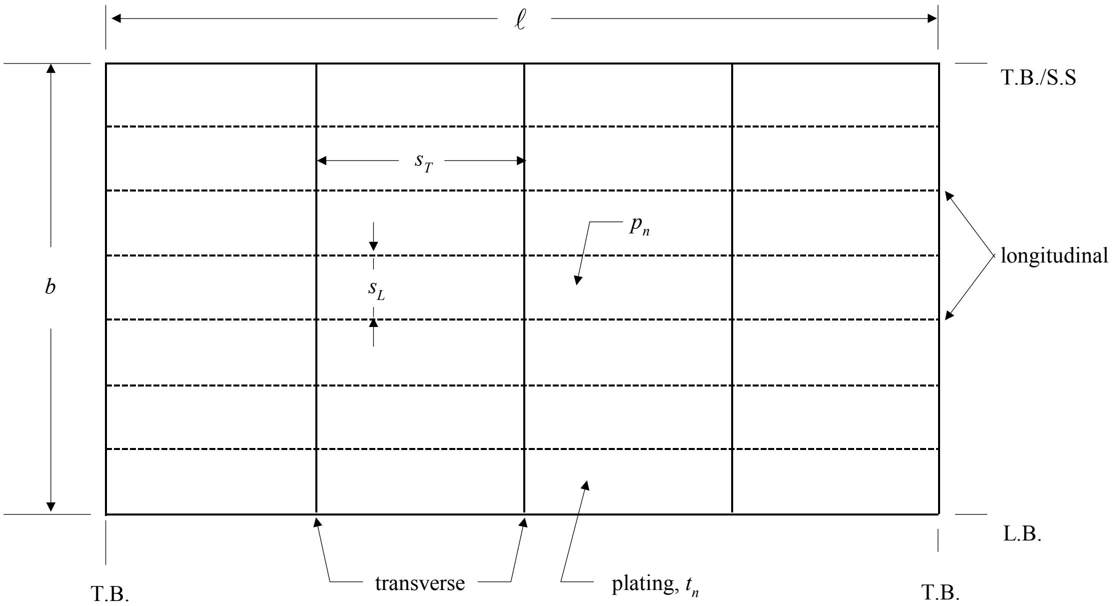
$$f'_{ci} = R_of_{ci} \qquad N/cm^2\ (kgf/cm^2,\ lbf/in^2)$$

where

R_o = $1 - 0.045(q_o - 5)$ for $q_o \geq 5$

For deck panels, $R_o = 1.0$ and $f'_{ci} = f_{ci}$.

FIGURE 2 *(December 2008)*



7.7.2 Corrugated Transverse Bulkheads

For corrugated transverse bulkheads, the critical buckling stresses with respect to uniaxial compression may be calculated from the equations given in 5A-3-4/7.7.1 above by replacing the subscripts "*L*" and "*T*" with "*V*" and "*H*" for the vertical and horizontal directions, respectively, and with the following modifications. The rigidities D_V are D_H are defined as follows.

$$D_V = EI_v / s$$

$$D_H = [s/(a + c)][Et^3/12(1 - \nu^2)]$$

$K_V = 4$ for $\ell/b \geq 0.5176(D_V/D_H)^{1/4}$

$= \dfrac{1}{\phi_V^2} + \phi_V^2$ for $\ell/b < 0.5176(D_V/D_H)^{1/4}$

$K_H = 4$ for $b/\ell \geq 0.5176(D_H/D_V)^{1/4}$

$= \dfrac{1}{\phi_H^2} + \phi_H^2$ for $b/\ell < 0.5176(D_H/D_V)^{1/4}$

where

I_v = moment of inertia of a unit corrugation with spacing s, $s = a + c\cos\phi$

= $t/4[c\sin\phi]^2(a + c/4 + c\sin\phi/12)$, in cm^4 (in^4)

a, c = widths of the flange and web panels, respectively, in cm (in.)

t = net thickness of the corrugations, in cm (in.)

E and ν are as defined in 5A-3-4/7.3.

ℓ = length of the corrugation, in cm (in.)

s_v, s_H = s

η, I_{pH}, A_{sH} = 0

A_{sV} = $tc \sin\phi$

ϕ is as defined in 5A-3-3/Figure 10 or 5A-3-3/Figure 11.

7.9 Stiffness and Proportions *(1 July 2009)*

To fully develop the intended buckling strength of the assemblies of structural members and panels, supporting elements of plate panels and longitudinals are to satisfy the following requirements for stiffness and proportion in highly stressed regions.

7.9.1 Stiffness of Longitudinals

The net moment of inertia of the longitudinals, i_o, with effective breadth of net plating, is to be not less than that given by the following equation:

$$i_o = \frac{st_n^3}{12(1-\nu^2)}\gamma_o \qquad \text{cm}^4 \text{ (in}^4\text{)}$$

where

γ_o	=	$(2.6 + 4.0\delta)\alpha^2 + 12.4\alpha - 13.2\alpha^{1/2}$
δ	=	A/st_n
α	=	ℓ/s
s	=	spacing of longitudinals, cm (in.)
t_n	=	net thickness of plating supported by the longitudinal, cm (in.)
ν	=	Poisson's ratio
	=	0.3 for steel
A	=	net sectional area of the longitudinal (excluding plating), cm^2 (in^2)
ℓ	=	unsupported span of the longitudinal, cm (in.)

7.9.2 Stiffness of Web Stiffeners

The net moment of inertia, i, of the web stiffener, with the effective breadth of net plating not exceeding s or 0.33ℓ, whichever is less, is not to be less than obtained from the following equations:

$i = 0.17\ell t^3(\ell/s)^3$ cm^4 (in^4) for $\ell/s \leq 2.0$

$i = 0.34\ell t^3(\ell/s)^2$ cm^4 (in^4) for $\ell/s > 2.0$

where

ℓ	=	length of stiffener between effective supports, in cm (in.)
t	=	required net thickness of web plating, in cm (in.)
s	=	spacing of stiffeners, in cm (in.)

7.9.3 Stiffness of Supporting Members

The net moment of inertia of the supporting members, such as transverses and webs, is not to be less than that obtained from the following equation:

$$I_s/i_o \geq 0.2(B_s/\ell)^3(B_s/s)$$

where

I_s	=	moment of inertia of the supporting member, including the effective plating, cm^4 (in^4)
i_o	=	moment of inertia of the longitudinals, including the effective plating, cm^4 (in^4)
B_s	=	unsupported span of the supporting member, cm (in.)

ℓ and s are as defined in 5A-3-4/7.9.1.

7.9.4 Proportions of Flanges and Face Plates

The breadth-thickness ratio of flanges and face plates of longitudinals and girders is to satisfy the limits given below:

$$b_2/t_f = 0.4(E/f_y)^{1/2}$$

where

b_2 = larger outstanding dimension of flange, as given in 5A-3-4/Figure 1, cm (in.)

t_f = net thickness of flange/face plate, cm (in.)

E and f_y are as defined in 5A-3-4/7.3.

7.9.5 Proportions of Webs of Longitudinals and Stiffeners

The depth-thickness ratio of webs of longitudinals and stiffeners is to satisfy the limits given below.

$d_w/t_w \le 1.5(E/f_y)^{1/2}$ for angles and tee bars

$d_w/t_w \le 0.85(E/f_y)^{1/2}$ for bulb plates

$d_w/t_w \le 0.5(E/f_y)^{1/2}$ for flat bars

where d_w and t_w, are as defined in 5A-3-4/7.5.2 and E and f_y are as defined in 5A-3-4/7.3.

When these limits are complied with, the assumption on buckling control stated in 5A-3-4/5.1.2(e) is considered satisfied. If not, the buckling strength of the web is to be further investigated, as per 5A-3-4/7.3.

9 Fatigue Life *(1995)*

9.1 General

An analysis is to be made of the fatigue strength of welded joints and details in highly stressed areas, especially where higher strength steel is used. Special attention is to be given to structural notches, cutouts and bracket toes, and also to abrupt changes of structural sections. A simplified assessment of the fatigue strength of structural details may be accepted when carried out in accordance with Appendix 5A-3-A2.

The following subparagraphs are intended to emphasize the main points and to outline procedures where refined spectral analysis techniques are used to establish fatigue strength.

9.1.1 Workmanship

As most fatigue data available were experimentally developed under controlled laboratory conditions, consideration is to be given to the workmanship expected during construction.

9.1.2 Fatigue Data

In the selection of S-N curves and the associated stress concentration factors, attention is to be paid to the background of all design data and its validity for the details being considered. In this regard, recognized design data, such as those by AWS (American Welding Society), API (American Petroleum Institute), and DEN (Department of Energy), should be considered. Sample fatigue data and their applications are shown in Appendix 5A-3-A2 "Fatigue Strength Assessment of Ship-Type Installations".

If other fatigue data are to be used, the background and supporting data are to be submitted for review.

In this regard, clarification is required whether or not the stress concentration due to the weld profile, certain structural configurations and also the heat effects are accounted for in the proposed S-N curve. Consideration is also to be given to the additional stress concentrations.

9.1.3 Total Stress Range

For determining total stress ranges, the fluctuating stress components resulting from the load combinations specified in 5A-3-A2/7.5 (for ship-type installations) or 5A-3-A2/21.3 (for trading vessels) are to be considered.

9.1.4 Design Consideration

In design, consideration is to be given to the minimization of structural notches and stress concentrations. Areas subject to highly concentrated forces are to be properly configured and stiffened to dissipate the concentrated loads. See also 5A-3-3/1.5.

9.3 Procedures

The analysis of fatigue strength for a welded structural joint/detail may be performed in accordance with the following procedures.

The class designations and associated loading patterns are given in 5A-3-A2/Table 1.

9.3.1 Step 1 – Classification of Various Critical Locations

Where deemed appropriate, the total applied stress range of the structural details classified in Step 1 may be checked against the permissible stress ranges as shown in Appendix 5A-3-A2.

9.3.2 Step 2 – Permissible Stress Range Approach

9.3.3 Step 3 – Refined Analysis

Refined analyses are to be performed, as outlined in 5A-3-4/9.3.3(a) or 5A-3-4/9.3.3(b) below, for the structural details for which the total applied stress ranges obtained from Step 2 are greater than the permissible stress ranges, or for which the fatigue characteristics are not covered by the classified details and the associated S-N curves.

The fatigue life of structures is generally not to be less than 20 years, unless otherwise specified.

9.3.3(a) Spectral analysis. Alternatively, a spectral analysis may be performed, as outlined in 5A-3-4/9.5 below, to directly calculate fatigue lives for the structural details in question.

9.3.3(b) Refined fatigue data. For structural details which are not covered by the detail classifications, proposed S-N curves and the associated SCFs, when applicable, may be submitted for consideration. In this regard, sufficient supporting data and background are also to be submitted for review. The refined SCFs may be determined by finite element analyses.

9.5 Spectral Analysis

Where the option in 5A-3-4/9.3.3(a) is exercised, a spectral analysis is to be performed in accordance with the following guidelines.

9.5.1 Representative Loading Patterns

Several representative loading patterns are to be considered to cover the worst scenarios anticipated for the design service life of the installation with respect to hull girder local loads.

9.5.2 Environmental Representation *(1 September 2007)*

Instead of the design wave loads specified in Section 5A-3-2, a wave scatter diagram (such as Walden's Data for North Atlantic Environment) is to be employed to simulate a representative distribution of all of the wave conditions expected for the design service life of the installation. In general, the wave data is to cover a time period of not less than 20 years. The probability of occurrence for each combination of significant wave height and mean period of the representative wave scatter diagram is to be weighted, based on the transit time of the installation at each wave environment within anticipated shipping routes or specific sites. Detailed environmental data requirements are given in 5A-1-3/3.11.3.

9.5.3 Calculation of Wave Load RAOs

The wave load RAOs with respect to the wave-induced bending moments, shear forces, motions, accelerations and hydrodynamic pressures can then be predicted by ship motion calculation for a selected representative loading condition.

9.5.4 Generation of Stress Spectrum

The stress spectrum for each critical structural detail (spot) may be generated by performing a structural analysis, accounting for all the wave loads separately for each individual wave group. For this purpose, the 3D structural model and 2D models specified in 5A-3-4/11 may be used for determining structural responses. The additional secondary and tertiary stresses are also to be considered.

9.5.5 Cumulative Fatigue Damage and Fatigue Life

Based on the stress spectrum and wave scatter diagram established above, the cumulative fatigue damage and the corresponding fatigue life can be estimated by the Palmgren-Miner linear damage rule.

11 Calculation of Structural Responses *(1995)*

11.1 Methods of Approach and Analysis Procedures *(1 July 2012)*

Maximum stresses in the structure are to be determined by performing structural analyses, as outlined below. Guidelines on structural idealization, load application and structural analysis are given in Appendix 5A-3-A4.

The strength assessment of the hull structure for new build FPIs is based on a three cargo tank lengths finite element model about midships where the strength assessment is focused on the results obtained from structures in the middle tank. For an FPI conversion, as an alternative, a complete hull length or full cargo block length finite element model including all cargo and ballast tanks in the hull structure can be used in lieu of the three cargo tank length model.

In the three tank length model the strength assessment is to be focused on the results obtained from the mid tank structure. However, the deck transverse, the side transverse, the vertical web on longitudinal bulkheads, the horizontal girder and the vertical web on transverse bulkheads and the cross ties are also to be assessed using the end tanks of the three tank length model analysis.

11.3 3D Finite Element Models *(1 July 2012)*

A simplified three-dimensional (3D) finite element model is required to determine the load distribution in the structure.

The three-hold length finite element model represents three bays of tanks within 0.4*L* amidships of the hull structure. The same 3D model may be used for hull structures beyond 0.4*L* amidships with modifications to the structural properties and the applied loads, provided that the structural configurations are such that they are considered as representative of the location under consideration.

The full length or cargo block length finite element model may be used for the alternative method of analysis for FPI conversions.

11.5 Local Structural Models *(December 2008)*

Local 3D fine mesh model are required to:

- Determine the stress distribution in major supporting structures, particularly at intersections of two or more structural members and/or
- Examine stress concentrations such as at bracket toes of main supporting members, at openings in way of critical locations, at intersections of longitudinals with transverses and at cut outs.

11.7 Load Cases *(December 2008)*

When performing structural analysis, the combined load cases specified in 5A-3-2/9.1 are to be considered. In general, the structural responses for the still-water conditions are to be calculated separately to establish reference points for assessing the wave-induced responses. Additional load cases may be required for special loading patterns and unusual design functions, such as sloshing loads, as specified in 5A-3-2/11. For the three hold length analysis, additional load cases may also be required for hull structures beyond the region of 0.4*L* amidships.

13 Critical Areas *(December 2008)*

13.1 General

The strength and fatigue capacity of the following critical areas is to be verified:

- Typical connections of transverse web frames in 5A-3-4/Figure 3
- Typical connections of horizontal girders on transverse bulkhead in 5A-3-4/Figure 4
- Typical connections buttress structure in 5A-3-4/Figure 5

13.3 Strength Evaluation

The allowable stress applicable to critical areas in 5A-3-4/13.1 is defined as a percentage of the minimum specified yield stress, f_y, times the strength reduction factor, S_m. Application of this allowable stress to rod and beam elements is based on the axial stress while von-Mises membrane stresses are employed for quadrilateral elements.

The allowable stress for fine mesh analysis is defined in 5A-3-4/Table 2 and depends on the mesh size. To calculate the local stress distribution in a main supporting member, it is often necessary to model details and discontinuities using various fine mesh sizes. In areas of high stress gradient, the allowable stresses are to be adjusted according to mesh sizes and are listed in 5A-3-4/Table 2.

The high stress FE results should be viewed in terms of the extent of the high stresses with respect to the mesh size and the structural arrangement in the high stress region.

TABLE 2
Allowable Stresses (kgf/cm^2) for Various Finite Element Fine Mesh Sizes *(1 July 2009)*

Mesh Size	*Stress Limit*	*Mild Steel* ($S_m = 1.000$)	*HT27* ($S_m = 0.980$)	*HT32* ($S_m = 0.950$)	*HT36* ($S_m = 0.908$)
$1 \times LS$ (1)	$1.00 \times S_m f_y$	2400	2646	3040	3269
$^1/_2 \times LS$ (1)	$1.06 \times S_m f_y$	2544	2805	3222	3465
$^1/_3 \times LS$ (1)	$1.12 \times S_m f_y$	2688	2963	3404	3661
$^1/_4 \times LS$ (1)	$1.18 \times S_m f_y$	2832	3122	3587	3857
$^1/_5 \times LS \sim {}^1/_{10} \times LS$ (1)	$1.25 \times S_m f_y$	3000	3308	3800	4086
Thickness (1, 2)	f_u or $1.50 \times S_m f_y$	4100	f_u or $1.50 \times S_m f_y$	4500	4903

Notes

1 Stress limits greater than $1.00 \times S_m f_y$ are to be restricted to small areas in way of structural discontinuities.

2 When the fatigue strength of the detail is found satisfactory, the hot spot stress in the detail may be allowed up to the minimum tensile strength of the material.

3 For intermediate mesh size, the stress limit may be obtained by linear interpolation.

4 *(1 July 2009) LS* = stiffener spacing

13.5 Fatigue Evaluation

The procedure for fatigue analysis of the critical details indicated in 5A-3-4/13.1 will follow Section 5A-3-A2 considering prior fatigue damage as a trading vessel, low cycle and high cycle fatigue damages as an FPI.

FIGURE 3
Critical Areas in Transverse Web Frame *(1 July 2009)*

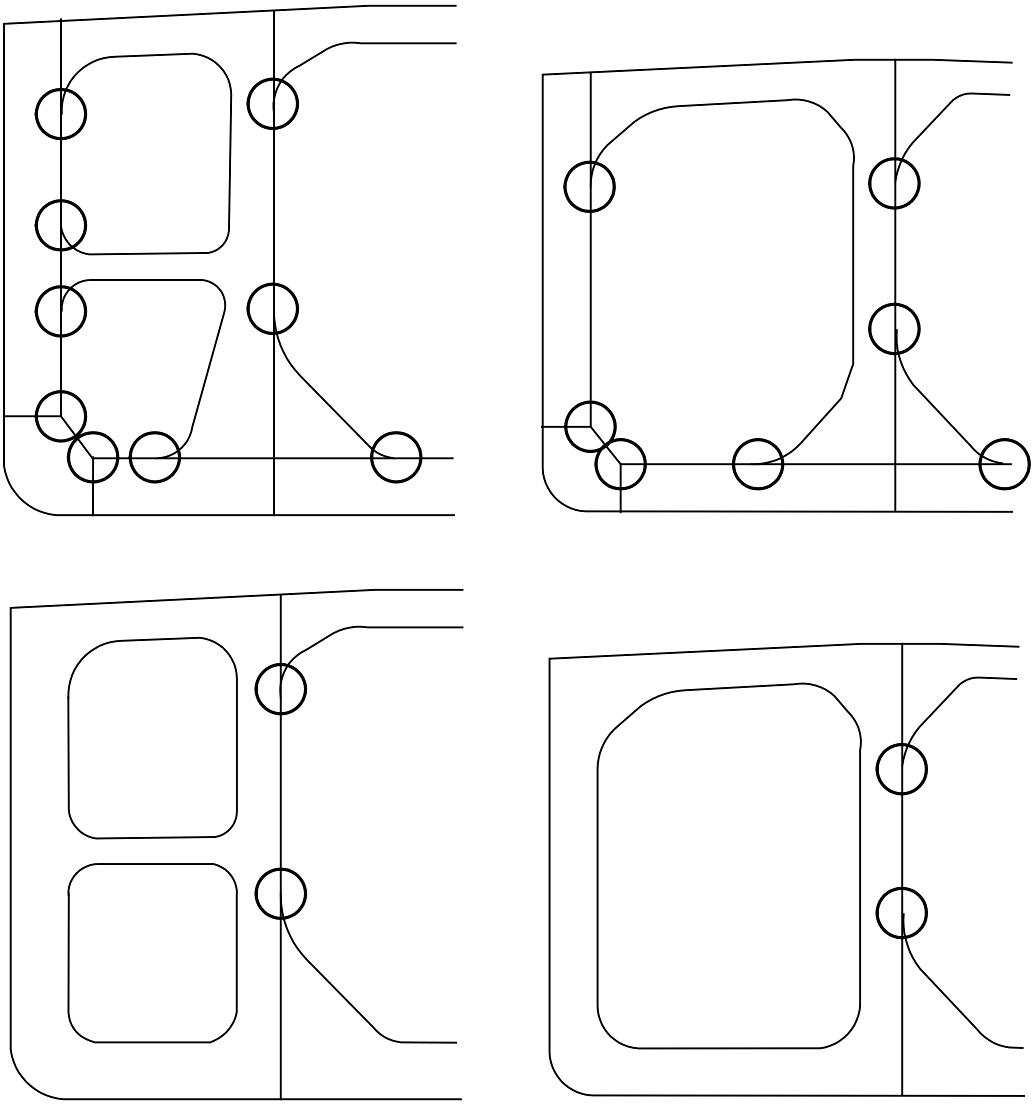


FIGURE 4
Critical Areas in Horizontal Girder on Transverse Bulkhead
(1 July 2009)

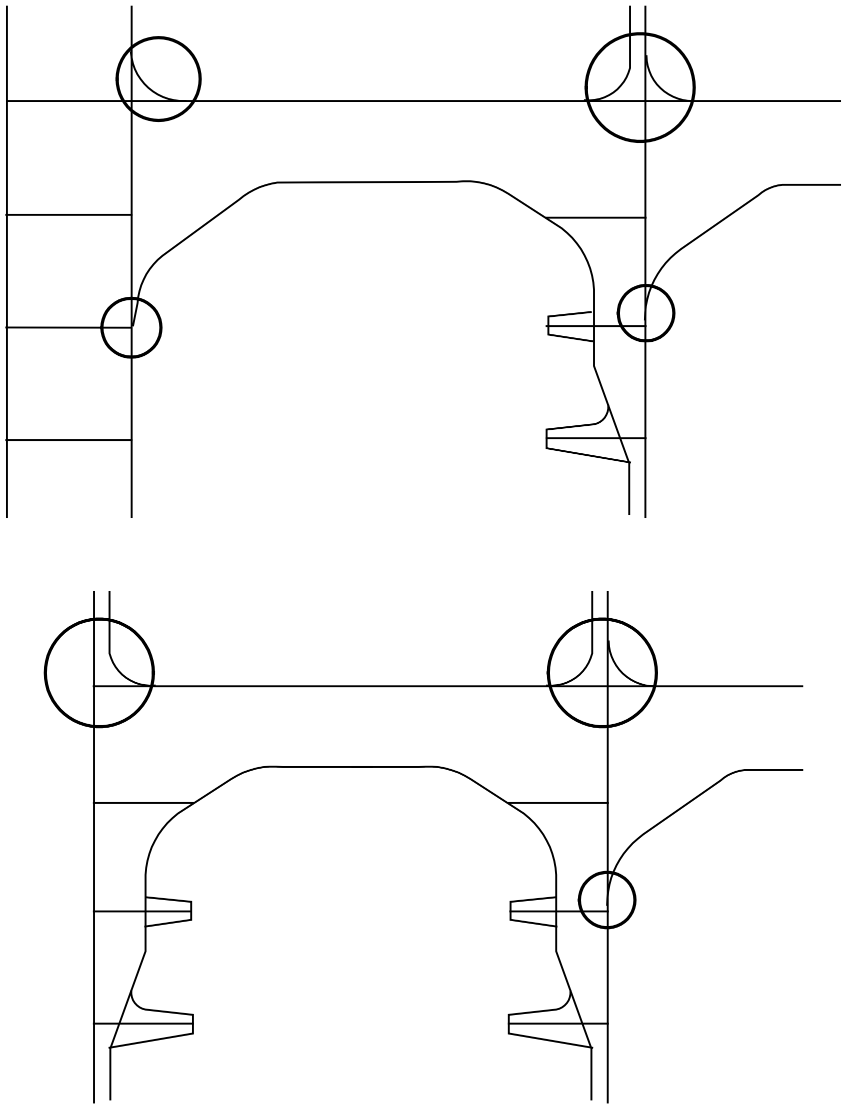
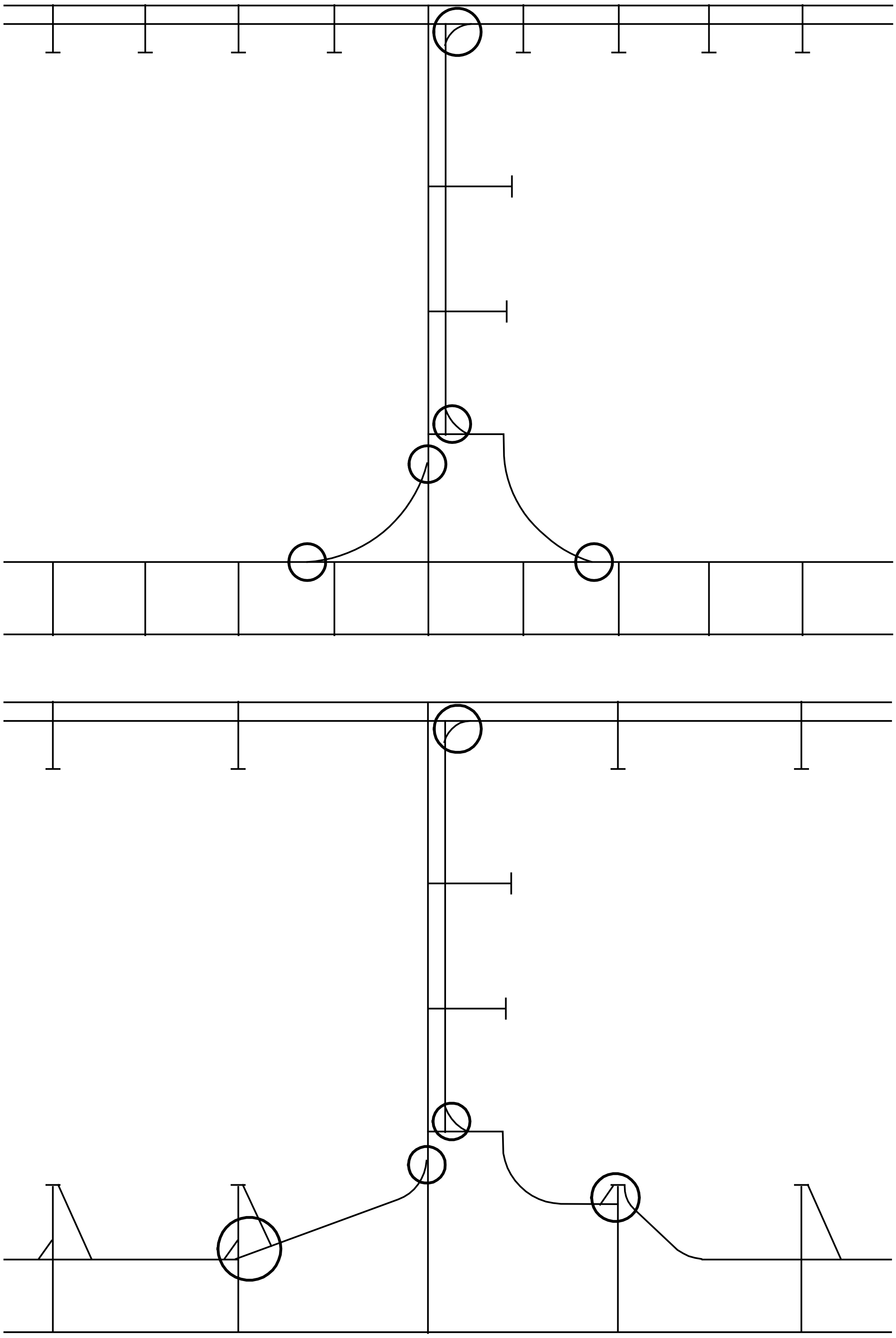


FIGURE 5
Critical Areas of Buttress Structure *(1 July 2009)*



PART

5A

CHAPTER **3 Structural Design Requirements**

SECTION **5 Hull Structure Beyond 0.4L Amidships**

1 General Requirements

1.1 General

The structural configurations, stiffening systems and design scantlings of the hull structures located beyond 0.4L amidships including the forebody, aft end and machinery spaces are to be in compliance with this Section of these Rules and 5A-4-2/17.

1.3 Structures within the Cargo Space Length *(2002)*

The scantlings of longitudinal structural members and elements in way of cargo spaces beyond 0.4L amidships may be gradually reduced toward 0.125L from the ends, provided that the hull girder section modulus complies with 3-2-1/3.7.1(a) of the *Steel Vessel Rules* and that the strength of the structure satisfies the material yielding, buckling and ultimate strength criteria specified in 5A-3-4/3 and 5A-3-4/5.

The scantlings of main supporting members in way of the cargo space length beyond 0.4L amidships are to comply with the requirements of 5A-3-3/11. Where the structural configuration is different from that amidships due to the hull form of the installation, additional evaluation is to be performed. The structural evaluation using the actual configuration is to be carried out to verify that the arrangement of openings necessary for access (5A-3-1/5.21), ventilation (5A-3-1/5.25), fabrication, etc. is satisfactory.

3 Forebody Side Shell Structure *(2000)*

In addition to the requirements specified in other relevant sections of the Rules, the scantlings of the structure forward of 0.4L amidships are also to satisfy the requirements in 5A-3-5/3.1, 5A-3-5/3.3 and 5A-3-5/3.5 below.

The nominal design corrosion values in the forepeak tank may be taken as 1.5 mm in determining design scantlings.

3.1 Side Shell Plating *(2002)*

3.1.1 Plating Forward of Forepeak Bulkhead

The net thickness of the side shell plating forward of the forepeak bulkhead is to be not less than t_1, t_2 and t_3, specified below.

$t_1 = 0.73s(k_1\, p/f_1)^{1/2}$ in mm (in.)

$t_2 = 0.73s(k_2\, p/f_2)^{1/2}$ in mm (in.)

$t_3 = 0.73sk(k_3 k_4\, p_b/f_3)^{1/2}$ in mm (in.) for side shell and bow plating above LWL in the region from the forward end to the forepeak bulkhead

where

s = spacing of stiffeners, in mm (in.)

k_1 = 0.342 for longitudinally and $0.50k^2$ for transversely stiffened plating

k_2 = $0.50k^2$ for longitudinally and 0.342 for transversely stiffened plating

k_3	=	0.50	
k_4	=	0.74	
k	=	$(3.075(\alpha)^{1/2} - 2.077)/(\alpha + 0.272)$,	$(1 \le \alpha \le 2)$
	=	1.0	$(\alpha > 2)$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
f_1	=	$0.65\ S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2) in the longitudinal direction	
f_2	=	$0.85\ S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2) in the transverse (vertical) direction	
f_3	=	$0.85\ S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)	
p	=	nominal pressure $\lvert p_i - p_e \rvert$, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified in 5A-3-2/Table 3, at the upper turn of bilge level amidships with the following modifications:	

i) A_i is to be calculated at the forward or aft end of the tank, whichever is greater

ii) A_e is to be calculated at the center of the panel in accordance with 5A-3-2/5.5.3, using L.C.7 with k_{fo} = 1.0 and x_o located amidships

iii) B_e is to be calculated at 0.05L from the FP in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1.1)

p_b	=	maximum bow pressure = $k_u p_{bij}$
k_u	=	1.1
p_{bij}	=	nominal bow pressure, as specified in 5A-3-2/13.1, at the lowest point of the panel, in N/cm^2 (kgf/cm^2, lbf/in^2)

S_m and f_y, as defined in 5A-3-3/7.3.1.

3.1.2 Plating between Forepeak Bulkhead and 0.125L from FP

Aft of the forepeak bulkhead and forward of 0.125L from the FP, the side shell plating is to be not less than as given in 5A-3-5/3.1.1 with B_e calculated at 0.125L and the following permissible stress.

f_1	=	permissible bending stress in the longitudinal direction, in N/cm^2 (kgf/cm^2, lbf/in^2)	
	=	$0.50 S_m f_y$,	for $L \ge 190$ m (623 ft)
	=	$[0.50 + 0.10(190 - L)/40]\ S_m f_y$,	for $L < 190$ m (623 ft)
f_2	=	$0.80 S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2), in the transverse (vertical) direction	

3.1.3 Plating between 0.3L and 0.125L from FP

The net thickness of the side shell plating between 0.3L and 0.125L from the FP is to be determined from the equations in 5A-3-3/5.3 and 5A-3-5/3.1.2 above with B_e calculated at the longitudinal location under consideration. Between 0.3L and 0.25L from the FP, the internal pressure need not be greater than that obtained amidships. The permissible stress f_1 between 0.3L and 0.2L from the FP is to be obtained by linear interpolation between midship region (5A-3-3/9.1) and the permissible stress f_1, as specified in 5A-3-5/3.1.2.

3.3 Side Frames and Longitudinals

3.3.1 Side Frames and Longitudinals Forward of 0.3L from FP

The net section modulus of side longitudinals and frames in association with the effective plating to which they are attached is to be not less than that obtained from the following equation:

$SM = M/f_{bi}$ in cm^3 (in^3)

$M = 1000ps\ell^2/k$ in N-cm (kgf-cm, lbf-in)

where

k = 12 (12, 83.33)

p = nominal pressure $|p_i - p_e|$, in N/cm^2 (kgf/cm^2, lbf/in^2), as specified in 5A-3-2/Table 3 with the following modifications:

i) A_i is to be calculated at the forward or aft end of the tank, whichever is greater. Between 0.3L and 0.25L aft of the FP, the internal pressure need not be greater than that obtained amidships.

ii) A_e is to be calculated at the center of the panel in accordance with 5A-3-2/5.5.3 using L.C.7 with k_{fo} = 1.0 and x_o located amidships.

iii) B_e is to be calculated at the center of the panel in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1.1), with the distribution of p_d, as shown in 5A-3-5/Figure 1, at the side longitudinal and frame under consideration.

Longitudinal distribution of p_d may be taken as constant from the FP to forepeak bulkhead as per 5A-3-5/3.1.1 and from 0.125L to the forepeak bulkhead as per 5A-3-5/3.1.2. p_d is to be calculated in accordance with 5A-3-2/5.5 between 0.3L and 0.125L from the FP as per 5A-3-5/3.1.3.

f_{bi} = 0.80 $S_m f_y$ in N/cm^2 (kgf/cm^2, lbf/in^2), for longitudinals between 0.125L and 0.2L from the FP

= 0.85 $S_m f_y$ in N/cm^2 (kgf/cm^2, lbf/in^2), for longitudinals forward 0.125L from the FP

= 0.85 $S_m f_y$ in N/cm^2 (kgf/cm^2, lbf/in^2), for vertical frames (other than hold frames)

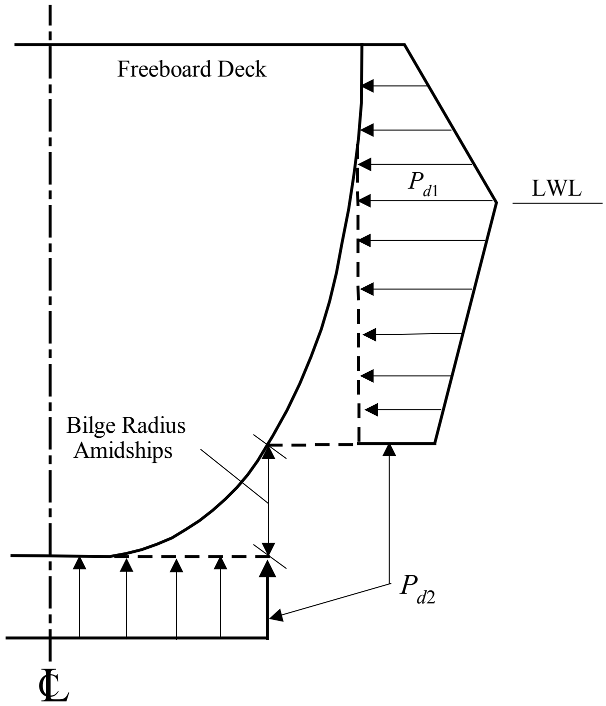
Between 0.3L and 0.2L from the FP, the permissible stress is to be obtained by linear interpolation between midship region and 0.80 $S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

s and ℓ are as defined in 5A-3-3/7.5.

For side longitudinal/stiffener in the region forward of 0.0125L from the FP and above LWL, the section modulus is not to be less than obtained from the above equation based on $p = p_b$, f_b = 0.95 $S_m f_y$ and k = 16 (16, 111.1), where p_b is as defined in 5A-3-5/3.1 above.

FIGURE 1
Transverse Distribution of p_d *(2000)*



3.5 Side Transverses and Stringers in Forebody *(2002)*

The requirements of the subparagraphs below apply to the region forward of the cargo spaces where single side skin construction is used.

3.5.1 Section Modulus

The net section modulus of side transverse and stringer in association with the effective side shell plating is not to be less than obtained from the following equation:

$SM = M/f_b$ in cm^3 (in^3)

3.5.1(a) Longitudinally Framed Side Shell

For side stringer

$M = 1000c_1c_2ps\ell_t\ell_s/k$ in N-cm (kgf-cm, lbf-in)

For side transverse, M is not to be less than M_1 or M_2, whichever is greater

$M_1 = 1000c_3ps\ell_t^2(1.0 - c_4\phi)/k$ in N-cm (kgf-cm, lbf-in)

$M_2 = 850p_1s\ell_{t1}^2/k$ in N-cm (kgf-cm, lbf-in)

where

k = 0.12 (0.12, 0.446)

c_1 = 0.125 + 0.875ϕ, but not less than 0.3

Coefficients c_2, c_3 and c_4 are given in the tables below.

Coefficient c_2

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Top Stringer			0.70
Stringers Between Top and Lowest Stringers	0.0	0.90	0.75
Lowest Stringer			0.80

Coefficient c_3

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Transverse above Top Stringer		0.55	0.55
Transverse Between Top and Lowest Stringers	0.85	—	0.64
Transverse Below Lowest Stringer		0.68	0.68

Coefficient c_4

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Transverses	0.0	0.75	0.80

p = nominal pressure, $|p_i - p_e|$, in kN/m^2 (tf/m^2, Ltf/ft^2), over the side transverses using the same load cases as specified in 5A-3-2/Table 3 for side transverses with the following modifications.

i) A_e is to be considered for case "a" and calculated in accordance with 5A-3-2/5.5.3 using L.C.7 with k_{fo} = 1.0 and x_o located amidships

ii) B_e is to be calculated in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1) with the distribution of p_d as shown in 5A-3-5/Figure 1

B_i, A_e and B_e may be taken at the center of the side shell panel under consideration.

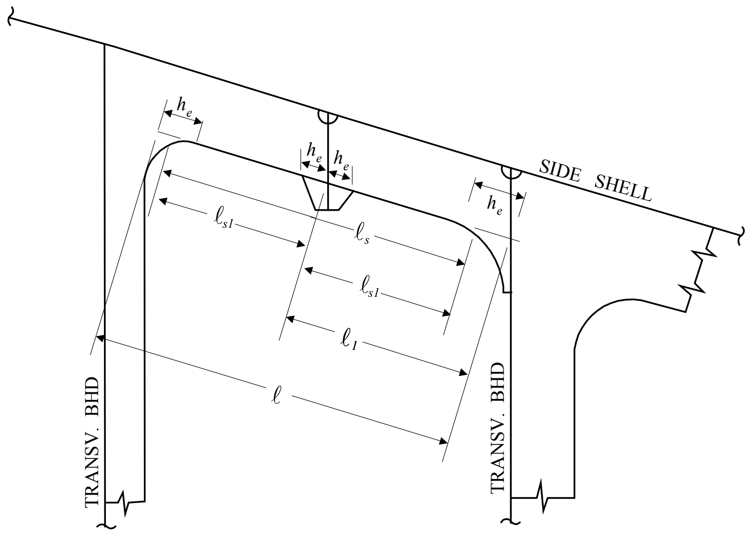
p_1 = nominal pressure, $|p_i - p_e|$, in kN/m^2 (tf/m^2, Ltf/ft^2), using the same load cases as specified in 5A-3-2/Table 3 for side transverses with the following modifications.

i) A_e is to be considered for case "a" and calculated in accordance with 5A-3-2/5.5.3 using L.C.7 with k_{fo} = 1.0 and x_o located amidships

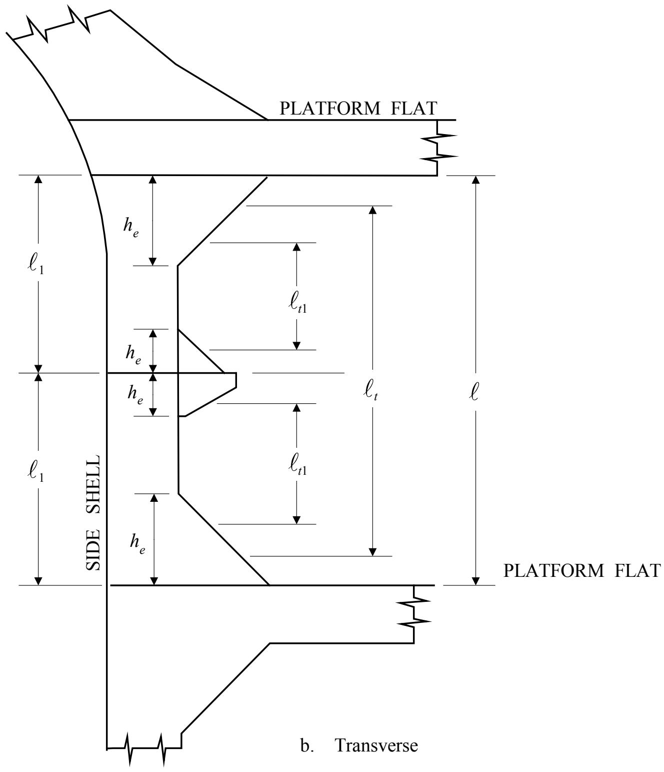
ii) B_e is to be calculated in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1) with the distribution of p_d as shown in 5A-3-5/Figure 1

B_i, A_e and B_e, calculated at the midspan ℓ_{s1} (between side stringers or between side stringer and platform, flat as shown in 5A-3-5/Figure 2) of the side transverse under consideration.

FIGURE 2
Definition of Spans *(2000)*



a. Stringer



b. Transverse

For side transverses

s = sum of half distances, in m (ft), between side transverse under consideration and adjacent side transverses or transverse bulkhead

For side stringers

s = $0.45\ell_s$

ϕ = $1/(1 + \alpha)$

α = $1.33(I_t/I_s)(\ell_s/\ell_t)^3$

I_t = moment of inertia, in cm^4 (in^4) (with effective side plating), of side transverse. I_t is to be taken as an average of those at the middle of each span ℓ_{t1} between side stringers or side stringer and platform (flat), clear of the bracket

I_s = moment of inertia, in cm^4 (in^4) (with effective side plating), of side stringer at the middle of the span $\ell_{s,}$ clear of the bracket

ℓ_t, ℓ_s = spans, in m (ft), of the side transverse (ℓ_t) and side girder (ℓ_s) under consideration, as shown in 5A-3-5/Figure 2

ℓ_{t1} = span, in m (ft), of side transverse under consideration between stringers, or stringer and platform (flat), as shown in 5A-3-3/Figure 2b

When calculating α, if more than one side transverse or stringer is fitted and they are not identical, average values of I_t and I_s within side shell panel (panel between transverse bulkheads and platforms, flats) are to be used.

f_b = permissible bending stress in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.75\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

The bending moment for side transverse below stringer (or below the platform if no stringer is fitted) is not to be less than 80% of that for side transverse above stringer (or above platform if no stringer is fitted).

3.5.1(b) Transversely Framed Side Shell

For side transverse:

$M = 1000c_1 ps\ell_t\ell_s/k$ in N-cm (kgf-cm, lbf-in)

For side stringer, M is not to be less than M_1 or M_2, whichever is greater:

$M_1 = 1000c_2 ps\,\ell_s^2(1.0 - c_3\phi_1)/k$ in N-cm (kgf-cm, lbf-in)

$M_2 = 1100p_1 s\,\ell_{s1}^2/k$ in N-cm (kgf-cm, lbf-in)

where

k = 0.12 (0.12, 0.446)

c_1 = $0.10 + 0.7\phi_1$, but not to be taken less than 0.085

If no side transverses are fitted between transverse bulkheads

c_2 = 1.1

c_3 = 0

If side transverses are fitted between transverse bulkheads

c_2 = 0.8

c_3 = 0.8

p = nominal pressure, $|p_i - p_e|$, in kN/m² (tf/m², Ltf/ft²), over the side stringers using the same load cases as specified in 5A-3-2/Table 3 for side transverses in lower wing tank. A_{ti}, A_e and B_e may be taken at the center of the side shell panel under consideration with the following modifications:

i) A_e is to be calculated in accordance with 5A-3-2/5.5.3 using L.C.7 with k_{fo} = 1.0 and x_o located amidships

ii) B_e is to be calculated in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1) with the distribution of p_d as shown in 5A-3-5/Figure 1

p_1 = nominal pressure, $|p_i - p_e|$, in kN/m² (tf/m², Ltf/ft²), using the same load cases as specified in 5A-3-2/Table 3 for side transverses in lower wing tank, with A_{ti}, A_e and B_e calculated at the midspan ℓ_{s1} (between side transverses or between side transverse and transverse bulkhead, as shown in 5A-3-5/Figure 2a) of the side stringer under consideration, with the following modifications:

i) A_e is to be calculated in accordance with 5A-3-2/5.5.3 using L.C.7 with k_{fo} = 1.0 and x_o located amidships

ii) B_e is to be calculated in accordance with 5A-3-2/5.5 ($p_s + k_u p_d$, full draft, heading angle = 0, k_u = 1) with the distribution of p_d as shown in 5A-3-5/Figure 1

For side stringers

s = sum of half distances, in m (ft), between side stringer under consideration and adjacent side stringers or platforms (flats)

For side transverses

s = $0.45\ell_t$

ϕ_1 = $\alpha/(1 + \alpha)$

ℓ_{s1} = span, in m (ft), of the side stringer under consideration between side transverses or side transverse and transverse bulkhead, as shown in 5A-3-5/Figure 2a

f_b = permissible bending stress, in N/cm² (kgf/cm², lbf/in²)

= $0.75\ S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

ℓ_t, ℓ_s and α are as defined in 5A-3-5/3.5.1(a) above.

3.5.2 Sectional Area of Web

The net sectional area of the web portion of the side transverse and side stringer is not to be less than obtained from the following equation:

$A = F/f_s$

3.5.2(a) Longitudinally Framed Side Shell

For side stringer:

$F = 1000kc_1p\ell s$ in N (kgf, lbf)

For side transverse, F is not to be less than F_1 or F_2, whichever is greater:

$F_1 = 850kc_2p\ell s(1.0 - c_3\phi - 2h_e/\ell)$ N (kgf, lbf)

$F_2 = 1700kc_2p_1s(0.5\ell_1 - h_e)$ N (kgf, lbf)

where

k = 0.5 (0.5, 1.12)

Coefficients c_1, c_2 and c_3 are given in the tables below.

Coefficient c_1

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Stringers	0.0	0.52	0.40

Coefficient c_2

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Transverses Above Top Stringer	1.0	0.9	0.9
Transverse Between Top and Lowest Stringers		—	0.95
Transverse Below Lowest Stringer		1.0	1.0

Coefficient c_3

Number of Side Stringers Between Platforms (Flats)	*No Stringer*	*One Stringer*	*More than One Stringer*
Transverses	0.0	0.5	0.6

ℓ = span, in m (ft), of the side transverse under consideration between platforms (flats), as shown in 5A-3-5/Figure 2b

ℓ_1 = span, in m (ft), of the side transverse under consideration between side stringers or side stringer and platform (flat), as shown in 5A-3-5/Figure 2b

h_e = length, in m (ft), of the end bracket of the side transverse, as shown in 5A-3-5/Figure 2b

To obtain F_1, h_e is equal to the length of the end bracket at the end of span ℓ of side transverse, as shown in 5A-3-5/Figure 2b.

To obtain F_2, h_e is equal to the length of the end bracket at the end of span ℓ_1 of side transverse, as shown in 5A-3-5/Figure 2b.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

p, p_1, ϕ and s are as defined in 5A-3-5/3.5.1(a) above.

The shear force for the side transverse below the lowest stringer (or below the platform if no stringer is fitted), is not to be less than 110% of that for the side transverse above the top stringer (or above the platform if no stringer is fitted).

3.5.2(b) Transversely Framed Side Shell

For side transverse

$F = 850kc_1p\ell s$ in N (kgf, lbf)

For side stringer, F is not to be less than F_1 or F_2, whichever is greater.

$F_1 = 1000kp\ell s(1.0 - 0.6\phi_1 - 2h_e/\ell)$ in N (kgf, lbf)

$F_2 = 2000kp_1s(0.5\ell_1 - h_e)$ in N (kgf, lbf)

where

k = 0.5 (0.5, 1.12)

c_1 = $0.1 + 0.7\phi_1$, but not to be taken less than 0.2

ℓ = span, in m (ft), of the side stringer under consideration between transverse bulkheads, as shown in 5A-3-5/Figure 2a

ℓ_1 = span, in m (ft), of the side stringer under consideration between side transverses or side transverse and bulkhead, as shown in 5A-3-5/Figure 2a

h_e = length, in m (ft), of the end bracket of the side stringer under consideration, as shown in 5A-3-5/Figure 2a

To obtain F_1, h_e is equal to the length of the end bracket at the end of span ℓ of the side stringer, as shown in 5A-3-5/Figure 2a.

To obtain F_2, h_e is equal to the length of the end bracket at the end of span ℓ_1 of the side stringer, as shown in 5A-3-5/Figure 2a.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

p, p_1, ϕ_1 and s are as defined in 5A-3-5/3.5.1(a) above.

3.5.3 Depth of Transverse/Stringer

The depths of side transverses and stringers, d_w, are neither to be less than obtained from the following equations nor to be less than 2.5 times the depth of the slots, respectively.

3.5.3(a) Longitudinally Framed Shell

For side transverse:

If side stringer is fitted between platforms (flats)

$d_w = (0.08 + 0.80\alpha)\ell_t$ for $\alpha \le 0.05$

$= (0.116 + 0.084\alpha)\ell_t$ for $\alpha > 0.05$

and need not be greater than $0.2\ell_t$

If no side stringer is fitted between platforms (flats), d_w is not to be less than $0.2\ell_t$ or $0.06D$, whichever is greater.

For side stringer:

$d_w = (0.42 - 0.9\alpha)\ell_s$ for $\alpha \le 0.2$

$= (0.244 - 0.0207\alpha)\ell_s$ for $\alpha > 0.2$

α is not to be taken greater than 8.0 to determine the depth of the side stringer.

ℓ_t, ℓ_s and α are as defined in 5A-3-5/3.5.1(a) above.

D is as defined in 3-1-1/7 of the *Steel Vessel Rules*.

3.5.3(b) Transversely Framed Side Shell

For side stringer:

If side transverse is fitted between transverse bulkheads

$d_w = (0.08 + 0.80\alpha_1)\ell_s$ for $\alpha_1 \le 0.05$

$= (0.116 + 0.084\alpha_1)\ell_s$ for $\alpha_1 > 0.05$

and need not be greater than $0.2\ell_s$

If no side transverse is fitted between transverse bulkheads

$$d_w = 0.2\ell_s$$

For side transverse:

$$d_w = (0.277 - 0.385\alpha_1)\ell_t \qquad \text{for } \alpha_1 \le 0.2$$

$$= (0.204 - 0.205\alpha_1)\ell_t \qquad \text{for } \alpha_1 > 0.2$$

α_1 is not to be taken greater than 7.5 to determine the depth of the side transverse

where

$$\alpha_1 = 1/\alpha$$

ℓ_t, ℓ_s and α are as defined in 5A-3-5/3.5.1(a) above.

3.5.4 Thickness

The net thickness of side transverse and stringer is not to be less than 9.5 mm (0.374 in.)

5 Transition Zone *(2000)*

In the transition zone between the forepeak and the No. 1 cargo tank region, due consideration is to be given to the proper tapering of major longitudinal members within the forepeak such as flats, decks, horizontal ring frames or side stringers aft into the cargo hold. Where such structure is in line with longitudinal members aft of the forward cargo tank bulkhead, this tapering may be introduced by fitting of large brackets. These brackets are to have a taper of 4:1.

7 Forebody Strengthening for Slamming

(1 July 2012) Where the hull structure is subject to slamming as specified in 5A-3-2/13, proper strengthening will be required as outlined below. For strengthening to account for bottom slamming, the requirements of this Subsection apply to installations with a heavy ballast draft forward of less than 0.04*L*.

7.1 Bottom Slamming

7.1.1 Bottom Plating

When bottom slamming, as specified in 5A-3-2/13, is considered, the bottom structure in the region of the flat of bottom forward of 0.25*L* measured from the FP is to be in compliance with the following requirement.

The net thickness of the flat of bottom plating forward of 0.25*L* measured from the FP is not to be less than *t* obtained from the following equation:

$$t = 0.73s(k_2\, k_3\, p_s/f)^{1/2} \qquad \text{in mm (in.)}$$

where

s	=	spacing of longitudinal or transverse stiffeners, in mm (in.)	
k_2	=	$0.5\,k^2$ for longitudinally stiffened plating	
k_3	=	0.74	
k	=	$(3.075\,(\alpha)^{1/2} - 2.077)/(\alpha + 0.272)$,	$(1 \le \alpha \le 2)$
	=	1.0	$(\alpha > 2)$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
p_s	=	the design slamming pressure = $k_u p_{si}$	

For determination of t, the pressure p_s is to be taken at the center of the supported panel.

p_{si} = nominal bottom slamming pressure, as specified in 5A-3-2/13.3.1, in N/cm^2 (kgf/cm^2, lbf/in^2)

k_u = slamming load factor = 1.1

The maximum nominal bottom slamming pressure occurring along the installation is to be applied to the bottom plating between the foremost extent of the flat of bottom and 0.125L from the FP. The pressure beyond this region may be gradually tapered to the longitudinal location where the nominal slamming pressure is calculated as zero.

f = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.85\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

7.1.2 Bottom Longitudinals and Stiffeners

The section modulus of the stiffener, including the associated effective plating on the flat of bottom forward of 0.25L measured from the FP, is not to be less than obtained from the following equation:

$SM = M/f_b$ in cm^3 (in^3)

$M = 1000 p_s s \ell^2/k$ in N-cm (kgf-cm, lbf-in)

where

k = 16 (16, 111.1)

p_s = design slamming pressure = $k_u p_{si}$

For determination of M, the pressure p_s is to be taken at the midpoint of the span ℓ.

p_{si} = nominal bottom slamming pressure, as specified in 5A-3-2/13.3.1, in N/cm^2 (kgf/cm^2, lbf/in^2)

k_u = slamming load factor = 1.1

The maximum nominal bottom slamming pressure occurring along the installation is to be applied to the bottom stiffeners between the foremost extent of the flat of bottom and 0.125L from the FP. The pressure beyond this region may be gradually tapered to the longitudinal location where the nominal slamming pressure is calculated as zero.

s = spacing of longitudinal or transverse stiffeners, in mm (in.)

ℓ = unsupported span of the stiffener, in m (ft)

f_b = $0.9 S_m f_y$ for transverse and longitudinal stiffeners in the region forward of 0.125L measured from the FP

= $0.8 S_m f_y$ for longitudinal stiffeners in the region between 0.125L and 0.25L measured from the FP

The effective breadth of plating b_e is as defined in 5A-3-3/7.5.

Struts connecting the bottom and inner bottom longitudinals are not to be fitted.

7.1.3 Bottom Floors

The arrangements and scantlings of floors are to be adequate for bottom slamming loads, as specified in 5A-3-2/13.

The spacing of floors forward of amidships need not be less than the spacing amidships.

7.3 Bowflare Slamming

When bowflare slamming, as specified in 5A-3-2/13.5, is considered, the side shell structure above the waterline in the region between 0.0125L and 0.25L from the FP is to be in compliance with the following requirements.

7.3.1 Side Shell Plating

The net thickness of the side shell plating between 0.0125L and 0.25L from the FP is not to be less than t_1 or t_2, whichever is greater, obtained from the following equations:

$t_1 = 0.73s(k_1 p_s/f_1)^{1/2}$ in mm (in.)

$t_2 = 0.73s(k_2 p_s/f_2)^{1/2}$ in mm (in.)

where

p_s = maximum slamming pressure = $k_u p_{ij}$

p_{ij} = nominal bowflare slamming pressure, as specified in 5A-3-2/13.5.1, at the lowest point of the panel, in N/cm^2 (kgf/cm^2, lbf/in^2)

k_u = slamming load factor = 1.1

f_1 = 0.85 $S_m f_y$ for side shell plating forward of 0.125L from the FP, in N/cm^2 (kgf/cm^2, lbf/in^2)

= 0.75 $S_m f_y$ for side shell plating in the region between 0.125L and 0.25L from the FP, in N/cm^2 (kgf/cm^2, lbf/in^2)

f_2 = 0.85 $S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

k_1 = 0.342 for longitudinally stiffened plating

= 0.5 for transversely stiffened plating

k_2 = 0.5 for longitudinally stiffened plating

= 0.342 for transversely stiffened plating

s, S_m and f_y are as defined in 5A-3-5/7.1.1 above.

7.3.2 Side Longitudinals and Stiffeners

The section modulus of the stiffener, including the associated effective plating, is not to be less than obtained from the following equation:

$SM = M/f_b$ in cm^3 (in^3)

$M = 1000 p_s s \ell^2/k$ in N-cm (kgf-cm, lbf-in)

where

k = 16 (16, 111.1)

ℓ = unsupported span of the stiffener, in m (ft)

p_s = maximum slamming pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in 5A-3-5/7.3.1, at the midpoint of the span ℓ

s and f_b are as defined in 5A-3-5/7.1 above.

The effective breadth of plating, b_e, is as defined in 5A-3-3/7.5.

7.3.3 Side Transverses and Side Stringers

The net section modulus and sectional area requirements for side transverses and side stringers, as specified in 5A-3-5/3.5, are to be met with the bow flare slamming pressure, as specified in 5A-3-2/13.5.2, for the region between 0.0125L and 0.25L from the FP.

9 Forebody Deck Structures *(1 July 2012)*

The deck plating, longitudinals, girders and transverses forward of 0.25L from the FP are to meet the requirements specified in 5A-3-3/9 and 5A-3-3/11 with the deck pressure, $p = p_g$, where p_g is the nominal green water loading given in 5A-3-2/13.7 and the permissible stresses as specified below.

9.1 Deck Plating

The net thickness of deck plating is to be not less than t_1 and t_2, as specified in 5A-3-3/9.3, with the following modifications:

$f_1 = 0.50\ S_m f_y$, in N/cm² (kgf/cm², lbf/in²), for main deck within 0.1L from the FP.

$f_1 = 0.60\ S_m f_y$, in N/cm² (kgf/cm², lbf/in²), for forecastle deck

$f_2 = 0.80\ S_m f_y$, in N/cm² (kgf/cm², lbf/in²)

where

S_m = strength reduction factor obtained from 5A-3-3/7.3

f_y = minimum specified yield point of deck plating material

The permissible stress, f_1, for main deck between 0.25L and 0.1L from the FP is to be obtained by linear interpolation between midship region ($f_1 = 0.15\ S_m f_y$ as in 5A-3-3/9.3) and the permissible stress at 0.1L from the FP, as specified above.

In addition, the net thickness of main deck plating is also not to be less than t_3, as specified below.

$t_3 = 0.30s(S_m f_y/E)^{1/2}$ mm (in.) for main deck within 0.1L from the FP

The net thickness, t_3, between 0.30L and 0.1L from the FP is to be obtained by linear interpolation between midship region and the t_3 above. t_3 in midship region is defined as:

$t_3 = cs(S_m f_y/E)^{1/2}$ mm (in.) .... (5A-3-3/9.3)

where

c = 0.5(0.6 + 0.0015L) for SI or MKS Units

= 0.5(0.6 + 0.00046L) for U.S. Units

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.

The net thickness of deck plating should not be less than the minimum gross thickness specified in Section 3-2-3 of the *Steel Vessel Rules (January 2005)* minus the nominal corrosion value specified in 5A-3-1/1.7.

Finally, the net thickness of deck plating is not to be less than 85% of the net thickness requirement based on nominal green water load, p_g, calculated for North Atlantic environment.

9.3 Deck Longitudinals

The net section modulus is not to be less than obtained from 5A-3-3/9, with the following modifications.

$f_b = 0.70\ S_m f_y$, in N/cm² (kgf/cm², lbf/in²), for main deck longitudinals within 0.1L from the FP and forecastle deck longitudinals

$f_b = 0.80\ S_m f_y$, in N/cm² (kgf/cm², lbf/in²), for main deck beams forward of the foremost hatch opening (No. 1 hatch) and forecastle deck beams

The permissible bending stress, f_b, for main deck longitudinals between 0.25L and 0.1L from the FP is to be obtained by linear interpolation between midship region (see 5A-3-3/9.5) and the permissible stress at 0.1L from the FP, as specified above.

Finally, the net section modulus of deck longitudinals is not to be less than 85% of the net section modulus requirement based on nominal green water load, p_g, calculated for North Atlantic environment.

9.5 Deck Transverse and Deck Girders

The deck girders and transverses forward of 0.25*L* from the FP are to be verified based on appropriate analysis (e.g., grillage analysis) and should meet the requirements specified in the following with the deck pressure, $p = p_g$, where p_g is the nominal green water loading given in 5A-3-2/13.7 and the permissible stresses as specified below.

Permissible bending stress for net thickness

$f_b = 0.70 S_m f_y$ (5A-3-3/11.3.1)

Permissible shear stress for net thickness

$f_b = 0.45 S_m f_y$ (5A-3-3/11.3.2)

The required section modulus of members such as girders, transverse etc., is to be obtained on an effective width of plating basis in accordance with 3-1-2/13.3 of the *Steel Vessel Rules (January 2005)*.

Finally, the net section modulus and sectional area of deck girders and transverses is not to be less than 85% of those required based on nominal green water load, p_g, calculated for North Atlantic environment.

PART
5A

CHAPTER **3 Structural Design Requirements**

SECTION **6 Application to Single Hull Ship-Type Installations**

1 General

Where due to the nature of the cargo, single hull construction is permitted, the design criteria and evaluation procedures specified in Section 5A-3-1 may also be applied to single hull ship-type installations with modifications as outlined in this Section.

1.1 Nominal Design Corrosion Values *(December 2008)*

Except as modified by the following, the nominal design corrosion values given in 5A-3-1/Table 1 are applicable to the corresponding structural elements of single hull ship-type installations based on the proposed usage of the individual space.

For bottom plating and contiguously attached structures, the nominal design corrosion values to be used are:

Wing Ballast Tanks	
Bottom Plating	1.00 mm
Bottom Longitudinals, Transverses and Girders (Web and Flange)	1.50 mm
Center or Wing Cargo Tanks	
Bottom Plating	1.00 mm
Bottom Longitudinals, Transverses and Girders (Web and Flange)	1.00 mm

Consideration may be given for modifying the nominal design corrosion values, depending upon the degree of cargo corrosiveness.

1.3 Load Criteria

The load criteria and load cases specified in 5A-3-2/1 through 5A-3-2/13 are generally applicable to single hull ship-type installations by considering the double bottom and wing ballast tanks, such as shown in 5A-3-2/Figures 1 and 18, as null, except that the load patterns are specified in 5A-3-6/Table 1 for bottom and side shell structures.

1.5 Strength Criteria

1.5.1 Shear Strength *(1 July 2009)*

For single hull ship-type installations with two or more longitudinal bulkheads, the net thickness of side shell and longitudinal bulkhead plating is not to be less than that specified in 5A-3-3/5, wherein the shear distribution factor, D_s and D_i, and local load correction, R_i, may be derived either from direct calculations or from Appendix 5A-4-A1.

1.5.2 Plating and Longitudinals/Stiffeners

The strength requirements for plating and longitudinals/stiffeners specified in 5A-3-3/7 through 5A-3-3/17 and Section 5A-3-5 are directly applicable to single hull ship-type installations by determining the internal pressure in accordance with the actual tank arrangement.

3 Main Supporting Structures

3.1 Bottom Transverses

3.1.1 Section Modulus of Bottom Transverses

The net section modulus of the bottom transverse, in association with the effective bottom plating, is not to be less than obtained from the following equation (see also 5A-3-3/1.3).

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps\,\ell_b^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

c = $0.83\alpha^2$ for center tank

= 1.4 for wing tank

α = $(\ell_g/\ell_b)[(I_b/I_g)(s_g/s)]^{1/4} \leq 1.0$ for ship-type installations with bottom girder

= 1.0 for ship-type installations without bottom girder

ℓ_b = span of the bottom transverse, in m (ft), as indicated in 5A-3-6/Figure 1; the length is to be not less than $0.125B$ or one-half the breadth of the tank, whichever is the greater

ℓ_g = span of the bottom girder, in m (ft), as indicated in 5A-3-6/Figure 1

s = spacing of the bottom transverse, in m (ft)

s_g = spacing of the bottom girder, in m (ft)

I_b, I_g = moments of inertia, in cm^4 (in^4), of the bottom transverse (I_b) and the bottom girder (I_g) with effective plating to which they are attached (clear of bracket)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the bottom transverse, as specified in 5A-3-6/Table 1

f_b = permissible bending stress

= $0.70\,S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

B = installation breadth, in m (ft)

3.1.2 Web Sectional Area of Bottom Transverse

The net sectional area of the web portion of the bottom transverse is not to be less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force, F, in N (kgf, lbf), can be obtained from the following equation (see also 5A-3-3/1.3).

$F = 1000k[ps(K_b\ell_s - h_e) + cDB_c s]$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

K_b = 0.5α for center tank

= 0.5 for wing tank

c	=	0	for center tank
	=	0.15	for wing tank without cross ties
	=	0.06	for wing tank with one cross tie
	=	0.03	for wing tank with two cross ties

ℓ_s = span of the bottom transverse, in m (ft), as indicated in 5A-3-6/Figure 1

h_e = length of the bracket of bottom transverse, in m (ft), as indicated in 5A-3-6/Figure 1

D = installation depth, in m (ft)

B_c = breadth of the center tank, in m (ft)

P, s and α are as defined in 5A-3-6/3.1.1.

f_s = permissible shear stress

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

3.3 Bottom Girders *(1 July 2012)*

3.3.1 Section Modulus of Bottom Girders

The net section modulus of the bottom girder, in association with the effective bottom plating, is not to be less than obtained from the following equation (see also 5A-3-3/1.3).

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps_g\,\ell_g^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

c = α^2

α = $(\ell_b/\ell_g)[(I_g/I_b)\,(s/s_g)]^{1/4} \leq 1.0$

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the bottom girder, as specified in 5A-3-6/Table 1

ℓ_b, ℓ_g, I_g, I_b, s and s_g are as defined in 5A-3-6/3.1.1.

f_b = $0.70S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

3.3.2 Web Sectional Area of Bottom Girder

The net sectional area of the web portion of the bottom girder is not to be less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force, F, in N (kgf, lbf), can be obtained from the following equation (see 5A-3-3/1.3).

$F = 1000kcps_g\,(0.5\ell_s - h_e)$

where

k = 1.0 (1.0, 2.24)

ℓ_s = span of the bottom girder, in m (ft), as indicated in 5A-3-6/Figure 1

h_e = length of bracket of bottom girder, in m (ft), as indicted in 5A-3-6/Figure 1

s_g is as defined in 5A-3-6/3.1.1.

c is as defined in 5A-3-6/3.3.1.

p is as defined in 5A-3-6/3.3.1.

f_s = permissible shear stress

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

TABLE 1
Design Pressure for Local and Supporting Structures *(1 July 2012)*

A. Plating & Longitudinals/Stiffeners

The nominal pressure, $p = |p_i - p_e|$, is to be determined from load cases "a" & "b" below, whichever is greater, with k_u = 1.10 and k_c = 1.0 unless otherwise specified in the table

	Case "a" – At fwd end of the tank				*Case "b" – At mid tank/fwd end of tank*			
Structural Members/ Components	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	p_e	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	p_e
1. Bottom Plating & Long'l	2/3 design draft/0°	Full center and wing tanks	A_i	A_e	Design draft/0°	Midtank of empty center and wing tanks	—	B_e
2. Side Shell Plating & Long'l	2/3 design draft/60°	Starboard side of full wing tank	B_i	A_e	Design draft/60°	Midtank of empty wing tank	—	B_e

B. Main Supporting Members

The nominal pressure, $p = |p_i - p_e|$, is to be determined at the midspan of the structural member at starboard side of installation from load cases "a" & "b" below, whichever is greater, with k_u = 1.0 and k_c = 1.0 unless otherwise specified in the table

	Midtank for Transverses				*Midtank for Transverses*			
Structural Members/ Components	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	p_e	*Draft/Wave Heading Angle*	*Location and Loading Pattern*	*Coefficients* p_i	p_e
3. Bottom Transverse & Girder	2/3 design draft/0°	Full center and wing tanks	A_i	A_e	Design draft/0°	Midtank of empty center and wing tanks	—	B_e
4. Side Transverses	2/3 design draft/60°	Wing tanks full	B_i	—	Design draft/60°	Midtank of empty wing tank	—	B_e
5 *(1 July 2012)* *Deck Transverses with cross ties in wing tanks (5A-3-6/Figure 1)	2/3 design draft/60°	Wing tanks full, Center tank empty	C_i	—	2/3 design draft/60°	Center tank full, wing tank empty	C_i	—

* See note 5

Notes:

1 For calculating p_i and p_e, the necessary coefficients are to be determined based on the following designated groups:

a) For p_i

A_i: w_v = 0.75, w_ℓ(fwd bhd) = 0.25, w_ℓ(aft bhd) = –0.25, w_t = 0.0, c_ϕ = –1.0, c_e = 0.0

B_i: w_v = 0.4, w_ℓ(fwd bhd) = 0.2, w_ℓ(aft bhd) = –0.2, w_t(starboard) = 0.4, w_t(port) = –0.4, c_ϕ = –0.7, c_e = 0.7

b) For p_e

A_e: $k_{\ell o}$ = 1.0, k_u = 1.0, k_c = –0.5

B_e: $k_{\ell o}$ = 1.0

TABLE 1 (continued)
Design Pressure for Local and Supporting Structures *(1 July 2012)*

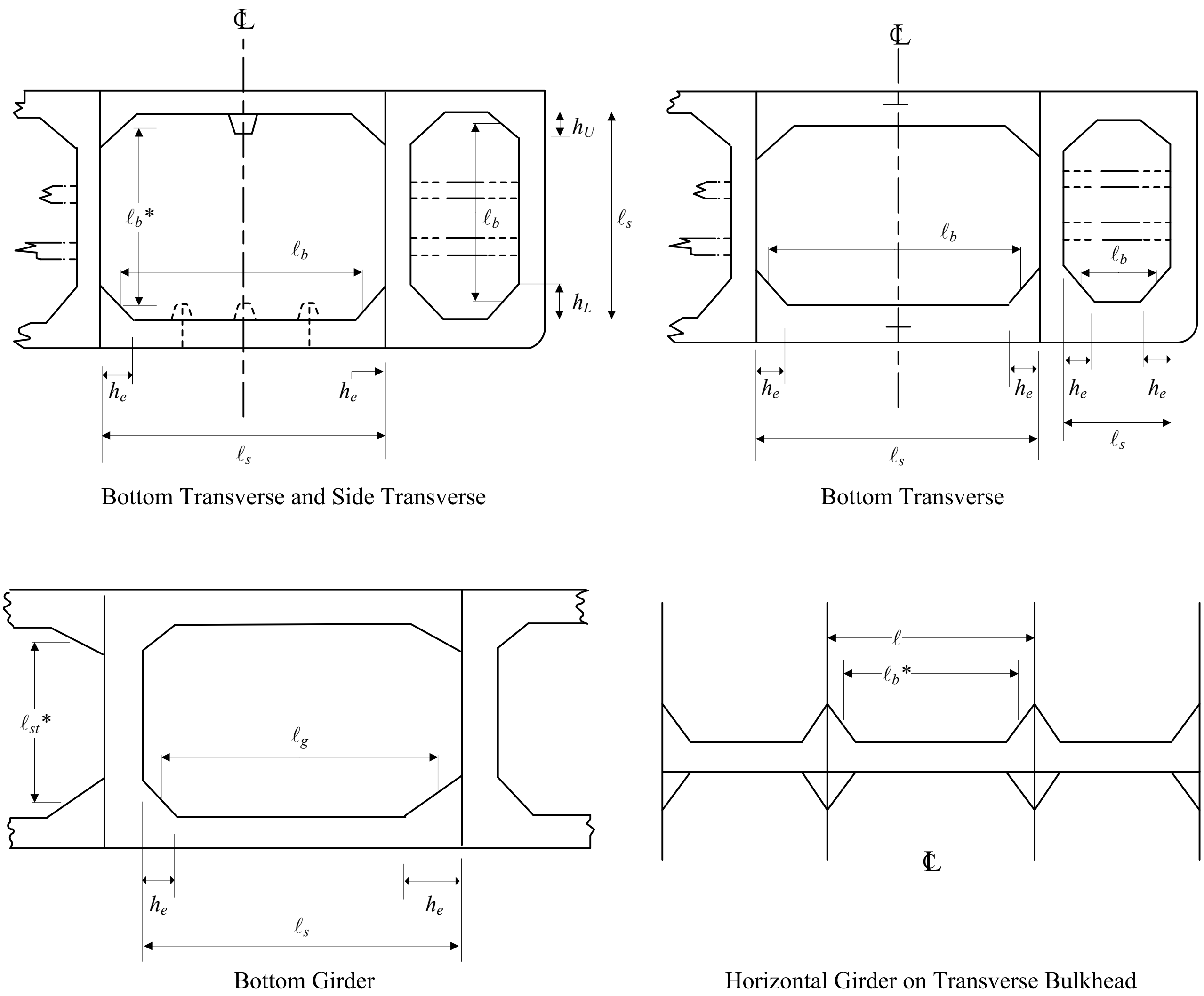
2 For structures within $0.4L$ amidships, the nominal pressure is to be calculated for a tank located amidships. The longest cargo and ballast tanks in the region should be considered as located amidships

3 In calculation of the nominal pressure, ρg of the liquid cargoes is not to be taken less than 0.1025 kgf/cm^2-m (0.4444 lbf/in^2-ft) for structural members 1 and 2 and is not to be taken less than 0.09 kgf/cm^2-m (0.3902 lbf/in^2-ft) for cargo tanks and 0.1025 kgf/cm^2-m (0.4444 lbf/in^2-ft) for ballast tanks for structural members 3 and 4.

4 For all other structures, 5A-3-2/Table 3 is applicable.

5 *(1 July 2012)* Case-a is applied for deck transverse in wing tanks and case-b is applied for deck transverse in center tank

FIGURE 1
Spans of Transverses and Girders *(1 July 2012)*



* Where both lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b or ℓ_{st} may be taken between the toes of the effective lower and upper brackets.

3.5 Side Transverses

3.5.1 Section Modulus of Side Transverses

The net section modulus of the side transverse, in association with the effective side plating, is not to be less than obtained from the following equation (see also 5A-3-3/1.3)

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps\,\ell_b^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

ℓ_b = span of side transverse, in m (ft), as indicated in 5A-3-6/Figure 1

s = spacing of side transverse, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span ℓ_b of the side transverse, as specified in 5A-3-6/Table 1

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\,S_m f_y$

c is given in 5A-3-6/Table 2.

S_m and f_y are as defined in 5A-3-3/7.3.1.

For ship-type installations without cross ties, the section modulus of the side transverse, as required above, is to extend at least up to $0.6\ell_b$ from the lower end of the span. The value of the bending moment, M, used for the calculation of the required section modulus of the remaining part of the side transverse may be reduced, but not more than 20%.

In the case of one cross tie, the section modulus of the lower (upper) side transverse, as required above, is to extend to the cross tie.

In the case of two cross ties, the section modulus of the lower (upper) side transverse, as required above, is to extend to the lower (upper) cross tie and may be linearly interpolated between the cross ties.

TABLE 2
Coefficient c for Side Transverse

Arrangement of Cross Ties	*For Upper Side Transverse*	*For Lower Side Transverse*
No Cross Tie	0.75	
One Cross Tie in Wing Tank	0.19	0.33
Two Cross Ties in Wing Tank	0.13	0.20

3.5.2 Web Sectional Area of Side Transverses

The net sectional area of the web portion of the side transverse is not to be less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force, F, in N (kgf, lbf), for the side transverse can be obtained from the following equation (see also 5A-3-3/1.3):

F = $1000ks[K_U\ell_s(P_U + P_L) - h_U P_U]$ for the upper part of the transverse

= $1000ks[K_L\ell_s(P_U + P_L) - h_L P_L]$ or $350ksK_L\ell_s(P_U + P_L)$, whichever is greater, for the lower part of the transverse

In no case is the shear force for the lower part of the transverse to be less than 120% of that for the upper part of the transverse.

where

k = 1.0 (1.0, 2.24)

ℓ_s = span of the side transverse, in m (ft), as indicated in 5A-3-6/Figure 1

s = spacing of the side transverse, in m (ft)

P_U = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of the upper bracket ($h_U/2$), as specified in 5A-3-6/Table 1

P_L = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of the lower bracket ($h_L/2$), as specified in 5A-3-6/Table 1

h_U = length of the upper bracket, in m (ft), as indicated in 5A-3-6/Figure 1

h_L = length of the lower bracket, in m (ft), as indicated in 5A-3-6/Figure 1

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

K_U and K_L are given in 5A-3-6/Table 3.

S_m and f_y are as defined in 5A-3-3/7.3.1.

For ship-type installations without cross ties, the sectional area of the lower side transverse, as required above, is to extend up to 0.15ℓ from the toe of the lower bracket or $0.3\ell_s$ from the lower end of the span, whichever is greater.

In the case of one cross ties, the sectional area of the lower (upper) side transverse as required above, is to extend to the cross tie.

In the case of two cross ties, the sectional area of the lower (upper) side transverse as required above, is to extend to the lower (upper) cross tie and may be linearly interpolated between the cross ties.

TABLE 3
Coefficients K_U and K_L for Side Transverses

Arrangement of Cross Ties	K_U	K_L
No Cross Tie	0.16	0.30
One Cross Tie in Wing Tank	0.09	0.21
Two Cross Ties in Wing Tank	0.075	0.16

3.7 Deck Transverses – Loading Pattern 1 *(1 July 2012)*

3.7.1 Section Modulus of Deck Transverses

The net section modulus of deck transverses, in association with the effective deck plating, is not to be less than obtained from the following equation (see also 5A-3-3/1.3).

$$SM = M/f_b \qquad \text{cm}^3 \text{ (in}^3\text{)}$$

For deck transverses in wing tanks:

$$M = k(10{,}000\, c_1 \varphi\, ps\, \ell_t^2 + \beta_s M_s) \geq M_o \qquad \text{N-cm (kgf-cm, lbf-in)}$$

For deck transverses in center tanks:

$$M = k(10{,}000\, c_1 \varphi\, ps\, \ell_t^2 + \beta_b M_b) \geq M_o \qquad \text{N-cm (kgf-cm, lbf-in)}$$

where

M_s = $10{,}000 c_2 p_s s \ell_s^2$

M_b = $10{,}000 c_2 p_b s \ell_b^2$

M_o = $10{,}000 k c_3 \varphi p s \ell_t^2$

k = 1.0 (1.0, 0.269)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the deck transverse under consideration, as specified in 5A-3-6/Table 1, Item 5

p_s = corresponding nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the side transverse (5A-3-2/Table 3 , Item 16)

p_b = corresponding nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web on longitudinal bulkhead (5A-3-2/Table 3 , Item 16)

c_1 = 0.42 for tanks without deck girder

= $0.42\alpha^2$ for tanks with deck girders, min. 0.05 and max. 0.42

α = $(\ell_g/\ell_t)[(s_g/s)(I_T/I_g)]^{1/4}$

ℓ_g = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c

ℓ_t = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A, but is not to be taken as less than 60% of the breadth of the tank

I_g, I_t = moments of inertia, in cm^4 (in^4), of the deck girder and deck transverse, clear of the brackets, respectively

s_g = spacing of the deck girders, in m (ft)

s = spacing of the deck transverses, in m (ft)

When calculating α, if more than one deck girder is fitted, the average values of s_g, ℓ_g and I_g are to be used when the girders are not identical.

φ = $1 - 5(h_a/\ell_t)\alpha^{-1}$, to be not less than 0.6 for cargo tanks with deck girders

= $1 - 5(h_a/\ell_t)$, to be not less than 0.6 for cargo tanks without deck girders

h_a = distance, in m (ft), from the end of the span to the toe of the end bracket of the deck transverse, as indicated in 5A-3-3/Figure 9

β_s = $0.9[(\ell_s/\ell_t)(I_t/I_s)]$, but is not to be taken less than 0.10 and need not be greater than 0.65

β_b = $0.9[(\ell_b/\ell_t)(I_t/I_b)]$, but is not to be taken less than 0.10 and need not be greater than 0.50

ℓ_s, ℓ_b = spans, in m (ft), of side transverse and vertical web on longitudinal bulkhead, respectively, as indicated in 5A-3-3/Figure 2A

I_s, I_b = moments of inertia, in cm^4 (in^4), clear of the brackets, of side transverses and vertical web on longitudinal bulkhead

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/ in^2)

= $0.70 S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

c_2 is given in 5A-3-6/Table 4 below.

c_3 = 0.83 for tanks without deck girders

= $1.1c_1$ for tanks with deck girders

Where no cross ties or other effective supporting arrangements are provided for the wing tank vertical webs, the deck transverses in the wing tanks are to have section modulus not less than 70% of that required for the upper side transverse.

TABLE 4
Coefficient c_2 For Deck Transverse *(1 July 2012)*

Arrangement of Cross Ties	*Center Tank*	*Wing Tank*
No Cross Tie	0.4	
One Cross Tie in Wing Tank	0.13	0.28
Two Cross Ties in Wing Tank	0.05	0.12

3.7.2 Web Sectional Area of Deck Transverse

The net sectional area of the web portion of deck transverses is not to be less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

$F = 1000k[c_1 ps(0.50\ell - h_e) + c_2 DB_c s]$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

c_1 = 1.30 for tanks without deck girder

= $0.90\alpha^{1/2}$ for tanks with deck girder, min. 0.50 and max. 1.0

c_2 = 0 for center tank

= 0.045 for wing tank

ℓ = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A

h_e = length of the bracket, in m (ft), as indicated in 5A-3-3/Figure 2A-c and d and 5A-3-3/Figure 9

D = depth of the ship-type vessel, in m (ft), as defined in 3-1-1/7 of the *Steel Vessel Rules*

B_c = breadth of the center tank, in m (ft)

p, s and α are as defined in 5A-3-6/3.7.1.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

Area A is not to be less than the area obtained based on 5A-3-3/11.9 and 5A-3-3/11.11.

3.8 Deck Transverses – Loading Pattern 2 *(1 July 2012)*

3.8.1 Section Modulus of Deck Transverses

In addition to satisfying the net section modulus requirements of 5A-3-3/3.7.1, the net section modulus of a deck transverse, that is loaded with reactions (forces and moments) from the topside structure, is to be obtained from the following equation:

$SM = M/f_b$ cm^3 (in^3)

3.8.1(a) For deck transverses in wing tanks

$M = 10^5\, k\,(M_p + M_g + M_s)$ N-cm (kgf-cm, lbf-in)

3.8.1(b) For deck transverses in center tanks

$M = 10^5\, k\,(M_p + M_g + M_b)$ N-cm (kgf-cm, lbf-in)

where

K = 1.0 (1.0, 0.269)

M_p = bending moment due to reactions from topside structure

= $\left|(M_v + M_m) f_t\right|$

M_v = $\ell_t \sum_n P_n (k_{1n} + k_{2n})$

M_m = $\sum_n M_n (k_{3n} + k_{4n})$

P_n = reaction deck force number n, in kN (tf, Ltf), applied to the deck transverse in tank under consideration, see 5A-3-3/Figure 8

M_n = reaction deck moment number n, in kN-m (tf-m, Ltf-ft), applied to the deck transverse in tank under consideration, see 5A-3-3/Figure 8

n = 1, 2,….., N_v to obtain bending moment M_v

= 1, 2,….., N_m to obtain bending moment M_m

N_v = total number of reaction forces at deck transverse under consideration, (in tank under consideration)

N_m = total number of reaction moments at deck transverse under consideration, (in tank under consideration)

ℓ_t = span of the deck transverse under consideration, in m (ft), as defined in 5A-3-3/Figure 2A

k_{1n} = $(1 - \bar{a}_n)^2 [\bar{a}_n - \bar{z}\,(1 + 2\bar{a}_n)]$

k_{2n} = 0 if $\bar{z} \le \bar{a}_n$

= $(\bar{z} - \bar{a}_n)$ if $\bar{z} > \bar{a}_n$

k_{3n} = $(1 - \bar{a}_n)(3\bar{a}_n - 1 - 6\bar{a}_n \bar{z})$

k_{4n} = 0 if $\bar{z} \le \bar{a}_n$

= 1 if $\bar{z} > \bar{a}_n$

$\bar{a}_n$ = a_n/ℓ_t

$\bar{z}$ = z/ℓ_t, $(0 \le \bar{z} \le 1)$

a_n = distance, in m (ft), from a point of application of reaction (force P_n or moment M_n) to the end of the deck transverse span ℓ_t, in m (ft), as shown in 5A-3-3/Figure 8

z = coordinate (measured from the end of the span ℓ_t) of the section of the deck transverse under consideration, in m (ft), as shown in 5A-3-3/Figure 8

For the toe of the deck transverse end brackets $\bar{z} = h_a/\ell_t$ and $\bar{z} = 1 - h_a/\ell_t$.

h_a = distance, in m(ft), from the end of the span to the toe of the end bracket of the deck transverse, as shown in 5A-3-3/Figure 9 of these Rules.

Note: For a wide topside bracket, the vertical load on a deck transverse can be considered uniformly distributed with pressure $q_n = P_n/c$, and the concentrated bending moment can be substituted by force couples.

$$P_m = M_n/(k\,c)$$

where

P_n, M_n = concentrated force and moment obtained from FE analysis of topside structure

c = width of the topside bracket

k = shape bracket factor, and may be taken as 0.8, unless otherwise specified

Bending moment at the toe of the end brackets due to green water pressure, M_g:

$$M_g = 0.1\,c_3\,\varphi\,P_{gi}\,s\,\ell_t^2$$

where

P_{gi} = nominal green water pressure imposed on the deck, in kN/m^2 (tf/m^2, Ltf/ft^2), as defined in 5A-3-2/13.8 of these Rules

s = spacing, in m (ft), of the deck transverses

c_3 = 0.83 for tanks without deck girders

= $1.1c_1$ for tanks with deck girders

φ = $1 - [5(h_a/\alpha\ell_t)]$, for cargo tanks with deck girders, 0.6 minimum

= $1 - 5(h_a/\ell_t)$, for cargo tanks without deck girders, 0.6 minimum

h_a = distance, in m (ft), from the end of the span to the toe of the end bracket of the deck transverse, as indicated in 5A-3-3/Figure 9

ℓ_t = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A, but is not to be taken as less than 60% of the breadth of the tank, except for ship-type vessels with a non-tight centerline bulkhead (5A-3-3/Figure 2A-b), for which the span is not to be taken as less than 30% of the breadth of the tank.

c_1 for tanks without deck girders:

= 0.30 for 5A-3-3/Figure 2A-c with non-tight centerline bulkhead

= 0.42 for all other cases

c_1 for tanks with deck girders:

= $0.30\alpha^2$ for 5A-3-3/Figure 2A-b with a non-tight centerline bulkhead, 0.05 min. and 0.30 max.

= $0.42\alpha^2$ for 5A-3-3/Figure 2A-a or 5A-3-3/Figure 2A-b with an oil-tight centerline bulkhead, 0.05 min. and 0.42 max.

α = $(\ell_g/\ell_t)[(s_g/s)(I_t/I_g)]^{1/4}$

ℓ_g = span of the deck girder, in m (ft), as indicated in 5A-3-3/Figure 2B-c of these Rules

I_g, I_t = moments of inertia, in cm^4 (in^4), of the deck girder and deck transverse with effective deck plating, clear of the end brackets, respectively

s_g = spacing of the deck girder, in m (ft) as shown in 5A-3-3/Figure 2A

s = spacing of the deck transverses, in m (ft)

When calculating α, if more than one deck girder is fitted, average values of s_g, ℓ_g and I_g are to be used when the girders are not identical.

Bending moments due to pressure on side transverse and vertical web of longitudinal bulkhead:

$$M_s = k_s \beta_s c_2 p_s s \ell_s^2$$

$$M_b = k_b \beta_b c_2 p_b s \ell_b^2$$

where k_s = 0.1, and k_b = 0.1, unless otherwise specified.

ℓ_s, ℓ_b = spans, in m (ft), of side transverse and vertical web on longitudinal bulkhead, respectively, as indicated in 5A-3-3/Figure 2A. Where a cross tie is fitted and is located at a distance greater than $0.7\ell_s$ or $0.7\ell_b$ from the deck transverse, the effective span of the side transverse or the vertical web may be taken as that measured from the deck transverse to the cross tie and all coefficients determined as if there were no cross tie.

p_s = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of side transverse when wing tank is empty, adjacent tanks full (5A-3-6/Table 1, item 4)

p_b = nominal internal cargo pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-span of the vertical web on longitudinal bulkhead when center tank is empty, adjacent tanks full (5A-3-2/Table 3, item 13)

β_s = $0.9[(\ell_s/\ell_t)(I_t/I_s)]$, 0.10 min. and 0.65 max.

β_b = $0.9[(\ell_b/\ell_t)(I_t/I_b)]$, 0.10 min. and 0.50 max.

I_s, I_b = moments of inertia, in cm^4 (in^4), clear of the brackets, of side transverse and vertical web on longitudinal bulkhead, respectively

c_2 are given in 5A-3-6/Table 4 of these Rules.

f_t = 1 for tanks without deck girders

f_t = $1 - [0.67/(1 + 2\delta)]$ is not to be taken less than 0.70 for tanks with deck girders

δ = $(\ell_g/\ell_t)^3 (I_t/I_g)$

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70 S_m f_y$

S_m and f_y as defined in 5A-3-3/7.3.1 of these Rules.

3.8.2 Web Sectional Area of Deck Transverse

In addition to satisfying the net web sectional area requirements of 5A-3-3/3.7.2, the net sectional area of the web portion of the deck transverse, that is loaded with reactions (forces and moments) from the topside structure, is to be obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

where

F = $1000\,k\,(F_p + F_g + c_2\,s\,D\,B_c)$, in N (kgf, lbf)

F_p = $\left|(F_v + F_m)f_1\right|$

F_v = $\sum_n \left[P_n(1-\overline{a}_n)^2(2\overline{a}_n + 1) + \Delta F\right]$

F_m = $6\sum_n \overline{a}_n(1-\overline{a}_n)M_n/\ell_t$

F_g = $c_1\,p_{gi}\,s\,(0.50\ell - h_e)$

k = 1.0 (1.0, 2.24)

ΔF = 0 if $\overline{z} \le \overline{a}_n$

= $-P_n$ if $\overline{z} > \overline{a}_n$

f_1 = $1 - [0.5/(1 + 4\delta)]$

c_1 = 1.30 for tanks without deck girder

= $0.90\alpha^{1/2}$ for tanks with deck girder, min. 0.50 and max. 1.0

c_2 = 0 for center tank

= 0.045 for wing tank

ℓ = span of the deck transverse, in m (ft), as indicated in 5A-3-3/Figure 2A of these Rules

h_e = length of the bracket, in m(ft), as indicated in 5A-3-3/Figures 2A and 2B and 5A-3-3/Figure 9 of these Rules

D = depth of a vessel, in m (ft), as defined in 3-1-1/7 of the *Steel Vessel Rules*

B_c = breadth of the center tank, in m (ft)

f_s = permissible shear stress

= $0.45\,S_m f_y$, in N/cm^2 (kgf/cm^2, lbf/in^2)

P_n, M_n, p_{gi}, ℓ_t, s, $\overline{a}_n$, $\overline{z}$, α, δ, S_m and f_y are as defined in 5A-3-6/3.8.1, above.

3.9 Longitudinal Bulkhead Vertical Webs

3.9.1 Section Modulus of Vertical Web on Longitudinal Bulkhead *(1 July 2012)*

The net section modulus of the vertical web, in association with the effective longitudinal bulkhead plating, is to be not less than obtained from the following equation (see also 5A-3-3/1.3):

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps\,\ell_b^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

ℓ_b = span of vertical web, in m (ft), as indicated in 5A-3-6/Figure 1. Where both lower and upper ends of the vertical web are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b may be taken between the toes of the effective lower and upper brackets.

s = spacing of vertical webs, in m (ft)

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2) at mid-span ℓ_b of the vertical web, as specified in 5A-3-2/Table 3

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\, S_m f_y$

c is given in 5A-3-6/Table 5.

S_m and f_y are as given in 5A-3-3/7.3.1.

For ship-type installations without cross ties, the section modulus of the vertical web, as required above, is to extend at least up to 0.6ℓ from the lower end of the span. The value of the bending moment M, used for the calculation of the required section modulus of the remaining part of vertical web, may be reduced, but not more than 20%.

In the case of one cross tie, the section modulus of the lower (upper) vertical web, as required above, is to extend to the cross tie.

In the case of two cross ties, the section modulus of lower (upper) vertical web, as required above, is to extend to the lower (upper) cross tie and may be linearly interpolated between cross ties.

TABLE 5
Coefficient c for Vertical Web on Longitudinal Bulkhead

Arrangement of Cross Ties	*For Upper Vertical Web*	*For Lower Vertical Web*
No Cross Tie	0.75	
One Cross Tie in Wing Tank	0.19	0.33
Two Cross Ties in Wing Tank	0.13	0.20

3.9.2 Web Sectional Area of Vertical Web on Longitudinal Bulkhead

The net sectional area of the web portion of the vertical web is not to be less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

The shear force, F, in N (kgf, lbf), for the vertical web can be obtained from the following equation (see also 5A-3-3/1.3):

F = $1000ks[K_U\ell(P_U + P_L) - h_U P_U]$ for upper part of web

= $1000ks[K_L\ell(P_U + P_L) - h_L P_L]$ or

= $350ksK_L\ell(P_U + P_L)$, whichever is greater, for lower part of web

In no case is the shear force for the lower part of the web to be less than 120% of that for the upper part of the vertical web.

where

k = 1.0 (1.0, 2.24)

ℓ = span of the vertical web, in m (ft), as indicated in 5A-3-3/Figure 2B-a

s = spacing of the vertical webs, in m (ft)

P_U = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of upper bracket (h_U/2), as specified in 5A-3-2/Table 3

P_L = nominal pressure, p, in kN/m^2 (tf/m^2, Ltf/ft^2), at the mid-length of the lower bracket (h_L /2), as specified in 5A-3-2/Table 3

h_U = length of the upper bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-a

h_L = length of the lower bracket, in m (ft), as indicated in 5A-3-3/Figure 2B-a

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\ S_m f_y$

K_U and K_L are given in 5A-3-6/Table 6.

S_m and f_y are as defined in 5A-3-3/7.3.1.

For ship-type installations without cross ties, the sectional area of lower vertical webs, as required above, is to extend up to 0.15ℓ from the toe of the lower bracket or 0.3ℓ from the lower end of the span, whichever is greater.

In the case of one cross tie, the sectional area of the lower (upper) vertical web, as required above, is to extend to the cross tie.

In the case of two cross ties, the sectional area of the lower (upper) vertical web, as required above, is to extend to the lower (upper) cross tie and may be linearly interpolated between the cross ties.

TABLE 6
Coefficients K_U and K_L for Vertical Web on Longitudinal Bulkhead

Arrangement of Cross Ties	K_U	K_L
No Cross Tie	0.16	0.30
One Cross Tie in Wing Tank	0.09	0.21
Two Cross Ties in Wing Tank	0.075	0.16

3.10 Horizontal Girder on Transverse Bulkhead *(1 July 2012)*

3.10.1 Section Modulus of Horizontal Girder on Transverse Bulkhead

The net section modulus of the horizontal girder is to be not less than obtained from the following equation (see also 5A-3-3/1.3).

$SM = M/f_b$ cm^3 (in^3)

$M = 10{,}000kcps\,\ell_b^2$ N-cm (kgf-cm, lbf-in)

where

k = 1.0 (1.0, 0.269)

ℓ_b = span of the horizontal girders, in m (ft), as indicated in 5A-3-6/Figure 1. Where both ends of the horizontal girder are fitted with a bracket of the same or larger size on the opposite side, the span ℓ_b may be taken between the toes of the effective brackets.

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

p = nominal pressure, in kN/m^2 (tf/m^2, Ltf/ft^2), calculated at the mid-span of the horizontal girder under consideration, as specified in 5A-3-2/Table 3

f_b = permissible bending stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.70\, S_m f_y$

S_m and f_y, as defined in 5A-3-3/7.3.1.

c = 0.83 in wing tanks of vessels for transverse bulkhead without vertical webs

= 0.63 in center tanks of vessels for transverse bulkhead without vertical webs

= $0.73\alpha^2$ for $\alpha < 0.5$ in center tanks of vessels for transverse bulkhead with vertical webs

= $0.467\alpha^2 + 0.0657$ for $0.5 \leq \alpha \leq 1.0$ in center tanks of vessels for transverse bulkhead with vertical webs

= $0.1973\alpha + 0.3354$ for $\alpha > 1.0$ in center tanks of vessels for transverse bulkhead with vertical webs

c is not to be taken less than 0.013 and need not be greater than 0.73.

α = $0.9(\ell_{st}/\ell_b)[(I/I_v)(s_v/s)]^{1/4}$

if more than one vertical web is fitted on the bulkhead, average values of ℓ_{st}, s_v and I_v are to be used when these values are not the same for each web.

ℓ_{st} = span of the vertical web, in m (ft) (5A-3-6/Figure 1)

s_v = spacing of the vertical webs, in m (ft)

I, I_v = moments of inertia, in cm^4 (in^4), of the horizontal girder and the vertical web clear of the end brackets

3.10.2 Web Sectional Area of the Horizontal Girder on Transverse Bulkhead

The net sectional area of the web portion of the horizontal girder is to be not less than obtained from the following equation:

$A = F/f_s$ cm^2 (in^2)

$F = 1000\, kscp(0.5\ell - h_e)$ N (kgf, lbf)

where

k = 1.0 (1.0, 2.24)

c = 0.80 for transverse bulkheads without vertical webs

= $0.72\alpha^{1/2}$ in center tanks of vessels for transverse bulkheads with vertical webs for $\alpha \geq 0.70$

= $0.452\alpha^{1/2}$ in center tanks of vessels for transverse bulkheads with vertical webs for $\alpha \geq 0.70$ if depth of centerline vertical web is the same or larger than that of horizontal girder under consideration

= $0.887\alpha - 0.02$ in center tanks of vessel for transverse bulkheads with vertical webs for $\alpha < 0.7$, min. 0.1 and max. 0.8

= $0.554\alpha - 0.02$ in center tanks of vessel for transverse bulkheads with vertical webs for $\alpha < 0.7$, min. 0.1 and max. 0.8 if depth of centerline vertical web is the same or larger than that of horizontal girder under consideration

ℓ = distance, in m (ft), between longitudinal bulkheads, as indicated in 5A-3-6/Figure 1

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

h_e = length of the bracket, in m (ft), as indicated in 5A-3-6/Figure 1

p and α are as defined in 5A-3-6/3.10.1.

f_s = permissible shear stress, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $0.45\, S_m f_y$

S_m and f_y are as defined in 5A-3-3/7.3.1.

The equations in 5A-3-6/3.10.1 and 5A-3-6/3.10.2 are not applicable to horizontal girders in wing cargo tanks of vessels where vertical webs exist. In that case, the load effects may be determined from 3D structural analysis as specified in 5A-3-3/1.3.

3.11 Other Main Supporting Members *(1 July 2012)*

The strength and stiffness requirements specified in 5A-3-3/11 and 5A-3-3/15 for deck girders, vertical webs on transverse bulkheads and cross ties are applicable to single hull ship-type installations.

3.13 Proportions

The following minimum requirements for web depth are supplemental to those given in 5A-3-3/11.11.

20% for bottom transverses without bottom girder

14% for bottom transverses with one girder

8% for bottom transverses with three girders

20% for bottom girders

12.5% for side transverses

5 Strength Assessment

5.1 General

The failure criteria and strength assessment procedures specified in Section 5A-3-4 are generally applicable to single hull ship-type installations, except for the special considerations outlined in 5A-3-6/5.3 below.

5.3 Special Considerations

For assessing buckling and fatigue strength in accordance with 5A-3-4/5 and 5A-3-4/9, due consideration is to be given to the buckling characteristics of large stiffened panels of the side shell and bottom structures, as well as the realistic boundary conditions of side and bottom longitudinals at transverse bulkheads for calculating the total stress range with respect to fatigue strength.

PART

5A

CHAPTER 3 Structural Design Requirements

APPENDIX 1 Determination of Environmental Severity Factors *(December 2008)*

1 General *(1 July 2012)*

This Appendix provides information for the determination of ESFs for ship-type installation design criteria to account for site-specific conditions compared to unrestricted service conditions.

The formulations from Part 5A, Chapter 1 and Section 5A-3-2 are modified to reflect the incorporation of various ESF β-types. In the modified formulations, the ESF (β) factors are applied to the dynamic load parameters in the load components.

The general concept of ESF α-types is to compare fatigue damage resulting from different environmental conditions. This type of ESF has two applications. First, it can be used to adjust the fatigue damage induced by the wave-induced dynamic loads at the installation site. Second, it can be used to assess the fatigue damage accumulated during previous services as either a trading vessel or an existing ship-type installation. The α-type ESFs are obtained at different locations for longitudinal stiffeners of the hull structure.

ESF (α) factors are applied to longitudinal stiffener members in the ISE fatigue analysis. ESF (β) factors are applied to the dynamic load components of the load formulations in the ISE strength analysis and the TSA strength and fatigue analysis.

3 ESFs of the Beta (β) Type *(1 July 2012)*

This type of ESF is used to introduce a comparison of the severity between the intended environment and a base environment, which is the North Atlantic unrestricted service environment.

A presentation of formulations that are modified to reflect the incorporation of the various β ESFs is given in Section 5A-3-2. In the modified formulations, the β factors apply only to the dynamic portions of the load components, and the load components that are considered "static" are not affected by the introduction of the β factors.

The definition of the severity measure β is as follows:

$$\beta = \frac{Ls}{Lu}$$

where

Ls = most probable extreme value based on the intended site (100 years return period), transit (10 years return period), repair/inspection (1 year return period) and fatigue (20 years return period) environments for the dynamic load parameters specified in 5A-3-A1/Table 1

Lu = most probable extreme value base on the North Atlantic environment for the dynamic load parameters specified in 5A-3-A1/Table 1

A β of 1.0 corresponds to the unrestricted service condition of a seagoing vessel. A value of β less than 1.0 indicates a less severe environment than the unrestricted case.

Extreme value analysis is to be performed for each dynamic load component to determine maximum value during the design life. Preference is given to an Extreme Value method that follows the so-called long-term approach commonly used for ship structure. However, the use of a validated short-term extreme value approach, which is appropriate to the installation type and installation site's environmental data, will also be considered. The supplementary use of such a short-term approach to confirm or validate the sensitivity of the long-term based design values is encouraged. The result of the short-term approach cannot be used to reduce the long-term extreme value. If the short-term result is significantly larger, the long-term extreme value is to be further studied and validated. The environments specified for use in the short-term approach are "response based", i.e., a 100-year design storm event is one that leads to the maximum responses expected to occur in 100-years. The return period is typically required to 10 years for transit condition, and 1 year for repair and inspection conditions.

There are 13 dynamic load components in the ABS Rules for which the β adjustment factors have been derived. These are for the following dynamic loads or load effects:

TABLE 1
The 13 Dynamic Load Parameters or ESFs (β_{NN}) *(December 2008)*

No.	*NN*	*Name*
1	VBM	Vertical Bending Moment
2	HBM	Horizontal Bending Moment
3	EPP	External Pressure Port
4	EPS	External Pressure Starboard
5	VAC	Vertical Acceleration
6	TAC	Transverse Acceleration
7	LAC	Longitudinal Acceleration
8	PMO	Pitch Motion
9	RMO	Roll Motion
10	RVM	Relative Vertical Motion at Forepeak
11	WHT	Wave Height
12	VSF	Vertical Shear Force
13	HSF	Horizontal Shear Force

As mentioned, the β values are a direct function of the long-term environmentally-induced loads at the installation site compared to the unrestricted service environment that is the basis of the Rules. The β values also need to address other differences and factors between the design basis of a sea going and a moored installation/transit/repair/inspection. These include:

i) Different design basis return periods for environmental loads (20 for unrestricted seagoing vs. 100 years for intended site, 10 years for transit and 1 year for repair/inspection condition).

ii) Effects of mooring system on predicted installation load effects (including weathervaning type behavior of a turret moored system).

iii) Different assumed wave energy spreading characterization between the open ocean and a site-specific situation.

iv) Different basis of extreme design storm characterization (i.e., long-term winter storm vs. hurricane dominated characterization).

v) Relative nearness of natural periods of global system response to significant environmentally-induced loadings at such periods (i.e., possible dynamic amplification effects).

If a direct analysis of a floating offshore installation were to be performed, the influences of the mentioned factors would need to be assessed and used in the installation's design. It is not the intention of the alternative approach offered here to discourage direct analysis, but it is expected that the approach based on the use of the ESFs will still be used as an important basis of structural design/assessment of a ship-type floating offshore installation.

Note: ABS intends to make computer software available to clients to help establish ESFs and a version of the ABS Eagle FPSO SEAS software that is modified to accommodate this concept. Clients are advised to contact ABS regarding the availability of this software.

Notwithstanding the listed β factors and their intended usage, it is still necessary to introduce a limit to prevent design parameters from being unrealistically low. This limit is that the result of an application of a β factor (e.g., in the calculation of a required scantling) is not to be less than 85 percent of the unrestricted service (Rule) value. The reasons for introducing this limit are to reflect successful service experience, a desire not to inadvertently create a reordering of the dominant structural failure modes, and to avoid the introduction of new controlling limit states (unacceptable deflections, vibrations, etc.).

It has also been necessary to introduce additional load cases or situations that reflect the relatively greater importance these cases may have for floating offshore installations with possibly reduced scantlings due to the calmer site conditions. Examples of these additional conditions are the more rigorous check of the tank test loading condition, inspection and repair conditions, and the hull strength assessment for the transit to site condition.

5 ESFs of the Alpha (α) Type *(1 July 2009)*

This type of ESF compares the fatigue damage between the specified environment and a base environment, which is the North Atlantic environment.

First, this type of ESF is used to adjust the expected fatigue damage induced from the dynamic components due to environmental loadings at the installation's site. Second it can be used to assess the fatigue damage accumulated during the historical service either as a trading vessel or as an FPI, including both the historical site(s) and historical transit routes.

The definition of the severity measure α is as follows:

$$\alpha = \left(\frac{Du}{Ds}\right)^C$$

where

Du = annual fatigue damage based on the North Atlantic environment (unrestricted service) at the details of the hull structure

Ds = annual fatigue damage based on a specified environment, for historical routes, historical sites, transit and intended site, at the details of the hull structure

C = 0.65

For fatigue damage calculation, a closed form spectral-based fatigue analysis procedure can be used. The fundamental task of a spectral fatigue analysis is the determination of the stress transfer function, which express the relationship between the stress at a particular structural location per unit wave amplitude and wave frequency and heading. The stress transfer function needs to be determined from the load transfer function and its corresponding stress factor, which is a conversion factor to obtain the stress transfer function from the load transfer function. The load transfer function, which depends on hull form geometry, is to be calculated for regular waves of unit amplitude for ranges of wave frequencies and wave heading. The stress factor can be obtained through structural analysis techniques, which can be either a simple beam theory or finite element analysis procedures. The sophistication of the structural analysis needed depends on the physical system to be analyzed, the type of structural detail and the type of structural loading considered. For the longitudinal stiffener, the stress factors may be calculated by the simple beam theory.

The response spectra of the stress transfer functions can be determined by given wave spectra. In the 'short-term closed form' approach, the stress range is normally expressed in terms of probability density functions for different short-term sea states. These short-term probability density functions are derived by a spectral approach based on the Rayleigh distribution method whereby it is assumed that the variation of stress is a narrow banded random Gaussian process. When a narrow banded assumption is not valid for the stress process, a damage correction factor, e.g. Wirsching's *"rainflow correction"* factor, is applied in the calculation of the short-term fatigue damage. Having calculated the short-term damage, the total fatigue damage is calculated through their weighted linear summation (using Miner's rule). More detailed mathematical representations of the steps of the fatigue damage calculation can be found in the ABS *Guide for the Fatigue Assessment of Offshore Structures*.

The α type ESFs are obtained for details of the hull structure, where these details follow those defined for ship-type installation hull structure in Part 5A, Chapter 3.

An α of 1.0 corresponds to the unrestricted condition of a seagoing vessel. A value of α greater than 1.0 indicates a less fatigue-inducing environment than the unrestricted case.

PART

5A

CHAPTER 3 Structural Design Requirements

APPENDIX 2 Fatigue Strength Assessment of Ship-Type Installations *(2013)*

1 General

1.1 Note

This Appendix provides a designer-oriented approach to fatigue strength assessment which may be used for certain structural details in lieu of more elaborate methods such as spectral fatigue analysis. The term "assessment" is used here to distinguish this approach from the more elaborate analysis.

The criteria in this Appendix are developed from various sources, including the Palmgren-Miner linear damage model, S-N curve methodologies, a long-term environment data of the North-Atlantic Ocean (Walden's Data), etc., and assume workmanship of commercial marine quality acceptable to the Surveyor. The capacity of structures to resist the fatigue is given in terms of fatigue damage to allow designers the maximum flexibility possible.

1.3 Applicability *(1995)*

The criteria in this Appendix are specifically written for ship-type installations to which Part 5A, Chapter 3 is applicable.

1.5 Loadings *(1995)*

The criteria have been written for ordinary wave-induced motions and loads. Other cyclic loadings, which may result in significant levels of stress ranges over the expected lifetime of the installation, are also to be considered by the designer.

1.7 Effects of Corrosion *(1995)*

To account for the mean wastage throughout the service life, the total stress range calculated using the net scantlings (i.e., deducting nominal design corrosion values, see 5A-3-1/Table 1) is modified by a factor C_f (see 5A-3-A2/9.1.1).

1.9 Format of the Criteria *(December 2008)*

The criteria are presented as a comparison of fatigue strength of the structure (capacity) and fatigue inducing loads (demands), in the form of a fatigue damage parameter, *DM*. The calculated fatigue damage, *DM*, is to be less than or equal to 1 for the design life of the installation, which corresponds to a fatigue life of 20 years.

3 Connections to be Considered for the Fatigue Strength Assessment

3.1 General *(1995)*

These criteria have been developed to allow consideration of a broad variation of structural details and arrangements, so that most of the important structural details in the installation can be subjected to an explicit (numerical) fatigue assessment using these criteria. However, where justified by comparison with details proven satisfactory under equal or more severe conditions, an explicit assessment can be exempted.

3.3 Guidance on Locations *(1995)*

As a general guidance for assessing fatigue strength for a ship-type installation, the following connections and locations are to be considered:

3.3.1 Connections of Longitudinal Stiffeners to Transverse Web/Floor and to Transverse Bulkhead

3.3.1(a) Two (2) to three (3) selected side longitudinals in the region from the 1.1 draft to about $^1/_3$ draft in the midship region and also in the region between 0.15L and 0.25L from F.P., respectively

3.3.1(b) One (1) to two (2) selected longitudinals from each of the following groups:

- Deck longitudinals, bottom longitudinals, inner bottom longitudinals and longitudinals on side longitudinal bulkheads
- One longitudinal on each of the longitudinal bulkheads within 0.1D from the deck is to be included

For these structural details, the fatigue assessment is to be first focused on the flange of the longitudinal at the rounded toe welds of attached flat bar stiffeners and brackets, as illustrated for Class F item 2) and Class F_2 item 1) in 5A-3-A2/Table 1.

Then, the critical spots on the web plate cut-out, on the lower end of the stiffener as well as the weld throat are also to be checked for the selected structural detail. For illustration, see 5A-3-A2/11.3.1 and 5A-3-A2/11.3.2(a), 5A-3-A2/11.3.2(b) and 5A-3-A2/11.3.2(c).

Where the longitudinal stiffener end bracket arrangements are different on opposing sides of a transverse web, both configurations are to be checked.

3.3.2 Shell, Bottom, Inner Bottom or Bulkhead Plating at Connections to Webs or Floors (for Fatigue Strength of Plating)

3.3.2(a) One (1) to two (2) selected locations of side shell plating near the summer LWL amidships and between 0.15L and 0.25L from F.P. respectively

3.3.2(b) One (1) to two (2) selected locations in way of bottom and inner bottom amidships

3.3.2(c) One (1) to two (2) selected locations of lower strakes of side longitudinal bulkhead amidships

3.3.3 Connections of the Slope Plate to Inner Bottom and Side Longitudinal Bulkhead Plating at the Lower Cargo Tank Corners

One selected location amidships at transverse web and between webs, respectively

For this structural detail, the value of f_R, the total stress range as specified in 5A-3-A2/9.1, is to be determined from fine mesh F.E.M. analyses for the combined load cases, as specified for Zone B in 5A-3-A2/7.5.2.

3.3.4 End Bracket Connections for Transverses and Girders

One (1) to two (2) selected locations in the midship region for each type of bracket configuration

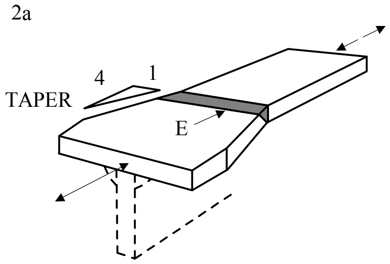
3.3.5 Other Regions and Locations

Other regions and locations, highly stressed by fluctuating loads, as identified from structural analysis.

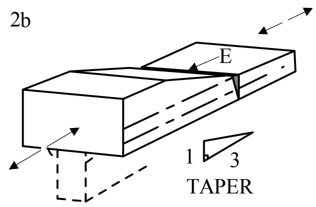
TABLE 1
Fatigue Classification for Structural Details *(December 2008)*

Class Designation	*Description*
B	Parent materials, plates or shapes as-rolled or drawn, with no flame-cut edges
C	1) Parent material with automatic flame-cut edges 2) Full penetration seam welds or longitudinal fillet welds made by an automatic submerged or open arc process, and with no stop-start positions within the length
D	1) Full penetration butt welds between plates of equal width and thickness made either manually or by an automatic process other than submerged arc, from both sides, in downhand position 2) Welds in C-2) with stop-start positions within the length
E	1) Full penetration butt welds made by other processes than those specified under D-1) 2) Full penetration butt welds made from both sides between plates of unequal widths machined to a smooth transition with a slope not more than 1 in 4. Plates of different thickness are to be likewise machined with a slope not more than 1 in 3, unless a transition within the weld bead is approved.

2a



2b



3) Welds of brackets and stiffeners to web plate of girders

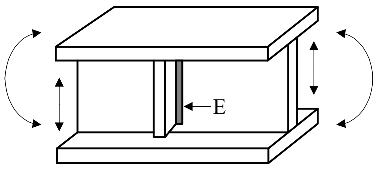
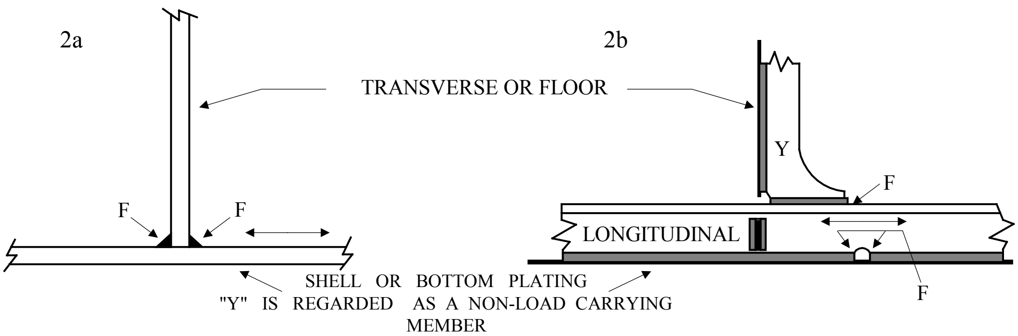
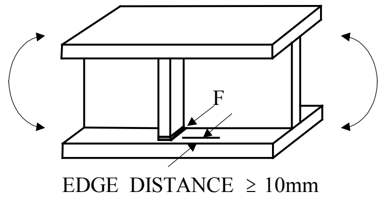


TABLE 1 (continued)
Fatigue Classification for Structural Details *(December 2008)*

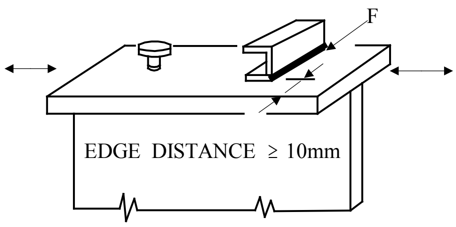
Class Designation	*Description*
F	1) Full penetration butt welds made on a permanent backing strip between plates of equal width/thickness or between plates of unequal width/thickness, as specified in E-2.
	2) Rounded fillet welds as shown below



3) Welds of brackets and stiffeners to flanges



4) Attachments on plate or face plate

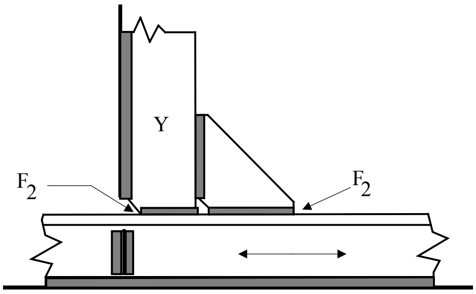


(Class G for edge distance < 10 mm)

TABLE 1 (continued)
Fatigue Classification for Structural Details *(December 2008)*

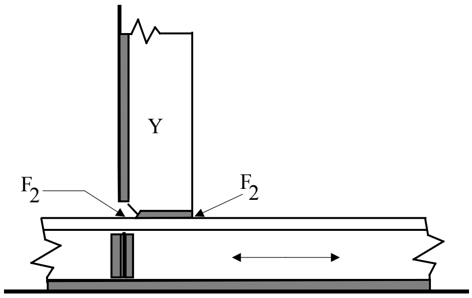
Class Designation	*Description*
F_2	1) Fillet welds as shown below with rounded welds and no undercutting

1a

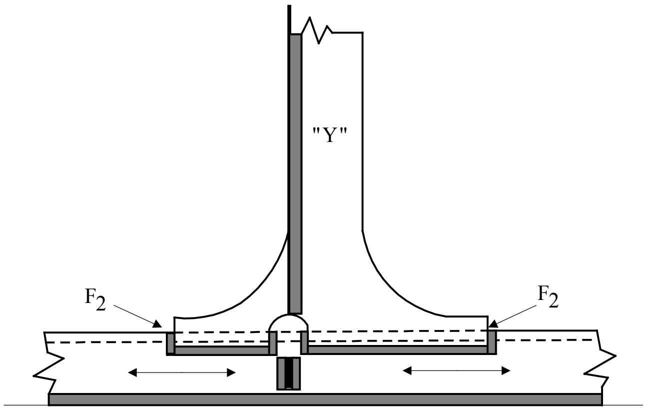


"Y" is a non-load carrying member

1b

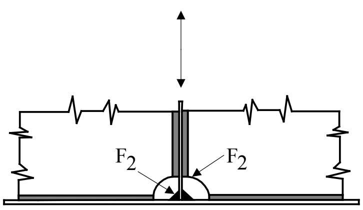


2) Overlapped joints with soft-toe brackets as shown below



3) Fillet welds with any undercutting at the corners dressed out by local grinding

3a



3b

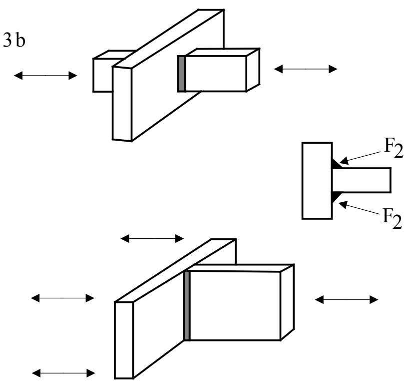
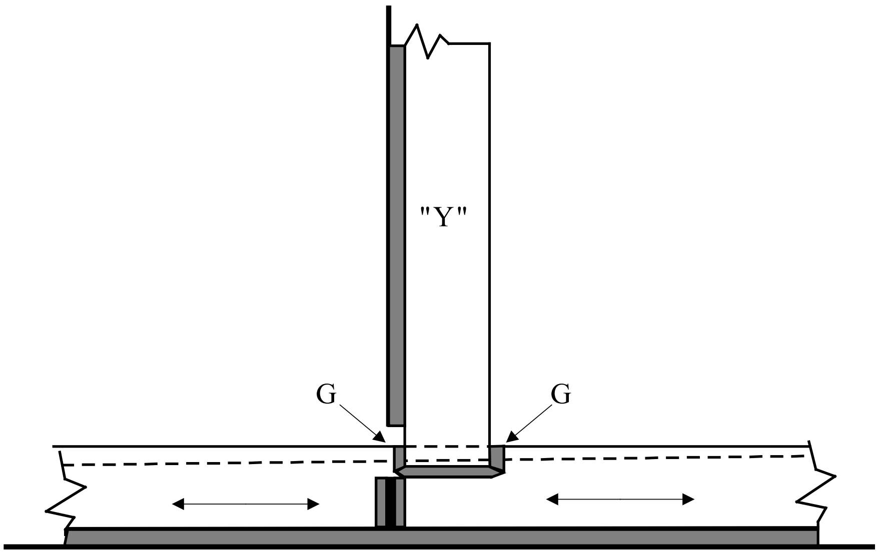


TABLE 1 (continued)
Fatigue Classification for Structural Details *(December 2008)*

Class Designation	*Description*
G	1) Fillet welds in F_2 – 1) without rounded toe welds or with limited minor undercutting at corners or bracket toes 2) Overlapped joints as shown below



3) Fillet welds in F_2 – 3) with minor undercutting

4) Doubler on face plate or flange

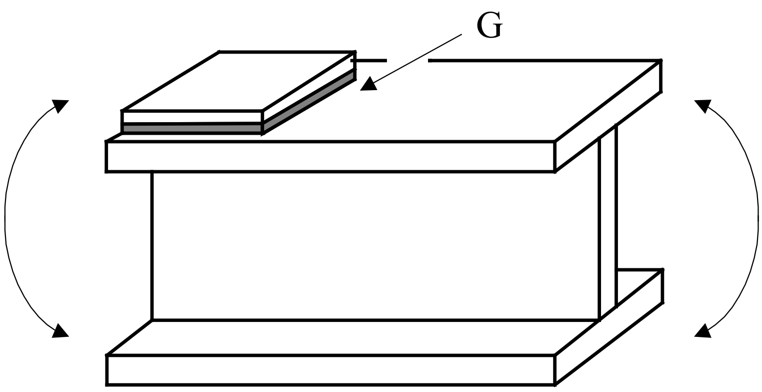
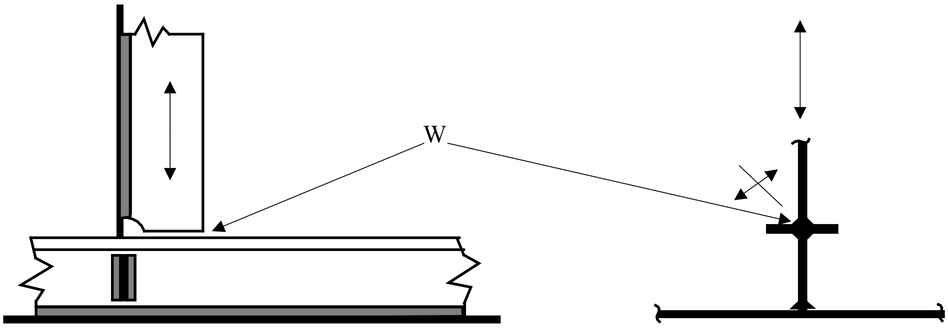


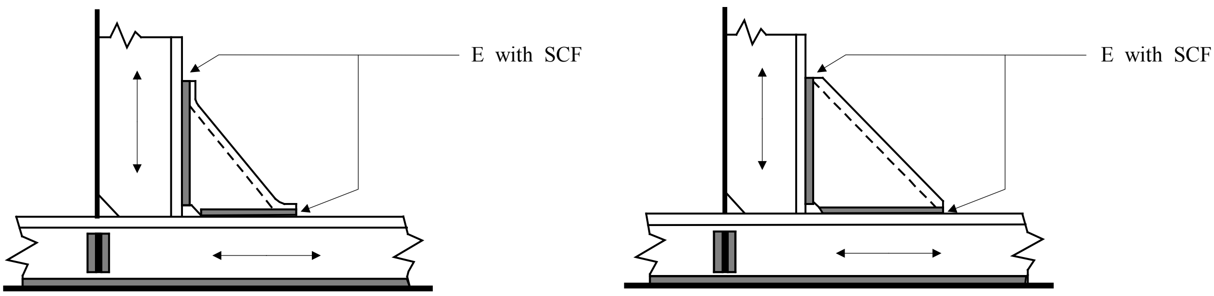
TABLE 1 (continued)
Fatigue Classification for Structural Details *(December 2008)*

Class Designation	*Description*
W	Fillet welds-weld throat



Notes:

1 For brackets connecting two or more load carrying members, an appropriate stress concentration factor (SCF) determined from fine mesh 3D or 2D finite element analysis is to be used. In this connection, the fatigue class at bracket toes may be upgraded to class E as shown below.



2 Additional information on stress concentration factors and the selection of compatible S-N data is given in 5A-3-A2/11.

5 Fatigue Strength Assessment

5.1 Assumptions *(1995)*

The fatigue strength of a structural detail under the loads specified here, in terms of fatigue damage, is to be evaluated using the criteria contained in this Subsection. The key assumptions employed are listed below for guidance.

- A linear cumulative damage model (i.e., Palmgren-Miner's Rule) has been used in connection with the S-N data in 5A-3-A2/Figure 1 (extracted from Ref. 1*).
- Cyclic stresses due to the loads in 5A-3-A2/7 have been used and the effects of mean stress have been ignored.
- The target life of the installation is taken at 20 years.
- The long-term stress ranges on a detail can be characterized using a modified long term stress distribution parameter (γ).
- Structural details are classified and described in 5A-3-A2/Table 1, "Fatigue Classification of Structural Details".
- Simple nominal stress (e.g., determined by P/A and M/SM) is the basis of fatigue assessment, rather than more localized peak stress in way of weld.

* Ref 1: "Offshore Installations: Guidance on Design, Construction and Certification", Department of Energy, U.K., Fourth Edition—1990, London: HMSO

The structural detail classification in 5A-3-A2/Table 1 is based on the joint geometry and the direction of the dominant load. Where the loading or geometry is too complex for a simple classification, a finite element analysis of the details is to be carried out to determine stress concentration factors. 5A-3-A2/13 contains guidance on finite element analysis modeling to determine stress concentration factors for weld toe locations that are typically found at longitudinal stiffener end connections.

5.3 Criteria *(December 2008)*

The criteria are presented as a comparison of fatigue strength of the structure (capacity), and fatigue inducing loads (demands), in the form of a fatigue damage parameter, *DM*. The calculated fatigue damage, *DM*, is to be less than or equal to 1 for the design life of the installation, which corresponds to a fatigue life of 20 years.

5.5 Long Term Stress Distribution Parameter, γ *(2002)*

In 5A-3-A2/Table 1, the permissible stress range is given as a function of the long-term distribution parameter, γ, as defined below.

$\gamma = 1.40 - 0.2\,\alpha L^{0.2}$ for $150 < L < 305$ m

$= 1.40 - 0.16\alpha L^{0.2}$ for $492 < L < 1000$ ft

$\gamma = 1.54 - 0.245\alpha^{0.8}L^{0.2}$ for $L > 305$ m

$= 1.54 - 0.19\alpha^{0.8}L^{0.2}$ for $L > 1000$ ft

where

α = 1.0 for deck structures, including side shell and longitudinal bulkhead structures within 0.1*D* from the deck

= 0.93 for bottom structures, including inner bottom and side shell, and longitudinal bulkhead structures within 0.1*D* from the bottom

= 0.86 for side shell and longitudinal bulkhead structures within the region of 0.25*D* upward and 0.3*D* downward from the mid-depth

= 0.80 for transverse bulkhead structures

α may be linearly interpolated for side shell and longitudinal bulkhead structures between $0.1D$ and $0.25D$ ($0.2D$) from the deck (bottom).

L and D are the installation's length and depth, as defined in 3-1-1/3.1 and 3-1-1/7 of the *Steel Vessel Rules*.

5.7 Cumulative Fatigue Damage *(1 July 2012)*

The content of this section is applicable to ship-type installations. For fatigue strength assessment for service as a trading vessel, refer to 5A-3-A2/21.1.

Unless otherwise specified, the resultant cumulative damage is to be taken as:

$$DM = 0.15DM_1 + 0.35DM_2 + 0.35DM_3 + 0.15DM_4$$

where

DM_i = cumulative fatigue damage ratio for the applicable loading condition i, where i =1 to 4, as specified in 5A-3-A2/Figure 2, including 8 loading cases, as shown in 5A-3-A2/Tables 2A through 2D

= $f_{i,1\text{-}2}DM_{i,1\text{-}2} + f_{i,3\text{-}4}DM_{i,3\text{-}4} + f_{i,5\text{-}6}DM_{i,5\text{-}6} + f_{i,7\text{-}8}DM_{i,7\text{-}8}$

$f_{i,j\text{-}k}$ = heading probability for loading condition i, to be based on submitted actual heading information.

In case the actual heading information is not available prior to application of these requirements, the following table of $f_{i,j\text{-}k}$ factors can be used.

$f_{i,j\text{-}k}$ **Factors** (1,2,3)

Loading Pair, j-k	*1-2*	*3-4*	*5-6*	*7-8*
Direction	*0*	*90*	*60*	*30*
A	0.40	0.10	0.20	0.30
B	0.60	0.00	0.10	0.30
C	1.00	0.00	0.00	0.00

Notes:

1 When an installation's mooring system type and arrangement, and heading orientation have not been determined prior to application of these requirements, cases A, B and C are to be investigated and more onerous results are to be used.

2 If an installation's mooring system type and arrangement have been determined, but the actual heading information is not available, case A and B are to be used for installations with spread mooring, or, installations with turrets located more than 25% of the installation length aft of the bow, or for locations with non-colinear wind, wave and current conditions regardless of the mooring system. More onerous results of these two cases are to be used.

3 If an installation's mooring system type and arrangement has been determined, but the actual heading information is not available, Case B and C are to be applied for installations with turrets located less than 25% of the installation length aft of the bow. More onerous results of these two cases are to be used.

Assuming the long term stress ranges fit a two-parameter long term stress distribution, the cumulative fatigue damage DM_i for each relevant condition is to be taken as:

$$DM_{i,j\text{-}k} = \frac{N_L}{K_2}\frac{(0.01 f_{Ri})^m}{(\ln N_R)^{m/\gamma}}\mu_i\Gamma\left(1+\frac{m}{\gamma}\right)$$

where

N_L = number of cycles for the expected design life. Unless stated otherwise, N_L to be taken as:

= $\dfrac{U}{4\log_{10} L}$

= The value is generally between 0.6×10^8 and 0.8×10^8 cycles for a design life of 20 years

U = design life, in seconds

= 6.31×10^8 for a design life of 20 years

L = rule length, in m

m = S-N curve parameter as defined in 5A-3-A2/Figure 1, Note a)

K_2 = S-N curve parameter as defined in 5A-3-A2/Figure 1, Note a)

f_{Ri} = stress range at the representative probability level of 10^{-4}, in N/cm^2

N_R = 10 000, number of cycles corresponding to the probability level of 10^{-4}

γ = long term stress distribution parameter, as defined in 5A-3-A2/5.5

Γ = Gamma function

μ_i = stress coefficient taking into account the change in slope of the S-N curve

$$= 1 - \frac{\left\{\Gamma_0\left(1+\frac{m}{\gamma}, v_i\right) - v_i^{-\frac{\Delta m}{\gamma}}\Gamma_0\left(1+\frac{m+\Delta m}{\gamma}, v_i\right)\right\}}{\Gamma\left(1+\frac{m}{\gamma}\right)}$$

$$v_i = \left(\frac{f_q}{0.01 f_{Ri}}\right)^{\gamma}\ln N_R$$

f_q = stress range at the intersection of the two segments of the S-N curve, see Table in 5A-3-A2/Figure 1, Note a), in N/mm^2

Δm = slope change of the upper-lower segment of the S-N curve

= 2

$\Gamma_0(a,x)$ = incomplete Gamma function, Legendre form

FIGURE 1
Basic Design S-N Curves *(1995)*

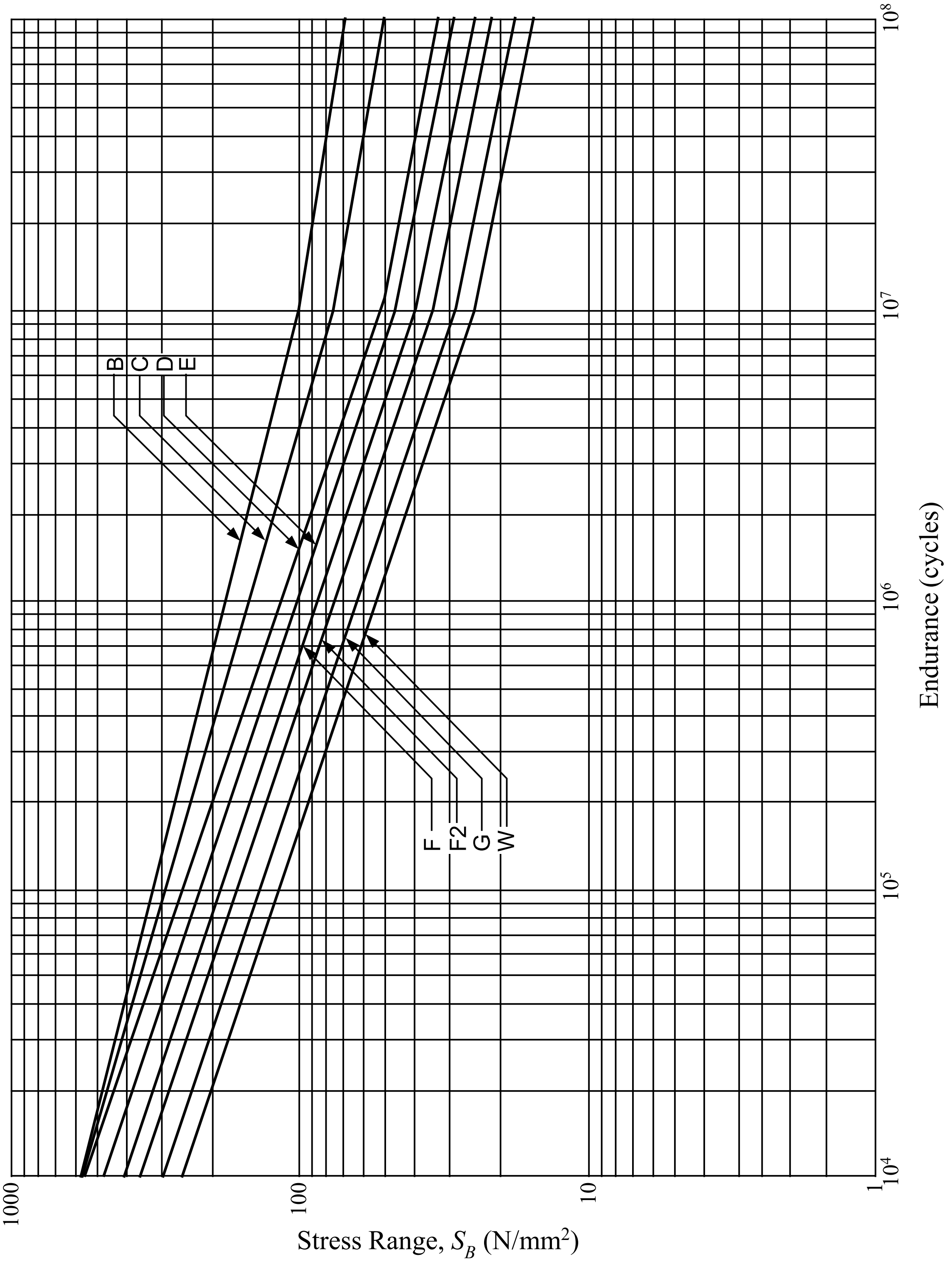


FIGURE 1 (continued)
Basic Design S-N Curves *(1995)*

Notes (For 5A-3-A2/Figure 1)

a) Basic design S-N curves

The basic design curves consist of linear relationships between $\log(S_B)$ and $\log(N)$. They are based upon a statistical analysis of appropriate experimental data and may be taken to represent two standard deviations below the mean line.

Thus the basic S-N curves are of the form:

$$\log(N) = \log(K_2) - m \log(S_B)$$

where

$$\log(K_2) = \log(K_1) - 2\sigma$$

N is the predicted number of cycles to failure under stress range S_B;

K_1 is a constant relating to the mean S-N curve;

σ is the standard deviation of $\log N$;

m is the inverse slope of the S-N curve.

The relevant values of these terms are shown in the table below.

The S-N curves have a change of inverse slope from m to $m + 2$ at $N = 10^7$ cycles.

Details of basic S-N curves (December 2008)

Class	K_1	K_1		m	*Standard deviation*		K_2	f_q N/mm^2
		$\log_{10}$	$\log_e$		$\log_{10}$	$\log_e$		
B	2.343×10^{15}	15.3697	35.3900	4.0	0.1821	0.4194	1.01×10^{15}	100.2
C	1.082×10^{14}	14.0342	32.3153	3.5	0.2041	0.4700	4.23×10^{13}	78.2
D	3.988×10^{12}	12.6007	29.0144	3.0	0.2095	0.4824	1.52×10^{12}	53.4
E	3.289×10^{12}	12.5169	28.8216	3.0	0.2509	0.5777	1.04×10^{12}	47.0
F	1.726×10^{12}	12.2370	28.1770	3.0	0.2183	0.5027	0.63×10^{12}	39.8
F$_2$	1.231×10^{12}	12.0900	27.8387	3.0	0.2279	0.5248	0.43×10^{12}	35.0
G	0.566×10^{12}	11.7525	27.0614	3.0	0.1793	0.4129	0.25×10^{12}	29.2
W	0.368×10^{12}	11.5662	26.6324	3.0	0.1846	0.4251	0.16×10^{12}	25.2

7 Fatigue Inducing Loads and Determination of Total Stress Ranges

7.1 General *(1995)*

This Subsection provides:

i) The criteria to define the individual load components considered to cause fatigue damage (see 5A-3-A2/7.3);

ii) The load combination cases to be considered for different regions of the hull containing the structural detail being evaluated (see 5A-3-A2/7.5); and

iii) Procedures to idealize the structural components to obtain the total stress range acting on the structure.

7.3 Wave-induced Loads – Load Components *(1995)*

The fatigue-inducing load components to be considered are those induced by the seaway. They are divided into the following three groups:

- Hull girder wave-induced bending moments (both vertical and horizontal), see 3-2-1/3.5 of the *Steel Vessel Rules* and 5A-3-2/5.1 of these Rules.
- External hydrodynamic pressures, and
- Internal tank loads (inertial liquid loads and added static head due to ship's motion).

7.5 Fatigue Assessment – Loading Conditions *(December 2008)*

The content in this Subsection is applicable to ship-type installations. For fatigue strength assessment for service as a trading vessel, refer to 5A-3-A2/21.3.

Four (4) loading conditions are considered in the calculation of stress range, as shown in 5A-3-A2/Figure 2. For each loading condition, eight (8) load cases, as shown in 5A-3-A2/Tables 2A through 2D, are defined to form four (4) pairs. The combinations of load cases are to be used to find the characteristic stress range corresponding to a probability of exceedance of 10^{-4}, as indicated below.

7.5.1 Standard Load Combination Cases

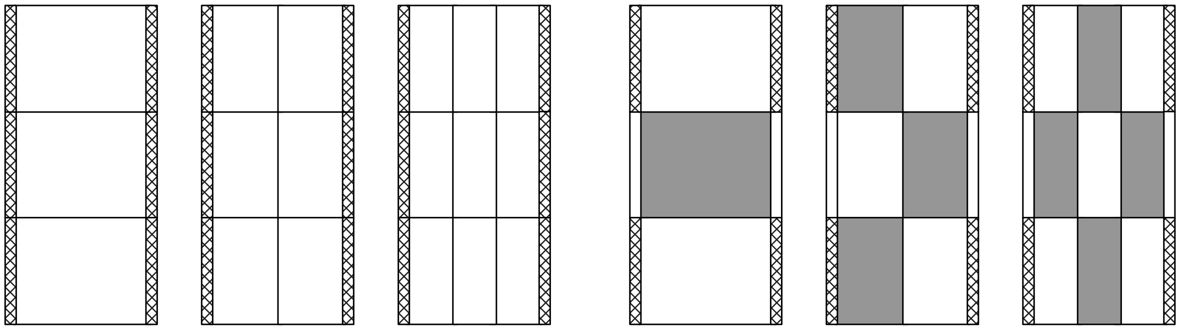
7.5.1(a) Calculate dynamic component of stresses for load cases FLC1 through FLC8, respectively, for each of the four loading conditions shown in 5A-3-A2/Figure 2.

7.5.1(b) Calculate four sets of stress ranges, one each for the following four pairs of combined loading cases: FLC1 and FLC2, FLC3 and FLC4, FLC5 and FLC6, and FLC7 and FLC8, for each of the four loading conditions shown in 5A-3-A2/Figure 2.

7.5.2 Installations with Either Special Loading Patterns or Special Structural Configuration

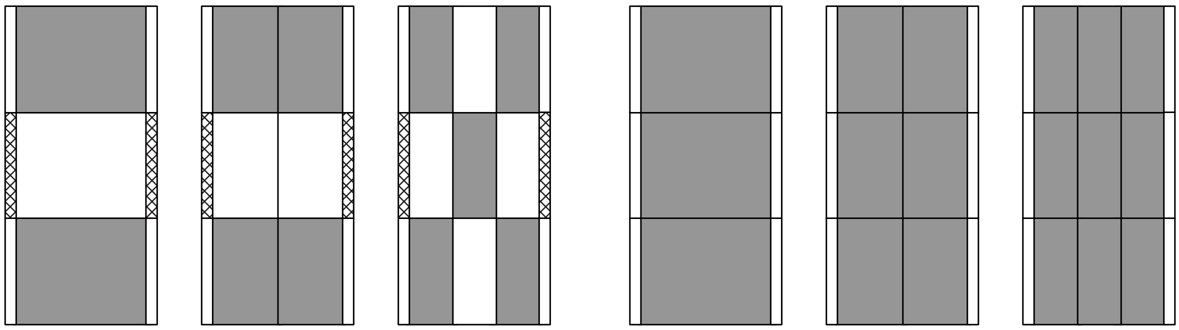
For installations with either special loading patterns or special structural configurations/features, additional load cases via appropriate probability may be required for determining the stress range.

FIGURE 2A
Loading Conditions for Fatigue Strength Assessment – Double Hull and Double Side Single Bottom FPSO/FSO *(1 July 2009)*



Loading Condition 1
0.4 * Scantling Draft (1)

Loading Condition 2
0.57 * Scantling Draft (2)



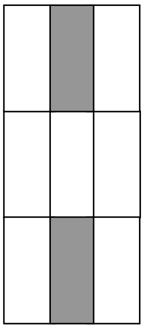
Loading Condition 3
0.73 * Scantling Draft (2)

Loading Condition 4
0.9 * Scantling Draft (3)

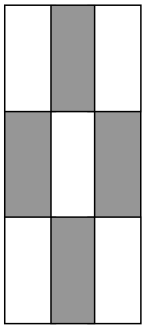
Notes:

1	Ballast condition draft –	if actual minimum on-site operating ballast draft is greater than 0.4 × scantling draft, actual draft can be used (but not to exceed 0.6 × scantling draft) This condition is also used for transit condition with actual transit draft between 0.1 × scantling draft and 0.6 × scantling draft
2	Intermediate drafts –	draft equally divided between Loading Conditions 1 and 4 drafts
3	Full load condition draft –	if actual maximum on-site operating full load draft is greater than 0.9 × scantling draft, actual draft can be used

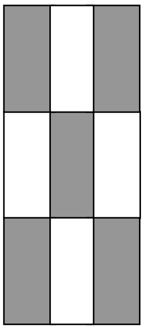
FIGURE 2B
Loading Conditions for Fatigue Strength Assessment – Single Hull FPSO/FSO
(1 July 2009)



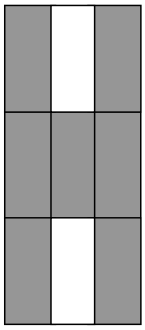
Loading Condition 1
0.4 * Scantling Draft (1)



Loading Condition 2
0.57 * Scantling Draft (2)



Loading Condition 3
0.73 * Scantling Draft (2)



Loading Condition 4
0.9 * Scantling Draft (3)

Notes:

1	Light draft condition –	if actual minimum on-site operating light draft condition is greater than 0.4 × scantling draft, actual draft can be used (but not to exceed 0.6 × scantling draft)
2	Intermediate drafts –	draft equally divided between Loading Conditions 1 and 4 drafts
3	Full load condition draft –	if actual maximum on-site operating full load draft is greater than 0.9 × scantling draft, actual draft can be used

TABLE 2A
Design Fatigue Load Cases for Fatigue Strength Assessment *(1 July 2009)*

(Load Combination Factors for Dynamic Load Components for Loading Condition 1)

	FLC1	*FLC2*	*FLC3*	*FLC4*	*FLC5*	*FLC6*	*FLC7*	*FLC8*
A. Hull Girder Loads								
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.30	0.30	0.75	0.75	0.70	0.70
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.60	0.60	0.30	0.30	0.55	0.55	0.10	0.10
Horizontal B.M.					(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.10	0.10	0.85	0.85	0.85	0.85
B. External Pressure								
k_c	0.80	0.80	1.00	1.00	0.70	0.70	0.45	0.45
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.40	0.40	1.00	1.00	0.75	0.75	0.40	0.40
w_v	0.40	-0.40	0.75	-0.75	0.10	-0.10	0.25	-0.25
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.50	Fwd Bhd -0.50	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.50	Aft Bhd 0.50	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -0.85	Port Bhd 0.85	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.05	Port Bhd 0.05
	—	—	Stbd Bhd 0.85	Stbd Bhd -0.85	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.05	Stbd Bhd -0.05
c_ϕ, Pitch	-0.15	0.15	-0.10	0.10	-0.30	0.30	-0.45	0.45
c_θ, Roll	0.00	0.00	1.00	-1.00	0.05	-0.05	0.05	-0.05
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes

1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 for M_{ws} and M_{wh})

2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 for M_h)

3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1 & FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.

4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM and Local Pressure Load Conditions.

TABLE 2B
Design Fatigue Load Cases for Fatigue Strength Assessment *(1 July 2009)*

(Load Combination Factors for Dynamic Load Components for Loading Condition 2)

	FLC1	*FLC2*	*FLC3*	*FLC4*	*FLC5*	*FLC6*	*FLC7*	*FLC8*
A. Hull Girder Loads								
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.25	0.25	0.95	0.95	0.75	0.75
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.55	0.55	0.15	0.15	0.70	0.70	0.25	0.25
Horizontal B.M.					(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.15	0.15	0.80	0.80	0.80	0.80
B. External Pressure								
k_c	0.85	0.85	0.90	0.90	0.90	0.90	0.55	0.55
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.55	0.55	0.70	0.70	0.20	0.20	0.40	0.40
w_v	0.60	-0.60	0.55	-0.55	0.15	-0.15	0.25	-0.25
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.45	Fwd Bhd -0.45	Fwd Bhd 0.75	Fwd Bhd -0.75
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.45	Aft Bhd 0.45	Aft Bhd -0.75	Aft Bhd 0.75
w_t	—	—	Port Bhd -0.95	Port Bhd 0.95	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.10	Port Bhd 0.10
	—	—	Stbd Bhd 0.95	Stbd Bhd -0.95	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.10	Stbd Bhd -0.10
c_ϕ, Pitch	-0.20	0.20	-0.05	0.05	-0.10	0.10	-0.35	0.35
c_θ, Roll	0.00	0.00	1.00	-1.00	0.05	-0.05	0.05	-0.05
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes

1. Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 for M_{ws} and M_{wh})
2. Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 for M_h)
3. For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1 & FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
4. For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM and Local Pressure Load Conditions.

TABLE 2C
Design Fatigue Load Cases for Fatigue Strength Assessment *(1 July 2009)*

(Load Combination Factors for Dynamic Load Components for Loading Condition 3)

	FLC1	*FLC2*	*FLC3*	*FLC4*	*FLC5*	*FLC6*	*FLC7*	*FLC8*
A. Hull Girder Loads								
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.25	0.25	0.90	0.90	0.70	0.70
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.55	0.55	0.10	0.10	0.65	0.65	0.30	0.30
Horizontal B.M.					(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.30	0.30	0.85	0.85	0.80	0.80
B. External Pressure								
k_c	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.75
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.55	0.55	0.75	0.75	0.10	0.10	0.40	0.40
w_v	0.55	-0.55	0.55	-0.55	0.15	-0.15	0.30	-0.30
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.40	Fwd Bhd -0.40	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.40	Aft Bhd 0.40	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -1.00	Port Bhd 1.00	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.15	Port Bhd 0.15
	—	—	Stbd Bhd 1.00	Stbd Bhd -1.00	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.15	Stbd Bhd -0.15
c_ϕ, Pitch	-0.15	0.15	-0.15	0.15	-0.20	0.20	-0.45	0.45
c_θ, Roll	0.00	0.00	1.00	-1.00	0.05	-0.05	0.10	-0.10
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes

1. Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 for M_{ws} and M_{wh})
2. Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 for M_h)
3. For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1 & FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
4. For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM and Local Pressure Load Conditions.

TABLE 2D
Design Fatigue Load Cases for Fatigue Strength Assessment *(1 July 2009)*

(Load Combination Factors for Dynamic Load Components for Loading Condition 4)

	FLC1	*FLC2*	*FLC3*	*FLC4*	*FLC5*	*FLC6*	*FLC7*	*FLC8*
A. Hull Girder Loads								
Vertical B.M.	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)	Sag (–)	Hog (+)
k_c	1.00	1.00	0.15	0.15	0.80	0.80	0.70	0.70
Vertical S.F.	(+)	(–)	(+)	(–)	(+)	(–)	(+)	(–)
k_c	0.55	0.55	0.20	0.20	0.50	0.50	0.40	0.40
Horizontal B.M.					(–)	(+)	(–)	(+)
k_c	0.00	0.00	0.25	0.25	1.00	1.00	1.00	1.00
Horizontal S.F.					(+)	(–)	(+)	(–)
k_c	0.00	0.00	0.25	0.25	0.85	0.85	0.80	0.80
B. External Pressure								
k_c	0.85	0.85	0.90	0.90	0.80	0.80	0.95	0.95
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.75	0.75	0.80	0.80	0.10	0.10	0.50	0.50
w_v	0.85	-0.85	0.60	-0.60	0.10	-0.10	0.30	-0.30
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.30	Fwd Bhd -0.30	Fwd Bhd 1.00	Fwd Bhd -1.00
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.30	Aft Bhd 0.30	Aft Bhd -1.00	Aft Bhd 1.00
w_t	—	—	Port Bhd -1.00	Port Bhd 1.00	Port Bhd -0.05	Port Bhd 0.05	Port Bhd -0.10	Port Bhd 0.10
	—	—	Stbd Bhd 1.00	Stbd Bhd -1.00	Stbd Bhd 0.05	Stbd Bhd -0.05	Stbd Bhd 0.10	Stbd Bhd -0.10
c_ϕ, Pitch	-0.30	0.30	-0.15	0.15	-0.10	0.10	-0.80	0.80
c_θ, Roll	0.00	0.00	1.00	-1.00	0.05	-0.05	0.15	-0.15
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes

1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 for M_{ws} and M_{wh})

2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 for M_h)

3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1 & FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.

4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM and Local Pressure Load Conditions.

7.7 Primary Stress f_{d1} *(1995)*

f_{d1v} and f_{d1h} may be calculated by a simple beam approach. For assessing fatigue strength of side shell and longitudinal bulkhead plating at welded connections, the value of wave-induced primary stress is to be taken as that of maximum principal stress at the location considered to account for the combined load effects of the direct stresses and shear stresses. For calculating the value of f_{d1v} for longitudinal deck members, normal camber may be disregarded.

7.9 Secondary Stress f_{d2}

f_{d2} may be obtained from orthotropic plating or grillage methods with appropriate boundary conditions.

For those connections specified in 5A-3-A2/3.3.1, the wave-induced secondary bending stress f_{d2} may be ignored.

7.11 Additional Secondary Stresses f^*_{d2} and Tertiary Stresses f_{d3}

7.11.1 Calculation of f^*_{d2} *(December 2008)*

Where required, the additional secondary stresses acting at the flange of a longitudinal stiffener, f^*_{d2}, may be approximated by

$$f^*_{d2} = C_t C_y M/SM \qquad \text{N/cm}^2 \text{ (kgf/cm}^2\text{, lbf/in}^2\text{)}$$

where

M = $C_d ps\ell^2/12$ N-cm (kgf-cm, lbf-in), at the supported ends of longitudinal

Where flat bar stiffeners or brackets are fitted, the bending moment, M, given above, may be adjusted to the location of the bracket's toe, i.e., M_X in 5A-3-3/Figure 6.

Where a longitudinal has remarkably different support stiffness at its two ends (e.g., a longitudinal connected to a transverse bulkhead on one end), considerations are to be given to the increase of bending moment at the joint.

C_d = 1.15 for longitudinal stiffener connections at the transverse bulkhead connection including swash bulkheads

= 1.0 elsewhere

p = wave-induced local net pressure, in N/cm² (kgf/cm², lbf/in²), for the specified location and load cases at the mid-span of the longitudinal considered

s = spacing of longitudinal stiffener, in cm (in.)

ℓ = unsupported span of longitudinal/stiffener, in cm (in.), as shown in 5A-3-3/Figure 5

SM = net section modulus of longitudinal with the associated effective plating, in cm³ (in³), at flange or point considered. The effective breadth, b_e, in cm (in.), may be determined as shown in 5A-3-3/Figure 6.

C_y = $0.656(d/z)^4$ for side shell longitudinals only where $z/d \geq 0.9$, but $C_y \geq 0.30$

= 1.0 elsewhere

z = distance above keel of side shell longitudinal under consideration

d = scantling draft, m (ft)

C_t = correction factor for the combined bending and torsional stress induced by lateral loads at the welded connection of the flat bar stiffener or bracket to the flange of longitudinal, as shown in 5A-3-3/Figure 5.

= $1.0 + \alpha_r$ for unsymmetrical sections, fabricated or rolled

= 1.0 for tee and flat bars

α_r = $C_n C_p SM/K$

C_p = $31.2 d_w (e/\ell)^2$

e = horizontal distance between web centerline and shear center of the cross section, including longitudinal and the effective plating

≈ $d_w b_f^2 t_f u/(2SM)$ cm (in.)

K = St. Venant torsion constant for the longitudinal's cross section, excluding the associated plating.

= $[b_f t_f^3 + d_w t_w^3]/3$ cm^4 (in^4)

C_n = coefficient given in 5A-3-A2/Figure 3, as a function of ψ, for point (1) shown in 5A-3-4/Figure 1

u = $1 - 2b_1/b_f$

ψ = $0.31\ell (K/\Gamma)^{1/2}$

Γ = warping constant

= $mI_{yf} d_w^2 + d_w^3 t_w^3/36$ cm^6 (in^6)

I_{yf} = $t_f b_f^3 (1.0 + 3.0u^2 A_w/A_s)/12$ cm^4 (in^4)

A_w = $d_w t_w$ cm^2 (in^2)

A_s = net sectional area of the longitudinals, excluding the associated plating, cm^2 (in^2)

m = $1.0 - u(0.7 - 0.1d_w/b_f)$

d_w, t_w, b_1, b_f, t_f, all in cm (in.), are as defined in 5A-3-4/Figure 1.

For general applications, a_r need not be taken greater than 0.65 for a fabricated angle bar and 0.50 for a rolled section.

For connection as specified in 5A-3-A2/3.3.2, the wave-induced additional secondary stress f_{d2}^* may be ignored.

7.11.2 Calculation of f_{d3}

For welded joints of a stiffened plate panel, f_{d3} may be determined based on the wave-induced local loads as specified in 5A-3-A2/7.11.1 above, using the approximate equations given below. For direct calculation, non-linear effect and membrane stresses in the plate may be considered.

For plating subjected to lateral load, f_{d3} in the longitudinal direction is determined as:

f_{d3} = $0.182p(s/t_n)^2$ N/cm^2 (kgf/cm^2, lbf/in^2)

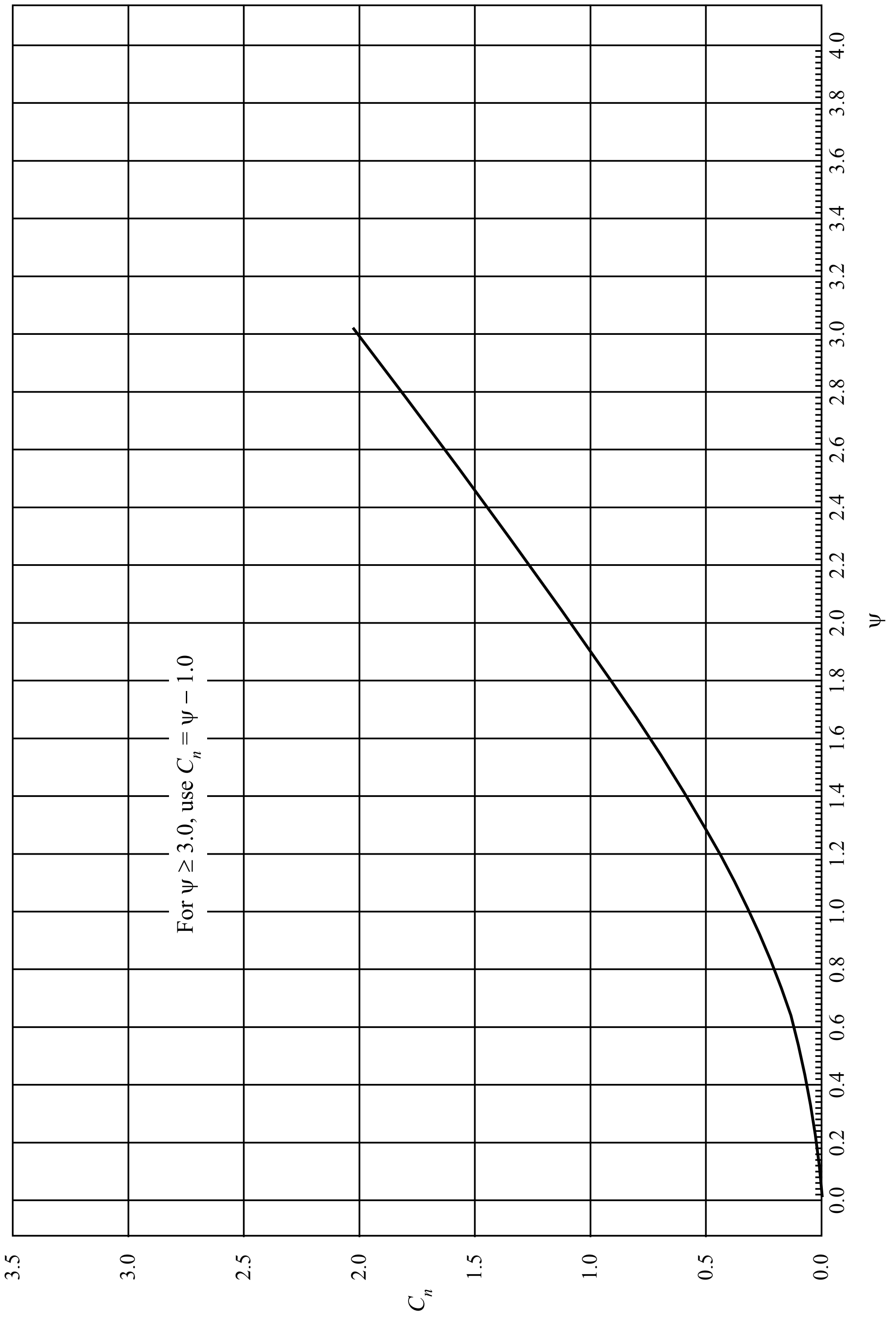
where

p = wave-induced local net pressure, in N/cm^2 (kgf/cm^2, lbf/in^2)

s = spacing of longitudinal stiffeners, in cm (in.)

t_n = net thickness of plate, in mm (in.)

FIGURE 3
$C_n = C_n\ (\psi)$ *(1995)*



9 Resulting Stress Ranges

9.1 Definitions *(December 2008)*

The content in this section is applicable to ship-type installations. For fatigue strength assessment for service as a trading vessel, refer to 5A-3-A2/21.5.

9.1.1

The total stress range, f_R, is computed as the sum of the two stress ranges, as follows:

$$f_R = k_p\, c_f\,(f_{RG} + f_{RL}) \qquad \text{N/cm}^2\ (\text{kgf/cm}^2,\ \text{lbf/in}^2)$$

where

f_{RG} = global dynamic stress range, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $|(f_{d1vi} - f_{d1vj}) + (f_{d1hi} - f_{d1hj})|$

f_{RL} = local dynamic stress range, in N/cm^2 (kgf/cm^2, lbf/in^2)

= $|(f_{d2i} + f^*_{d2i} + f_{d3i}) - (f_{d2j} + f^*_{d2j} + f_{d3j})|$

k_p = load factor for adjusting the probability of exceedance

= 0.5

c_f = adjustment factor to reflect a mean wasted condition

= 0.95

f_{d1vi}, f_{d1vj} = wave-induced component of the primary stresses produced by hull girder vertical bending, in N/cm^2 (kgf/cm^2, lbf/in^2), for load case *i* and *j* of the selected pairs of combined load cases, respectively

f_{d1hi}, f_{d1hj} = wave-induced component of the primary stresses produced by hull girder horizontal bending, in N/cm^2 (kgf/cm^2, lbf/in^2), for load case *i* and *j* of the selected pairs of combined load cases, respectively

f_{d2i}, f_{d2j} = wave-induced component of the secondary bending stresses produced by the bending of cross-stiffened panels between transverse bulkheads, in N/cm^2 (kgf/cm^2, lbf/in^2), for load case *i* and *j* of the selected pairs of combined load cases, respectively

f^*_{d2i}, f^*_{d2j} = wave-induced component of the additional secondary stresses produced by the local bending of the longitudinal stiffener between supporting structures (e.g., transverse bulkheads and web frames), in N/cm^2 (kgf/cm^2, lbf/in^2), for load case *i* and *j* of the selected pairs of combined load cases, respectively

f_{d3i}, f_{d3j} = wave-induced component of the tertiary stresses produced by the local bending of plate elements between the longitudinal stiffeners in, N/cm^2 (kgf/cm^2, lbf/in^2), for load case *i* and *j* of the selected pairs of combined load cases, respectively

For calculating the wave-induced stresses, sign convention is to be observed for the respective directions of wave-induced loads, as specified in 5A-3-A2/Tables 2A through 2D. The wave-induced local loads are to be calculated with the sign convention for the external and internal loads. However, the total of the external and internal pressures, including both static and dynamic components, need not be taken less than zero.

These wave-induced stresses are to be determined based on the net ship scantlings (see 5A-3-A2/1.3) and in accordance with 5A-3-A2/7.5 through 5A-3-A2/7.11. The results of direct calculation, where carried out, may also be considered.

11 Determination of Stress Concentration Factors (SCFs)

11.1 General *(1995)*

This Subsection contains information on stress concentration factors (SCFs) to be considered in the fatigue assessment.

Where, for a particular example shown, no specific value of SCF is given when one is called for, it indicates that a finite element analysis is needed. When the fine mesh finite element approach is used, additional information on calculations of stress concentration factors and the selection of compatible S-N data is given in 5A-3-A2/13.

11.3 Sample Stress Concentration Factors (SCFs) *(1 July 2001)*

11.3.1 Cut-outs (Slots) for Longitudinals *(1995)*

SCFs, fatigue classifications and peak stress ranges may be determined in accordance with 5A-3-A2/Table 3 and 5A-3-A2/Figure 4.

TABLE 3
K_s (SCF) Values

Configuration	K_s *(SCF)*					
	Unsymmetrical Flange			*Symmetrical Flange*		
Location	[1]	[2]	[3]	[1]	[2]	[3]
Single-sided Support	2.0	2.1	—	1.8	1.9	—
Single-sided Support with F.B. Stiffener	1.9	2.0	—	1.7	1.8	—
Double-sided Support	3.0	2.6	2.4	2.7	2.4	2.2
Double-sided Support with F.B. Stiffener	2.8	2.5	2.3	2.5	2.3	2.1

Notes:

a The value of K_s is given, based on nominal shear stresses near the locations under consideration.

b Fatigue classification

Locations [1] and [2]: Class C or B as indicated in 5A-3-A2/Table 1

Location [3]: Class F

c The peak stress range is to be obtained from the following equations:

1 For locations [1] and [2] *(1999)*

$f_{Ri} = c_f\,[K_{si} f_{si} + f_{ni}]$

where

c_f = 0.95

f_{si} = $f_{sc} + \alpha_i f_{swi}$, $f_{si} \geq f_{sc}$

α_i = 1.8 for single-sided support

= 1.0 for double-sided support

f_{ni} = normal stress range in the web plate

f_{swi} = shear stress range in the web plate

= F_i/A_w

F_i is the calculated web shear force range at the location considered. A_w is the area of web.

f_{sc} = shear stress range in the support (lug or collar plate)

= $C_y P/(A_c + A_s)$

f_{sc} = shear stress range in the support (lug or collar plate)

= $C_y P/(A_c + A_s)$

C_y is as defined in 5A-3-A2/7.11.1.

P = $s\ell p_o$

p_o = fluctuating lateral pressure

A_c = sectional area of the support or of both supports for double-sided support

TABLE 3 (continued)
K_s (SCF) Values

A_s = sectional area of the flat bar stiffener, if any

K_{si} = SCFs given above

s = spacing of longitudinal/stiffener

ℓ = spacing of transverses

2 For location [3]

$$f_{R3} = c_f[f_{n3}^2 + (K_s f_{s2})^2]^{1/2}$$

where

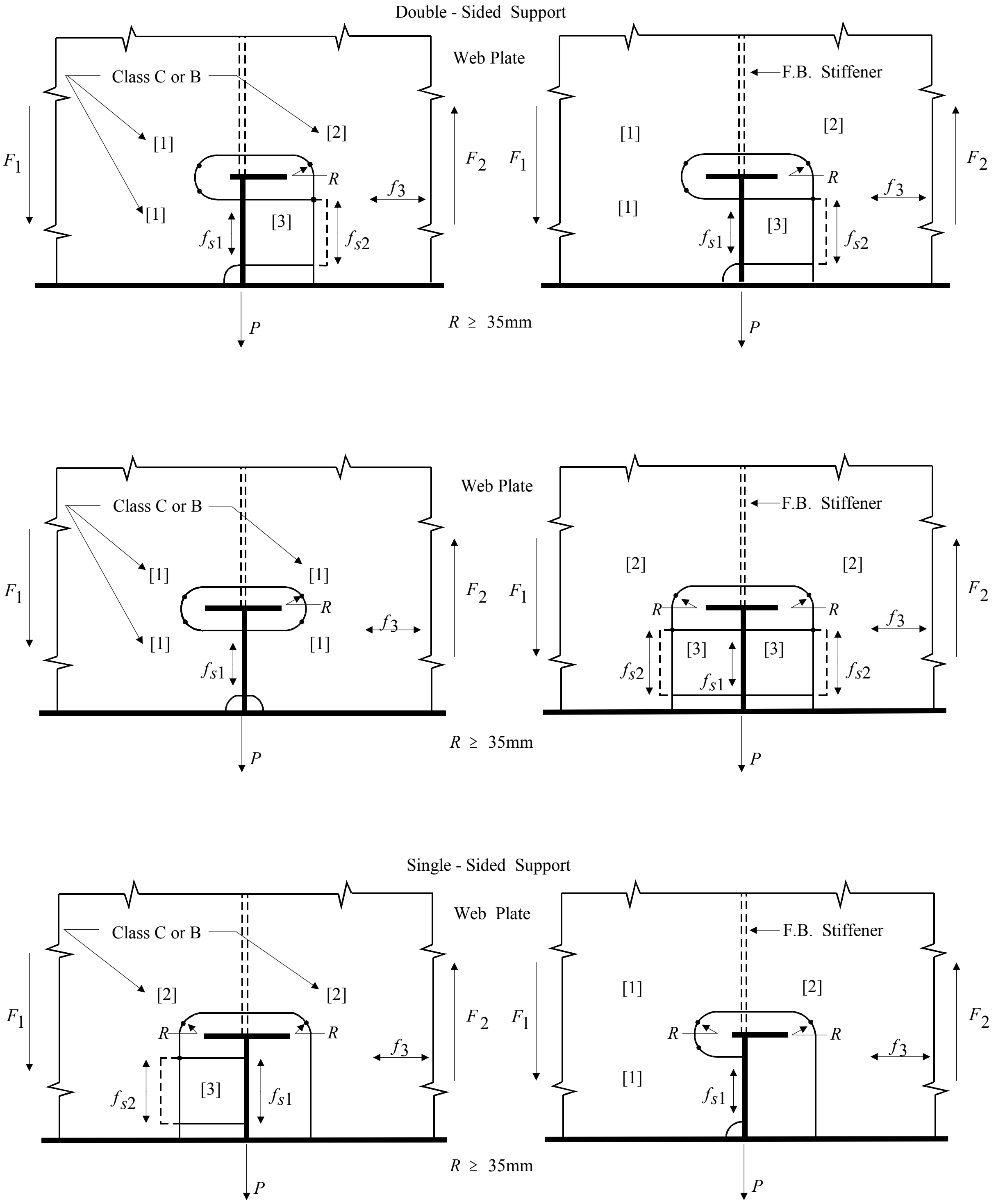
c_f = 0.95

f_{n3} = normal stress range at location [3]

f_{s2} = shear stress range, as defined in 1 above, near location [3].

K_s = SCFs given above

FIGURE 4
Cut-outs (Slots) For Longitudinal *(1995)*



11.3.2 Flat Bar Stiffener for Longitudinals *(1999)*

11.3.2(a) For assessing fatigue life of a flat bar stiffener at location [1] or [2] as shown in 5A-3-A2/Figure 5, the peak stress range is to be obtained from the following equation:

$$f_{Ri} = [(\alpha_i f_s)^2 + f_{Li}^2]^{1/2} \qquad (i = 1 \text{ or } 2)$$

where

f_s = nominal stress range in the flat bar stiffener.

= $k_p\, c_f\, C_y\, P/(A_s + A_c)$

P, A_s, A_c, c_f are as defined in 5A-3-A2/11.3.1 and C_y in 5A-3-A2/7.11.1. For a flat bar stiffener with soft-toed brackets, the brackets may be included in the calculation of A_s.

k_p = load factor for adjusting the probability of exceedance

= 0.5

f_{Li} = stress range in the longitudinal at Location i (i = 1 or 2), as specified in 5A-3-A2/9

α_i = stress concentration factor at Location i (i = 1 or 2) accounting for misalignment and local distortion

At location [1]

For flat bar stiffener without brackets

α_1 = 1.50 for double-sided support connection

= 2.00 for single-sided support connection

For flat bar stiffener with brackets

α_1 = 1.00 for double-sided support connection

= 1.25 for single-sided support connection

At location [2]

For flat bar stiffener without brackets

α_2 = 1.25 for single or double-sided support connection

For flat bar stiffener with brackets

α_2 = 1.00 for single or double-sided support connection

11.3.2(b) For assessing the fatigue life of the weld throat as shown in 5A-3-A2/Table 1, Class W, the peak stress range f_R at the weld may be obtained from the following equation:

$$f_R = 1.25 f_s\, A_s/A_{sw}$$

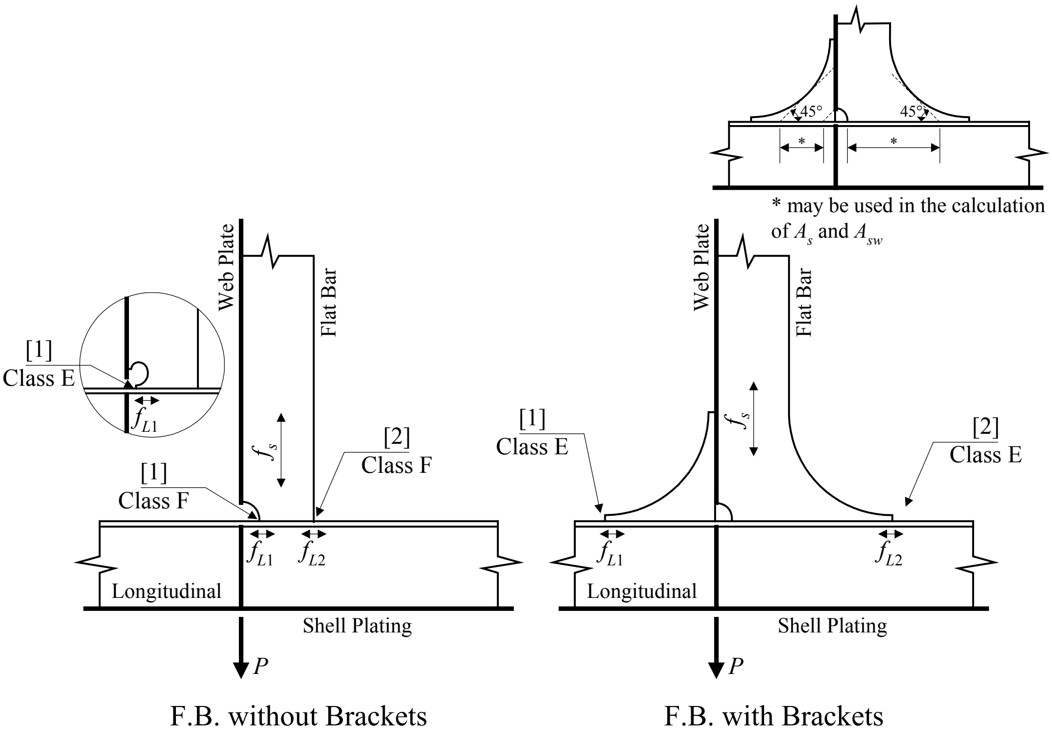
where

A_{sw} = sectional area of the weld throat. Brackets may be included in the calculation of A_{sw}.

f_s and A_s are as defined in 5A-3-A2/11.3.2(a) above.

11.3.2(c) For assessing fatigue life of the longitudinal, the fatigue classification given in 5A-3-A2/Table 1 for a longitudinal as the only load-carrying member is to be considered. Alternatively, the fatigue classification shown in 5A-3-A2/Figure 5, in conjunction with the combined stress effects, f_R, may be used. In calculation of f_R, the α_i may be taken as 1.25 for both locations [1] and [2].

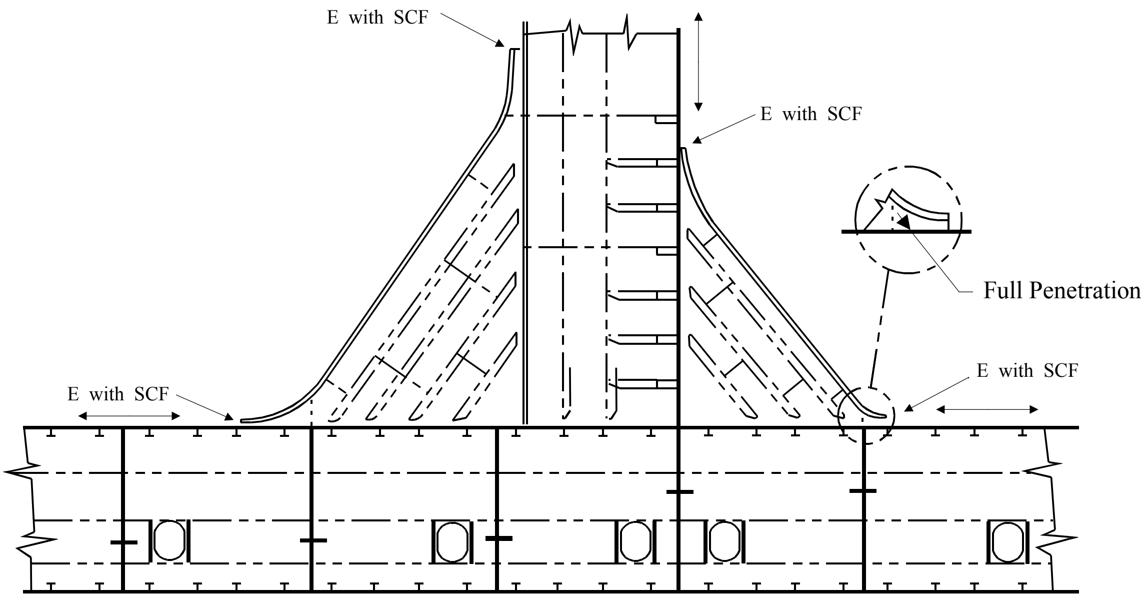
FIGURE 5
Fatigue Classification for Longitudinals in way of Flat Bar Stiffener



11.3.3 Connection Between Transverse Bulkhead Vertical Web and Double Bottom Girder *(1995)*

Fatigue class designation and SCFs may be determined as shown in 5A-3-A2/Figure 6.

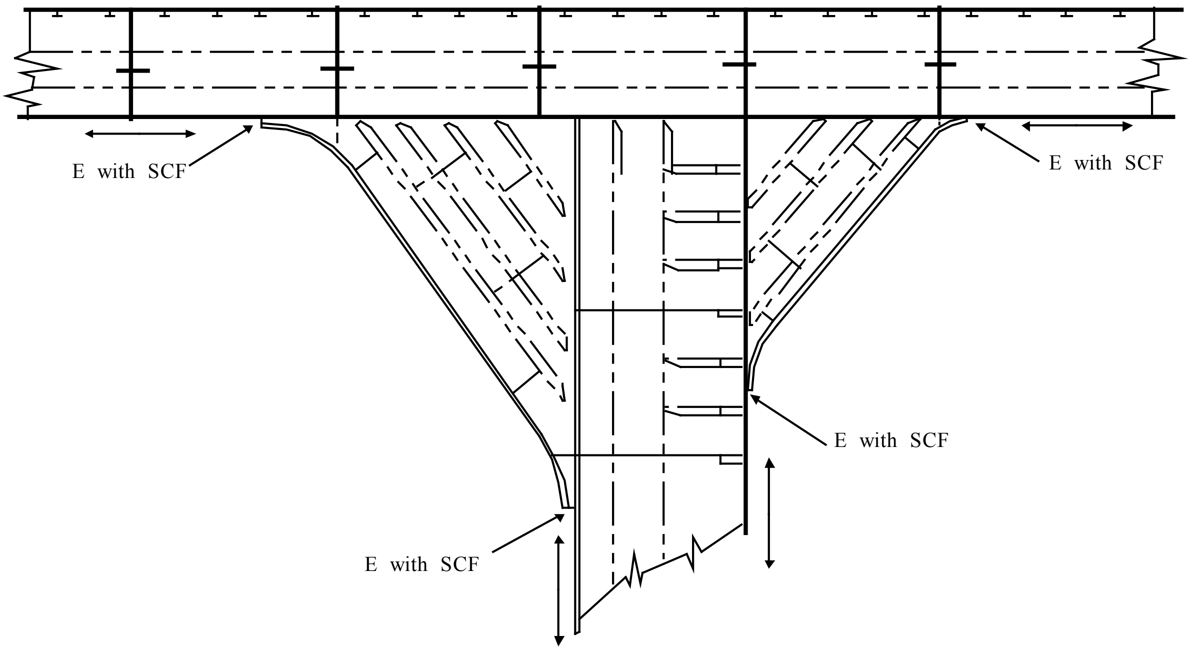
FIGURE 6



11.3.4 Connection Between Transverse Bulkhead Vertical Web and Deck Girder *(1995)*

Fatigue class designation and SCFs may be determined as shown in 5A-3-A2/Figure 7.

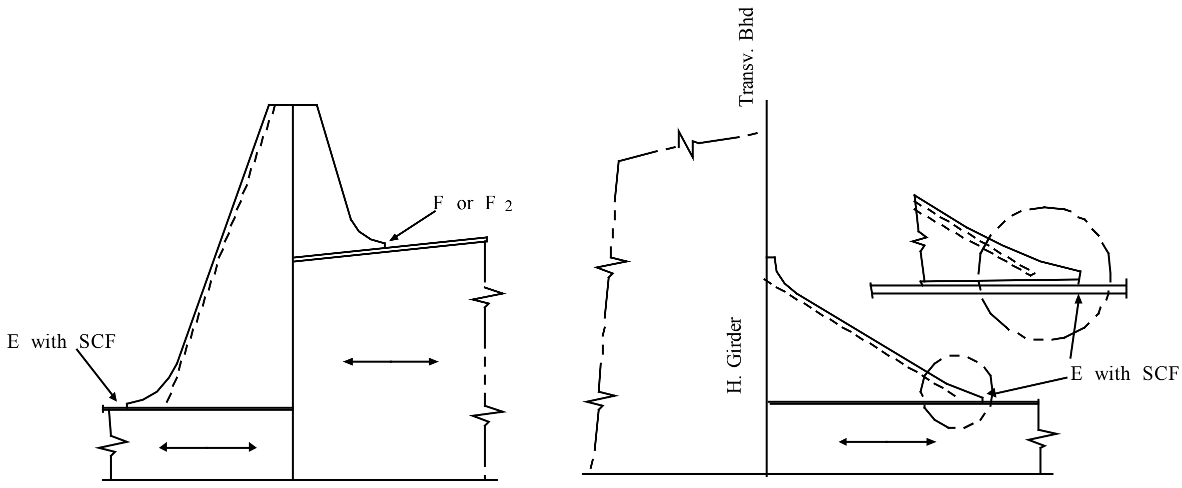
FIGURE 7



11.3.5 End Connections of Transverse Bulkhead Horizontal Girder to Longitudinal of Side Shell or Longitudinal Bulkhead *(1995)*

Fatigue class designation and SCFs may be determined as shown in 5A-3-A2/Figure 8.

FIGURE 8

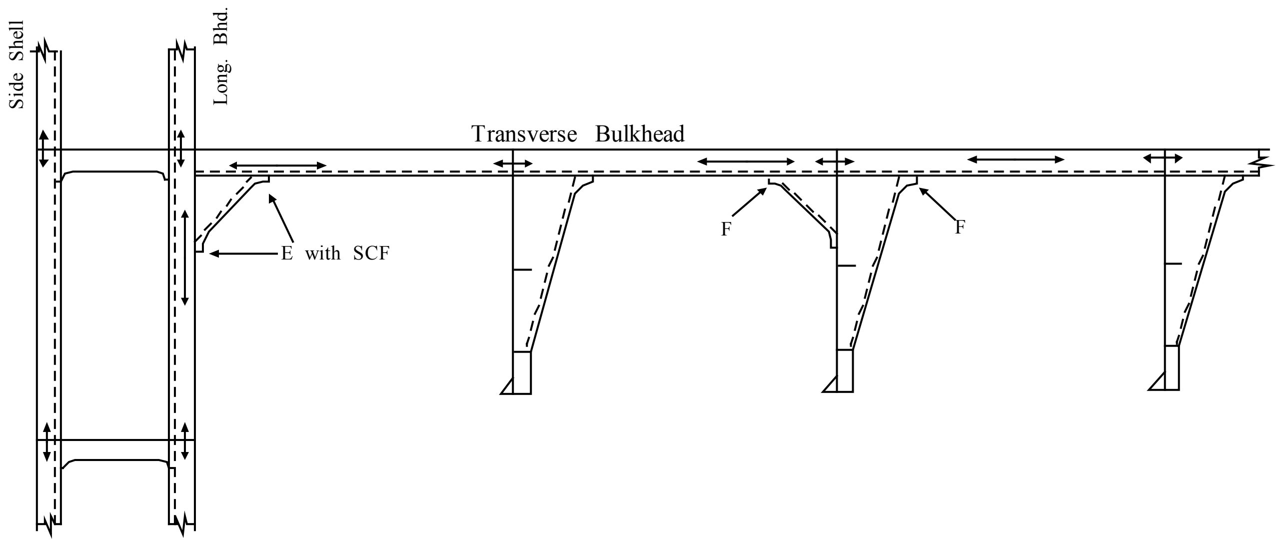


Side Shell or Longitudinal Bulkhead

11.3.6 Connection of Transverse Bulkhead to Longitudinal Bulkhead *(1995)*

Fatigue class designation and SCFs may be determined as shown in 5A-3-A2/Figure 9.

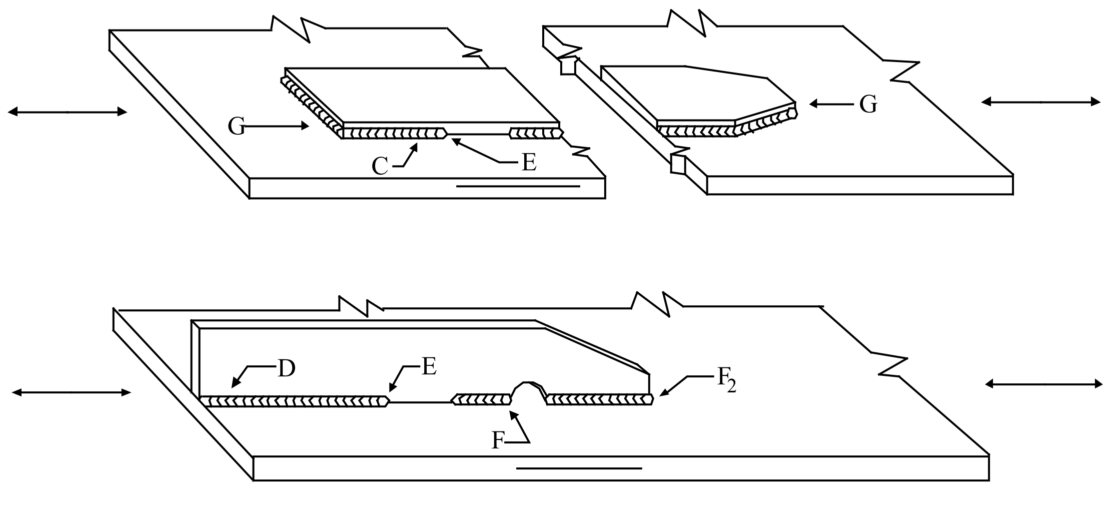
FIGURE 9



11.3.7 Doublers and Non-load Carrying Members on Deck or Shell Plating *(1995)*

Fatigue class designation may be determined as shown in 5A-3-A2/Figure 10.

FIGURE 10
Doublers and Non-load Carrying Members on Deck or Shell Plating



13 Stress Concentration Factors Determined From Finite Element Analysis

13.1 Introduction *(1995)*

S-N data and stress concentration factors (SCFs) are related to each other and therefore are to be considered together so that there is a consistent basis for the fatigue assessment.

The following guidance is intended to help make correct decisions.

13.3 S-N Data *(1995)*

S-N data are presented as a series of straight-lines plotted on log-log scale. The data reflect the results of numerous tests, which often display considerable scatter. The recommended design curves for different types of structural details and welded connections recognize the scatter in test results in that the design curves have been based on the selection of the lower bound, 95% confidence limit. In other words, about 2.5% of the test failure results fall below this curve. Treating the design curve in this manner introduces a high, yet reasonable degree of conservatism in the design and fatigue evaluation processes.

Individual S-N curves are presented to reflect certain generic structural geometry or arrangements. 5A-3-A2/Table 1 and 5A-3-A2/11.3 contain sketches of weld connections and other details typically found in ship structures, giving a list of the S-N classification. This information is needed to assess the fatigue strength of a detail. Also needed is a consistent way to establish the demands or load effects placed on the detail, so that a compatible assessment can be made of the available strength versus the demand. Here is where interpretation and judgment enter the fatigue assessment.

S-N curves are obtained from laboratory sample testing. The applied reference stress on the sample which is used to establish the S-N data is referred to as the nominal stress. The nominal stress is established in a simple manner, such as force divided by area and bending moment divided by section modulus (P/A & M/SM). The structural properties used to establish the nominal stress are taken from locations away from any discontinuities to exclude local stress concentration effects arising from the presence of a weld or other local discontinuity. In an actual structure, it is rare that a match will be found with the tested sample geometry and loading. One is then faced with the problem of making the appropriate interpretation.

13.5 S-N Data and SCFs *(2003)*

Selection of appropriate S-N data appears to be rather straightforward with respect to "standard details" offered in 5A-3-A2/Table 1 or other similar reference. However, in the case of welded connections in complex structures, it is required that SCFs be used to modify the nominal stress range. An often quoted example of the need to modify nominal stress for fatigue assessment purposes is one shown in 5A-3-A2/Figure 11 below, relating to a hole drilled in the middle of a flat plate traversed by a butt weld.

In this example, the nominal stress S_N is P/Area, but the stress to be used to assess the fatigue strength at point A is S_A or $S_N \cdot$ SCF. This example is deceptively simple because it does not tell the entire story. The most obvious deficiency of the example is that one needs to have a definitive and consistent basis to obtain the SCF. There are reference books which indicate that based on the theory of elasticity, the SCF to be applied in this case is 3.0. However, when the SCF is computed using the finite element analysis techniques, the SCF obtained can be quite variable depending on the mesh size. The example does not indicate which S-N curve is to be applied, nor does the example say how it may be necessary to alter the selection of the design S-N data in consideration of the aforementioned finite element analysis issues. Therefore, if such interpretation questions exist for a simple example, the higher difficulty of appropriately treating more complex structures is evident.

Referring to the S-N curves to be applied to welded connections (for example, S-N curves D-W in 5A-3-A2/Figure 1), the SCFs resulting from the presence of the weld itself are already accounted for in these curves. If one were to have the correct stress distribution in the region – from the weld to a location sufficiently away from the weld toe (where the stress is suitably established by the nominal stress obtained from P/A and M/SM) – the stress distribution may be generically separated into three distinct segments, as shown in 5A-3-A2/Figure 12 below.

- Region III is a segment where the stress gradient is controlled by the nominal stress gradient.
- Region II is a segment where the nominal stress gradient is being modified due to the presence of other structure, such as the bracket end shown in the figure. This must be accounted for to obtain an appropriate stress to be used in the fatigue analysis at the weld toe.
- Region I is a segment where the stress gradient is being modified due to the presence of the weld metal itself. The stress concentration due to the weld is already accounted for in the S-N design curve and will not be discussed further. Since the typical way to determine the stress distribution is via planar/linear elements which ignore the weld, this is consistent with the method of analysis.

This general description of the stress distribution is again inconclusive because one does not know in advance and with certainty the distances from the weld toe to where the indicated changes of slope for the stress gradient occur. For this reason, definite rules need to be established to determine the slopes, and with this knowledge, criteria established to be used to find the stress at the weld toe which is to be used in the fatigue assessment.

In this regard, two approaches can be used to find the stress at the weld toe, which reflect two methods of structural idealization. One of these arises from the use of a conventional beam element idealization of the structure including the end bracket connection, and the other arises from the use of a fine mesh finite element idealization.

Using a beam element idealization, the nominal stress at any location (i.e., P/A and M/SM) can be obtained (see 5A-3-3/Figure 6 for a sample beam element model).

In the beam element idealization, there will be questions as to whether or not the geometric stress concentration due to the presence of other structure is adequately accounted for. This is the "Segment II" stress gradient previously described. In the beam modeling approach shown in the figure, the influence on stresses arising from the "carry over" of forces and bending moments from adjacent structural elements has been accounted for (albeit approximately). At the same time, the strengthening effect of the brackets has been conservatively ignored. Hence for engineering purposes, this approach is considered to be sufficient in conjunction with the nominal stress obtained at the location of interest and the nominal S-N curve, i.e., the F or F_2 Class S-N data, as appropriate.

In the fine mesh finite element analysis approach, one needs to define the element size to be used. This is an area of uncertainty because the calculated stress distribution can be unduly affected by both the employed mesh size and the uniformity of the mesh adjacent to the weld toe. Therefore, it is necessary to establish "rules", as given below, to be followed in the producing of the fine mesh model adjacent to the weld toe. Furthermore, since the area adjacent to the weld toe (or other discontinuity of interest) may be experiencing a large and rapid change of stress (i.e., a high stress gradient), it is also necessary to provide a rule which can be used to establish the stress at the location where the fatigue assessment is to be made.

5A-3-A2/Figure 13 shows an acceptable method which can be used to extract and interpret the "near weld toe" element stresses and to obtain a (linearly) extrapolated stress at the weld toe. When plate or shell elements are used in the modeling, it is recommended that each element size is to be equal to the plate thickness. When stresses are obtained in this manner, the use of the E Class S-N data is considered to be acceptable.

Weld hot spot stress can be determined from linear extrapolation of surface component stresses at $t/2$ and $3t/2$ from weld toe. The principal stresses at hot spot are then calculated based on the extrapolated stresses and used for fatigue evaluation. Description of the numerical procedure is given in 5A-3-A2/13.7 below.

FIGURE 11
(1995)

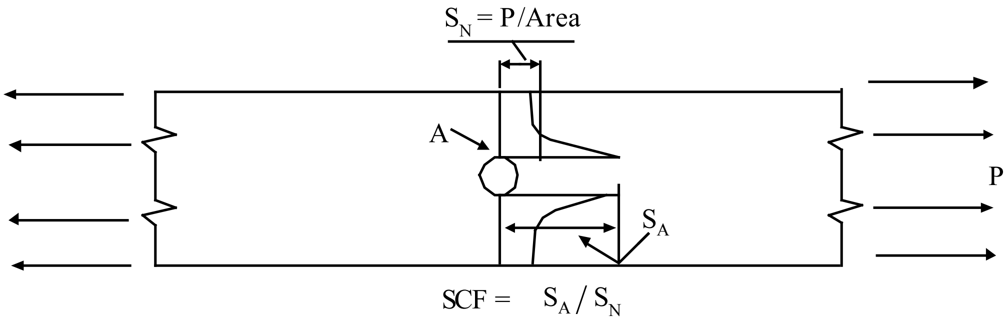
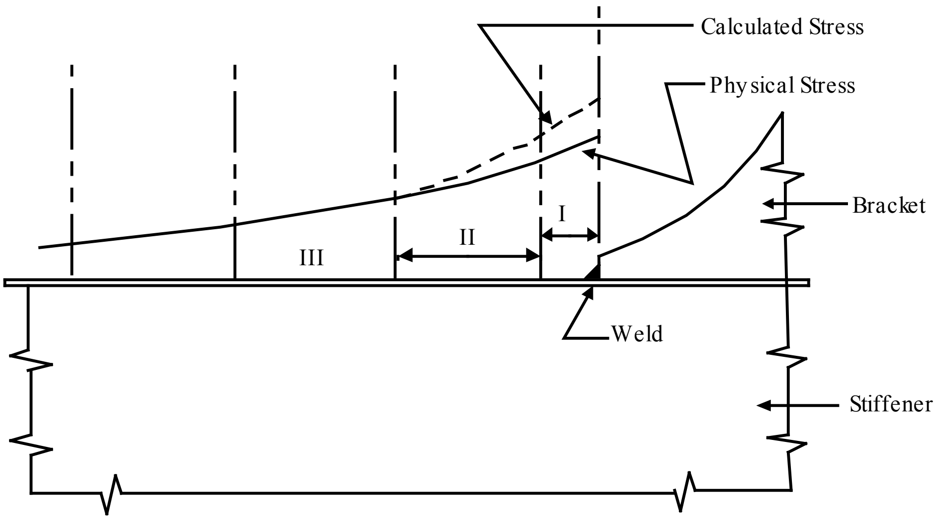


FIGURE 12
(1995)

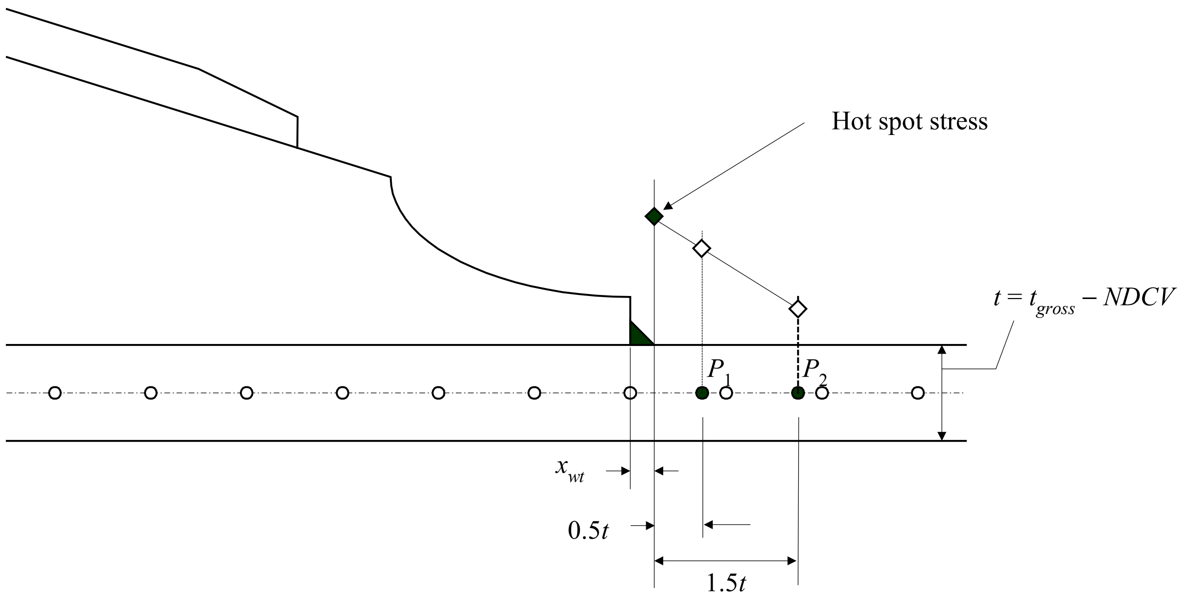


13.7 Calculation of Hot Spot Stress for Fatigue Analysis *(December 2008)*

The following method is applied to obtain the hot spot stress at the toe of a weld.

A very fine mesh is to be used in the region of the hotspot stress with a mesh size equal to plate thickness. The hot spot stress is to be determined by using a linear extrapolation as described in 5A-3-A2/Figure 13. Assuming that the applicable surface component stresses of the two points, P_1 and P_2, measured by the distances $0.5t$ and $1.5t$ from the weld toe, respectively, have been determined from FEM analysis by the linear interpolation of stresses at centroids of the adjacent two elements, the corresponding hot spot stress can be extrapolated at the hot spot location from the stresses at P_1 and P_2. The weld toe distance, x_{wt}, is not to be taken larger than $0.5t_{gross}$.

FIGURE 13
(December 2008)



15 Fatigue Assessment of Structures Considering Low Cycle Fatigue
(December 2008)

15.1 Introduction

Certain duty cycles associated with operations of a ship-type installation may produce oscillatory stresses whose magnitudes exceed the yield strength of the material. For welded joints in certain members of ship-type installations during the loading/offloading process, the total number of cycles during the service life is expected to be less than 10^4. Fatigue associated with cyclic plasticity ("low cycle fatigue") is addressed in the following sections. The appropriate low cycle fatigue design S-N curve is defined, the process for computing oscillatory pseudo stress is provided, and the acceptance criterion for total damage, low cycle plus high cycle fatigue, is specified.

15.3 Applicability

Subsections 5A-3-A2/15 and 5A-3-A2/17 define the procedure for a simplified fatigue assessment which is to be used to evaluate the fatigue strength of critical structural details subjected to low cycle fatigue. The fatigue assessment uses a hot spot stress approach based on FE analysis.

15.5 Loads

Traditionally, the fatigue strength analysis considers the following dynamic loads (high cycle load) for calculation of the long term distribution of stresses:

- Hull girder loads (i.e., vertical and horizontal wave bending moments)
- Dynamic wave pressure
- Dynamic tank pressure loads resulting from installation motion

However, from low cycle fatigue point of view, fatigue due to the following static loads need to be considered:

- Static cyclic loads due to cargo loading and offloading

15.7 Selection of Loading Conditions for Low Cycle Fatigue *(1 July 2009)*

Fatigue analyses are to be carried out for representative loading conditions according to the intended installation's operation. The following two loading conditions are to be examined:

i) For locations at longitudinal end connections:

- Full load condition with design still water bending moment, see loading condition 4 in 5A-3-A2/Figures 2A and 2B
- Ballast or light draft condition at with design still water bending moment, see loading condition 1 in 5A-3-A2/Figures 2A and 2B

ii) For locations other than longitudinal end connections:

The maximum low cycle fatigue damage calculated from the following two pairs:

Pair 1

- Full load condition with design still water bending moment, see loading condition 4 in 5A-3-A2/Figures 2A and 2B
- Ballast or light draft condition with design still water bending moment, see loading condition 1 in 5A-3-A2/Figures 2A and 2B

Pair 2

- Intermediate condition with design still water bending moment, see loading condition 3 in 5A-3-A2/Figures 2A and 2B
- Intermediate condition with design still water bending moment, see loading condition 2 in 5A-3-A2/Figures 2A and 2B

15.9 Acceptance Criteria

The criteria stated in 5A-3-A2/15 and 5A-3-A2/17 are presented as a comparison of fatigue strength of the structural detail (capacity), and fatigue inducing loads (demands), in the form of a fatigue damage parameter, DM. The combined fatigue damage including damages from both low cycle fatigue and high cycle fatigue, DM_{comb}, is to be less than or equal to 1.0 for the design life of the installation, which is not to be taken as less than 20 years.

15.11 Fatigue Assessment Methods

The hot spot stress approach is to be used for fatigue evaluation of the following details:

15.11.1 Connections of Longitudinal Stiffeners to Transverse Web/Floor and to Transverse Bulkhead

15.11.1(a) Two (2) to three (3) selected side longitudinals in the region from the 1.1 draft to about $^1/_3$ draft in the midship region and also in the region between $0.15L$ and $0.25L$ from F.P., respectively

15.11.1(b) One (1) to two (2) selected longitudinals from each of the following groups:

- Deck longitudinals, bottom longitudinals, inner bottom longitudinals and longitudinals on side longitudinal bulkheads
- One longitudinal on each of the longitudinal bulkheads within $0.1D$ from the deck is to be included

For these structural details, the fatigue assessment is to be first focused on the flange of the longitudinal at the rounded toe welds of attached flat bar stiffeners and brackets, as illustrated for Class F item 2) and Class F_2 item 1) in 5A-3-A2/Table 1.

Then, the critical spots on the web plate cut-out, on the lower end of the stiffener as well as the weld throat are also to be checked for the selected structural detail. For illustration, see 5A-3-A2/11.3.1 and 5A-3-A2/11.3.2(a), 5A-3-A2/11.3.2(b) and 5A-3-A2/11.3.2(c).

Where the longitudinal stiffener end bracket arrangements are different on opposing sides of a transverse web, both configurations are to be checked.

15.11.2 Shell, Bottom, Inner Bottom or Bulkhead Plating at Connections to Webs or Floors (for Fatigue Strength of Plating)

15.11.2(a) One (1) to two (2) selected locations of side shell plating near the summer LWL amidships and between 0.15*L* and 0.25*L* from F.P. respectively

15.11.2(b) One (1) to two (2) selected locations in way of bottom and inner bottom amidships

15.11.2(c) One (1) to two (2) selected locations of lower strakes of side longitudinal bulkhead amidships

15.11.3 Connections of the Slope Plate to Inner Bottom and Side Longitudinal Bulkhead Plating at the Lower Cargo Tank Corners

One selected location amidships at transverse web and between webs, respectively

For this structural detail, the value of f_R, the total stress range as specified in 5A-3-A2/9.1, is to be determined from fine mesh F.E.M. analyses for the combined load cases, as specified for Zone B in 5A-3-A2/7.5.2.

15.11.4 End Bracket Connections for Transverses and Girders

One (1) to two (2) selected locations in the midship region for each type of bracket configuration.

15.11.5 Other Regions and Locations

Other regions and locations, highly stressed by fluctuating loads, as identified from structural analysis.

17 Low Cycle Fatigue Damage *(December 2008)*

17.1 Low Cycle Fatigue Load

When fatigue is of concern, structural responses are assumed to result from two external sources, the wave loading on the installation and the process of loading and offloading the installation resulting in uneven buoyancy. This loading/offloading process produces very low frequency static loads including oscillatory still water bending moment (SWBM) and still water pressure. Some structural components experience cyclic plasticity when the combination of the two load sources produces cyclic stresses that exceed the yield strength of the material. Typically this occurs at the toe of a weld. Described in this section is the process of defining damage due to low cycle fatigue.

17.3 Loading Conditions

Static cyclic loads including still-water bending moments and static pressure due to cargo loading and offloading are considered.

17.5 Stress Range Calculation

17.5.1 Elastic Hot Spot Stress Range Calculation

In the following, all reference to stress is to be interpreted as the elastic hot spot stress at the toe of a weld in question. Also, at the outset, it will be assumed that the S-N curve defining fatigue strength is given in pseudo hot spot stress. In the elastic high cycle range a pseudo hot spot stress will be the same as an elastic hot spot stress. They will differ in the low cycle range.

As shown in 5A-3-A2/Figure 14, the stress process in certain structural components of an installation can be considered as a superposition of wave induced stresses, $S_W(t)$, and stresses associated with static load, $S_B(t)$. The cycles of S_B result from the loading/offloading process.

The total or net stress process will be:

$$S(t) = S_B(t) + S_W(t)$$

FIGURE 14
Sample Functions of S_W and S_B *(December 2008)*

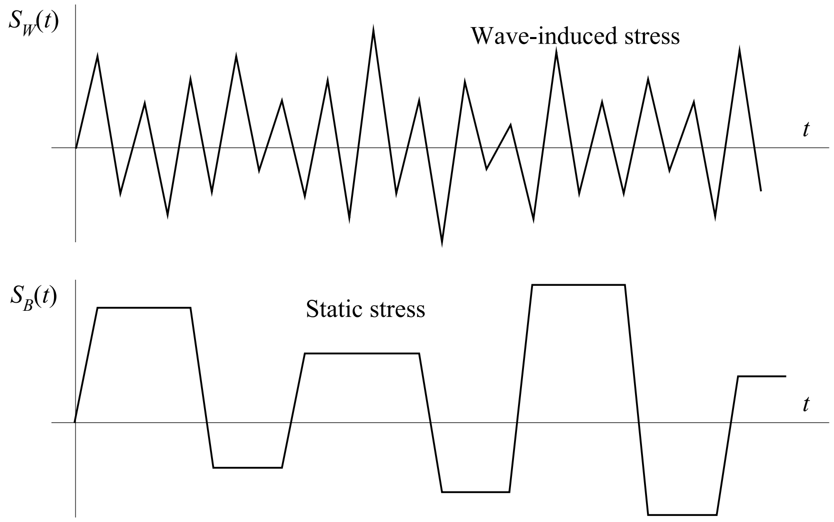
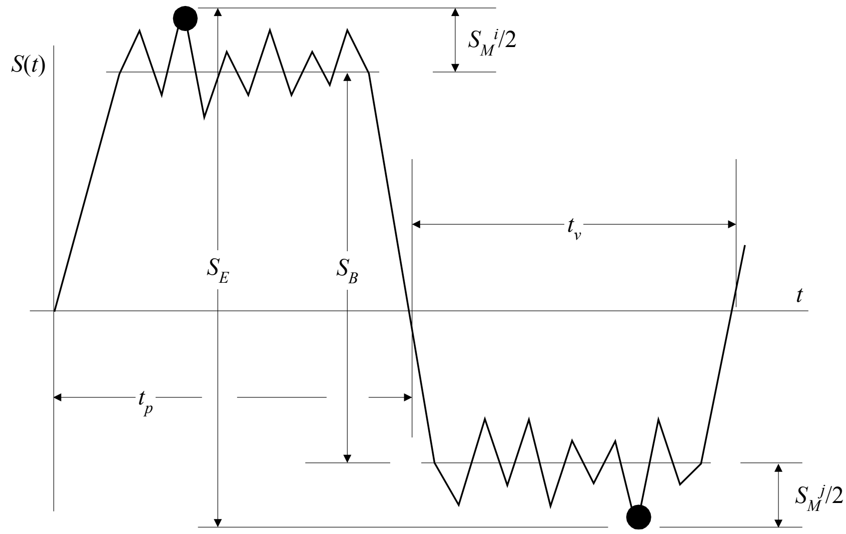


FIGURE 15
A Single Loading/Offloading Cycle *(December 2008)*



In one cycle of the static process, as shown in 5A-3-A2/Figure 15, the total stress range associated with this cycle is S_E.

$$S_E = S_B + 0.5(S_M^i + S_M^j)$$

where

S_B	=	static stress range for this cycle
S_M^i	=	median of the largest stress range of wave induced load for *i*-th load condition
S_M^j	=	median of the largest stress range of wave induced load for *j*-th load condition

From extreme value theory, the median largest stress range S_M^i in *n* cycles is given as:

$$\frac{S_M^i}{\delta} = \left[-\ln\left(1 - 0.5^{1/n}\right)\right]^{1/\gamma}$$

where γ and δ are the long term stress shape and scale factors, respectively. δ can be determined statistically from long term records of stress ranges or can be calculated by the formula:

$$\delta = \frac{f_R}{\left[\ln\left(N_s\right)\right]^{1/\gamma}}$$

where f_R is the stress range associated with a probability of exceedance of $1/N_s$, as defined in 5A-3-A2/9.1, and N_s is equal to 10^4.

n may be computed by taking the estimated time for a half cycle divided by the estimated wave period.

The number of cycles for installation's loading and unloading, n_{LCF}, is assumed to be no less than 1200 for 20 years.

Assume there are 10^8 wave cycles within 20 years, n is then equal to:

$$\frac{10^8}{n_{LCF} \times 2}$$

In general, it is expected that the time in tension will not equal the time in compression. For a conservative analysis, the larger of the two might be selected.

17.5.2 Pseudo Hot Spot Stress Range Calculation

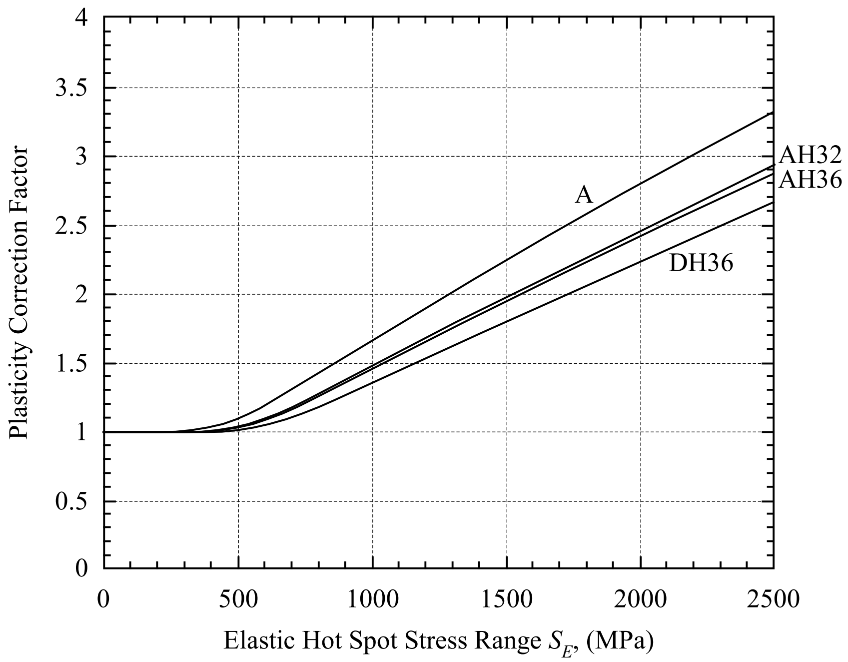
To transform elastic hot spot stress range to pseudo hot spot stress range, a plasticity correction factor, k_e, is defined as:

$$k_e = \frac{S_L}{S_E}$$

where S_L is the pseudo hot spot stress range.

A plot of k_e as a function of S_E is given in 5A-3-A2/Figure 16.

FIGURE 16
k_e as a Function of S_E *(December 2008)*



An approximate analytical formula derived from 5A-3-A2/Figure 16 can be used:

$k_e = 0.5 + k_m S_E$, but is not to be less than 1.0

Values of k_m

Material	Mild	HT32	HT36	HT40
k_m	11.20×10^{-4}	9.60×10^{-4}	9.40×10^{-4}	8.56×10^{-4}

17.5.3 Low Cycle S-N Curve and Damage Calculation

The design S-N curve in the low cycle region is defined in 5A-3-A2/Figure 17. It may be considered to be a modified D-Curve.

The low cycle fatigue (LCF) design S-N curve is given as:

$NS^q = B$ for $100 < N < 10^4$

where

q = 2.4

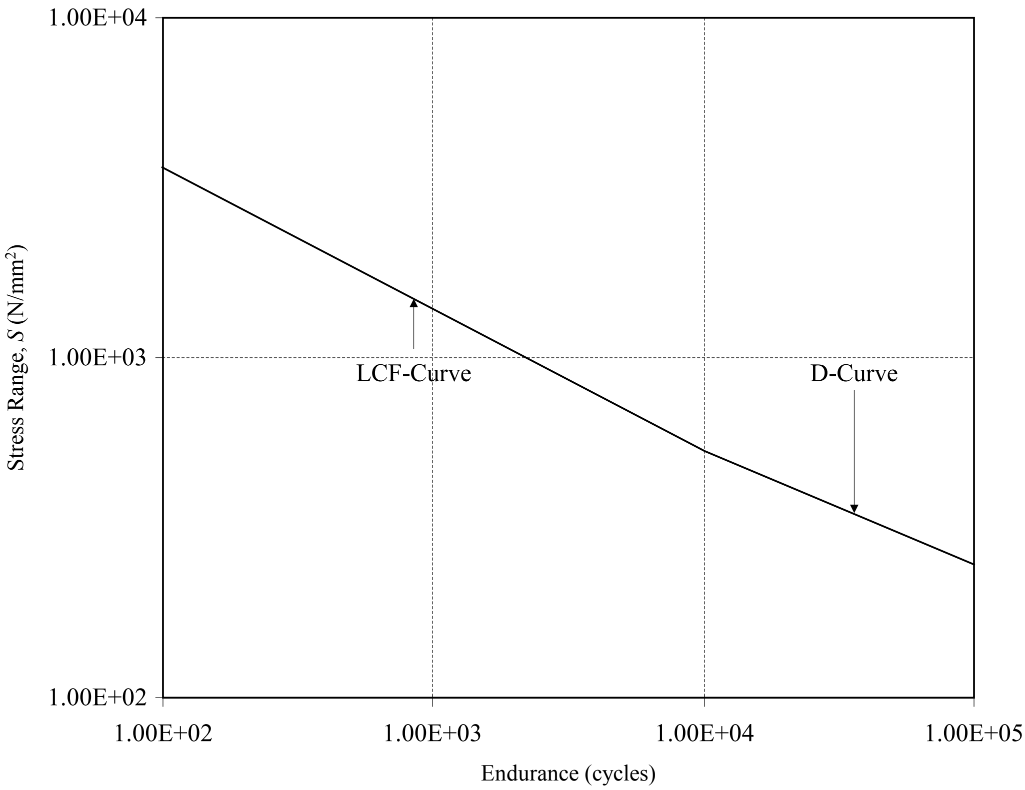
B = 3.51×10^{10} (MPa units)

It is assumed that the LCF design S-N curve is applicable to static induced stresses. Basic application of Miner's rule produces the expression of static stress damage DM_{LCF} is:

$$DM_{LCF} = \frac{N_{LCF} S_L^q}{B}$$

n_{LCF} is the total cycles of loading/offloading, which is not to be less than 1200 for a ship-type installation to be operated for 20 years.

FIGURE 17
Low Cycle Fatigue Design Curve *(December 2008)*



19 Combined Fatigue Damage *(December 2008)*

The total fatigue damage due to both low cycle and high cycle stress can be calculated by

$$DM_{comb} = \frac{\left(DM_{LCF}^2 + 2\delta DM_{LCF} DM_{HCF} + DM_{HCF}^2\right)}{\sqrt{DM_{LCF}^2 + DM_{HCF}^2}}$$

where

δ = 0.02

DM_{LCF} = low cycle fatigue damage

DM_{HCF} = high cycle fatigue damage

For Longitudinal Stiffener Connections, the total fatigue damage due to both low cycle and high cycle stress can be calculated by

$$DM_{comb} = \frac{\left(DM_{LCF}^2 + 2\delta DM_{LCF} DM_{HCF} / \alpha_{Site} + (DM_{HCF} / \alpha_{Site})^2\right)}{\sqrt{DM_{LCF}^2 + (DM_{HCF} / \alpha_{Site})^2}}$$

where

α_{Site} = environmental severity factor for the intended site, see 5A-3-A1/5

21 Fatigue Strength Assessment for Service as a Trading Vessel *(December 2008)*

21.1 Cumulative Fatigue Damage for Trading Vessels

The cumulative fatigue damage ratio, *DM*, as a trading vessel, is equal to 1.0 which corresponds to a fatigue life of 20 years. The design life is not to be less than 20 years. Unless otherwise specified, the cumulative damage is to be taken as:

$$DM = \frac{N_L}{K_2} \frac{(0.01 f_R)^m}{(\ln N_R)^{m/\gamma}} \mu \Gamma\left(1 + \frac{m}{\gamma}\right)$$

where

N_L = number of cycles for the expected design life. Unless stated otherwise, N_L to be taken as:

= $\dfrac{f_0 U}{4 \log_{10} L}$

The value is generally between 0.5×10^8 and 0.7×10^8 cycles for a design life of 20 years

f_0 = 0.85, factor taking into account non-sailing time for operations such as loading and unloading, repairs, etc.

U = design life, in seconds

= 6.31×10^8 for a design life of 20 years

L = rule length, in m

m = S-N curve parameter as defined in 5A-3-A2/Figure 1, Note a)

K_2 = S-N curve parameter as defined in 5A-3-A2/Figure 1, Note a)

f_R = stress range at the representative probability level of 10^{-4}, in N/cm^2

N_R = 10,000, number of cycles corresponding to the probability level of 10^{-4}

γ = long term stress distribution parameter, as defined in 5A-3-A2/5.5

Γ = Gamma function

μ = stress coefficient taking into account the change in slope of the S-N curve

$$= 1 - \frac{\left\{ \Gamma_0\left(1+\frac{m}{\gamma}, \nu\right) - \nu^{-\frac{\Delta m}{\gamma}} \Gamma_0\left(1+\frac{m+\Delta m}{\gamma}, \nu\right) \right\}}{\Gamma\left(1+\frac{m}{\gamma}\right)}$$

$$\nu = \left(\frac{f_q}{0.01 f_R}\right)^{\gamma} \ln N_R$$

f_q = stress range at the intersection of the two segments of the S-N curve, see Table in 5A-3-A2/Figure 1, Note a), in N/mm^2

Δm = slope change of the upper-lower segment of the S-N curve

= 2

$\Gamma_0(a,x)$ = incomplete Gamma function, Legendre form

21.3 Fatigue Assessment Zones and Controlling Load Combination for Vessels

Eight loading patterns are considered in the calculation of stress range, as shown in 5A-3-2/Figure 1A or 1B depending on whether the existing vessel to be converted is a single hull or double hull vessel.

Depending on the location of the structural details undergoing the fatigue assessment, different combinations of load cases are to be used to find the appropriate stress range, as indicated below for indicated respective zones.

21.3.1 Zone A

Zone A consists of deck and bottom structures, and side shell and longitudinal bulkhead structures within 0.1*D* (*D* is installation's molded depth) from deck and bottom, respectively. For Zone A, stresses are to be calculated based on the wave-induced loads specified in 5A-3-2/Table 1A, as follows.

21.3.1(a) Calculate dynamic component of stresses for load cases LC1 through LC4, respectively.

21.3.1(b) Calculate two sets of stress ranges, one each for the following two pairs of combined loading cases.

LC1 and LC2, and

LC3 and LC4

21.3.1(c) Use the greater of the stress ranges obtained by 5A-3-A2/21.3.1(b).

21.3.2 Zone B

Zone B consists of side shell and longitudinal bulkhead structures within the region between 0.25 upward and 0.30 downward from the mid-depth and all transverse bulkhead structures. The total stress ranges for Zone B may be calculated based on the wave-induced loads specified in 5A-3-2/Table 1A, as follows:

21.3.2(a) Calculate dynamic component of stresses for load cases LC5 through LC8, respectively.

21.3.2(b) Calculate two sets of stress ranges, one each for the following two pairs of combined loading cases.

LC5 and LC6, and

LC7 and LC8

21.3.2(c) Use the greater of the stress ranges obtained by 5A-3-A2/21.3.2(b).

21.3.3 Transitional Zone

Transitional zone between A and B consists of side shell and longitudinal bulkhead structures between $0.1D$ and $0.25D$ ($0.2D$) from deck (bottom).

$$f_R = f_{R(B)} - [f_{R(B)} - f_{R(A)}]\, y_u/0.15D \qquad \text{for upper transitional zone}$$

$$f_R = f_{R(B)} - [f_{R(B)} - f_{R(A)}]\, y_\ell/0.1D \qquad \text{for lower transitional zone}$$

where

$f_{R(A)}, f_{R(B)}$ = the total stress range based on the combined load cases defined for Zone A or Zone B, respectively

y_u, y_ℓ = vertical distances from $0.25D$ ($0.3D$) upward (downward) from the mid-depth to the location considered

21.3.4 Installations with Either Special Loading Patterns or Special Structural Configuration

For installations with either special loading patterns or special structural configurations/features, additional load cases may be required for determining the stress range.

21.5 Definitions for Resulting Stress Ranges for Trading Vessels

The total stress range, f_R, is computed as the sum of the two stress ranges, as follows:

$$f_R = k_p\, c_f\, (f_{RG} + f_{RL}) \qquad \text{N/cm}^2 \text{ (kgf/cm}^2\text{, lbf/in}^2\text{)}$$

where

f_{RG} = global dynamic stress range, in N/cm² (kgf/cm², lbf/in²)

= $|(f_{d1vi} - f_{d1vj}) + (f_{d1hi} - f_{d1hj})|$

f_{RL} = local dynamic stress range, in N/cm² (kgf/cm², lbf/in²)

= $c_w|(f_{d2i} + f^*_{d2i} + f_{d3i}) - (f_{d2j} + f^*_{d2j} + f_{d3j})|$

c_f = adjustment factor to reflect a mean wasted condition

= 0.95

c_w = coefficient for the weighted effects of the two paired loading patterns

= 0.75

k_p = load factor for adjusting the probability of exceedance

= 0.5

f_{d1vi}, f_{d1vj} = wave-induced component of the primary stresses produced by hull girder vertical bending, in N/cm² (kgf/cm², lbf/in²), for load case i and j of the selected pairs of combined load cases, respectively

f_{d1hi}, f_{d1hj} = wave-induced component of the primary stresses produced by hull girder horizontal bending, in N/cm² (kgf/cm², lbf/in²), for load case i and j of the selected pairs of combined load cases, respectively

f_{d2i}, f_{d2j} = wave-induced component of the secondary bending stresses produced by the bending of cross-stiffened panels between transverse bulkheads, in N/cm² (kgf/cm², lbf/in²), for load case i and j of the selected pairs of combined load cases, respectively

f^*_{d2i}, f^*_{d2j} = wave-induced component of the additional secondary stresses produced by the local bending of the longitudinal stiffener between supporting structures (e.g., transverse bulkheads and web frames), in N/cm² (kgf/cm², lbf/in²), for load case i and j of the selected pairs of combined load cases, respectively

f_{d3i}, f_{d3j} = wave-induced component of the tertiary stresses produced by the local bending of plate elements between the longitudinal stiffeners in, N/cm² (kgf/cm², lbf/in²), for load case i and j of the selected pairs of combined load cases, respectively

For calculating the wave-induced stresses, sign convention is to be observed for the respective directions of wave-induced loads, as specified in 5A-3-2/Table 1A. The wave-induced local loads are to be calculated with the sign convention for the external and internal loads. However, the total of the external and internal pressures, including both static and dynamic components, need not be taken less than zero.

These wave-induced stresses are to be determined based on the net ship scantlings (see 5A-3-A2/1.3) and in accordance with 5A-3-A2/7.5 through 5A-3-A2/7.11. The results of direct calculation, where carried out, may also be considered.

PART

5A

CHAPTER 3 Structural Design Requirements

APPENDIX 3 Hull Girder Ultimate Strength *(December 2008)*

(1 July 2009) The hull girder ultimate strength calculation is based on the "gross" ship approach, wherein the nominal design corrosion values are not considered. The hull girder ultimate bending capacity M_u for the design environmental condition (DEC) is to satisfy the limit state specified in 5A-3-3/3.5.

The method for calculating the ultimate hull girder ultimate bending capacity M_u is to identify the critical failure modes of the main longitudinal structural elements. Structural elements compressed beyond their buckling limit have reduced strength according to their buckling and ultimate strength characteristics. All relevant failure modes for individual structural elements, such as plate buckling, beam-column buckling, torsional stiffener buckling, local buckling of stiffeners, and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

In applying the incremental-iterative approach, the following assumptions and limitations are generally to be observed:

- The ultimate strength, M_u, is calculated for the hull transverse sections between two adjacent transverse frames;
- The transverse main supporting members, including frames, girders and floors, and their associated effective plating are to have a moment of inertia not less than I_G obtained from the following equation:

  $I_G/i_o \geq 0.2(B_s/\ell)^3(B_s/s)$

  where I_G, i_o, B_s, ℓ and s are defined in 5A-3-4/7.9.3.
- The hull transverse section remains plane during each curvature increment application;
- The hull material has an elasto-plastic behavior;
- The element stress, f_i, corresponding to the element strain, ε_i, is selected as the minimum stress among the values obtained from each of the relevant load-end shortening curves, f_i -ε_i, in Appendix 5A-3-A3;
- The hull transverse section is divided into a set of individual elements; the elements while considered to be acting independently are combined to provide the ultimate strength resistance of the hull's transverse cross section. These elements are:
  - Plate element, for unstiffened plates;
  - Stiffener element, consisting of a stiffener with an associated effective width of plating;
  - Corner element, consisting of a plate intersection with a web plate.

The procedure for calculating the hull girder ultimate capacity, M_u, based on the incremental-iterative approach is described below.

Each step of the incremental procedure is represented by the calculation of the bending moment M^j, which acts on the hull transverse section as the effect of an imposed curvature χ^j.

For each step, the value χ^j is obtained by adding an increment of curvature, $\Delta\chi$, to the curvature χ^{j-1} value from the previous step. The increment of curvature corresponds to an increment of rotation of the hull's transverse section around its instantaneous horizontal neutral axis.

The rotation angle increment induces axial strain, ε, in each structural element of the hull section, whose value depends on the distance between the element's location and the instantaneous horizontal neutral axis. In the sagging condition, the structural elements above the instantaneous horizontal neutral axis are shortened, whereas the elements below the instantaneous horizontal neutral axis are lengthened. This is reversed in the hogging condition.

The structural element stress, f_i, induced by strain, ε_i, is to be obtained from the load-end shortening curve f_i -ε_i of the element, as described in Appendix 5A-3-A3, which takes into account the nonlinear elasto-plastic behavior of the element. The stress in each element is converted to a force. The equilibrium of the element forces is then used in an iterative process to determine the instantaneous horizontal neutral axis position of the hull's transverse cross-section.

Once the position of the instantaneous horizontal neutral axis is determined with the relevant element force distribution, the bending moment capacity of the section, M^j, about the instantaneous horizontal neutral axis, is obtained by combining the contribution from each element.

5A-3-A3/Figure 1 is a flow chart showing the main steps of the incremental-iterative approach.

The nonlinear material behavior for in-plane tension or compression is different for different element types. When a structural element is in tension, full plasticity beyond yield (up to a rupture limit) is normally anticipated. However, when a structural element is under compression, elasto-plastic material and nonlinear geometric behavior occur. The tensile and compressive behavior for the different structural elements used in calculating hull girder ultimate strength can be described by the so-called, 'load-end shortening' curves, as described in detail in the following.

1 Plate Element

Unstiffened plates comprising the hull transverse sections may collapse in one of two failure modes:

- Yielding in tension
- Buckling in compression

The load-end shortening curve, f_i - ε_i, for unstiffened plate buckling, is shown in 5A-3-A3/Figure 2 and is defined by the following equations:

1.1 Yielding in Tension

When an unstiffened plate is stretched in tension, the load-end shortening curve, f_i - ε_i, is idealized as the elastic-perfectly plastic relationship:

$$\frac{f_i}{f_y} = \begin{cases} \bar{\varepsilon}_i & \text{for} \quad 0 \le \bar{\varepsilon}_i \le 1 \\ 1 & \text{for} \quad \bar{\varepsilon}_i > 1 \end{cases} \qquad \text{(A3.1)}$$

1.3 Buckling in Compression

The stress acting on an unstiffened plate, f_i, is to be limited to its ultimate strength, f_u, and not less than critical buckling stress, f_c, as specified in the following. The load-end shortening curve, f_i - ε_i, for unstiffened plate buckling, is defined by the following equation:

- When $\bar{\varepsilon}_i \le f_u/f_y$

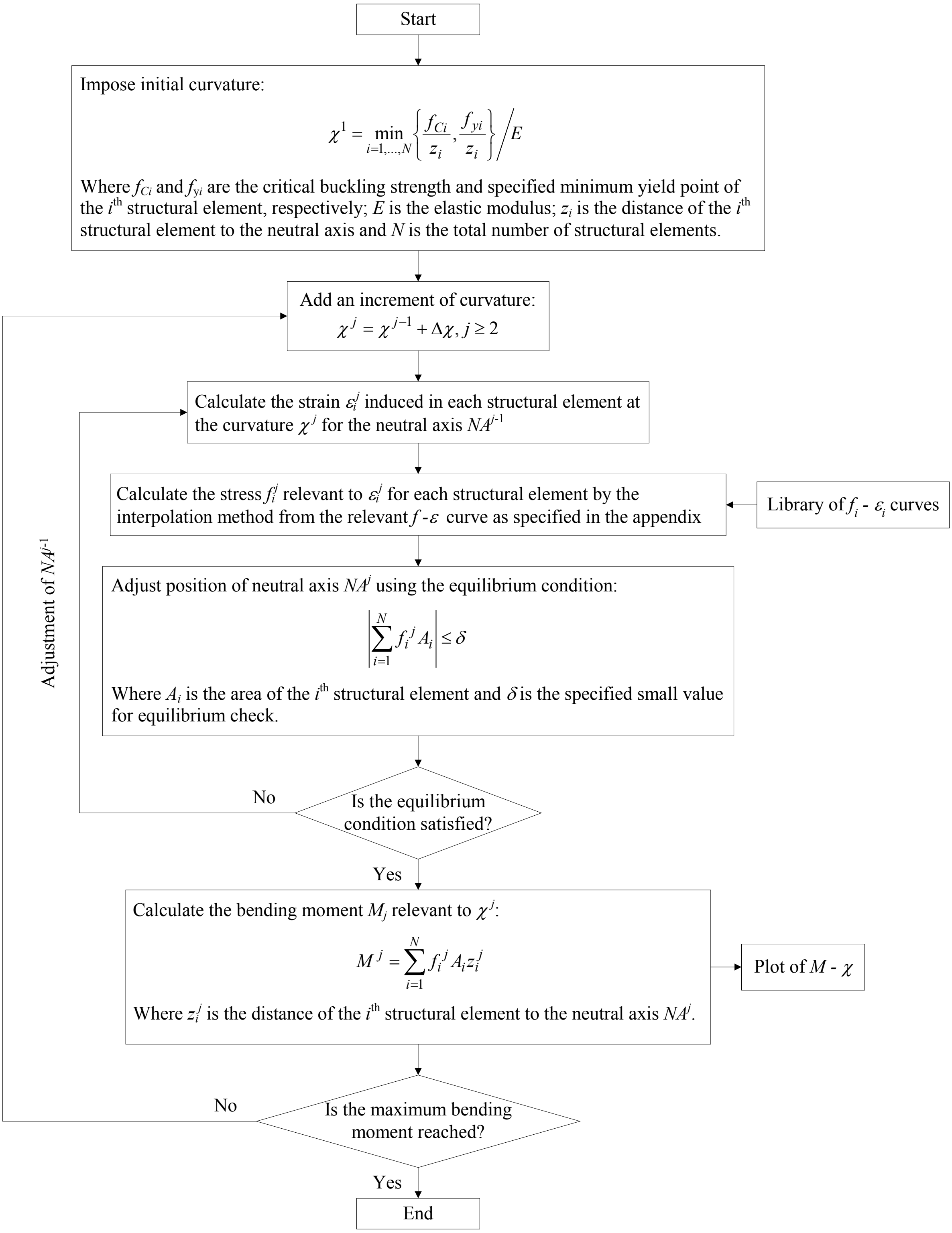
$$f_i^E = f_y \bar{\varepsilon}_i$$

- When $\bar{\varepsilon}_i > f_u/f_y$

$$\frac{f_{ip}^E}{f_y} = \begin{cases} C_E & \text{for} \quad \alpha \ge 1 \\ C_E \cdot \dfrac{s}{\ell} + 0.1\left(1 - \dfrac{s}{\ell}\right)\left(1 + \dfrac{1}{\beta_E^2}\right)^2 & \text{for} \quad \alpha < 1 \end{cases}$$

$$f_{ci}^E \le f_{ip}^E \le f_u$$

FIGURE 1
Flow Chart for the Evaluation of the Bending Moment-Curvature Curve, M-χ *(December 2008)*



where

C_E = 1.0 for $\beta_E \le 1.0$

= $2/\beta_E - 1/\beta_E^2$ for $\beta_E > 1.0$

β_E = $s/t\sqrt{\bar{\varepsilon}_i^n f_y / E}$

f_{ci}^E = $\dfrac{f_{ei}}{\bar{\varepsilon}^n}$ for $f_e \le P_r f_y \bar{\varepsilon}^n$

= $f_y\left[1 - P_r(1 - P_r)\dfrac{f_y \bar{\varepsilon}_i^n}{f_{ei}}\right]$ for $f_e > P_r f_y \bar{\varepsilon}^n$

$\bar{\varepsilon}_i$ = relative strain ratio, equal to $\varepsilon_i/\varepsilon_y$

ε_i = element axial strain

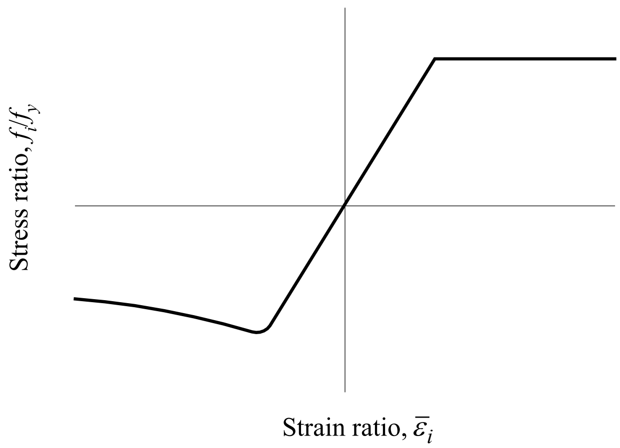
ε_y = initial yield strain

n = exponent to $\bar{\varepsilon}$ denoting post-buckling behavior, which may be taken as 2.0 for steel

f_u = plate ultimate strength $\ge f_c$

f_c and f_u are set equal to f_{ci} and f_{ip} when $n = 0$.

FIGURE 2
Load-End Shortening Curve for Plate Element *(December 2008)*



3 Stiffener Element

A longitudinal plate stiffener (i.e., axis is normal to the hull's transverse section) may fail in one of four modes:

- Yielding in tension
- Beam-column buckling
- Torsional-flexural buckling
- Local buckling of stiffeners

The load-end shortening curves, f_i - ε_i, for each failure mode are described below.

3.1 Yielding in Tension

The load-end shortening curve for yielding in tension is the same as in 5A-3-A3/1.

3.3 Beam-Column Buckling

The load-end shortening curve, f_i - ε_i, as shown in 5A-3-A3/Figure 3 for beam-column buckling is defined by the following equation:

- When $\bar{\varepsilon}_i \le f_{ca}/f_y$

$$f_{ci} = f_y\,\bar{\varepsilon}_i$$

- When $\bar{\varepsilon}_i > f_{ca}/f_y$

$$f_{ci} = f_{ca}^E \frac{A_s + s_e^E t}{A_s + st} \le f_{ca} \frac{A_s + s_e t}{A_s + st}$$

where

$$f_{ca}^E = \frac{f_{E(C)}}{\bar{\varepsilon}_i^n} \qquad \text{for } f_{E(C)} \le P_r f_y \bar{\varepsilon}^n$$

$$= f_y\left[1 - P_r(1 - P_r)\frac{f_y \bar{\varepsilon}_i^n}{f_{E(C)}}\right] \qquad \text{for } f_{E(C)} > P_r f_y \bar{\varepsilon}^n$$

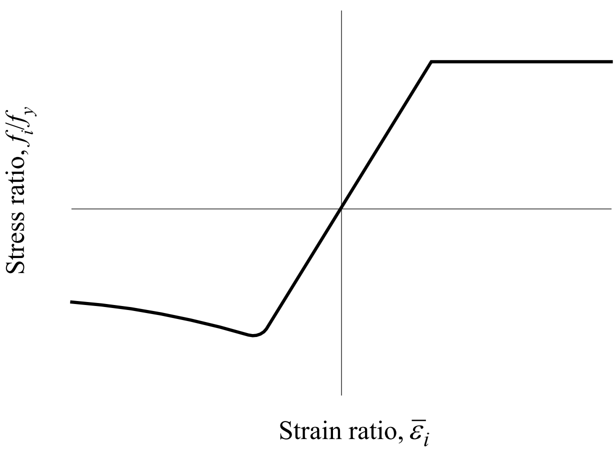
$$s_e^E = C_E s$$

$$C_E = 1.0 \qquad \text{for } \beta_E \le 1.0$$

$$= 2/\beta_E - 1/\beta_E^2 \qquad \text{for } \beta_E > 1.0$$

f_{ca} is set equal to f_{ca}^E when n =0

FIGURE 3
Load-End Shortening Curve for Beam-Column Buckling *(December 2008)*



3.5 Torsional-Flexural Buckling

The load-end shortening curves, f_i - ε_i, as shown in 5A-3-A3/Figure 4 for torsional-flexural buckling is defined by the following equation:

- When $\bar{\varepsilon}_i \le f_{ct}/f_y$

$$f_i = f_y\ \bar{\varepsilon}_i$$

- When $\bar{\varepsilon}_i > f_{ct}/f_y$

$$f_i = \frac{f_{ct}^E A_s + f_{ip}^E st}{A_s + st}$$

where

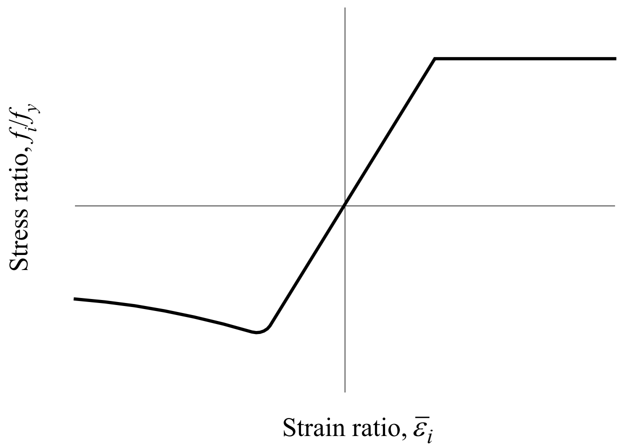
$$f_{ct}^E = \frac{f_{ET}}{\bar{\varepsilon}_i^n} \qquad \text{for } f_{ET} \le P_r f_y \bar{\varepsilon}^n$$

$$= f_y \left[1 - P_r(1 - P_r)\frac{f_y \bar{\varepsilon}_i^n}{f_{ET}}\right] \qquad \text{for } f_{ET} > P_r f_y \bar{\varepsilon}^n$$

f_{ct}^E is to be less than f_{ct}.

f_{ct} and f_{ET} are the critical and elastic torsional/flexural buckling stresses and are calculated in 5A-3-4/7.5.2, where gross scantlings are used.

FIGURE 4
Load-End Shortening Curve for Torsional-Flexural Buckling
(December 2008)



3.7 Local Buckling of Stiffeners

This failure mode is to be assessed if the proportions of stiffeners specified in 5A-3-4/7.9 are not satisfied.

The load-end shortening curve, f_i - ε_i, as shown in 5A-3-A3/Figure 5 for local buckling of stiffeners is defined by the following equation:

- When $\bar{\varepsilon}_i \le f_{c\ell}/f_y$

$$f_i = f_y\,\bar{\varepsilon}_i$$

- When $\bar{\varepsilon}_i > f_{c\ell}/f_y$

$$f_i = \frac{f_{c\ell}^E A_s + f_{ip}^E st}{A_s + st}$$

where

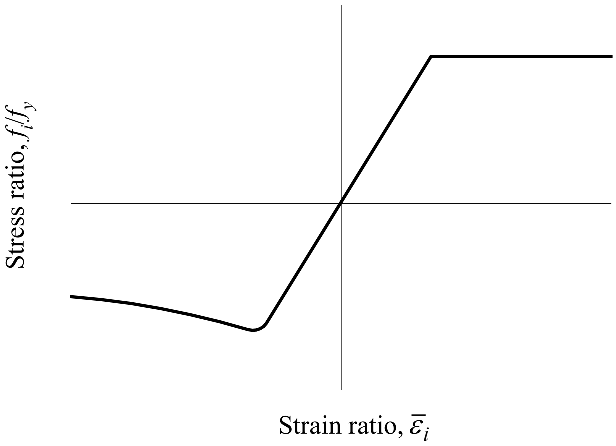
$$f_{c\ell}^E = \frac{f_{e\ell}}{\bar{\varepsilon}^n} \qquad \text{for } f_{e\ell} \le P_r f_y \bar{\varepsilon}^n$$

$$= f_y\left[1 - P_r(1-P_r)\frac{f_y\bar{\varepsilon}_i^n}{f_{e\ell}}\right] \qquad \text{for } f_{e\ell} > P_r f_y \bar{\varepsilon}^n$$

$f_{c\ell}^E$ is to be less than $f_{c\ell}$.

$f_{c\ell}$ and $f_{e\ell}$ are local critical and elastic buckling stress and are calculated in 5A-3-4/7.3, where gross scantlings are used.

FIGURE 5
Load-End Shortening Curve for Local Buckling *(December 2008)*

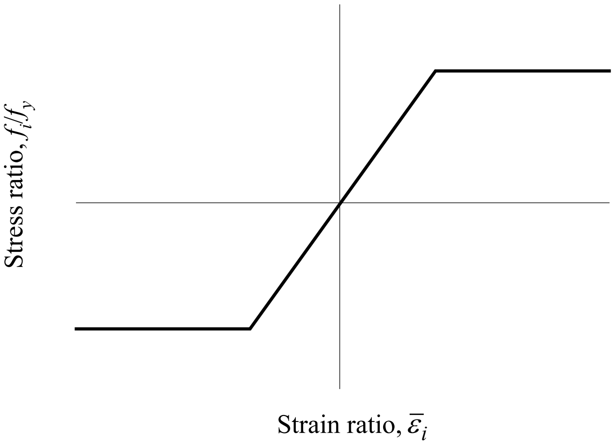


5 Corner Element

Corner elements are considered stocky elements, which collapse due to 'fully plastic' development. The relevant load-end shortening curve, f_i - ε_i, as shown in 5A-3-A3/Figure 6, is idealized by the elastic-perfectly plastic relationship given in the following:

$$\frac{f_i}{f_y} = \begin{cases} -1 & \text{for} \quad \bar{\varepsilon}_i < -1 \\ \bar{\varepsilon}_i & \text{for} \quad -1 \le \bar{\varepsilon}_i \le 1 \\ 1 & \text{for} \quad \bar{\varepsilon}_i > 1 \end{cases}$$

FIGURE 6
Load-End Shortening Curve for a Corner Element *(December 2008)*



PART
5A

CHAPTER **3 Structural Design Requirements**

APPENDIX **4 Finite Element Analysis for Ship-Type Installations** *(2014)*

1 Objective

This Appendix provides guidance for the calculation of structural responses by performing finite element analysis of the ship structures, as required by the Total Strength Assessment (TSA) in Section 5A-3-4.

In general, this guidance is based on the requirements for a three cargo tank length model as outlined in 5A-3-4/11. However the guidance provided on selection of element types and mesh size, and fine mesh analysis is also applicable to a cargo block or full ship length model.

With this Appendix, it is intended that the structural idealization, load application, and analysis procedure used for the finite element structural analysis are performed in a consistent manner and based on sound engineering judgment.

3 Scope of Application

The strength requirements specified in Section 5A-3-4 are based on a "net" ship approach. For new construction, the nominal design corrosion margins, given in 5A-3-1/Table 1 and 5A-3-1/Figure 1 for the double hull ship-type installations and 5A-3-6/1.1 for the single hull ship-type installations, are to be deducted from the scantlings for the finite element analysis and strength assessment of the hull structures. For an installation being converted from a vessel to FPI service, the reassessed net scantlings are used for the finite element analysis and strength assessment. The reassessed net scantlings are obtained by deducting the nominal design corrosion margins from the reassessed scantlings.

The analysis includes a three-dimensional global model of the three-hold hull girder and local fine-mesh models as follows:

- Transverse web frames, longitudinal girders, horizontal girders, side stringers, and centerline ring frames, etc.

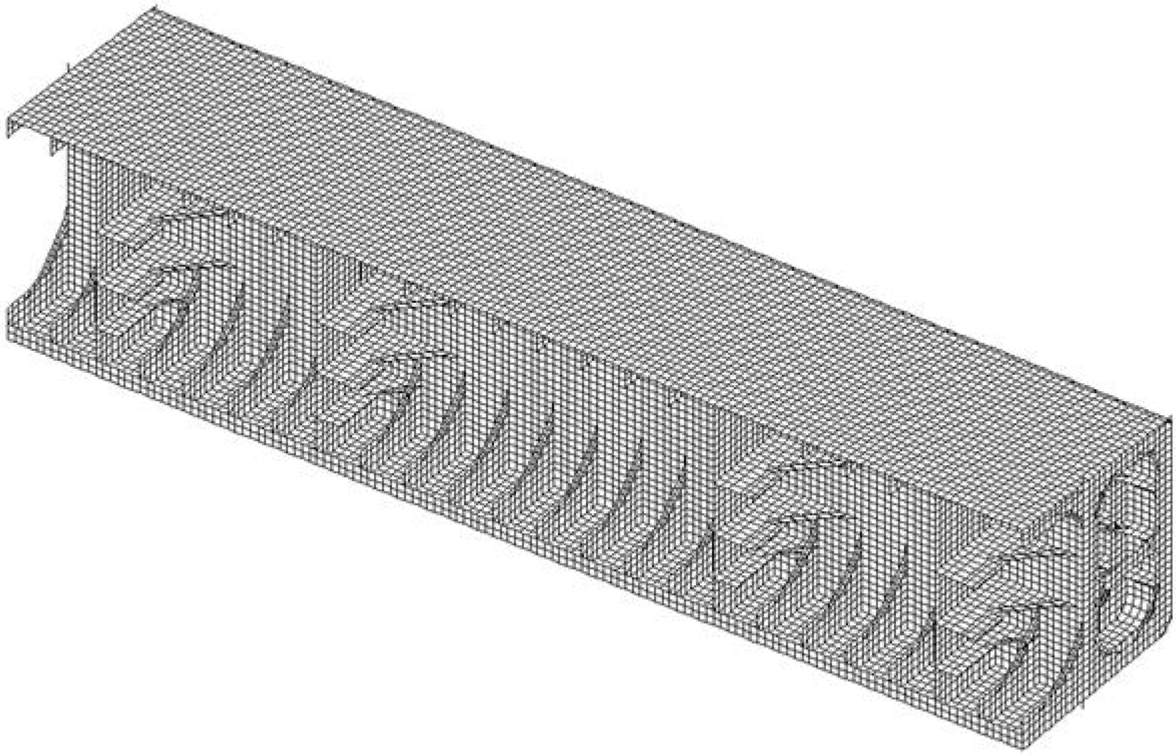
These local fine-mesh models are used to determine the additional requirement for critical areas of the main supporting members of the hull girder.

The guidelines described herein regarding structural idealization, finite element modeling techniques, and analysis procedures are also applicable to general hull structural analyses.

5 Extent of the 3-D Global Finite Element Model

The purpose of the 3-D global FE analysis is to determine the overall structural response of the hull girder structure, including primary and secondary bending, and also to obtain appropriate boundary conditions for use in the local fine-mesh FE analysis of local structures. The extent of the hull structure to be modeled is to cover three cargo tank lengths located at about amidships, as shown in 5A-3-A4/Figure 1. It is to extend two frames fore and aft of the two end bulkheads. All primary load-carrying members are to be modeled. Secondary structural members which may affect the overall load distribution are also to be appropriately accounted for.

FIGURE 1
Extent of 3-D Global Finite Element Model *(December 2008)*



7 Coordinate System of the Model

The global coordinate (right-hand) system of this reference finite element model is defined as follows:

X axis: Longitudinal direction, positive forward,

Y axis: Vertical direction, positive upwards from baseline,

Z axis: Transverse direction, positive toward starboard from centerline,

Origin: At the intersection of baseline and centerline at first watertight bulkhead of the aft end of the model

The six degrees of freedom for the nodes are defined with respect to the Cartesian global X, Y and Z axes of the 3-D finite element model, (See 5A-3-A4/Figure 1), as u_x, u_y, and u_z for the three translational degrees of freedom, and θ_x, θ_y, and θ_z for the three rotational degrees of freedom.

9 Element Types

The structural elements, whose geometry, configuration and stiffness approximate the actual ship's hull structure, are of three types commonly used.

i) *Rod (or truss) elements,* with axial stiffness only and constant cross-sectional area along the length of the element.

ii) *Bar (or Beam) elements without offset,* with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element.

iii) *Shell (or bending plate) elements,* with in-plane stiffness and out-of-plane bending stiffness with constant thickness.

Higher order element types exist, however the above three *simple* types of element are sufficient for a good representation of the hull girder. The appropriate usage of the aforementioned element types in the modeling procedure is discussed in the following sections.

9.1 Plate Elements

For finite element modeling of a hull structure, the plating is typically represented by bending plate elements.

In general, the plate element mesh is to follow the stiffener system as far as practicable, hence representing the actual plate panels between stiffeners. The mesh size is to satisfy the following requirements:

i) One element between every longitudinal stiffeners, see 5A-3-A4/Figure 2. Longitudinally, the element length is not to be greater than 2 longitudinal spaces.

ii) One element between every vertical stiffener on transverse bulkheads, see 5A-3-A4/Figure 3.

iii) *(1 July 2012)* One element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see 5A-3-A4/Figure 2 and 5A-3-A4/Figure 4.

iv) At least three elements over the depth of double bottom girders and floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads.

v) For cross tie, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, representation using two elements over the depth is acceptable provided that there is at least one element between every web stiffener. The mesh size of the adjacent structure is to be adjusted to suit.

vi) The mesh on the hopper tank web frame shall be fine enough to represent the shape of the web ring opening, see 5A-3-A4/Figure 2.

vii) The curvature of the free edge on large brackets of primary supporting members is to be modeled accurately to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable.

viii) The bracket toe may be terminated at the nearest nodal point provided that the modeled length of bracket arm does not exceed the actual bracket arm length.

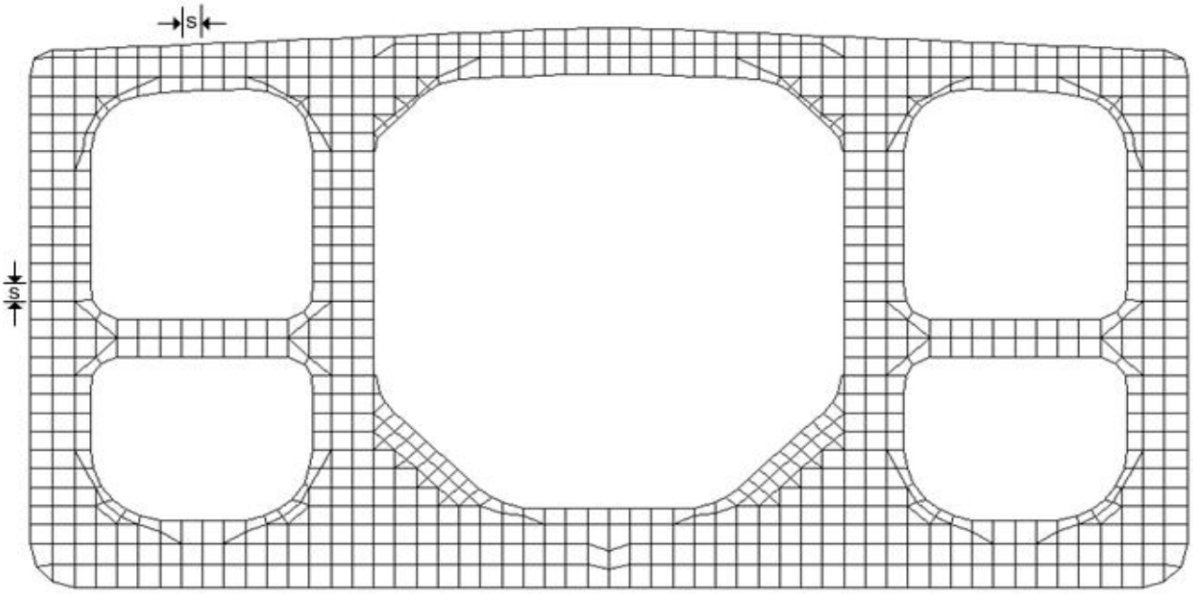
ix) *(1 July 2012)* The bracket flange of a transverse is not to be connected to the longitudinal plating, see 5A-3-A4/Figure 5. An acceptable mesh is shown in 5A-3-A4/Figure 5.

x) The aspect ratio of the plate elements is in general not to exceed three. The use of triangular plate elements is to be kept to a minimum. Where possible, the aspect ratio of plate elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to one and the use of triangular elements is to be avoided.

xi) *(1 July 2012)* Typical mesh arrangements of the cargo tank structures are shown in 5A-3-A4/Figure 1.

Manholes on transverse and longitudinal structures, such as double bottom floors and longitudinal girders, are generally ignored in the global model. Leaving out plate elements or reducing plate thicknesses to account for such manholes in the 3-D model are not advisable, because this would sometimes result in unrealistic shearing stresses for the thinned plates or the adjacent elements. The actual behavior of a round or elliptical manhole with or without a flange is quite different from the modeled thin plate or element opening which is usually rectangular.

FIGURE 2
Typical Finite Element Mesh on Web Frame *(December 2008)*



s = stiffener spacing

FIGURE 3
Typical Finite Element Mesh on Transverse Bulkhead *(December 2008)*

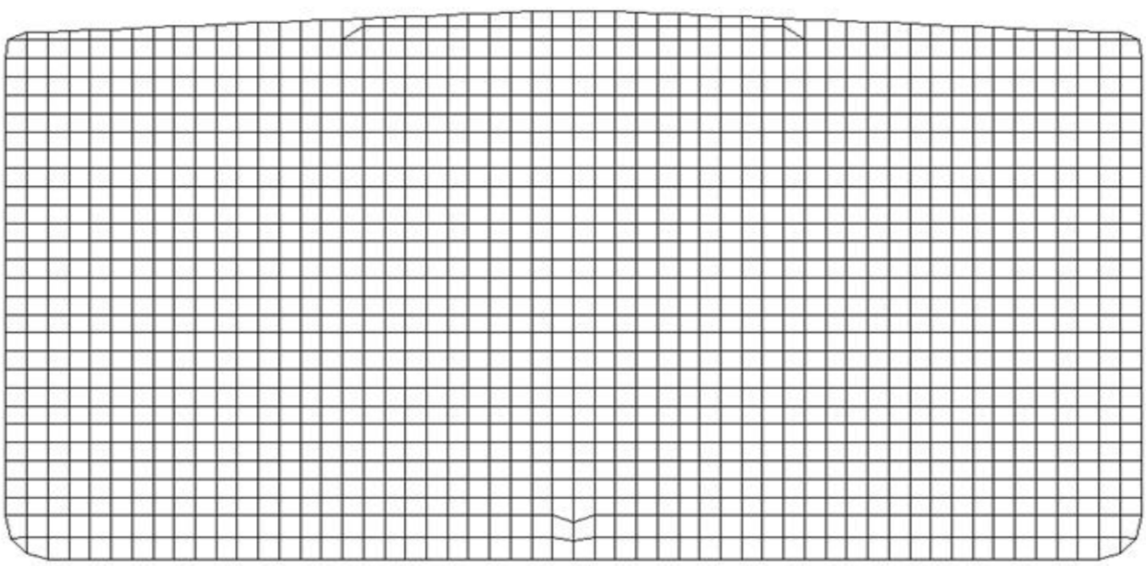


FIGURE 4
Typical Finite Element Mesh on Horizontal Transverse Stringer on Transverse Bulkhead *(December 2008)*

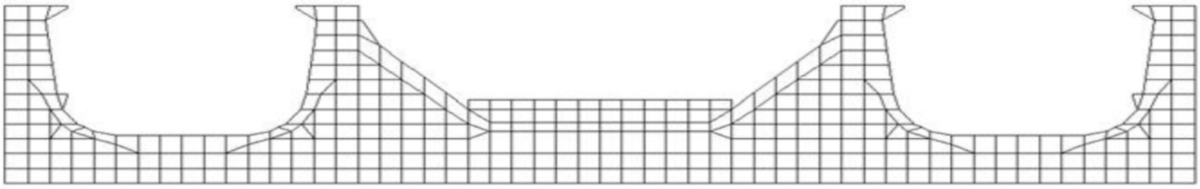
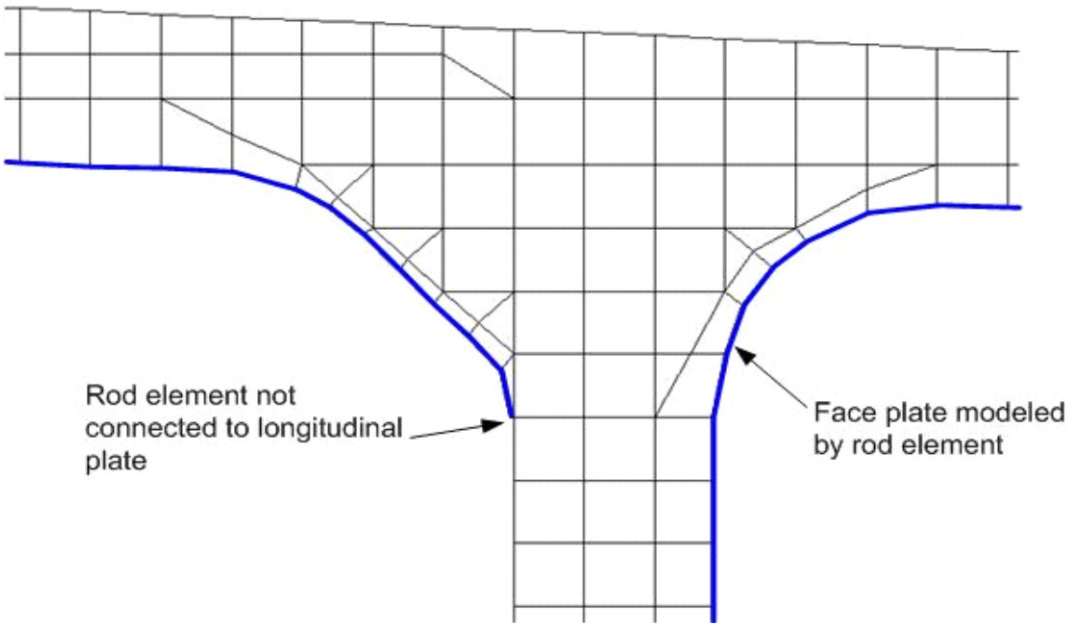


FIGURE 5
Typical Finite Element Mesh on Transverse Web Frame Main Bracket *(December 2008)*



9.3 Bar (or Beam) Elements for Stiffeners

All local stiffeners are to be modeled. The stiffeners may be modeled using line elements positioned in the plane of the plating. Bar elements are to be used in areas under action of lateral loads whilst rod elements in 5A-3-A4/9.5 may be used to represent local stiffeners on internal structural members under no lateral loads.

The bar elements are to have the following properties:

i) Stiffeners are typically modeled by bar elements without offset.

ii) The bar element cross sectional area is based on the net stiffener area excluding the area of the attached plating.

iii) Out of plane bending properties are to represent the inertia of the combined plating and stiffener.

iv) The width of the attached plate is to be taken as half + half stiffener spacing on each side of the stiffener.

v) The eccentricity of the neutral axis is not required to be modeled.

9.5 Rod (or Truss) Elements for Stiffeners

Web stiffeners on primary support members are to be modeled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilization factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverse and stringers parallel to the flange are to be modeled. These stiffeners may be modeled using rod elements.

9.7 Rod Elements for Face Plates of Primary Supporting Members *(1 July 2012)*

All face plates are to be accounted for and may be modeled by rod elements.

For a typical hull structure, there are numerous secondary flat bars, stiffeners, tripping brackets and panel "breakers". These structural members are mainly to provide local stiffness to plate panels against buckling or vibration. These secondary stiffening members generally need not be included in the global model as their influence on the overall response of the hull structure is negligible.

11 General Guidance for 3-D Global FE Modeling

The approach of finite element modeling adopted here is to use a 3-D global finite element model to obtain the overall response of the hull girder under the imposed sea loading. The stress results of the global model are used not only to assess the hull girder plating of the deck, side shell, bottom, inner bottom, longitudinal bulkheads, transverse bulkheads and stools or deck box girders but also to assess the main supporting members. The boundary conditions for the local FE models are the appropriate nodal displacements obtained from the 3-D global model analysis. Therefore, in developing the 3-D global finite element model, special attention is to be paid to the following general guidance:

i) The finite element model is to include all primary load-carrying members. Secondary structural members which may affect the overall load distribution are also to be appropriately accounted for.

ii) Structural idealization is to be based on the stiffness and anticipated response of the structure, not wholly on the geometry of the structure itself.

iii) A common mistake is to simply match the finite element mesh with the configuration of the structure. Very often a finite element model, created in this way, which "looks good" and represents the structural geometry well, but in reality it represents the structural properties and performance poorly.

iv) It is desirable to have consistent modeling throughout the entire length of the three cargo tanks considered. However, the middle tank is to always have the desired mesh, where more accurate results are expected (due to boundary effects) and are therefore used in the strength assessment. If approximations have to be made, do so only in the two end-tanks.

v) It is important to consider the relative stiffness between associated structural members and their anticipated response under the specified loading.

vi) Bottom transverses in single-hull vessels and double bottom floors in double-hull vessels usually have high restraint at the ends, and therefore require an adequate mesh to achieve reasonable accuracy.

13 Loading Conditions

13.1 Combined Load Cases and Loading Pattern

The standard combined load cases as specified in 5A-3-2/Tables 1A through 1C with the corresponding loading pattern specified in 5A-3-2/Figure 1 are to be used in the FE analysis.

13.3 Sloshing Load Cases

In assessing the strength of tank boundary supporting structures, the two combined load cases as specified in 5A-3-2/Table 2 with the corresponding loading pattern specified in 5A-3-2/Figure 18 are to be considered in the FE analysis.

13.5 Target Hull Girder Vertical Bending Moment and Vertical Shear Force *(1 July 2012)*

13.5.1 Hull Girder Vertical Bending Moment

The hull girder vertical bending moment is to reach the following required target value, $M_{v\text{-}targ}$, which is a combination of the rule-required still water bending moment and the wave- induced vertical bending moment, at a section within the length of the middle tank of the three tanks FE model:

$$M_{v\text{-}targ} = M_{sw} + k_u k_c \beta_{VBM} M_{wv}$$

where

M_{sw} = still water bending moment to be applied to the FE load case, as specified in 3-2-1/3.7 of the *Steel Vessel Rules*

M_{wv} = vertical wave bending moment for the dynamic load case under consideration, calculated in accordance with 3-2-1/3.5 of the *Steel Vessel Rules*

β_{VBM} = ESF for vertical bending moments as defined in 5A-3-A1/3

k_u = load factor, is taken as 1.0 as specified in 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3

k_c = correlation factor, is taken value as specified in 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3

13.5.2 Hull Girder Vertical Shear Force

The hull girder vertical shear force is to reach the following required F_{targ} value at the forward transverse bulkhead position of the middle tank. The target hull girder vertical shear force is a combination of the rule-required still water shear force and the wave-induced vertical shear force:

$$F_{targ} = F_{sw} + k_u k_c \beta_{VSF} F_{wv}$$

where

F_{sw} = vertical still water shear force to be applied to the FE load case, as specified in 3-2-1/3.9 of the *Steel Vessel Rules*

F_{wv} = vertical wave shear force for the dynamic load case under consideration, calculated in accordance with 3-2-1/3.5 of the *Steel Vessel Rules*

β_{VSF} = ESF for vertical shear force as defined in 5A-3-A1/3

k_u = load factor, is taken as 1.0 as specified in 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3

k_c = correlation factor, is taken value as specified in 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3

13.5.3 Balance of Hull Girder Bending Moment and Shear Force

The required target values of hull girder vertical bending moment and shear force are to be achieved in the same load case where required by 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3. The procedure to apply the required shear force and bending moment distributions is described in 5A-3-A4/15.1.

13.7 Target Hull Girder Horizontal Wave Bending Moment *(1 July 2012)*

The hull girder horizontal wave bending moment at a section within the length of the middle tank of the three tanks FE model is to reach the target value required by the dynamic load case where required by 5A-3-2/Tables 1A through 1C and 5A-3-2/Table 3, calculated in accordance with 5A-3-2/7.3.2.

The procedure to adjust the required hull girder horizontal bending moment is described in 5A-3-A4/15.1.

15 Procedure to Adjust Hull Girder Shear Force and Bending Moment

15.1 General *(1 July 2012)*

The procedure described in this Subsection is to be applied to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distributions on the three cargo tanks FE model to achieve the required target values.

Vertical distributed loads are applied to each frame position, together with a vertical bending moment applied to the model ends to produce the required target value of vertical shear force at the forward bulkhead of the middle tank of the FE model, and the required target value of vertical bending moment at a section within the length of the middle tank of the FE model. The required target values are specified in 5A-3-A4/13.5.

A horizontal bending moment is applied to the ends of the model to produce the required target value of horizontal bending moment at a section within the length of the middle tank of the FE model. The required values are specified in 5A-3-A4/13.7.

15.3 Shear Force and Bending Moment due to Local Loads

15.3.1 Vertical Shear Forces

The vertical shear forces generated by the local loads are to be calculated at the transverse bulkhead positions of the middle tank of the FE model. The vertical bending moment distribution generated by the local loads is to be calculated along the length of the middle tank of the three cargo tank FE model. The FE model can be used to calculate the shear forces and bending moments. Alternatively, a simple beam model representing the length of the 3-tank FE model with simply supported ends may be used to determine the shear force and bending moment values.

15.3.2 Horizontal Bending Moment Distribution

For beam and oblique sea conditions, the horizontal bending moment distribution due to dynamic sea pressure and dynamic tank pressure is to be calculated along the length of the middle tank of the FE model.

15.3.3 Local Loads

The following local loads are to be applied for the calculation of hull girder shear forces and bending moments:

i) Ship structural weight distribution over the length of the 3-tank model (static loads). Where a simple beam model is used, the weight of the structure of each tank can be distributed evenly over the length of the cargo tank. The structural weight is to be calculated based on a thickness of the net scantlings to be considered as used in the construction of the cargo tank FE model, see 5A-3-A4/3.

ii) Weight of cargo and ballast (static loads)

iii) Static sea pressure and dynamic wave pressure

iv) Dynamic tank pressure

15.5 Procedure to Adjust Vertical Shear Force Distribution to Target Values *(1 July 2012)*

15.5.1 Adjustment in Shear Forces at Transverse Bulkhead Positions

The required adjustment in shear forces at the transverse bulkhead positions (ΔQ_{aft} and ΔQ_{fwd} as shown in 5A-3-A4/Figure 6) are to be generated by applying vertical load at the frame positions as shown in 5A-3-A4/Figure 7. It is to be noted that vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward tank and any frames aft of the aft tank of the FE model. The sum of the total vertical correction loads applied is equal to zero.

15.5.2 Adjustment in Shear Forces at Aft and Forward Transverse Bulkheads of Middle Tank of FE Model

The required adjustments in shear forces at the aft and forward transverse bulkheads of the middle tank of the FE model in order to generate the required target shear forces at the bulkheads are given by:

$$\Delta Q_{aft} = -Q_{targ} - Q_{aft}$$

$$\Delta Q_{fwd} = Q_{targ} - Q_{fwd}$$

where

ΔQ_{aft} = required adjustment in shear force at aft bulkhead of middle tank

ΔQ_{fwd} = required adjustment in shear force at forward bulkhead of the middle tank

Q_{targ} = required shear force value to be achieved at forward bulkhead of middle tank, see 5A-3-A4/13.5.2

Q_{aft} = shear force due to local loads at aft bulkhead of middle tank

Q_{fwd} = shear force due to local loads at fore bulkhead of middle tank

15.5.3 Vertical Loads to be Applied to Each Frame

The value of the vertical loads to be applied to each frame to generate the increase in shear force at the bulkheads may be calculated using a simple beam model. For the case where a uniform frame spacing is used within each tank, the amount of vertical force to be distributed at each frame may be calculated in accordance with the equations below. The length and frame spacing of individual cargo tanks may be different.

$$\delta w_1 = \frac{\Delta Q_{aft}(2\ell - \ell_2 - \ell_3) + \Delta Q_{fwd}(\ell_2 + \ell_3)}{(n_1 - 1)(2\ell - \ell_1 - 2\ell_2 - \ell_3)}$$

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

$$\delta w_3 = \frac{-\Delta Q_{fwd}(2\ell - \ell_1 - \ell_2) - \Delta Q_{aft}(\ell_1 + \ell_2)}{(n_3 - 1)(2\ell - \ell_1 - 2\ell_2 - \ell_3)}$$

$$F = 0.5\left(\frac{W1(\ell_2 + \ell_1) - W3(\ell_2 + \ell_3)}{\ell}\right)$$

where

ℓ_1 = length of aft cargo tank of model

ℓ_2 = length of middle cargo tank of model

ℓ_3 = length of forward cargo tank of model

ΔQ_{aft} = required adjustment in shear force at aft bulkhead of middle tank, see 5A-3-A4/Figure 6

ΔQ_{fwd} = required adjustment in shear force at fore bulkhead of middle tank, see 5A-3-A4/Figure 6

F = end reactions due to application of vertical loads to frames.

$W1$ = total evenly distributed vertical load applied to aft tank of FE model

= $(n_1 - 1)\,\delta w_1$

$W2$ = total evenly distributed vertical load applied to middle tank of FE model

= $(n_2 - 1)\ \delta w_2$

$W3$ = total evenly distributed vertical load applied to forward tank of FE model

= $(n_3 - 1)\ \delta w_3$

n_1 = number of frame spaces in aft cargo tank of FE model

n_2 = number of frame spaces in middle cargo tank of FE model

n_3 = number of frame spaces in forward cargo tank of FE model

δw_1 = distributed load at frame in aft cargo tank of FE model

δw_2 = distributed load at frame in middle cargo tank of FE model

δw_3 = distributed load at frame in forward cargo tank of FE model

$\Delta\ell_{end}$ = distance between end bulkhead of aft cargo tank to aft end of FE model

$\Delta\ell_{fore}$ = distance between fore bulkhead of forward cargo tank to forward end of FE model

ℓ = total length of FE model (beam) including portions beyond end bulkheads:

= $\ell_1 + \ell_2 + \ell_3 + \Delta\ell_{end} + \Delta\ell_{fore}$

Notes

1 Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with 5A-3-A4/Figure 6 and 5A-3-A4/Figure 7.

2 $W1 + W3 = W2$

15.5.4 Adjusting Load to be Applied to Structural Parts of Transverse Frames

The amount of adjusting load to be applied to the structural parts of each transverse frame section to generate the vertical load, δw_i, is to be in accordance with 5A-3-A4/Figure 8. This load is to be distributed at the finite element grid points of the structural parts. Where 4-node or 3-node finite plate elements are used, the load to be applied at each grid point of a plate element is given by:

$$F_{i-grid} = \frac{\sum_{1}^{n} 0.5\, A_{i-elem}}{A_s} F_s$$

where

$F_{i\text{-}grid}$ = load to be applied to the *i*-th FE grid point on the individual structural member under consideration (i.e., side shell, longitudinal bulkheads and bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in 5A-3-A4/Figure 8)

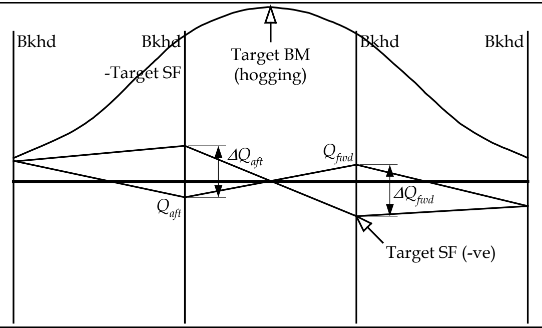
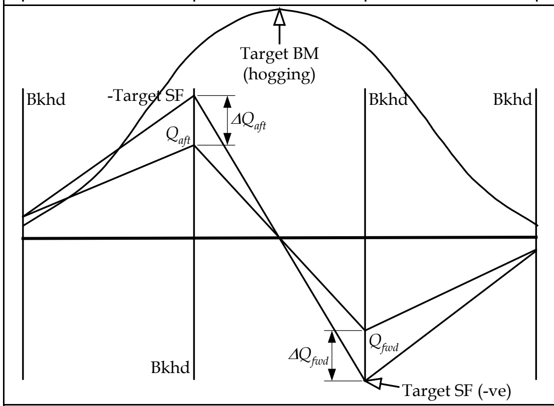
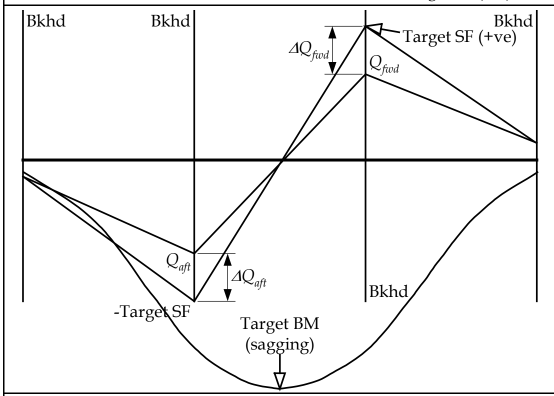
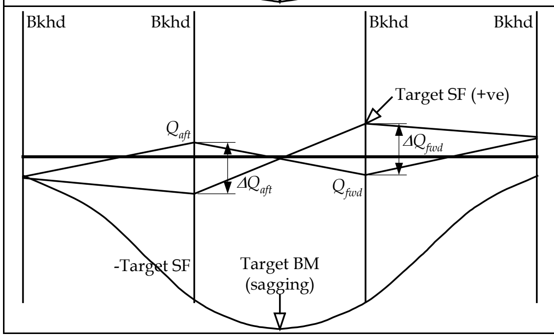
$A_{i\text{-}elem}$ = sectional area of each plate element in the individual structural member under consideration (see 5A-3-A4/Figure 8), which is connected to the *i*-th grid point

n = number of plate elements connected to the *i*-th grid point

F_s = total load applied to an individual structural member under consideration, as specified in 5A-3-A4/Figure 8

A_s = plate sectional area of the individual structural member under consideration (i.e., side shell, longitudinal bulkheads, bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in 5A-3-A4/Figure 8)

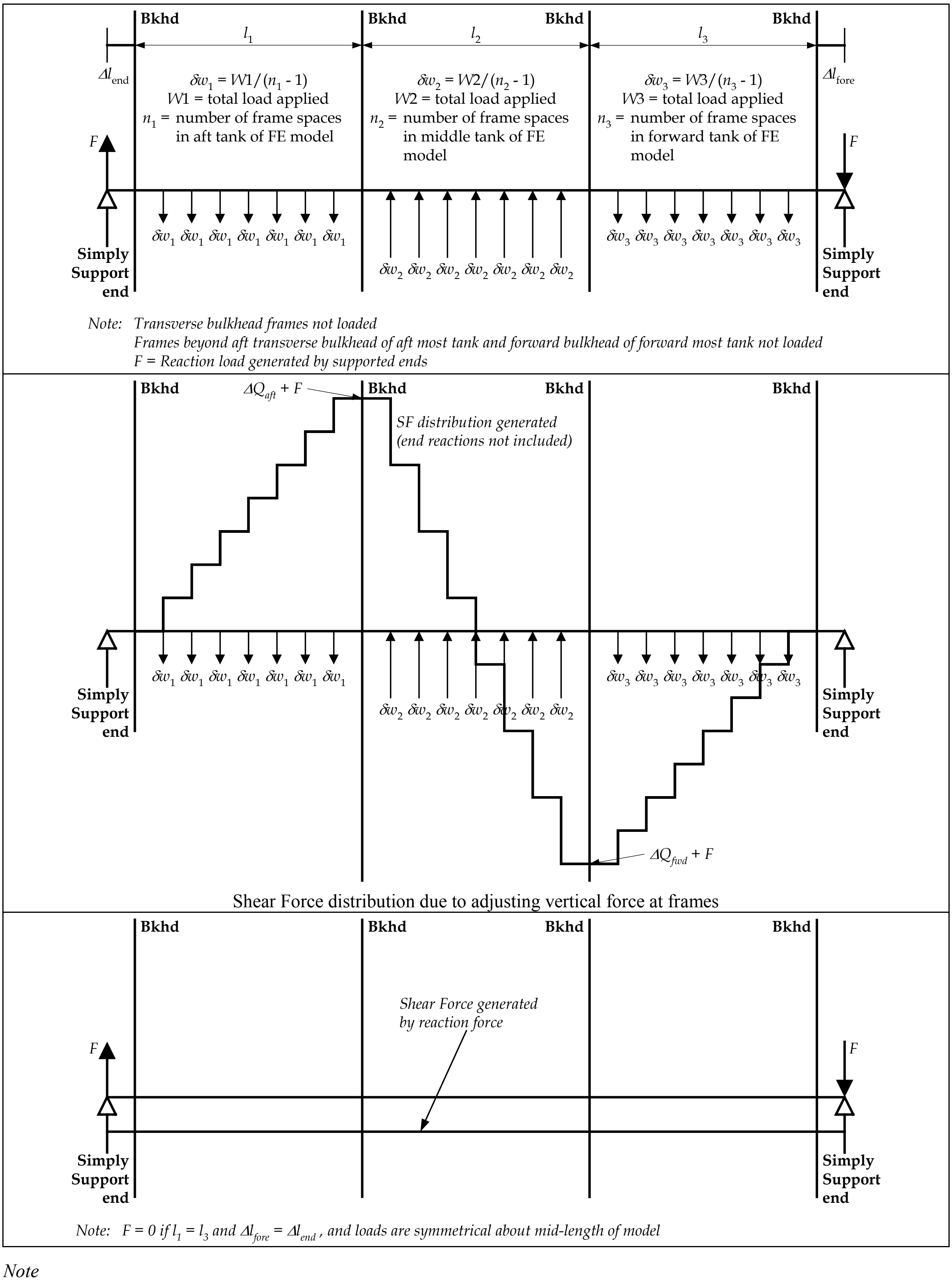
FIGURE 6
Position of Target Shear Force and Required Shear Force Adjustment at Transverse Bulkhead Positions *(December 2008)*

Condition	*Target*			*Aft Bhd*		*Fore Bhd*	
	BM	*SF*	*Bhd pos*	*SF*	ΔQ_{aft}	*SF*	ΔQ_{fwd}
	Hog	*–ve*	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (*–ve*)	$Q_{targ} - Q_{fwd}$
	Hog	*–ve*	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (*–ve*)	$Q_{targ} - Q_{fwd}$
	Sag	*+ve*	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (*+ve*)	$Q_{targ} - Q_{fwd}$
	Sag	*+ve*	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (*+ve*)	$Q_{targ} - Q_{fwd}$

Note

For definition of symbols, see 5A-3-A4/15.5.2.

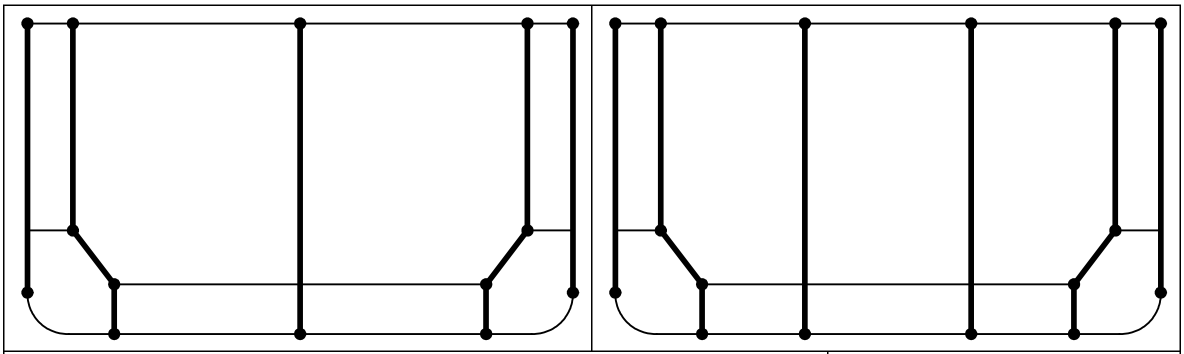
FIGURE 7
Distribution of Adjusting Vertical Force at Frames and Resulting Shear Force Distributions *(December 2008)*



Note

For definition of symbols, see 5A-3-A4/15.5.3.

FIGURE 8
Distribution of Adjusting Load on a Transverse Section *(December 2008)*



Structural Member	*Applied Load F_s*
Side Shell	$f \cdot \delta w_i$
Longitudinal bulkhead including bottom girder beneath	$f \cdot \delta w_i$
Inner hull longitudinal bulkhead (vertical part)	$f \cdot \delta w_i \cdot \frac{A_{Ih}}{A_2}$
Hopper plate	$f \cdot \delta w_i \cdot \frac{A_{Hp}}{A_2}$
Upper slope plating of inner hull	$f \cdot \delta w_i \cdot \frac{A_{Usp}}{A_2}$
Outboard girder	$f \cdot \delta w_i \cdot \frac{A_{Og}}{A_2}$

Where

δw_i = vertical load to be applied to each transverse frame section, see 5A-3-A4/15.5.3

f = shear force distribution factor of structural part calculated at the mid-tank position in accordance with 5A-3-A4/Table 1

A_{Ih} = plate sectional area of individual inner hull longitudinal bulkhead

A_{Hp} = plate sectional area of individual hopper plate

A_{Usp} = Plate sectional area of individual upper slope plate of inner hull

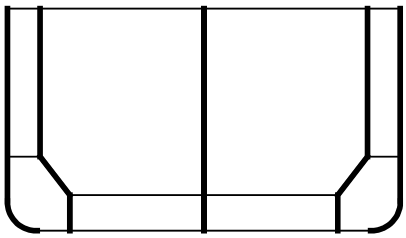
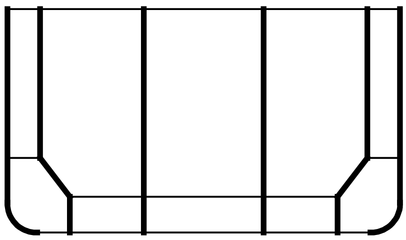
A_{Og} = plate sectional area of individual outboard girder

A_2 = plate sectional area calculated in accordance with 5A-3-A4/Table 1

Notes

1. Adjusting load is to be applied in plane to the hopper slope plate and upper slope plate of inner hull.
2. Adjusting load given is to be applied to individual structural member.

TABLE 1
Shear Force Distribution Factors *(December 2008)*

	Side Shell	$f = 0.055 + 0.097\frac{A_1}{A_2} + 0.020\frac{A_2}{A_3}$
	Inner hull	$f = 0.193 - 0.059\frac{A_1}{A_2} + 0.058\frac{A_2}{A_3}$
	CL longitudinal bulkhead	$f = 0.504 - 0.076\frac{A_1}{A_2} - 0.156\frac{A_2}{A_3}$
	Side Shell	$f = 0.028 + 0.087\frac{A_1}{A_2} + 0.023\frac{A_2}{A_3}$
	Inner hull	$f = 0.119 - 0.038\frac{A_1}{A_2} + 0.072\frac{A_2}{A_3}$
	Longitudinal bulkhead	$f = 0.353 - 0.049\frac{A_1}{A_2} - 0.095\frac{A_2}{A_3}$

Where

A_1 = plate sectional area of individual side shell (i.e., on one side), including bilge

A_2 = plate sectional area of individual inner hull longitudinal bulkhead (i.e., on one side), including hopper slope plate, double bottom side girder in way and, where fitted, upper slope plating of inner hull.

A_3 = plate sectional area of individual longitudinal bulkhead, including double bottom girder in way

Notes

1 Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.

2 All plate areas are to be calculated based on the modeled thickness of the cargo tank FE model.

15.7 Procedure to Adjust Vertical and Horizontal Bending Moments to Target Values *(1 July 2012)*

15.7.1 End Vertical Bending Moment

An additional vertical bending moment is to be applied at both ends of the cargo tank finite element model to generate the required target vertical bending moment in the middle tank of the model. This end vertical bending moment can be calculated as follows:

$$M_{v\text{-}end} = M_{v\text{-}targ} - M_{v\text{-}peak}$$

where

$M_{v\text{-}end}$ = additional vertical bending moment to be applied at both ends of finite element model

$M_{v\text{-}targ}$ = required target hogging (positive) or sagging (negative) vertical bending moment, as specified in 5A-3-A4/13.5.1

$M_{v\text{-}peak}$ = maximum or minimum bending moment within the length of the middle tank due to the local loads described in 5A-3-A4/15.3.3 and the additional vertical loads applied to generate the required shear force, see 5A-3-A4/15.5. $M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative). $M_{v\text{-}peak}$ can be obtained from FE analysis. Alternatively, $M_{v\text{-}peak}$ may be calculated as follows based on a simply supported beam model:

= $\max\{M_o + xF + M_{lineload}\}$

M_o = vertical bending moment at position x, due to the local loads described in 5A-3-A4/15.3.3

$M_{lineload}$ = vertical bending moment at position x, due to application of vertical line loads at frames to generate required shear force, see 5A-3-A4/15.5

F = reaction force at ends due to application of vertical loads to frames, see 5A-3-A4/15.5

x = longitudinal position of frame in way of the middle tank of FE model from end, see 5A-3-A4/15.5

15.7.2 End Horizontal Bending Moment

For beam and oblique sea load cases, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate the required target horizontal bending moment at a section within the length of the middle tank of the model. The additional horizontal bending moment can be calculated as follows:

$$M_{h\text{-}end} = M_{h\text{-}targ} - M_{h\text{-}peak}$$

where

$M_{h\text{-}end}$ = additional horizontal bending moment to be applied to ends of FE model

$M_{h\text{-}targ}$ = required positive or negative target horizontal bending moment, see 5A-3-A4/13.7

$M_{h\text{-}peak}$ = maximum or minimum horizontal bending moment within the length of the middle tank due to the local loads described in 5A-3-A4/13.3.3. $M_{h\text{-}peak}$ is to be taken as the maximum horizontal bending moment if $M_{h\text{-}targ}$ is positive (starboard side in tension) and as the minimum horizontal bending moment if $M_{h\text{-}targ}$ is negative (port side in tension).

15.7.3 Application of End Bending Moments to Achieve Target Values

The vertical and horizontal bending moments are to be calculated over the length of the middle tank of the FE model to identify the position and value of each maximum/minimum bending moment as specified in 5A-3-A4/15.7.1 and 5A-3-A4/15.7.2.

The additional vertical bending moment, $M_{v\text{-}end}$, and horizontal bending moment, $M_{h\text{-}end}$, are to be applied to both ends of the cargo tank model.

The vertical and horizontal bending moments may be applied at the model ends by distributing axial nodal forces to all longitudinal elements according to the simple beam theory as follows:

$$(F_x)_i = \frac{M_{v-end}}{I_z}\frac{A_i}{n_i}y_i \qquad \text{for vertical bending moment}$$

$$(F_x)_i = \frac{M_{h-end}}{I_y}\frac{A_i}{n_i}z_i \qquad \text{for horizontal bending moment}$$

where

$M_{v\text{-}end}$ = vertical bending moment to be applied to the ends of the model

$M_{h\text{-}end}$ = horizontal bending moment to be applied to the ends of the model

$(F_x)_i$ = axial force applied to a node of the i-th element

I_z = hull girder vertical moment of inertial of the end section about its horizontal neutral axis

I_y = hull girder horizontal moment of inertial of the end section about its vertical neutral axis (normally centerline)

y_i = vertical distance from the neutral axis to the center of the cross sectional area of the i-th element

z_i = horizontal distance from the neutral axis to the center of the cross sectional area of the i-th element

A_i = cross sectional area of the i-th element

n_i = number of nodal points of i-th element on the cross section, n_i = 2 for 4-node plate element

17 Boundary Conditions

17.1 General *(1 July 2012)*

All boundary conditions described in this Subsection are in accordance with the global co-ordinate system defined in 5A-3-A4/7. The boundary conditions to be applied at the ends of the cargo tank FE model are given in 5A-3-A4/Table 2. The analysis may be carried out by applying all loads to the model as a complete load case or by combining the stress responses resulting from several separate sub-cases.

Ground spring elements (i.e., spring elements with one end constrained in all 6 degrees of freedom) with stiffness in global z degree of freedom are to be applied to the grid points along deck, inner bottom and bottom shell as shown in 5A-3-A4/Figure 9.

Ground spring elements with stiffness in global y degree of freedom are to be applied to the grid points along the vertical part of the side shells, inner hull longitudinal bulkheads and oil-tight longitudinal bulkheads as shown in 5A-3-A4/Figure 9.

FIGURE 9
Spring Constraints at Model Ends *(December 2008)*

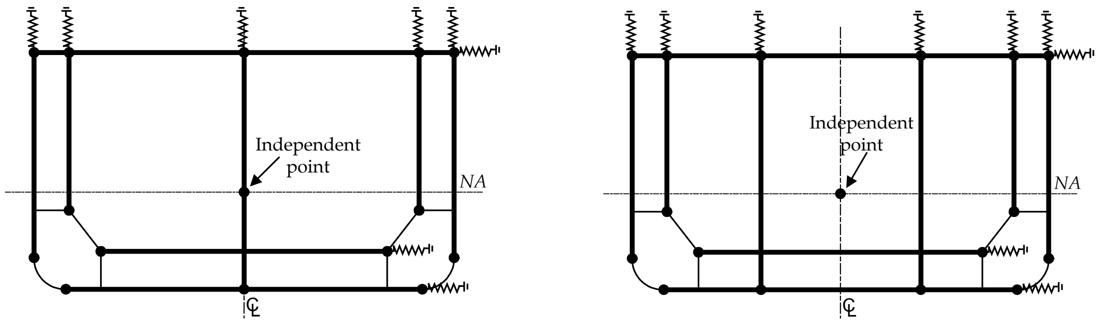


TABLE 2
Boundary Constraints at Model Ends *(December 2008)*

Location	*Translation*			*Rotation*		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Aft end (all longitudinal elements)	RL	–	–	–	RL	RL
Independent point aft end, see 5A-3-A4/Figure 9	Fix	–	–	–	$M_{h\text{-}end}$	$M_{v\text{-}end}$
Deck, inner bottom and outer shell	–	Springs	–	–	–	–
Side, inner skin and longitudinal bulkheads	–	–	Springs	–	–	–
Fore End						
Fore end (all longitudinal elements)	RL	–	–	–	RL	RL
Independent point fore end, see 5A-3-A4/Figure 9	–	–	–	–	$M_{h\text{-}end}$	$M_{v\text{-}end}$
Deck, inner bottom and outer shell	–	Springs	–	–	–	–
Side, inner skin and longitudinal bulkheads	–	–	Springs	–	–	–

Where:

– No constraint applied (free)

RL Nodal points of all longitudinal elements rigidly linked to independent point at neutral axis on centerline

Notes:

1 All translation and rotation displacements are in accordance with the global coordinate system defined in 5A-3-A4/7.

2 Where $M_{h\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_y.

3 Where $M_{v\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_z.

4 Where no bending moment is applied, the independent points at the fore and aft ends are to be free in θ_y and θ_z.

5 Where bending moment is applied as nodal forces, the independent points at the fore and aft ends are to be free in the corresponding degree of freedom of rotations (i.e., θ_y and/or θ_z).

17.3 Calculation of Spring Stiffness

The springs are typically represented by rod elements, having only axial stiffness. The stiffness is equivalent to the support given to the considered end bulkhead by the cutout longitudinal structural members. The resulting cross-sectional can be determined by the following formula:

$$A = \left(\frac{1}{1+\nu}\right)\frac{A_s \ell}{\ell_{tk} n} = 0.77\frac{A_s \ell}{\ell_{tk} n} \quad \text{cm}^2$$

where

A = cross-sectional area of the bar, in cm^2

A_s = shearing area of the individual structural member under consideration (i.e., plating of deck, inner bottom, bottom shell, side shell, inner hull longitudinal bulkheads or oil-tight longitudinal bulkhead). A_s is to be calculated based on the thickness of the cargo tank finite element model for areas indicated in 5A-3-A4/Table 3 for the appropriate structural member under consideration, in cm^2

ν = Poisson's ratio of the material, taken as 0.3

ℓ_{tk} = length of cargo tank, between bulkheads of the middle tank of the FE model, in cm

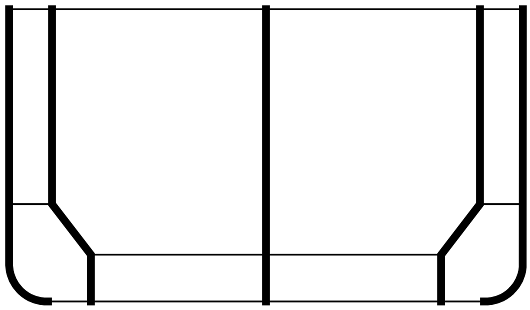
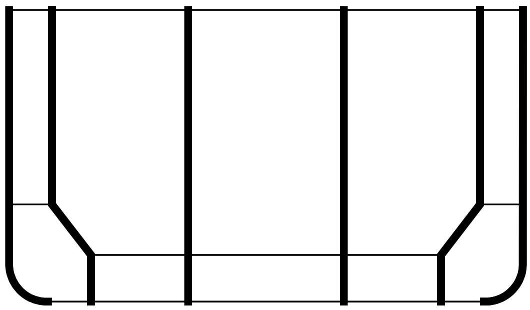
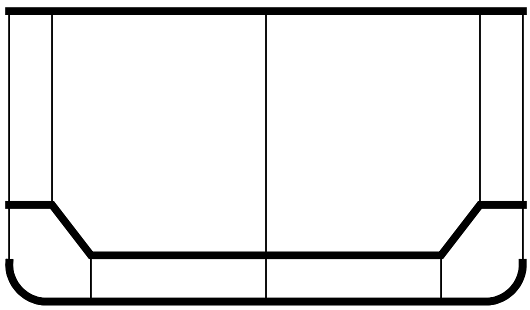
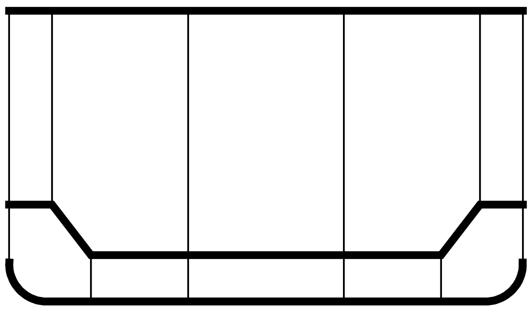
n = number of nodal points to which the spring elements are applied to the structural member under consideration

ℓ = length of the bar, in cm

The bar area A is determined by a given bar length ℓ, which can be any value. In practice, however, all values of ℓ in the finite element model are conveniently chosen to be the same round figure, for example, equal to 100 cm.

One end of the rod is to be constrained in all six degrees of freedom.

TABLE 3
Shear Areas to be Considered for the Calculation of Spring Stiffness *(December 2008)*

<table>
<tr><td colspan="3">Vertical springs</td></tr>
<tr><td rowspan="3"></td><td>Side</td><td>Area of side shell plating, including bilge</td></tr>
<tr><td>Inner hull longitudinal bulkheads</td><td>Area of inner skin plating, including hopper slope plate and double bottom side girder in way</td></tr>
<tr><td>Longitudinal bulkheads</td><td>Area of longitudinal bulkhead plating, including double bottom girder in way</td></tr>
<tr><td></td><td colspan="2">Note: Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.</td></tr>
<tr><td colspan="3">Horizontal springs</td></tr>
<tr><td rowspan="3"></td><td>Deck</td><td>Area of deck plating</td></tr>
<tr><td>Inner bottom</td><td>Area of inner bottom plating, including hopper slope plate and horizontal stringer in way</td></tr>
<tr><td>Bottom shell</td><td>Area of bottom shell plating, including bilge</td></tr>
<tr><td></td><td colspan="2">Note: Where part of the structural member is not horizontal the area is to be calculated using the projected area in the horizontal direction.</td></tr>
</table>

19 Validation of 3-D Global Response

19.1 Correlation with Beam Theory

It has been shown that the primary hull girder bending stress and deflection obtained by the finite element analysis are in good agreement with classical beam theory results, even with the open deck configuration of the hull girder. In order to verify that proper modeling of the hull structure has been made, and that appropriate loading and boundary conditions have been imposed on the model, it is useful to compare the results with that obtained by beam theory. The check is usually carried out for the vertical bending moment since it is the most predominate bending moment and for which a high proportion of the hull girder section modulus is used.

The comparison is to be made in areas where local loads have minimal effects and also at the minimum section modulus, i.e., mid-hold. The best correlation is obtained at the deck at side where the section modulus is calculated for and also has the minimum effect of local loading.

Because of secondary bending, shear lag, or stresses due to alternate hold or upper wing ballast loading, some variation in hull girder bending stresses can be expected between the resultant FEA stresses as compared to classical beam theory stresses.

19.3 Additional Remarks

When comparison of hull girder stresses shows good correlation with beam theory, it can be concluded that the overall response of the finite element model to applied loads is correct.

However, it is still possible that at some local areas of the model, stress levels and deflections are not consistent with the applied loading. A large-scale local deflection display of the questionable area will usually provide some clues as to the cause for such unreasonable results. If it is a problem of element connectivity, the display will clearly show a separation of adjoining members. Certainly, errors in element properties are always a possibility, and can be easily checked in the appropriate display of the model.

In general, the experienced or knowledgeable user should be able to predict the structural behavior and stress level distributions under the specified loading. There will be logical conclusions for any variance in the predicted stress and deformation patterns of the finite element model.

If possible, before starting the structural analysis, the engineer is to take the time to review previously-performed structural analyses on similar installations, in order to better visualize the analysis procedures and resultant structural response.

21 Detailed Stress Assessment – Local FEA

21.1 General

21.1.1 Application

This Subsection describes the procedure for the detailed stress assessment with refined meshes to evaluate highly stressed areas of primary supporting members.

21.3 Analysis Model

21.3.1 Areas to be Refined

Where the global cargo hold analysis is carried out using a model complying with the modeling criteria of this Appendix, the areas listed in 5A-3-A4/Table 4 are to be refined at the locations whose calculated stresses exceed 95% of the allowable stress as specified in 5A-3-4/3.3.

TABLE 4
Typical Details to be Refined *(December 2008)*

- Critical Areas in Transverse Web Frame
- Critical Areas in Horizontal Girders on Transverse Bulkhead
- Critical Areas of Buttress Structure

21.3.2 Refining Method

Two methods can be used for refining the high stressed areas:

- Detailed stresses in refined areas can be analyzed by separate sub-models.
- Refined areas can be directly included in FE model used for the global cargo hold analysis.

21.3.3 Modeling

21.3.3(a) Element Type. Each structural member is to be modeled by using proper element type for the structure in accordance with the principle in this guidance.

21.3.3(b) Mesh. The element size in refined areas is to be approximately one fourth of the representative spacing of ordinary stiffeners in the corresponding area (i.e., 200 × 200 mm mesh size for structures whose ordinary stiffener spacing is 800 mm). In addition, the web height of primary supporting members is to be divided at least into 3 elements.

The aspect ratio of element is not to exceed 3. Quad elements are to have 90° angles as much as practicable, or to have angles between 45° and 135°.

21.3.3(c) Extent of Sub-model. The minimum extent of sub-model is to be such that the boundaries of the sub-model correspond to the locations of adjacent supporting members.

21.3.4 Loading Conditions

Loading conditions, which are applied to the 3-D FE model for the global cargo hold analysis, are to be considered in the detailed stress assessment.

21.3.5 Boundary Conditions

Nodal forces or nodal displacements obtained from the global cargo hold analysis are to be applied to the sub-models. Where nodal forces are given, the supporting members located at the boundaries of a sub-model are to be included in the sub-model. Where nodal displacements are given and additional nodes are provided in sub-models, nodal displacements at the additional nodes are to be determined by proper interpolations.

21.5 Analysis Criteria

21.5.1 Allowable Stress *(1 July 2012)*

Von Mises equivalent stresses in plate elements and axial stresses in line elements within refined areas are not to exceed the allowable stresses defined in 5A-3-4/13.3.

23 Fatigue Assessment – Fatigue FEA *(1 July 2009)*

23.1 General

23.1.1 Application

The Hot Spot Stresses are to be calculated based on the method specified in Appendix 5A-3-A2 for the critical details addressed in 5A-3-4/13 for fatigue evaluation.

Detailed description of fatigue assessment (e.g., loading conditions, acceptance criteria, S-N curve, etc.) is also specified in Appendix 5A-3-A2.

PART
5A

CHAPTER **3 Structural Design Requirements**

APPENDIX **5 Offshore Hull Construction Monitoring Program**
(1 July 2012)

1 Introduction

The structural strength criteria specified in the ABS Rules are used by designers to establish acceptable scantlings in order for vessels constructed to such standards and properly maintained will to have adequate durability and capability to resist the failure modes of yielding, buckling and fatigue.

The application of the *FPI Rules* and other review techniques to assess a design for compliance with Rule criteria also gives the designer and ABS the ability to identify areas that are considered critical to satisfactory in-service performance.

Knowing that the actual structural performance is also a function of construction methods and standards, it is prudent to identify 'critical' areas, particularly those approaching design limits, and use appropriate specified construction quality standards and associated construction monitoring and reporting methods to limit the risk of unsatisfactory in-service performance.

Accordingly, this Appendix defines what is meant by critical areas, describes how they are to be identified and recorded, delineates what information the shipyard is to include in the construction monitoring plan and lays out the certification regime to be followed.

3 Application

Ship-type installations designed and reviewed to the *FPI Rules* are to comply with the requirements of this Appendix and have the notation **OHCM**.

5 Critical Area

The term critical area, as used in these Rules, is defined as an area within the structure that may have a higher probability of failure during the life of the vessel compared to the surrounding areas, even though they may have been modified in the interest of reducing such probability. The higher probability of failure can be a result of stress concentrations, high stress levels and high stress ranges due to loading patterns, structural discontinuities or a combination of these factors.

In order to provide an even greater probability of satisfactory in-service performance, the areas that are approaching the acceptance criteria can be identified so that additional attention may be paid during fabrication.

The objective of heightened scrutiny of building tolerance and monitoring in way of the critical areas is to minimize the effect of stress increases incurred as a result of the construction process. Improper alignment and fabrication tolerances may be potentially influential in creating construction-related stress.

7 Determination of Critical Areas

Critical areas can be determined in a number of ways, including but not limited to:

i) The results of engineering strength and fatigue analyses, such as specified in the *FPI Rules*, Finite Element Analysis or a Dynamic Loading Approach analysis, particularly for areas approaching the allowable criteria.

ii) The application of ABS Rules, such as 3-1-2/15.3.

iii) Details where fabrication is difficult, such as blind alignment, complexity of structural details and shape, limited access, etc.

iv) Input from owners, designers and/or shipyards based on previous in-service experience from similar vessels, such as corrosion, wear and tear, etc.

9 Construction Monitoring Plan

The Construction Monitoring Plan for critical areas is to be prepared by the shipyard and submitted for ABS approval prior to the start of fabrication. The plan is to include:

i) Structural drawings indicating the location of critical areas as identified by the ABS review (see 5A-3-A5/7)

ii) Construction standards and control procedures to be applied

iii) Verification and recording procedures at each stage of construction, including any proposed nondestructive testing

iv) Procedures for defect correction

An approved copy of the Construction Monitoring Plan is to be placed onboard the floating installation.

11 Surveys After Construction

To monitor critical areas during service, an approved copy of the Construction Monitoring Plan is to be available on board for all subsequent surveys.

13 Notation

Ship-type installations having been found in compliance with the requirements of these Rules may be distinguished in the *Record* with the notation **OHCM**.

PART

5A

CHAPTER 4 Ship-Type Installations Under 150 meters (492 feet) in Length

CONTENTS

PART
5A

CHAPTER 4 Ship-Type Installations Under 150 meters (492 feet) in Length

SECTION 1 Introduction

1 General

1.1 Classification *(1 September 2007)*

See Section 1-1-2 of these Rules.

1.3 Application *(1995)*

1.3.1 Structural Arrangement

The requirements contained in this section are intended to apply to longitudinally framed, all-welded tank installations having proportions in accordance with 3-1-2/7 of the *Steel Vessel Rules*, machinery aft and two or more continuous longitudinal bulkheads. Where the arrangement differs from that described, the scantlings may require adjustment to provide equivalent strength.

1.3.2 Installations of Similar Type and Arrangement *(December 2008)*

The requirements are also intended to apply to other installations of similar type and arrangement.

Double hull ship-type installation: A monohull 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 within cargo area to prevent liquid cargo outflow in stranding/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.

Double side, single bottom ship-type installation: A monohull having full depth wing water ballast tanks or other non-cargo spaces and single bottom structure.

Single hull ship-type installation: A monohull that does not have double side and double bottom spaces fitting the definition of *Double hull ship-type installation*.

1.3.3 Engineering Analysis

It is recommended that compliance with the following requirements be accomplished through a detailed investigation of the magnitude and distribution of the imposed longitudinal and transverse forces by using an acceptable method of engineering analysis. The following paragraphs are to be used as a guide in determining scantlings. Where it can be shown that the calculated stresses using the loading conditions specified in 5A-4-2/13.5 are less than those stated to be permissible, consideration will be given to scantlings alternative to those recommended by this Section.

1.5 Detail Design of Internal Members

The detail design of internals is to follow the guidance given in 3-1-2/15 of the *Steel Vessel Rules*.

See also Appendix 5A-3-A2, "Fatigue Strength Assessment of Ship-Type Installations".

1.7 Breaks

Special care is to be taken throughout the structure to provide against local stresses at the ends of the oil spaces, superstructures, etc. The main longitudinal bulkheads are to be suitably tapered at their ends, and effective longitudinal bulkheads in the poop are to be located 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 0.5*L*, the required shell and deck scantlings for the midship 0.4*L* may be required to be extended to effect a gradual taper of structure, and the deck stringer plate and sheer strake are to be increased. See 5A-4-2/3.3 and 5A-4-2/5.1. Where the breaks of the forecastle or poop are appreciably beyond the midship 0.5*L*, the requirements of 5A-4-2/3.3 and 5A-4-2/5.1 may be modified.

1.9 Variations

Ship-type installations of special type or design differing from those described in the following will be specially considered on the basis of equivalent strength.

1.11 Loading Guidance

Loading guidance is to be as required by 3-2-1/7 of the *Steel Vessel Rules*.

1.13 Higher-strength Materials

In general, applications of higher-strength materials for installations intended to carry oil in bulk are to meet the requirements of this section, but may be modified generally as outlined in the following Sections:

- Section 3-2-4 of the *Steel Vessel Rules* for longitudinals
- Section 3-2-7 of the *Steel Vessel Rules* for longitudinals
- 3-2-8/9.3 of the *Steel Vessel Rules* for deep longitudinal members
- Section 3-2-10 of the *Steel Vessel Rules* for bulkhead plating
- Section 3-2-2 of the *Steel Vessel Rules* for shell plating
- Section 3-2-3 of the *Steel Vessel Rules* for deck plating

In such cases, the allowable shearing stresses will be specially considered.

1.15 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 installation [see 5C-1-7/11.11.2 of the S*teel Vessel Rules*], 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.

1.17 Protection of Structure

For the protection of structure, see 3-2-18/5 of the *Steel Vessel Rules*.

1.19 Aluminum Paint

Paint containing aluminum is not to be used in cargo tanks, on tank decks in way of cargo tanks, in pump rooms and cofferdams, or in any other area where cargo vapor may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the fire hazard.

1.21 Tank Design Pressures *(1993)*

The requirements of this section are for tanks intended for the carriage of liquid cargoes with specific gravities not greater than 1.05. Where the specific gravity is greater than 1.05, the design heads, *h*, are to be increased by the ratio of specific gravity to 1.05. See also 5C-1-7/11 of the S*teel Vessel Rules* with regard to pressure-vacuum valve setting and liquid level control.

3 Special Requirements for Deep Loading *(2003)*

Where an installation is intended to operate at the minimum freeboard allowed by the International Convention on Load Lines, 1966, for Type-A installations, the conditions in 5A-4-1/3.1 through 5A-4-1/3.9 are to be complied with.

3.1 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 at least 1.8 m (5.9 ft) for installations up to and including 75 m (246 ft) in length, and 2.3 m (7.5 ft) for installations 125 m (410 ft) or more in length. The minimum height at intermediate lengths is to be obtained by interpolation. The bulkheads at the forward ends of these structures are to be of not less scantlings than required for bridge-front bulkheads. (See 3-2-11/3 of the *Steel Vessel Rules*) 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 of the *Steel Vessel Rules* 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 of the *Steel Vessel Rules*. The sill of the exterior door is not to be less than 600 mm (23.5 in.), and of the second door not less than 230 mm (9 in.).

3.3 Access *(1998)*

Satisfactory arrangements are to be provided to safeguard the crew in reaching all parts used in the necessary work of the installation. See 3-2-17/3 of the *Steel Vessel Rules*.

3.5 Hatchways

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

3.7 Freeing Arrangements

Ship-type installations with bulwarks are to have open rails fitted for at least half the length of the exposed parts of the freeboard and superstructure deck or other effective freeing arrangements. 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 whole length of the exposed parts of the freeboard deck.

3.9 Flooding *(2003)*

For reference only, 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 of the *Steel Vessel Rules*) to which freeboards less than those based solely on Table B are assigned must be able to withstand the flooding of certain compartments.

3.11 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 of the *Steel Vessel Rules*.

5 Arrangement *(1994)*

The arrangements of the installation are to comply with the requirements in Annex 1 to International Convention for the Prevention of Pollution from Ships, with regard to segregated ballast tanks (Regulation 13), their protective locations (Regulation 13E – where the option in Regulation 13F (4) or (5) is exercised), collision or stranding considerations (Regulation 13F), hypothetical outflow of oil (Regulation 23), limitations of size and arrangement of cargo tanks (Regulation 24) and slop tanks [Regulation 15 (2)(c)]. A valid International Oil Pollution Certificate issued by the Administration may be accepted as an evidence for compliance with these requirements.

5.1 Subdivision

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

5.3 Cofferdams

Cofferdams, thoroughly oiltight and vented, having widths as required for ready access, are to be provided for the separation of 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 in compliance with this requirement.

5.5 Gastight Bulkheads

Gastight bulkheads are to be provided for the isolation of all cargo pumps and piping from spaces containing stoves, boilers, propulsion 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 of the *Steel Vessel Rules*.

5.7 Cathodic Protection *(1996)*

5.7.1 Anode Installation Plan

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

5.7.2 Magnesium and Magnesium Alloy Anodes

Magnesium and magnesium alloy anodes are not to be used.

5.7.3 Aluminum Anodes

Aluminum anodes may be used in cargo tanks of ship-type installations, only 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 its 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, 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.

5.7.4 Anode Attachment

Anodes are to have steel cores sufficiently rigid to avoid resonance in the anode support and 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 are to be used.

The supports at each end of an anode are not to be attached to items of structure which 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.

5.9 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 port, 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.

5.11 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 installation 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 5A-4-1/5.21.

5.13 Structural Fire Protection

The applicable requirements of Section 3-4-1 of the *Steel Vessel Rules* are to be complied with.

5.15 Allocation of Spaces *(1994)*

5.15.1 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.

5.15.2 Double Bottom Spaces and Wing Tank Spaces

For installations of 5000 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.

5.17 Access to Upper Parts of Ballast Tanks on Double Hull Ship-Type Installations *(1993)*

Where the structural configuration within the ballast tank is such that it will prevent access to upper parts of tanks for required close-up examination [see 7-3-2/5.13.3 of the ABS *Rules for Survey After Construction (Part 7)*] by conventional means, such as a raft on partly filled tank, permanent means of safe access is to be provided. The details of access are to be submitted for review.

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

5.19 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 of the *Steel Vessel Rules*) 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.

For installations less than 5000 tons deadweight, smaller dimensions than above may be approved, provided that the ability to remove an injured person can be demonstrated to the satisfaction of the Surveyor.

5.21 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 of the *Steel Vessel Rules* and in addition 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 installation, 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 of the *Steel Vessel Rules*.

5.23 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 the 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 of the *Steel Vessel Rules*. Efficient means are to be provided for clearing the oil spaces of dangerous vapors by means of artificial ventilation or steam. For the venting of the cargo tanks, see 5C-1-7/11 and 5C-1-7/21 of the *Steel Vessel Rules*.

5.25 Pumping Arrangements

See applicable requirements in Section 5C-1-7 of the *Steel Vessel Rules*.

5.27 Electrical Equipment *(2004)*

See 5C-1-7/31 and 5C-1-7/33 of the *Steel Vessel Rules*.

5.29 Testing

Requirements for testing are contained in Part 3, Chapter 7 of the *Steel Vessel Rules*.

5.31 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.

PART

5A

CHAPTER **4 Ship-Type Installations Under 150 meters (492 feet) in Length**

SECTION **2 Hull Structure**

1 Hull Girder Strength

1.1 Normal-strength Standard

The longitudinal hull girder strength is to be not less than required by the equations given in 3-2-1/3.7 and 3-2-1/3.9 of the *Steel Vessel Rules*.

1.3 Still-water Bending Moment Calculations

For still-water bending moment calculations, see 3-2-1/3.3 of the *Steel Vessel Rules*.

3 Shell Plating

3.1 Amidships

Shell plating within the midship 0.4*L* is to be of not less thickness than is required for longitudinal hull girder strength, or than that obtained from 5A-4-2/3.1.1 through 5A-4-2/3.1.3.

3.1.1 Bottom Shell Thickness

The thickness *t* of the bottom shell plating is not to be less than obtained from 5A-4-2/3.1.1(a) and 5A-4-2/3.1.1(b).

3.1.1(a)

$$t = S(L + 8.54)/(42L + 2318) \quad \text{mm}$$

$$t = S(L + 28)/(42L + 7602) \quad \text{in.}$$

where

S = frame spacing, in mm (in.), but is not to be taken as less than 88% of that given in 3-2-5/1.7 of the *Steel Vessel Rules* or 864 mm (34 in.), whichever is less

L = length of installation, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)

Where the bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1 of the *Steel Vessel Rules*, and still-water bending moment calculations are submitted, the thickness of bottom shell may be obtained from the above equation multiplied by the factor, R_b. Special consideration will be given to installations constructed of higher-strength steel.

$$R_b = \sqrt{\frac{SM_R}{SM_A}} \quad \text{is not to be taken less than 0.85}$$

where

SM_R = hull girder section modulus required by 3-2-1/3.7.1 of the *Steel Vessel Rules*, in cm^2-m (in^2-ft)

SM_A = bottom hull girder section modulus of installation, in cm^2-m (in^2-ft), with the greater of the bottom shell plating thickness obtained when applying R_n or R_b

3.1.1(b)

$$t = 0.006s\sqrt{0.7d + 0.02(L - 50)} + 2.5 \quad \text{mm}$$

$$t = 0.00331s\sqrt{0.7d + 0.02(L - 164)} + 0.1 \quad \text{in.}$$

Where the bottom hull girder section modulus, SM_A, is greater than required by 3-2-1/3.7.1 of the *Steel Vessel Rules*, and still-water bending moment calculations are submitted, the thickness of bottom shell may be obtained from the above equation multiplied by the factor, R_n. Special consideration will be given to installations constructed of higher-strength steel.

$$R_n = \sqrt{\frac{1}{\frac{f_p}{\sigma_t}\left(1 - \frac{SM_R}{SM_A}\right) + 1}} \qquad \text{is not to be taken less than 0.85}$$

where

f_p	=	nominal permissible bending stress, in kN/cm^2 (tf/cm^2, Ltf/in^2), as given in 3-2-1/3.7.1 of the *Steel Vessel Rules*
σ_t	=	$KP_t(s/t)^2$, in kN/cm^2 (tf/cm^2, Ltf/in^2)
K	=	0.34 for longitudinal framing
P_t	=	$(0.638H + d)a$ kN/cm^2 (tf/cm^2, Ltf/in^2)
a	=	1.005×10^{-3} (1.025×10^{-4}, 1.984×10^{-4})
t	=	bottom shell plating thickness required by the equation in 5A-4-2/3.1.1(b) above, in mm (in.)
H	=	wave parameter defined in 3-2-2/3.13.2 of the *Steel Vessel Rules*

SM_R and SM_A are as defined in 5A-4-2/3.1.1(a) and L, s and d are as defined in 5A-4-2/3.1.2(b).

SM_R/SM_A is not to be taken as less than 0.70.

3.1.2 Side Shell Thickness

The thickness t of the side shell plating is not to be less than obtained from 5A-4-2/3.1.2(a) and 5A-4-2/3.1.2(b).

3.1.2(a)

$$t = 0.01L(6.5 + 21/D) \quad \text{mm}$$

$$t = 0.0003937L(2.0 + 21/D) \quad \text{in.}$$

3.1.2(b)

$$t = 0.0052s\sqrt{0.7d + 0.02L} + 2.5 \quad \text{mm}$$

$$t = 0.00287s\sqrt{0.7d + 0.02L} + 0.1 \quad \text{in.}$$

where

L	=	length of installation, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*
d	=	molded draft to the summer load line, as defined 3-1-1/9 of the *Steel Vessel Rules*, in m (ft)
D	=	molded depth, as defined in 3-1-1/7.1 of the *Steel Vessel Rules*, in m (ft)
s	=	spacing of bottom longitudinals or spacing of side longitudinals or vertical side frames, in m (ft)

3.1.3 Shell Thickness

Where a double bottom is fitted and is not to be used for the carriage of cargo oil, the bottom shell thickness may be in accordance with 3-2-2/3.13 of the *Steel Vessel Rules*, and if a double skin is provided and is not to be used for the carriage of cargo oil, the side shell thickness may be in accordance with 3-2-2/3.9 of the *Steel Vessel Rules*.

3.3 Sheer Strake

The thickness of the sheer strake is to be not less than the thickness of the side-shell plating, nor less than required by 5A-4-2/5.1.2. The thickness is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). See 5A-4-1/1.7.

3.5 Keel Plate

The thickness of the flat plate keel is to be not less than that required for the bottom shell plating at that location increased by 1.5 mm (0.06 in.), except where the submitted docking plan (see 3-1-2/11 of the *Steel Vessel Rules*) specifies all docking blocks be arranged away from the keel.

3.7 Flat of Bottom Forward *(2002)*

Where the heavy weather ballast draft forward is less than 0.04L, the plating on the flat of bottom forward of the location in 3-2-4/Table 1 of the *Steel Vessel Rules* is to be not less than required in 3-2-2/5.5 of the *Steel Vessel Rules*. For this assessment, the heavy weather ballast draft forward is to be determined by using segregated ballast tanks only.

3.9 Plating Outside Midship 0.4L

The bottom and side shell, including the sheer strake beyond the midship 0.4L, is generally to be in accordance with the requirements of 3-2-2/5 of the *Steel Vessel Rules* and is to be gradually reduced from the midship thickness to the end thickness.

3.11 Installations under 76 m (250 ft)

In installations under 76 m (250 ft) in length, the thickness of the bottom shell is to be obtained from 3-2-2/3 of the ABS *Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length*.

3.13 Bilge Keels

Bilge keels are to comply with 3-2-2/13 of the *Steel Vessel Rules*.

5 Deck Plating

5.1 Amidships

The strength deck within the midship 0.4L is to be of not less thickness than is required to provide the deck area necessary for longitudinal strength in accordance with 5A-4-2/1; nor is the thickness to be less than determined by the following equations for thickness of deck plating.

5.1.1

$$t = 0.0016s\sqrt{L-53} + 0.32\frac{L}{D} - 2.5 \quad \text{mm}$$

$$t = 0.000883s\sqrt{L-174} + 0.0126\frac{L}{D} - 0.1 \quad \text{in.}$$

5.1.2

$$t = \frac{s(30.48+L)}{4981+40L} \qquad L < 150 \text{ m}$$

$$t = \frac{s(100+L)}{16339+40L} \qquad L < 492 \text{ ft}$$

where

t = plate thickness, in mm (in.)

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

L = length of installation, as defined in 3-1-1/3.1 of the *Steel Vessel Rules*, in m (ft)

D = molded depth, as defined in 3-1-1/7.1 of the *Steel Vessel Rules*, in m (ft)

The thickness of the stringer plate is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). See 5A-4-1/1.7. The required deck area is to be maintained throughout the midship 0.4L of the installation or beyond the end of a superstructure at or near the midship 0.4L point. From these locations to the ends of the installation, the deck area may be gradually reduced in accordance with 3-2-1/11.3 of the *Steel Vessel Rules*. Where bending moment envelope curves are used to determine the required hull girder section modulus, the foregoing requirements for strength deck area may be modified in accordance with 3-2-1/11.3 of the *Steel Vessel Rules*. Where so modified, the strength deck area is to be maintained a suitable distance from superstructure breaks and is to be extended into the superstructure to provide adequate structural continuity.

5.3 Installations under 76 m (250 ft)

In installations under 76 m (250 ft) in length, the thickness of deck plating is to be obtained from 3-2-3/3 of the ABS *Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length*.

7 Bulkhead Plating

7.1 Plating Thickness

The plating is to be of not less thickness than is required for deep-tank bulkheads by 3-2-10/3 of the *Steel Vessel Rules*, where h is measured from the lower edge of the plate to the top of the hatch or to a point located 1.22 m (4 ft) above the deck at side amidships, whichever is greater. The upper strakes are to be increased above these requirements to provide a proper margin for corrosion. It is recommended that the top strake of a complete longitudinal bulkhead be not less than 9.5 mm ($^3/_8$ in.) in installations of 91.5 m (300 ft) length, and 12.5 mm ($^1/_2$ in.) in installations of 150 m (492 ft) length, and that the strake below the top strake be not less than 9.5 mm ($^3/_8$ in.) in installations of 122 m (400 ft) length and 10.5 mm ($^{13}/_{32}$ in.) in installations of 150 m (492 ft) in length, with intermediate thicknesses for intermediate lengths. See also 5A-4-1/1.15.

9 Long or Wide Tanks

9.1 Oiltight Bulkheads

In installations fitted with long tanks, the scantlings of oiltight transverse bulkheads in smooth-sided tanks are to be specially considered when the spacing between tight bulkheads, nontight bulkheads or partial bulkhead exceeds 12 m (40 ft) in the case of corrugated-type construction, or 15 m (50 ft) in the case of flat-plate type of construction. Special consideration is to be given to the scantlings of longitudinal oiltight bulkheads forming the boundaries of wide tanks. Where the length of the smooth-sided tanks exceeds 0.1L or the breadth exceeds 0.6B, nontight bulkheads are to be fitted, unless calculations are submitted to prove that no resonance due to sloshing will occur in service.

Alternatively, reinforcements to the bulkheads and decks, without nontight bulkheads, may be determined by an acceptable method of engineering analysis.

9.3 Nontight Bulkheads

Nontight bulkheads are to be fitted in line with transverse webs, bulkheads or other structures with equivalent rigidity. They are to be suitably stiffened. Openings in the nontight bulkhead are to have generous radii and their aggregate area is not to exceed 33%, nor be less than 10% of the area of the nontight bulkhead. Plating is to be of not less thickness than that required by 5A-4-2/Table 2. Section moduli of stiffeners and webs may be one half of the requirements for watertight bulkheads in 3-2-9/5.3 and 3-2-9/5.7 of the *Steel Vessel Rules*. Alternatively, the opening ratio and scantlings may be determined by an acceptable method of engineering analysis.

11 Double Bottom Structure

11.1 General

Where a double bottom is fitted, it is generally to be arranged with a centerline girder, or equivalent, and, where necessary, with full depth side girders similar to Section 3-2-4 of the *Steel Vessel Rules*. The arrangements and scantlings of the double bottom structure as given in Section 3-2-4 of the *Steel Vessel Rules* may be used, except where modified by this section. Increases in scantlings may be required where tanks other than double bottom tanks are designed to be empty with the installation in a loaded condition. Alternatively, consideration will be given to arrangements and scantlings determined by an acceptable method of engineering analysis, provided that the stresses are in compliance with 5A-4-2/13. Where ducts forming a part of the double bottom structure are used as a part of the piping system for transferring cargo oil or ballast, the structural integrity of the duct is to be safeguarded by suitable relief valves or other arrangement to limit the pressure in the system to the value for which it is designed.

11.3 Floors and Girders

In general, the thickness of floors and girders is to be as required by Section 3-2-4 of the *Steel Vessel Rules*. Where tanks adjacent to the double bottom are designed to be empty with the installation in a loaded condition, the floors and girders in the double bottom are to be specially considered. Where the heavy weather ballast draft forward is less than 0.04L the fore-end arrangement of floors and side girders is to comply with 3-2-4/13.1 and 3-2-4/13.3 of the *Steel Vessel Rules*.

11.5 Inner Bottom

The thickness of the inner-bottom plating is to be not less than required by Section 3-2-10 of the *Steel Vessel Rules*, with a head to 1.22 m (4 ft) above the deck at side amidships or to the top of the hatch, whichever is greater.

11.7 Inner-bottom Longitudinals

Scantlings for inner-bottom longitudinals are to be not less than required in 5A-4-2/15.3, using c = 1.00. Where effective struts are fitted between inner-bottom and bottom longitudinals, the inner-bottom longitudinals are not to be less than required in 5A-4-2/15.3, using c = 0.55, or 85% of the requirement in 3-2-4/11.3 of the *Steel Vessel Rules* for bottom longitudinals, using c = 0.715, whichever is greater.

11.9 Bottom Longitudinals

Scantlings for bottom longitudinals are to be not less than required by 3-2-4/11.3 of the *Steel Vessel Rules*. Where effective struts are fitted between bottom and inner-bottom longitudinals, the bottom longitudinals are to be not less than 90% of the inner-bottom longitudinal requirement in 5A-4-2/15.3, using c = 0.55, or the requirement in 3-2-4/11.3 of the *Steel Vessel Rules*, using c = 0.715, whichever is greater. Where the heavy weather ballast draft forward is less than 0.04L, the flat of bottom-forward longitudinals are to be not less than required by 3-2-4/13.5 of the *Steel Vessel Rules*.

13 Deep Supporting Members

13.1 General

Webs, girders and transverses which support longitudinal frames, beams or bulkhead stiffeners, generally are to be in accordance with the following paragraphs. It is recommended that deep girders be arranged in line with webs and stringers to provide complete planes of stiffness. In installations without a longitudinal centerline bulkhead or effective centerline supporting member, a center vertical keel having sufficient strength to serve as one line of support is to be provided where centerline keel blocks are used in drydocking operations.

13.3 Section Modulus

Each member is to have a section modulus, *SM*, in cm^3 (in^3), not less than that obtained from the following equation:

$SM = M/f$ cm^3 (in^3)

where

M = maximum bending moment along the member between the toes of the end brackets as computed by an acceptable method of engineering analysis, in kN-cm (kgf-cm, Ltf-in.)

f = permissible maximum bending stress, as determined from the following table.

Values of *f* (Ordinary-strength Steel)

	kN/cm²	*kgf/cm²*	*Ltf/in²*
Transverse members	13.9	1420	9
Longitudinal members	9.3	947	6

Note: Local axial loads on webs, girders or transverses are to be accounted for by reducing the maximum permissible bending stress.

In addition, the following equation is to be used in obtaining the required section modulus *SM*.

$SM = 4.74chs\ell_b^2$ cm^3 $SM = 0.0025chs\ell_b^2$ in^3

c for bottom and deck transverses as shown in 5A-4-2/Figure 1.

= 2.00 for bottom girders, vertical webs on transverse bulkheads, horizontal girders and stringers

= 2.50 for deck girders

c for side transverses and vertical webs on longitudinal bulkheads

= 1.50 without struts

= 0.85 with one horizontal strut

= 0.65 with two horizontal struts

= 0.55 with three horizontal struts

= Where a centerline longitudinal bulkhead is fitted, the value of c for side-shell transverses and vertical webs on longitudinal wing bulkheads will be subject to special consideration.

Where no struts or other effective supporting arrangements are provided for the wing-tank vertical transverses, the deck transverses in the wing tanks are to have section modulus values not less than 70% of that for the vertical side transverses. In no case are the deck transverses in the wing tank to have less than 70% of the section modulus for the corresponding members in the center tanks.

s = spacing of transverses, or width of area supported, in m (ft)

h = bottom transverses and girders of the depth of the installation, D, in m (ft). See also 5A-4-1/1.15.

= side transverses and vertical webs on longitudinal bulkheads, vertical webs on transverse bulkheads and horizontal girders and stringers, the vertical distance, in m (ft) from the center of the area supported to a point located 1.22 m (4 ft) above the deck at side amidships in installations 61 m (200 ft) in length, and to a point located 2.44 m (8 ft) above the deck at side amidships in installations 122 m (400 ft) in length and above; for intermediate lengths, intermediate points may be used. The value of h is to be not less than the vertical distance from the center of the area supported to the tops of the hatches, in m (ft). See also 5A-4-1/1.15.

= deck transverses and girders, in m (ft), is to be measured as indicated above for side transverses, etc., except that in no case is it to be less than 15% of the depth of installation.

ℓ_b = span of the member, in m (ft), measured between the points of support as indicated in 5A-4-2/Figure 1. Where effective brackets are fitted, the length ℓ_b is to be measured as indicated in 5A-4-2/Figure 2a and 5A-4-2/Figure 2b; nor is the length for deck and bottom transverses in wing tanks to be less than $0.125B$ or one-half the breadth of the wing tank, whichever is the greater. Where a centerline longitudinal bulkhead is also fitted, this minimum length will be specially considered.

13.5 Local Loading Conditions

In addition to withstanding the loads imposed by longitudinal hull girder shearing and bending action, the structure is to be capable of withstanding the following local loading conditions without exceeding the permissible bending and average shearing stresses stated in 5A-4-2/13.3 and 5A-4-2/13.7.

- Center tank loaded; wing tanks empty; $^1/_3$ summer load line draft
- Center tank empty; wing tanks loaded; $^1/_3$ summer load line draft
- Center and wing tanks loaded; $^1/_3$ summer load line draft

Note: For loaded tanks, the head h is to be measured to a point located 2.44 m (8 ft) above the deck at side, except in the case of installations less than 122 m (400 ft) in length, as explained in 5A-4-2/13.3. See also 5A-4-1/1.15.

In addition, where the arrangement of the installation involves tanks of relatively short length, or tanks designated as permanent ballast tanks, it is recommended that the following appropriate loading conditions also be investigated:

- Center tank loaded; wing tanks empty; summer load line draft
- Center tank empty; wing tank loaded; summer load line draft

In all cases, the structure is to be reviewed for other realistic loading conditions associated with the installation's intended service.

13.7 Web Portion of Members

The net sectional area of the web portion of the member, including effective brackets where applicable, is not to be less than that obtained from the following equation.

$A = F/q$ cm^2 (in^2)

where

F = shearing force at the point under consideration, kN (kgf, Ltf)

q = allowable average shearing stress in the web of the supporting member, as determined from 5A-4-2/Table 1.

For longitudinal supporting members, the value of q is to be 80% of the value shown in 5A-4-2/Table 1.

Where individual panels exceed the limits given in 5A-4-2/Table 1, detailed calculations are to be submitted in support of adequate strength against buckling.

The thickness of the web portions of the members is not to be less than given in 5A-4-2/Table 2 for minimum thickness. Reduced thickness may be considered for higher strength materials if the buckling and fatigue strength is proven adequate.

It is recommended that compliance with the foregoing requirement be accomplished through a detailed investigation of the magnitude and distribution of the imposed shearing forces by means of an acceptable method of engineering analysis. Where this is not practicable, the following equations may be used as guides in approximating the shearing forces.

$F = csD(K\ell_s - h_e)$ for bottom transverses

$F = cs\left[K_L \ell_s h - h_e\left(h + \frac{\ell_s}{2} - \frac{h_e}{2}\right)\right]$ for lower side transverses or vertical transverses on longitudinal bulkheads

$F = cs\left[K_U \ell_s h - h_e\left(h - \frac{\ell_s}{2} + \frac{h_e}{2}\right)\right]$ for upper side transverses or vertical transverses on longitudinal bulkheads

where

c = 10.05 (1025, 0.0285)

s = spacing of transverses, in m (ft)

D = depth of installation, as defined in 3-1-1/7 of the *Steel Vessel Rules*, in m (ft)

B = breadth of installation as defined in 3-1-1/5 of the *Steel Vessel Rules*, in m (ft)

ℓ_s = span of transverse, in m (ft), as indicated in 5A-4-2/Figure 3

h_e = effective length or height of bracket, in m (ft), as indicated in 5A-4-2/Figure 3. In no case is h_e to be greater than $0.33\ell_s$

h = vertical distance, in m (ft), as defined in 5A-4-2/13.3, for the particular member in question. See also 5A-4-1/1.15.

K = bottom members, K is as shown in 5A-4-2/Figure 3 for the point under consideration

K_L = lower side transverses or vertical transverses on longitudinal bulkheads

= 0.65 without struts

= 0.55 with one strut

= 0.43 with two struts

= 0.38 with three or more struts

K_U = upper side transverses or vertical transverses on longitudinal bulkheads

= 0.35 without struts

= 0.25 with one strut

= 0.20 with two struts

= 0.17 with three or more struts

Where a centerline longitudinal bulkhead is fitted, the tabulated values of K_L and K_U will be specially considered.

The net sectional area of the lower side transverse, as required by the foregoing paragraphs, should be extended up to the lowest strut, or to $0.33\ell_s$, whichever point is the higher. The required sectional area of the upper side transverse may be extended over the upper $0.33\ell_s$ of the member.

13.9 Proportions

Webs, girders and transverses are to be not less in depth than required by the following, where the required depth of member is expressed as a percentage of the span.

12.5% for side and deck transverses, for webs and horizontal girders of longitudinal bulkheads, and for stringers.

20% for deck and bottom centerline girders, bottom transverses, and webs and horizontal girders of transverse bulkheads.

The depth of side transverses and vertical webs is to be measured at the middle of ℓ_b, as defined in 5A-4-2/13.3, and the depth may be tapered from bottom to top by an amount not exceeding 8 mm per 100 mm (1 in. per ft). In no case are the depths of members to be less than three (3) times the depth of the slots for longitudinals. The thickness of webs is to be not less than required by 5A-4-2/13.7, nor is it to be less than the minimum thickness given in 5A-4-2/Table 2.

13.11 Brackets

Brackets are generally to be of the same thickness as the member supported, are to be flanged at their edges and are to be suitably stiffened.

13.13 Stiffeners and Tripping Brackets

13.13.1 Web Stiffeners

Stiffeners are to be fitted for the full depth of the deep supporting member at the following intervals, unless specially approved based on the structural stability of deep supporting members:

Location	*Interval*
Bottom	every longitudinal
Side	every second longitudinal
Bulkhead	every second stiffener
Deck	every third longitudinal

Special attention is to be given to the stiffening of web plate panels close to change in contour of web or where higher strength steel is used.

The moment of inertia, I, of the above stiffener, with the effective width of plating not exceeding s or 0.33ℓ, whichever is less, is not to be less than the following equations:

$$I = 0.19\ell t^3 (\ell/s)^3 \quad \text{cm}^4 \text{ (in}^4\text{)} \quad \text{for } \ell/s \le 2.0$$

$$I = 0.38\ell t^3 (\ell/s)^2 \quad \text{cm}^4 \text{ (in}^4\text{)} \quad \text{for } \ell/s > 2.0$$

where

ℓ = length of stiffener between effective supports, in cm (in.)

t = required thickness of web plating, in cm (in.), but need not be greater than $s/80$

s = spacing of stiffeners, in cm (in.)

Web stiffeners are to be attached to the deep webs, longitudinals and stiffeners by continuous fillet welds.

Where depth/thickness ratio of the web plating exceeds 200, a stiffener is to be fitted parallel to the flange at approximately one-quarter depth of the web from the face plate. Special attention is to be given to providing for compressive loads.

13.13.2 Tripping Bracket

Tripping brackets, arranged to support the flanges, are to be fitted at intervals of about 3 m (10 ft), close to change of section, and in line with or as near as practicable to the flanges of struts.

13.15 Slots and Lightening Holes

Slots and lightening holes, where cut in webs, are to be kept well clear of other openings. The slots are to be neatly cut and well rounded. Lightening holes are to be located midway between the slots and at about one-third of the depth of the web from the shell, deck or bulkhead. Their diameters are not to exceed one-fourth the depth of the web. In general, lightening holes are not to be cut in those areas of webs, girders and transverses where the shear stresses are high. Similarly, slots for longitudinals are to be provided with filler plates or other reinforcement in these same areas. Where openings are required in high shear stress areas, they are to be effectively compensated. Continuous fillet welds are to be provided at the connection of the filler plates to the web and of the filler plate to the longitudinals.

13.17 Struts *(1994)*

Where one or more struts are fitted as an effective supporting system for the wing-tank members, they are to be spaced so as to divide the supported members into spans of approximately equal length. The value of W for struts is obtained from the following equation:

$W = nbhs$ kN (tf, Ltf)

where

n = 10.5 (1.07, 0.03)

b = mean breadth, in m (ft), of the area supported

h = vertical distance, in m (ft), from the center of the area supported to a point located 1.22 m (4 ft) above the deck at side amidships in installations 61 m (200 ft) in length and to a point located 2.44 m (8 ft) above the deck at side amidships in installations 122 m (400 ft) in length and above; for intermediate lengths, intermediate points may be used. The value of h is not to be less than the vertical distance, in m (ft), from the center of the area supported to the tops of the hatches.

The permissible load of struts, W_a, is to be determined by the following equation and is to be equal to or greater than the calculated W as determined above.

$W_a = (k - n\ell/r)A$ kN (tf, Ltf)

where

k	=	12.09 (1.232, 7.83)	ordinary strength steel
	=	16.11 (1.643, 10.43)	HT32
	=	18.12 (1.848, 11.73)	HT36
ℓ	=	unsupported span of the strut, in cm (ft)	
r	=	least radius of gyration, in cm (in.)	
A	=	cross sectional area of the strut, in cm (in.)	
n	=	0.0444 (0.00452, 0.345)	ordinary strength steel
	=	0.0747 (0.00762, 0.581)	HT32
	=	0.0900 (0.00918, 0.699)	HT36

Special attention is to be paid to the end connections for tension members, as well as to the stiffening arrangements at their ends, to provide effective means for transmission of the compressive forces into the webs. In addition, horizontal stiffeners are to be located in line with and attached to the first longitudinal above and below the ends of the struts.

15 Frames, Beams and Bulkhead Stiffeners

15.1 Arrangement

The sizes of the longitudinals or stiffeners as given in this paragraph are based on the transverses or webs being regularly spaced. Longitudinals or horizontal stiffeners are to be continuous or attached at their ends to effectively develop their sectional area. This requirement may be modified in the case of stiffeners on transverse bulkheads. Longitudinals and stiffeners are to be attached to the transverses or webs to effectively transmit the loads onto these members. Consideration is to be given to the effective support of the plating in compression when selecting the size and spacing of longitudinals.

15.3 Structural Sections

15.3.1 Section Modulus

Each structural section for longitudinal frames, beams or bulkhead stiffeners, in association with the plating to which it is attached, is to have a section modulus *SM* not less than obtained from the following equation:

$SM = 7.8chs\ell^2$ cm^3 $SM = 0.0041chs\ell^2$ in^3

where

c	=	1.40	for bottom longitudinals
	=	0.95	for side longitudinals
	=	1.25	for deck longitudinals
	=	1.00	for vertical frames
	=	1.00	for horizontal or vertical stiffeners on transverse bulkheads and vertical stiffeners on longitudinal bulkheads
	=	0.90	for horizontal stiffeners on longitudinal bulkheads.

h = distance, in m (ft), from the longitudinals, or from the middle of ℓ for vertical stiffeners, to a point located 1.22 m (4 ft) above the deck at side amidships in installations of 61 m (200 ft) length, and to a point located 2.44 m (8 ft) above the deck at side amidships in installations of 122 m (400 ft) length and above; at intermediate lengths, h is to be measured to intermediate heights above the side of the installation. The value of h for bulkhead stiffeners and deck longitudinals is not to be less than the distance, in m (ft), from the longitudinal, or stiffener to the top of the hatch. See also 5A-4-1/1.15.

s = spacing of longitudinals or stiffeners, in m (ft)

ℓ = length between supporting points, in m (ft)

The section modulus *SM* of the bottom longitudinals may be obtained from the above equation multiplied by R_1 where,

15.3.1(a) The bottom hull girder section modulus, SM_A, is greater than required by 3-2-1/3.7.1, at least throughout 0.4*L* amidships,

15.3.1(b) Still-water bending moment calculations are submitted, and

15.3.1(c) Adequate buckling strength is maintained.

The bottom longitudinals with this modified section modulus are to meet all other Rule requirements.

$R_1 = n/[n + f_p(1 - SM_R/SM_A)]$ but is not to be taken less than 0.69

where

n = 7.69 (0.784, 4.978)

f_p = nominal permissible bending stress, as given in 3-2-1/3.7.1 of the *Steel Vessel Rules*

SM_R = hull girder section modulus required by 3-2-1/3.7.1 of the *Steel Vessel Rules*, in cm^2-m (in^2-ft)

SM_A = bottom hull girder section modulus, cm^2-m (in^2-ft), with the longitudinals modified as permitted above.

Where the heavy weather ballast draft forward is less than 0.04*L*, the flat of bottom forward longitudinals are not to be less than required by 3-2-4/13.5 of the *Steel Vessel Rules*

15.3.2 Web Thickness *(1993)*

In addition to the requirements in 3-1-2/13.5.2 of the *Steel Vessel Rules*, the thickness of web portion is to be not less than the thickness given in 5A-4-2/Table 2, reduced by 1.0 mm (0.04 in.).

15.5 Bilge Longitudinals

Longitudinals around the bilge are to be graded in size from that required for the lowest side longitudinals to that required for the bottom longitudinals.

15.7 Installations under 76 m (250 ft)

In installations under 76 m (250 ft) in length, the coefficient c for use in the above equation for bottom longitudinals may be reduced to 1.30.

17 Structure at Ends

Beyond the cargo spaces, the scantlings of the structure may be as required in way of the oil spaces, in association with the values of h in the various equations measured to the upper deck, except that in way of deep tanks, h is to be not less than the distance, in m (ft), measured to the top of the overflow. In way of dry spaces, the deck beams and longitudinals are to be as required in Section 3-2-7 of the *Steel Vessel Rules*. The value of h for deck transverses in way of dry spaces is to be obtained from Section 3-2-7 of the *Steel Vessel Rules* and the section modulus SM is to be obtained from the following equation:

$SM = 4.74chs\ell^2$ cm^3 $\qquad$ $SM = 0.0025chs\ell^2$ in^3

where

c = 1.23

s = spacing of transverses, in m (ft)

ℓ = span, in m (ft)

The transition from longitudinal framing to transverse framing is to be effected in as gradual a manner as possible, and it is recommended that a system of closely spaced transverse floors be adopted in way of the main machinery.

FIGURE 1
Coefficients and Lengths for Transverses

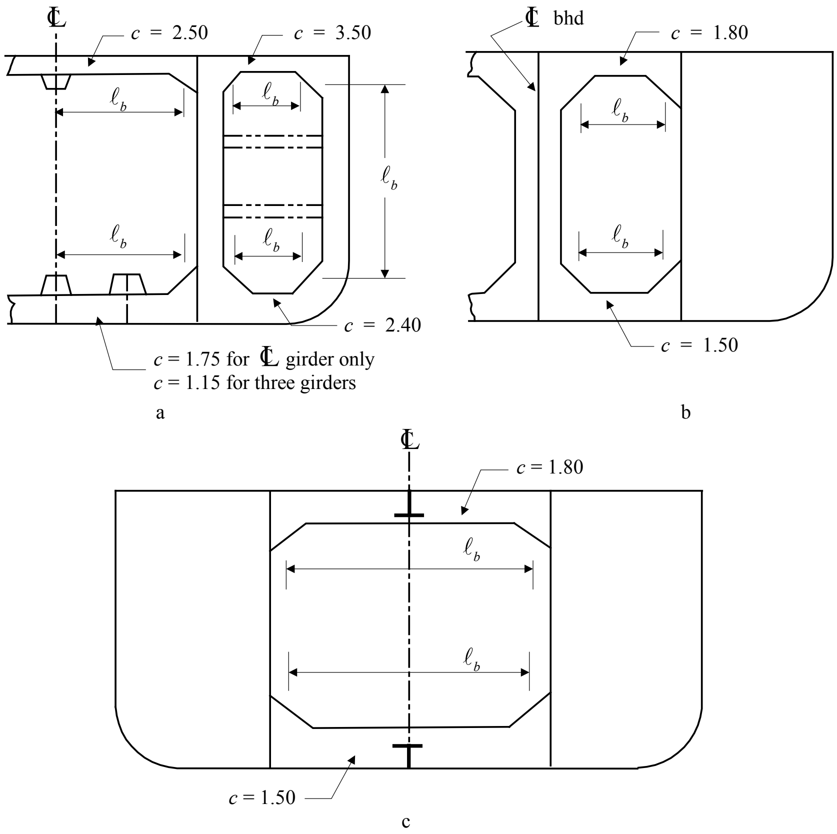
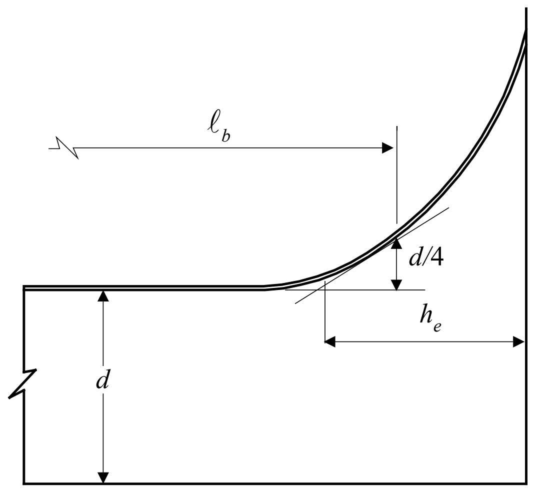
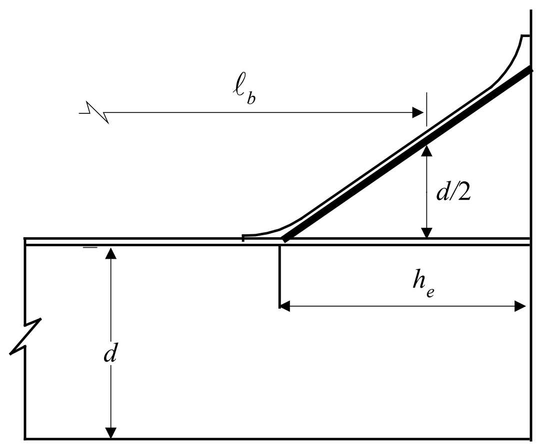


FIGURE 2
Lengths with Brackets



Where face plate area on the member is carried along the face of the bracket

a



Where face plate area on the member is not carried along the face of the bracket, and where face plate area on the bracket is at least one-half the face plate area on the member

b

FIGURE 3
Spans of Members and Effective Lengths or Heights of Brackets

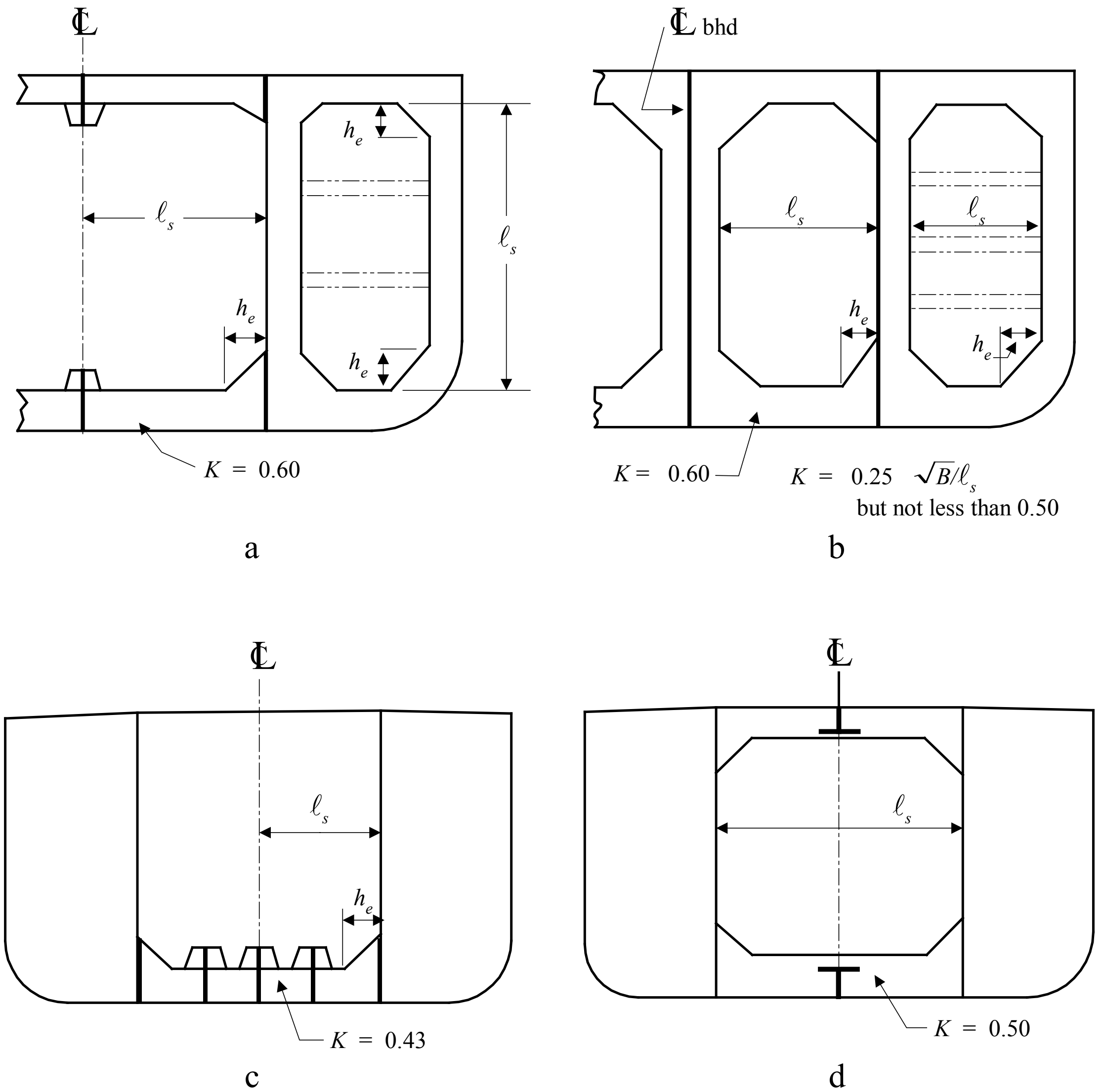


TABLE 1
Values of q for Ordinary Strength Steel

s = spacing of stiffeners or depth of web plate, whichever is the lesser, in cm (in.)

t = thickness of web plate, in cm (in.)

s/t	*kN/cm²*	*kgf/cm²*	*Ltf/in²*
80 and less	8.5	870	5.5
160 maximum	5.4	550	3.5

TABLE 2
Minimum Thickness for Web Portions of Members

L is the length of the installation, in m (ft), as defined in 3-1-1/3 of the *Steel Vessel Rules*. For installations of lengths intermediate to those shown in the table, the thickness is to be obtained by interpolation.

L meters	*t* mm
61	8.5
82	9
118	10
150	11

L feet	*t* in.
200	0.34
270	0.36
390	0.40
492	0.44

PART
5A

CHAPTER 4 Ship-Type Installations Under 150 meters (492 feet) in Length

SECTION 3 Cargo Oil and Associated Systems

See Section 5C-1-7 of the *Steel Vessel Rules*.

PART

5A

CHAPTER 4 **Ship-Type Installations Under 150 meters (492 feet) in Length**

APPENDIX 1 **Hull Girder Shear Strength for Ship-Type Installations** *(2013)*

1 Introduction

This Appendix is a supplement to 3-2-1/3.5 of the *Steel Vessel Rules* and is intended to provide a simplified method for determining the allowable still-water shearing forces, in accordance with the Rule requirements, for ship-type installations having two or three longitudinal oil-tight bulkheads, where the wing bulkheads are located no closer than 20% of the breadth from the side shell.

The computational method presented in this Appendix is deduced from shear flow and three-dimensional finite element calculation results and is applicable to ship-type installations having single bottom construction with deep bottom transverses and swash transverse bulkheads. For ship-type installations having either double bottom, double skin or deep bottom girders, the allowable still-water shear force will be subject to special consideration.

With the present Rule side shell thickness, local load effects are not considered for the side shell, as the longitudinal bulkhead generally governs the permissible shear force at any particular location.

3 Allowable Still-water Shearing Force

The allowable still-water shearing force, in kN (tf, Ltf), at any transverse section of the installation is the lesser of the *SWSF* obtained from 5A-4-A1/3.1 and 5A-4-A1/3.3 with any applicable modification as specified in 5A-4-A1/3.5.

3.1 Considering the Side Shell Plating

$$SWSF = \frac{0.935 f_s t_s D_s}{N_s} - F_w$$

3.3 Considering Various Longitudinal Bulkhead Plating

$$SWSF = \frac{1.05 f_s t_b D_b}{K_1 N_b} - F_w$$

In general, in the absence of a local load, two locations need be checked for each bulkhead: the lower edge of the thinnest strake and at the neutral axis of the section. When a local load is present, the *SWSF* is to be computed at the base of each longitudinal bulkhead strake for use with 5A-4-A1/3.5. For installations having three longitudinal bulkheads, the *SWSF* is to be calculated considering both the centerline and wing bulkheads.

F_w = wave induced shear force, as specified by 3-2-1/3.5.3 of the *Steel Vessel Rules*, in kN (tf, Ltf)

f_s = permissible total shear stress, as specified in 3-2-1/3.9.1 of the *Steel Vessel Rules*, in kN/cm^2 (tf/cm^2, Ltf/in^2)

t_s = thickness of the side shell plating at the neutral axis of the section in, cm (in.)

t_b = thickness of the centerline or wing longitudinal bulkhead plating at the location under consideration, in cm (in.)

D_s = depth of the hull girder at the section under consideration, in cm (in.)

D_b = depth of the longitudinal bulkhead at the section under consideration, in cm (in.)

N_s, N_b = shear distribution factors for side shell and longitudinal bulkheads, respectively, and may be determined by 5A-4-A1/5.

K_1 = $1 + y/(8\bar{y})$

y = distance measured from the deck or bottom (depending on whether the strake considered is above or below the neutral axis of the section) to the lower edge of the bulkhead strake under consideration, in cm (in.)

$\bar{y}$ = distance measured from the deck (bottom) to the neutral axis of the section, when the strake under consideration is above (below) the neutral axis, in cm (in.)

3.5 Reduction for Local Loads

When the loading head in the center tank is different from that in an adjacent wing tank, then the allowable *SWSF* computed at the various bulkhead locations in 5A-4-A1/3.3 may have to be reduced, as follows.

3.5.1

For the case of a two longitudinal bulkhead installation, when the center tank head is less than that in any adjacent wing tank, no reduction need be made.

3.5.2

For two and three bulkhead installations, when the center tank head exceeds that in a wing tank, within the center tank region, a hull girder shear force reduction, R, is to be computed at the corresponding locations on the bulkheads used in 5A-4-A1/3.3. These reductions are to be determined for both wing and centerline bulkheads, and may be calculated as follows.

$$R = W_c\left(\frac{2.1K_2N_w}{3K_1N_b} - 1\right) \quad \text{kN (tf, Ltf)}$$

If $2.1K_2N_w$ is less than or equal to $3K_1N_b$, R is to be taken as zero.

K_1, N_b = as previously defined

N_w = distribution factor for local loads, as specified in 5A-4-A1/5

K_2 = $1 + (A/A_b)$

A = total area of the longitudinal bulkhead plating above the lower edge of the strake under consideration, in cm^2 (in^2)

A_b = total area of the longitudinal bulkhead plating under consideration, in cm^2 (in^2)

W_c = effective local load which may be denoted by W_{c1} and W_{c2}, at the fore and aft ends of the center tank, respectively

$$W_{c1} = \frac{wb_c}{\ell_c}\left[h_{c1}\ell_1\left(\ell_2 + \frac{\ell_1}{2}\right) + h_{c2}\frac{\ell_2^2}{2}\right]$$

$$W_{c2} = \frac{wb_c}{\ell_c}\left[h_{c1}\frac{\ell_1^2}{2} + h_{c2}\,\ell_2\left(\ell_1 + \frac{\ell_2}{2}\right)\right]$$

w = density of the cargo (ballast), in kgf/m^3 (tf/m^3, Ltf/ft^3)

ℓ_c, b_c = length and breadth, respectively, of the center tank, in m (ft)

h_{c1}, h_{c2} = excess fluid heads in the center tank. Where the head in a wing tank exceeds that in the center tank, see 5A-4-A1/3.5.3 below.

ℓ_1, ℓ_2 = longitudinal distances from the respective center tank ends to the succeeding wing tank transverse bulkheads

3.5.3

When the head in wing tanks exceeds that in the center tank, within the center tank region, h_c is to be taken as zero for two longitudinal bulkhead installations. However, a reduction is to be applied only to the *SWSF* computed while considering the centerline bulkhead in 5A-4-A1/3.3. This reduction may be computed by the equations in 5A-4-A1/3.5.2, except that b_c is to be taken as the combined breadth of both wing tanks ($b_c = 2b_w$), and h_c is the excess head in the wing tank above that in the center tank.

3.5.4

Where adjacent tanks are loaded with cargoes of different densities, the heads in 5A-4-A1/3.5 are to be corrected to account for the difference in density.

5 Distribution Factors

The distribution factors N_s, N_b and N_w may be determined by the following equations.

5.1 For Installations Having Two Longitudinal Bulkheads

$N_b = 0.32 - 0.06(A_s/A_b)$

$N_s = 0.5 - N_b$

$N_w = 0.31(n - 1)/n$

where

A_s = total projected area of the side shell plating, in cm^2 (in^2)

A_b = as previously defined

n = total number of transverse frame spaces in the center tank

5.3 For Installations Having Three Longitudinal Bulkheads

N_b (center) = $0.26 - 0.044(A_s/A_b) + C_1$

N_b (wing) = $0.25 - 0.044(A_s/A_b) - C_2$

N_s = $0.5 - 0.5N_b$ (center) $- N_b$ (wing)

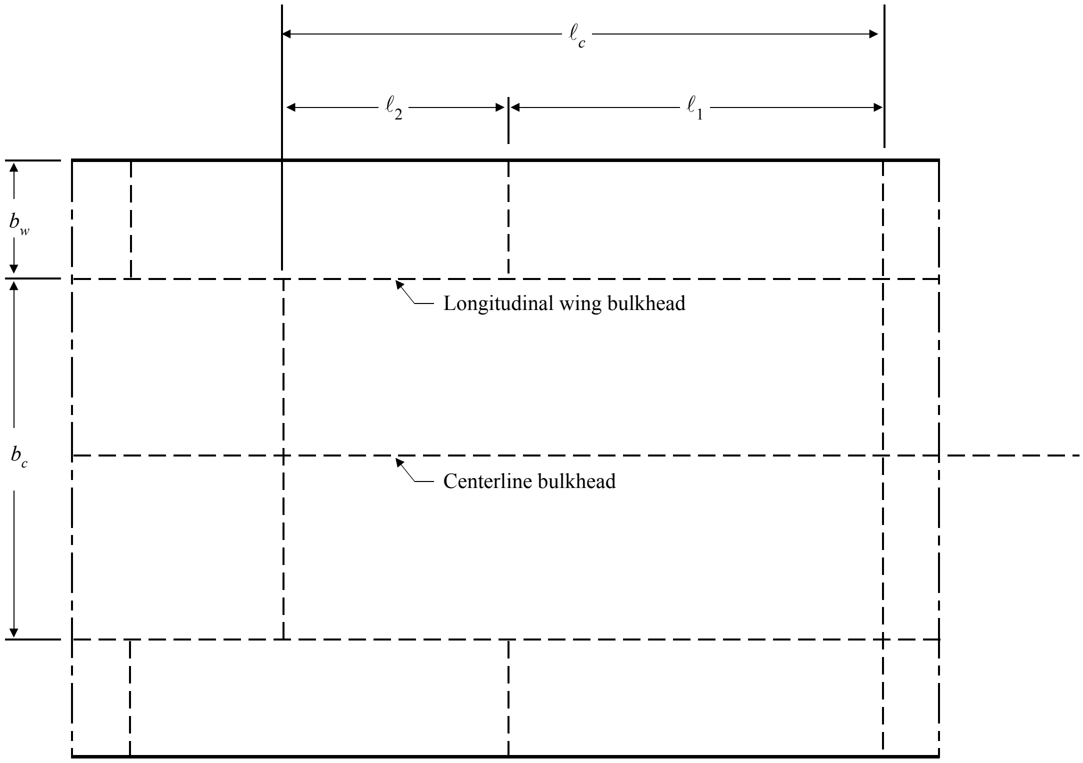
N_w (center) = $(0.7N_b + 0.15)(n - 1)/n$

N_w (wing) = $(1.5N_b - 0.1)(n - 1)/n$

A_s, A_b, n are as previously defined, however, A_b is to be either the center or wing bulkhead area, depending on which is being considered.

C_1	=	0	for $K > 0.9$
C_1	=	$0.1(1 - K) - 0.005$	for $K \leq 0.9$
K	=	A_b (wing)/A_b (center)	
C_2	=	0	for $K > 0.9$
C_2	=	$0.04(1 - K)$	for $K \leq 0.9$

FIGURE 1
Center Tank Region



PART

5B

Other Installation Types

CONTENTS

PART

5B

CHAPTER 1 Column-Stabilized Installations

CONTENTS

PART

5B

CHAPTER 1 Column-Stabilized Installations

SECTION 1 General Requirements *(1 July 2009)*

1 General

The design and construction of column-stabilized type installations are to be based on the applicable requirements of the *MODU Rules*. However, the design criteria, as given in the *MODU Rules*, can be modified to reflect the different structural performance and demands expected of a mobile installation, compared to an installation positioned at a particular site on a long-term basis. In addition, the applicable criteria contained in the Load Line, SOLAS and MARPOL Conventions issued by the International Maritime Organization are to be considered. It is further suggested that the local authorities having jurisdiction where the installation is to operate be contacted to obtain any further criteria that are applicable to the Floating Installation.

3 Definitions

A column stabilized floating production installation consists of a main deck connected to the underwater hull or footings by columns or caissons. The deck is noted in these Rules as "Topside Deck Structure".

The installation depends upon the buoyancy of columns or caissons for flotation and stability. Lower hulls or footings are normally provided at the bottom of the columns for additional buoyancy and the most common arrangements are either twin pontoons connected by braces or a ring (continuous) pontoon. The topside deck structure can be of an enclosed hull type or an open space truss frame construction. The topside deck structure is interconnected with the stability columns of the hull to form the installation's overall strength.

5 Loading Criteria

5.1 Loads

An installation's modes of operation in pre-service (loadout, transportation, installation) and in-service (in-place) conditions should be investigated using anticipated loads, including gravity loads together with relevant environmental loads due to the effects of wind, waves, currents, and, where deemed necessary by the Owner or designer, the effects of earthquake, temperature, fouling, ice, etc.

These loads are to include, as applicable, but should not be limited to, the following loads:

i) *Environmental loads.* Loads due to wind, waves, and current are to be considered. Directionality of wind, waves, and current may be considered if accurate data is available. Where there is no accurate data available, the directionality of wind, waves, and current that generates the most severe local and global load effects are to be used for design. Adequate headings for the environment are to be analyzed such that the most critical heading for the environment has been covered.

ii) *Hydrostatic pressures and buoyancy.* Hydrostatic pressures and buoyancy are to be considered for all submerged structural members.

iii) *Gravity.* Gravity of the structure and equipment steel and the variables in the topside deck structure and hull are to be considered.

iv) *Inertia loads.* Inertia loads due to motions of the column-stabilized installation are to be considered.

v) *Operational loads.* Loads induced by operations of drilling and production are to be considered.

vi) *Mooring and riser loads.* Loads due to mooring and riser systems are to be considered.

vii) *Marine operation loads.* Loads encountered during transportation and installation are to be taken into account in the design. These loads include loads exposed during transport (wet or dry), launch, or float-off.

viii) *Slamming.* Wave slamming loads are to be considered for members such as pontoons, columns, braces, and members forming the underside of the topside deck structure that are subject to wave slamming during transportation and operation. Breaking wave slamming loads are also to be considered, if applicable.

Combinations of these loads that produce the most severe local and global effects on the installation, as determined by the operational and installation requirements of the in-service and pre-service conditions, should be used. The global effects that are critical to the installation's global strength are given in 5B-1-2/5.1.2(a).

A loading plan is to be prepared to show the maximum uniform and concentrated loadings to be considered for the decks of the topside deck structure for each mode of operation. In the preparation of this plan, the following loadings are to be considered as minimums.

- *Crew spaces (walkways, general traffic area, etc.)*

  4510 N/m^2 (460 kgf/m^2, 94 lbf/ft^2) or 0.64 m (2.1 ft) head

- *Work areas*

  9020 N/m^2 (920 kgf/m^2, 188 lbf/ft^2) or 1.28 m (4.2 ft) head

- *Storage areas*

  13000 N/m^2 (1325 kgf/m^2, 272 lbf/ft^2) or 1.84 m (6.0 ft) head.

5.3 Environmental Conditions

A column-stabilized installation is to be designed to withstand a specified extreme storm in the Design Environmental Condition and operate in the Design Operating Condition. The environmental conditions required are defined in 3-2-3/1.1 and 3-2-3/1.3 and the environmental criteria required for these design conditions are defined in Section 3-2-4. Additionally, the column-stabilized installation is to be designed for all operations in pre-service conditions such as loadout, transportation, and installation. The environmental conditions for loadout and installation are to be specified by the designers or Owners. The environmental condition for transportation is to be of a 10-year return event of the selected transit route, unless a weather routing plan is to be implemented for the voyage.

In the design of the column-stabilized installation in-service and pre-service strength, the following environmental conditions are to be considered:

- *Design Environmental Conditions (DEC).* Please refer to 3-2-3/1.1. For structural strength design, environmental conditions that produce responses having a minimum return period of 100 years are to be used.
- *Design Operating Conditions (DOC).* Please refer to 3-2-3/1.3. For structural design, environmental conditions that produce responses having a minimum return period of 1 year are to be used.
- *Calm Conditions.* Environmental conditions such that the effects of wind, waves and current are insignificant and can be ignored. Where such a situation exists, the design case is permitted to use calm conditions.

7 Global Performance Analyses

7.1 General

Global performance analyses of a column-stabilized installation are aimed at determining the global effects of environmental loads on the overall installation and its components, such as mooring lines, risers, etc. The key function of the analyses is to establish that the column-stabilized installation meets all of the pre-service and in-service requirements. It is suggested that global response analysis be performed for each of the most critical design phases. The following aspects are to be included in the global performance analyses:

i) Installation motions in six degrees of freedom

ii) Mooring line tensions, including the maximum and minimum tensions and mooring line fatigue loads for mooring component design

iii) Equivalent design wave heights and periods for the global structural analysis

iv) Hull hydrodynamic pressure loads for global structural analysis

v) Installation accelerations for the determination of inertia loads

vi) Deck clearance – please refer to 5B-1-1/7.7.

Global analyses with various loading conditions are required because complex motion characteristics of the column-stabilized installation will have different impacts on different structural components. Therefore, the topside deck structure, hull, moorings and risers are to be included in these analyses. Several analytical methods with varying degrees of complexity may be used to achieve this goal. Loading and response predictions for the topside deck structure and hull, and those for the moorings and risers can be performed either separately or in an integrated form. Methods and models employed in the analyses are to account for the relevant nonlinear and motion coupling effects. Due to numerical efficiency and limitations of each method, frequency domain analyses are usually performed for all of the load cases. For those cases that are determined to be critical to the column-stabilized installation global performance or to have highly nonlinear effects, a time-domain analysis should be performed. For the detailed discussion of various available global analysis methods of column-stabilized installations, refer to API RP 2SK.

7.3 Frequency Domain Analyses

Frequency domain analyses include those in six degrees of freedom of the column-stabilized installation in both the wave frequency and the low frequency domains.

In order to evaluate the first-order installation and mooring responses, linear wave theory is usually employed in the wave frequency analysis. However, an alternative method may be applied to evaluate the effects of finite amplitude waves. The low frequency analysis is also to be carried out to evaluate the effects caused by wind dynamics and wave drift forces. The damping levels used in the analyses are to be properly determined and documented.

7.5 Time Domain Analyses

Time domain analysis is a preferable approach to include the nonlinear effects in global response analyses of the column-stabilized installation. These nonlinear effects include hull drag forces, finite wave amplitude effects, nonlinear restoring forces from moorings and risers, and coupling effects of hull, moorings, and risers in deep waters. In time domain analysis, a relevant wave spectrum is to be transferred to random time series for simulating irregular wave elevations and kinematics.

For deepwater applications, a time domain analysis of fully coupled motions of installation, moorings, and risers may be required for the load cases that are shown to govern the column-stabilized installation's global performance. When strong nonlinear responses are expected, a time domain mooring analysis is to be performed and submitted for review.

In an area with a strong current extending deep into the ocean, possible VIV effects are to be assessed and documented.

7.7 Deck Clearance

Unless topside deck structures are satisfactorily designed for wave impact, reasonable clearance between the bottom of the topside deck structures and the wave crests is to be ensured for all afloat modes of operation, taking into account the predicted motion of the installation relative to the surface of the sea.

A clearance is to be maintained between the lowest point of the topside deck and the wave crest. The deck clearance is normally determined by an appropriate model test. Alternatively, the deck clearance can also be determined by a detailed hydrodynamic analysis that accounts for relative motions between the column-stabilized installation and waves. The following items are to be considered to determine the deck clearance:

i) Various environmental headings

ii) All motions due to wind, waves, and current

iii) Nonlinearity of wave profile

iv) Wave diffraction and run-up

v) Tide and water level effects

Deck clearance is also to be checked at various points on the underside of the topside deck for all of the critical environmental conditions.

The deck clearance analysis establishes the elevation of topside deck structure in still water condition so that the bottom of topside deck structure is not subjected to wave impact in Design Environmental Conditions (DEC), unless the topside deck structure bottom is designed for such loading.

Where topside deck structural members are designed for passage of waves or if wave impact on the underside of the topside deck structure is anticipated, local strengthening of these members is required. Structures and equipment subject to wave run-up or green water are to be designed for the associated forces.

7.9 Model Testing

Model testing for deriving some of the design parameters, such as deck clearance and nonlinear effects, is recommended as the final check of column-stabilized installation designs if innovative components emerge in the design. Relevant environmental conditions are to be covered in the model testing. The primary objectives of model tests are listed below:

i) To determine the responses of a particular design, such as to calibrate low-frequency damping coefficients.

ii) To verify analysis tools for prediction of system responses or simply to correlate the analysis results.

iii) To derive design information as a substitute for numerical analysis.

PART
5B

CHAPTER **1 Column-Stabilized Installations**

SECTION **2 Structures** *(1 July 2009)*

1 Structural Design

The design of the installation is to be based on the applicable portions of the *MODU Rules*. Where the conditions at the installation site are less than those for a mobile installation that are the bases of the *MODU Rules*, the design criteria for various components of the installation structure may be reduced to reflect these differences. However, when the installation site conditions produce more arduous demands, it is mandatory that the design criteria be increased appropriately.

1.1 Scantlings

Installation's scantlings, including topside deck structure, columns, braces, and pontoons are to be designed in accordance with 5B-1-2/3.

1.3 Deckhouses

Deckhouses such as living quarters, utility buildings, etc., which are not an integral part of the upper deck structure are to have sufficient strength for their size, function, and location, with due consideration given to the environmental conditions to which the installation may be exposed. Special considerations should be given to deckhouses which act as foundations for vital machinery or equipment.

1.5 Helicopter Deck

The design of the helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules*.

1.7 Protection of Openings in Decks and Columns

All openings in decks or column tops, hatch covers and companionway sills are to comply with 5A-4-1/3 of these Rules. Portlights or other similar openings are not to be fitted in columns.

1.9 Guards and Rails

Guards and rails are to comply with the requirements of 5-3-1/5 of the *MODU Rules*.

3 Scantling Design of the Hull Structure

The initial scantling design of the hull is to be based on the applicable portions of the *MODU Rules* and the *Steel Vessel Rules*. The aspects that are not covered by these Rules are to be based on the recognized codes and standards. For curved shells, the minimum scantlings of shell plating and ring girders are to be determined on the basis of established shell analysis methods, using the heads given in 5B-1-2/3.1 and safety factors appropriate to the method employed. As a minimum, a detailed local analysis is to be performed, with failure modes meeting the criteria in 5B-1-2/5.1.6.

3.1 Hull – Pontoons, Columns, and Braces

Pontoons, columns, and braces may be considered either as framed or unframed shells. Ring girders, bulkheads, or other suitable diaphragms are to be adequate to maintain shape and stiffness under all anticipated loadings in association with established analysis methods.

3.1.1 Scantlings of Framed Shells

Where the components of braces, columns, or pontoons incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., for shells and interior boundary bulkheads and flats may be determined in accordance with the requirements for tanks, as given in 5B-1-2/3.5, in association with the following.

3.1.1(a) Tank Space. Where the internal space is a tank, the head, h, is to be taken to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, or to a point 0.91 m (3 ft) above the top of the tank, whichever is greater. For tanks intended to carry contents with a specific gravity in excess of 1.05, the head is to be suitably increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.1(b) Void Compartment Spaces. Where the internal space is a void compartment, the head is to be taken to the maximum permissible draft of the installation in service.

3.1.1(c) Areas Subject to Wave Immersion. For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

3.1.1(d) Minimum Scantlings. In general, the scantlings of boundaries are not to be less than those required by 5B-1-2/3.3, in association with a head to the maximum damaged waterline.

3.1.2 Scantlings of Unframed Shells

Where braces, columns, or pontoons do not incorporate framing members, the minimum scantlings of shell plating and ring girders are to be determined on the basis of established shell analysis methods using the heads given in 5B-1-2/3.1.1 and safety factors appropriate to the methods employed. Interior boundary bulkheads and flats are to be considered on the basis of framed shells, as given in 5B-1-2/3.1.1.

3.1.3 Additional Structural Requirements for Scantlings

Scantlings of braces, columns, and pontoons as determined above are minimum requirements for hydrostatic loads. Where wave and current loadings are superimposed, the scantlings of the local structure of the shell are to be increased as necessary, to meet the strength requirements of 5B-1-2/5.1.6.

3.3 Watertight Boundary Formula

3.3.1 Plating

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

$$t = sk\sqrt{qh}\,/290 + 1.5 \text{ mm} \qquad t = sk\sqrt{qh}\,/525 + 0.06 \text{ in.}$$

but not less than 6 mm (0.24 in.) or s/200 + 2.5 mm (s/200 + 0.10 in.), whichever is greater.

where

t	=	thickness in mm (in.)	
s	=	spacing of stiffeners in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	for $1 \le \alpha \le 2$
	=	1.0	for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
q	=	$235/Y$ ($24/Y$, $34{,}000/Y$)	
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)	
h	=	distance, in m (ft), from the lower edge of the plating to a point defined in 5B-1-2/3.1	

3.3.2 Stiffeners and Beams

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

$$SM = Q f c h s \ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

Q = $489.55/(Y + 2U/3)$ (SI Units)

Q = $49.92/(Y + 2U/3)$ (MKS Units)

Q = $70900/(Y + 2U/3)$ (US Units)

f = 7.8 (0.0041)

c = 0.56 for stiffeners with ends attached

= 0.60 for stiffeners with no end attachment

h = distance, in m (ft), from the middle of ℓ to a point defined in 5B-1-2/3.1

s = spacing of stiffeners, in m (ft)

ℓ = length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 3-2-2/Table 2 of the *MODU Rules*, the length of ℓ maybe measured to a point on the bracket equal to 25% of the length of the bracket.

Y = specified minimum yield strength, in N/mm^2 (kgf/mm^2, psi)

U = specified minimum tensile strength of the higher-strength material, in N/mm^2 (kgf/mm^2, psi)

3.3.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = Q f h s \ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

f = 4.7 (0.0025)

h = distances, in m (ft), from the middle of the area supported to a point defined in 5B-1-2/3.1

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-1-2/3.3.2

3.5 Tank Boundary Formula

3.5.1 Plating

Plating is to be the thickness derived from the following equation:

$$t = sk\sqrt{qh}/254 + 2.5 \text{ mm} \qquad t = sk\sqrt{qh}/460 + 0.10 \text{ in.}$$

but not less than 6.5 mm (0.25 in.) or $s/150 + 2.5$ mm ($s/150 + 0.10$ in.), whichever is greater.

where

t	=	thickness, in mm (in.)
s	=	spacing of stiffeners, in mm (in.)
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$
	=	1.0 for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)
q	=	$235/Y$ $(24/Y, 34{,}000/Y)$
Y	=	specified minimum yield point or yield strength, in N/mm² (kgf/mm², psi)
h	=	distance, in m (ft), from the lower edge of the plating to a point defined in 5B-1-2/3.1

When the specific gravity of the liquid contents of a tank is greater than 1.05, the head, *h*, specified above is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.5.2 Stiffeners and Beams

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

$$SM = Q f c h s \ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

f	=	7.8 (0.0041)
c	=	0.9 for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders
	=	1.0 for stiffeners supported at both ends by girders
h	=	distance, in m (ft), from the middle of ℓ to a point defined in 5B-1-2/3.1
s	=	spacing of stiffeners, in m (ft)
ℓ	=	length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.
Q	=	factor defined in 5B-1-2/3.3.2

3.5.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = Q f c h s \ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

f	=	4.74 (0.0025)
c	=	1.5
h	=	distances, in m (ft), from the middle of the area supported to a point defined in 5B-1-2/3.1
s	=	sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-1-2/3.3.2

5 Engineering Analysis of the Installation's Primary Structure

5.1 Hull and Topside Deck Structure

5.1.1 General

Documents necessary to verify the structural strength of the installation, including yielding, buckling, and fatigue of the hull, topside deck structure and main intersections of primary structural components of the hull and topside deck structure are to be submitted for review. The criteria in this Subsection relate to the analyses required to verify the scantlings selected in the basic design in 5B-1-2/3. The results of analysis that are required in this Subsection cannot be used to reduce the scantlings established from 5B-1-2/3. Depending on the specific features of the offshore installations, additional analyses to verify and help design other portions of the installation structural components will be required. Such additional analyses include those for the topside deck structural components supporting deck-mounted equipment/machinery and the installation structure interface with the position mooring and riser systems. Analysis criteria for interface structures are given in 5B-1-2/7.

5.1.2 Global Strength Analysis

The primary structural components of the hull and topside deck structure are to be analyzed using the loading and environmental conditions stipulated below. Conditions representative of all modes of operation are to be considered to determine critical cases. Calculations for critical conditions are to be submitted for review. The analyses are to be performed using recognized calculation methods and fully documented and referenced.

Design conditions are to be developed in accordance with Section 3-2-3, "Design Conditions" and Section 3-2-4, "Environmental Conditions". 5B-1-2/Table 1 below shows the required environmental events and safety factors to be considered for each design condition in the global strength analysis:

TABLE 1
Required Environmental Events and Safety Factors *(1 July 2009)*

Design Conditions	*Environmental Events*	*Safety Factors*
Loadout	Calm or specified by designer or Owner	1.67
Ocean Transit (Dry Tow)	10 year return storm for the selected route condition or specified by designer or Owner if weather routing plan is to be implemented for the voyage	1.25
Field Transit (Wet Tow)	1 year return storm for the selected route condition or specified by designer or Owner	1.25
In-place Design Operating	1 year return storm (minimum)	1.67
In-place Design Environmental	100 year return storm	1.25
In-place Damaged	1-year return storm	1.25

5.1.2(a) Critical Responses for Global Strength. The global strength of the installation is to be designed for withstanding the maximum global effects (noted in these Rules as "critical responses") induced by the loads specified in 5B-1-1/5.1. The critical responses that control the installation strength design are prying/squeezing loads, deck inertia loads, torsional moments, and longitudinal shear forces between pontoons. The critical responses that control the topside deck structure strength design are the deck inertia loads. As indicated in 5B-1-2/Table 1, the in-place intact strength is to be designed for these critical responses with a return period of 100 years in the Design Environmental Condition (DEC).

The highest wave may not always produce the most critical responses. So that the most critical responses are captured, a sufficient number of design cases are to be used, considering the following permutations:

i) Variation in environmental conditions and headings

ii) Variation in variables (deck payloads)

iii) Variation in ballasting distributions

iv) Variation in riser arrangements

5.1.3 Major Joint Analysis – Analysis for Main Intersections of Primary Structures

Since it is difficult to adequately capture the details of the main intersections in the global strength model, local FEM analyses are to be used, as required, to design these areas. These main intersections include connections of pontoon to pontoon, column to pontoon, and column to topside deck structure. For twin-pontoon column stabilized installations, special attention should be given to brace connections to braces, columns, pontoons, and topside deck structure.

5.1.4 Fatigue Analysis

Fatigue analysis is to be performed to verify adequate strength against fatigue failure within its design life. The fatigue analysis is to consider the loading history of the column-stabilized installation including transport and in-place conditions. Special attention is to be given to the major joints mentioned above. Attention is also to be given to the designs of structural notches, cutouts, brackets, toes, and abrupt changes of structural sections where they are prone to fatigue damages.

5.1.5 Structural Redundancy Analysis

The hull structural redundancy analysis is required to verify that there is adequate redistribution of stress in the damaged condition defined in 5B-1-2/Table 1. The damaged conditions are to consider loss of one compartment buoyancy and loss of one brace for twin-pontoon column stabilized installations.

For topside deck structures constructed with open space trusses, the redundancy analysis is also required for the damaged condition with loss of one primary member in association with a factor of safety of 1.0.

5.1.6 Acceptance Criteria

5.1.6(a) Material Yielding (1 July 2012). For the hull and topside deck structure, the yielding criteria based on the safety factors in 5B-1-2/Table 1 are to be used for bar and beam elements. For plate structures the allowable von Mises equivalent stress is to be 0.7 of the yield strength for the Design Operating and Loadout Conditions, and 0.9 of the yield strength for the Design Environmental, Transit and Damaged Conditions.

Note: The yield strength is to be based on the specified minimum yield point or yield stress as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for higher strength material or 72 percent of the specified minimum tensile strength, whichever is the lesser.

5.1.6(b) Buckling and Ultimate Strength. For the hull and topside deck structure, the criteria specified in ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures* are to be used. Alternatively, the criteria specified in the API Bulletin 2U and 2V and other recognized standards acceptable to ABS can be used. The safety factors are to be based on 5B-1-2/Table 1 of these Rules.

5.1.6(c) Fatigue (1 July 2012). For the hull, including the main intersections defined in 5B-1-2/5.1.3, the fatigue damages can be calculated using the ABS Offshore S-N curves for environment in air, in seawater with cathodic protection, and free corrosion, as specified in Section 3 of the ABS *Guide for the Fatigue Assessment of Offshore Structures*. The S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm ($^7/_8$ in.). For members of greater thickness, thickness correction is to be applied with an exponent of 0.25. Other recognized standards equivalent to ABS requirements are also acceptable.

The fatigue life is determined by safety factors and the design life of the column-stabilized installation. Safety factors depend on the inspectability, repairability, redundancy, the ability to predict failure damage, as well as the consequence of failure of the structure. Minimum safety factor requirements are listed in 5B-1-2/Table 2.

TABLE 2
Safety Factors for Fatigue Life of Hull, Integrated Deck, and Column Top Frame *(1 July 2009)*

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	3	5
Critical	5	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

For topside deck structure, ABS Offshore S-N curves and AWS S-N curves can be used. 5B-1-2/Table 3 provides general safety factor requirements for fatigue life.

TABLE 3
Safety Factors for Fatigue Life of Topside Deck Structures *(1 July 2012)*

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	2	5
Critical	3	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

For existing installations, the remaining fatigue life of the installation is to be assessed and the supporting calculations are to be submitted for review. Special consideration is to be given to the effects of corrosion and wastage on the remaining fatigue life of existing structures.

Any areas determined to be critical to the structure are to be free of cracks, and the effects of stress risers is to be determined and minimized. Critical areas may require special analysis and survey.

7 Analysis and Design of Other Major Structures

The analysis and design criteria to be applied to the other pertinent features of the installation structural design are to conform to recognized practices acceptable to ABS. For installations, there will be a need to consider in the hull and topside deck structure design the interface between the mooring system and the installation, the interface between the riser system and the installation, and the effects of structural support reactions from deckhouses and deck-mounted equipment/machinery. The criteria to be applied for these cases are presented below.

7.1 Hull Interface with Riser System (Riser Porches, Supports, and Guides)

The riser porches, guides, and supports, including the hull backup structures (the reinforcements for the hull), are to be designed for the maximum anticipated riser loads with a safety factor of 1.25 in the Design Environmental Condition (DEC) and with a safety factor of 1.67 in the Design Operating Condition (DOC).

Fatigue strength is to be designed to meet the requirements in 5B-1-2/5.1.6(c), taking into account the effects of both local drag and inertia loads on the risers and the global motions of the installation.

7.3 Hull Interface with Mooring System (Fairlead, Chain Stopper, and Winch Foundations)

Each individual foundation and back-up structure of the fairlead, chain jack, and winch is to be designed for the breaking strength of the mooring line with a safety factor of 1.25. The foundation and back-up structure for multiple fairleads, chain jacks, or winches is to be designed for the maximum anticipated mooring loads with a safety factor of 1.25 in the Design Environmental Condition (DEC) and with a safety factor of 1.67 in the Design Operating Condition (DOC).

Fatigue strength is to be designed to meet the requirements in 5B-1-2/5.1.6(c), taking into account the effects of both local drag and inertia loads on the moorings and the global motions of the installation.

7.5 Topside Deck Structure Interface with Deckhouses and Deck Mounted Equipment/ Machinery

The topside deck structure may require reinforcements to resist the reaction forces from equipment/ machinery foundations or deck modules. The reinforcements of the topside deck structure are referred to as backup structures. The forces to be resisted by the backup structures of the topside deck structure are to be designed for the maximum anticipated gravity, functional, and environmental loads together with the inertia loads induced by the installation motions with a safety factor of 1.25 in the Design Environmental Condition and 1.67 in the Design Operating Condition. If deemed necessary, the fatigue strength is to meet the requirements of 5B-1-2/5.1.6(c). Special attention should also be given to the following interface structures:

7.5.1 Lifeboat Platform

The strength of a lifeboat platform is to be designed to meet the following requirement:

- The most adverse combination of list and trim of 20° with Safe Working Load (total weight of lifeboat, passengers and supplies) with allowable stresses equal to Ultimate Tensile stress divided by a factor of 4.5.

7.5.2 Crane Pedestal and Foundation

The crane pedestal is to be designed in accordance with the recognized standard that the crane is certified to, such as Chapter 2, "Guide for Certification of Cranes" of the ABS *Guide for Certification of Lifting Appliances* or API Spec. 2C.

9 Materials and Welding

9.1 Hull and Topside Deck Structure

Sections 3-2-6 and 3-2-7 of the *MODU Rules* are to be used to establish the welding requirements for the hull. The weld type and size are to be shown on the scantling drawings or in the form of a welding schedule, and are to comply with the Rules that govern the steel selection. Special attention is to be given to the weld details for fatigue sensitive areas, if necessary. Weld improvements by means of toe grinding and weld profiling are to be used if required by fatigue analysis results.

Section 3-1-3 of the *MODU Rules* is to be used for the material selections for the hull and topside deck structure. The hull and topside deck structure are grouped into the following material application categories for the purpose of material grade selection:

Special Application Structure	• External shell structure in way of main intersections of columns, topside deck structure, pontoons, braces, mooring foundations, and riser porches • Portions of topside deck structure which receive major concentrated loads • Intersections of topside deck structure's main truss members • External brackets, portions of bulkheads, flats, and frames which receive concentrated loads at main intersections of columns, topside deck structure, pontoons, braces, mooring foundations, and riser porches • "Through" material used at main intersections of columns, topside deck structure, pontoons, braces, mooring foundations, and riser porches, which provide proper alignment and adequate load transfer
Primary Application Structure	• External shell structure of columns, pontoons, braces, topside deck structure (barge hull), and riser porches • Topside deck structure's main truss members • Bulkheads, flats, and framing which provide local reinforcement or continuity of structure in way of main intersections, except where the structure is considered special application • Bulkheads, girders, decks that are designed to provide global strength to the installation
Secondary Application Structure	• Internal structure, including bulkheads and girders in columns, topside deck structure, and pontoons, except where the structure is considered primary or special applications • Decks of topside deck structure, except where the structure is considered primary or special applications

9.3 Corrosion Protection and Control

A corrosion protection and control system utilizing anodes and coating in accordance with the recognized industry standards such as API and NACE is to be provided. The design life of the corrosion protection and control system is to be the design life of the installation. In the splash zone, corrosion allowance is to be added to the external shell plating.

PART

5B

CHAPTER 1 Column-Stabilized Installations

SECTION 3 Stability

1 Stability *(1 July 2012)*

1.1 Transit Voyage Stability

Stability during wet tow to location is to comply with Coastal and Flag State requirements. If personnel will be on board during the tow, the stability is to meet the criteria for column-stabilized units in the ABS *MODU Rules* at all transit drafts in association with wind speeds to be agreed with ABS based on the environmental parameters and procedures associated with the tow route.

During the installation phase (ballasting and deballasting on site), the installation is to have a positive metacentric height (GM) after correction for free surface effects. When evaluating GM, the effect of free surface from partially filled tanks during the ballasting/deballasting sequence is to be considered.

1.3 On-Site Stability

All installations are to have positive metacentric height (GM) in calm water equilibrium position for all afloat conditions after correction for free surface effects. The minimum GM used in design is to be specified by the designer and included in the operations manual.

Installations are to comply with the intact and damage stability criteria of 3-3-2/1 and 3-3-2/3 of the *MODU Rules* using the site-specific wind or 50 knots (25.7 m/s), whichever is greater. Height profile is to be taken from the *MODU Rules* or other recognized standard.

i) *Wind speed for normal operations* V_n – the 1-year, 1-minute average wind in the DOC as defined in 5B-3-1/5.3

ii) *Wind speed for storm survival* V_s – the 100-year, 1-minute average wind in the DEC as defined in 5B-3-1/5.3

iii) *Wind speed for damage conditions* V_d – the 1-year 1-minute average wind in the DOC as defined in 5B-3-1/5.3

The design wind velocities are to be selected by the designer and submitted with the design documentation.

1.5 Lightweight and Center of Gravity

The inclining test required by 3-3-1/3 of these Rules is to be carried out while the installation is floating at a draft where pontoons are submerged. Braces or other structures should not affect the waterplane properties at any point during the test.

Alterations in the lightweight data during service (e.g., new equipment, structural modifications) are to be recorded in the operation manual and be taken into account in daily operation.

1.7 Watertight and Weathertight Integrity

Watertight and weathertight integrity are to be established in accordance with 3-3-2/5 of the *MODU Rules*.

1.9 Penetrations *(1 July 2013)*

Penetrations are to comply with 3-3-2/5.5 of the *MODU Rules*.

Cable penetrations are to be installed in accordance with the manufacturer's specifications and procedures. Evidence of prototype testing at the water pressure of the watertight boundary under consideration is to be provided.

During installation of deck and bulkhead watertight and fire-rated cable penetrations, the attending Surveyor is to confirm that the installer is familiar with and has access to the manufacturer's installation procedures for stuffing tubes, transit devices or pourable materials.

After installation, all watertight and fire-rated cable penetrations are to be visually examined. Watertight cable penetrations are to be tested as required by 3-7-1/Table 1 of the *Steel Vessel Rules*.

PART
5B

CHAPTER 1 Column-Stabilized Installations

SECTION 4 Machinery and Systems

1 Marine Piping Systems

Marine piping systems are those systems (such as bilge, ballast, fuel oil and tank venting) that are required to conduct marine operations and are not associated with process facilities. Marine piping systems are to comply with Part 4, Chapter 2 of the *MODU Rules* and Chapter 3, Section 5 of the *Facilities Rules*, as applicable.

3 Electrical Systems

Electrical systems are to comply with Part 4, Chapters 1 and 3 of the *MODU Rules* and Chapter 3, Section 6 of the *Facilities Rules*. Where the Flag Administration permits, the minimum number of required main power sources may be reduced to one. For area classification requirements, refer to Section 4-1-9 of these Rules.

5 Fire Fighting Systems and Equipment

Fire fighting systems and equipment for installation service functions not associated with the process facilities are to be in accordance with Part 5, Chapter 2 of the *MODU Rules*. Fire fighting systems and equipment for protection of hydrocarbon process and associated systems are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*.

7 Machinery and Equipment

Machinery and equipment not associated with the process facilities are to be in accordance with the applicable requirements of Part 4, Chapter 1 of the *MODU Rules*, and Part 4, Chapters 2, 4, and 6 of the *Steel Vessel Rules*, as applicable. Machinery and equipment forming a part of the hydrocarbon processing facilities are to be in accordance with the applicable requirements of the *Facilities Rules*. (See 5A-1-3/1.15 of these Rules regarding machinery and equipment foundations.)

9 Hydrocarbon Storage in Hull Tanks *(1 July 2012)*

If the Column-Stabilized Installation is designed to store hydrocarbons in hull tanks, criteria for hull storage of hydrocarbons are to meet flag and coastal state requirements and applicable international requirements. The designs for scantlings and strength for such storage tanks are to be in accordance with 5B-1-2/1. See 3-5/5.9 of the *Facilities Rules* for the storage facility arrangement requirements.

11 Additional Plans and Data to be Submitted

The following information is to be submitted and appropriate relevant information is to be provided in the Operating Manual:

i) Inspection plans for all compartments below the maximum immersion line.

ii) Closure means for external openings whose lower edges are below the levels to which weathertight integrity is to be ensured, as shown by the diagrams submitted in accordance with Section 1-1-4 of the *MODU Rules* Supplement to the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*, defining their appropriate extent for each mode of operation afloat, for example, Normal Operating, Severe Storm Conditions and Transit Condition. (See 3-3-1/3.3.1 of the *MODU Rules*.)

iii) A plan identifying the disposition (open or closed) of all non-automatic closing devices and locations of all watertight and weathertight closures for each mode of operation afloat is to be submitted for review prior to the installation's delivery. Upon satisfactory review, the plan is to be incorporated into the Operating Manual. (See Section 1-1-4 and 3-3-1/9 of the *MODU Rules*.)

iv) Means for detection of and recovery from flooding of compartments that lie partly or completely below the operating or survival drafts and are adjacent to the sea or contain salt water piping or pumping equipment. (See 3-3-1/3.3.3 of the *MODU Rules*.)

v) The estimated time to deballast the installation from operating to survival draft. (See 4-2-4/13 of the *MODU Rules*.)

vi) Means of preventing progressive flooding via sounding tubes, tank vents and overflows, ventilating systems, trunks, etc., from compartments within the assumed damaged areas. (See 3-3-1/7.3 and 3-3-1/9 and 4-2-3/1.3 of the *MODU Rules*.)

vii) Means of detecting flooding of and means of water removal from void spaces not connected to the bilge or ballast systems. (See 3-3-1/1.3.3 and 4-2-4/3.3 of the *MODU Rules*.)

viii) Means of closure and evacuation of water from chain lockers. (See 4-2-4/1.1 of the *MODU Rules*.)

ix) The remaining or "residual" range of stability resulting from the damaged condition and the type and location of appropriate closures to prevent downflooding. (See 3-3-1/3.3.3 of the *MODU Rules* for the definition of "residual" stability.)

x) Means of sounding tanks. (See 4-2-3/3 of the *MODU Rules*.)

xi) A description of the ballast piping and control system describing the items listed below. (See 4-2-1/7.19, 4-2-2/21.9 and 4-2-4/13 of the *MODU Rules*.)

1. Redundancy of pumps, valves and controls and alternate means of valve operation.
2. Valve operating and indicating means.
3. Means of manual and remote operation of ballast pumps and valves.
4. Communication means between ballast control spaces and pump rooms, including those means of communication that are independent of the ship's service communication system.
5. Means of determining the failure of critical ballast system components and means to overcome their failure.

PART
5B

CHAPTER 2 Tension Leg Platforms

CONTENTS

PART
5B

CHAPTER 2 **Tension Leg Platforms**

SECTION 1 **General Requirements**

1 General

The design and construction of a Tension Leg Platform (TLP) are to be based on all applicable requirements of the *MODU Rules*, *Offshore Installations Rules* and API RP 2T. However, the design criteria, as given in the *MODU Rules* and *Offshore Installations Rules*, can be modified to reflect the different structural performance and demands expected of a TLP in offshore service. In addition, in the absence of equivalent Coastal State requirements, the applicable criteria contained in the Load Line, SOLAS and MARPOL Conventions issued by the International Maritime Organization (IMO) may be considered. It is further suggested that the local authorities having jurisdiction where the installation is to operate be contacted to obtain any further criteria that are applicable to the TLP installations.

3 Definitions

A TLP consists of structural components of hull, column top frame, topside deck, tendon system and foundation system. The hull consists of buoyant pontoons and columns. The tops of the columns are connected to a column top frame or a topside deck forming the global strength of the hull. For the hull with a column top frame, the topside deck is not integrated as part of the global strength of the hull. This topside deck is noted as "Non-integrated Deck" in these Rules. The topside deck integrated with the hull to form the global strength of the hull is noted as "Integrated Deck" in these Rules.

Tendon System: A vertical mooring system that forms the link between the hull and the foundation for the purpose of mooring the TLP.

Foundation System: The foundations used to anchor the tendon legs to the seafloor.

5 Loading Criteria

5.1 Loads

The TLP's modes of operation in pre-service (loadout, transportation, installation) and in-service (in-place) conditions are to be investigated using anticipated loads, including gravity loads together with relevant environmental loads due to the effects of wind, waves, current and other phenomena such as earthquake, temperature, fouling, ice, etc., depending upon the specific installation site.

The TLP is to be designed for the loading conditions that produce the most severe local and global effects on the structure, as determined by the most severe operational or installation requirements.

Applied loading combinations considered for structural design are to include, as applicable, but not be limited to, the following loads:

i) *Environmental loads.* Loads due to wind, waves and current are to be considered. Directionality of wind, waves and current may be considered if accurate data is available. Where there is no accurate data available, the directionality of wind, waves and current that generates the most severe local and global load effects are to be used for design. Adequate headings for the environment are to be analyzed such that the most critical heading for the environment has been covered.

ii) *Hydrostatic pressures and buoyancy.* Hydrostatic pressures and buoyancy are to be considered for all submerged structural members.

iii) *Gravity.* Gravity of the structure and equipment steel and the variables in the topside deck and hull are to be considered.

iv) *Inertia loads.* Inertia loads due to motions of the TLP are to be considered.

v) *Operational loads.* Loads induced by operations of drilling and production are to be considered.

vi) *Tendon and riser loads.* Loads due to tendon and riser systems are to be considered, as applicable.

vii) *Marine operation loads.* Loads encountered during transportation and installation are to be taken into account in the design. These loads include loads exposed during transport (wet or dry), launch or float-off and during ballasting and deballasting operations when the topside deck is being installed and during tendon installation procedure.

viii) *Slamming.* Wave slamming loads are to be considered for members such as pontoons, columns, top column frame members and members forming the underside of the topside deck that are subject to wave slamming during transportation and operation.

5.3 Environmental Conditions *(1 September 2007)*

The TLP is to be designed to withstand a specified extreme storm in the Design Environmental Condition and operate in the Design Operating Condition. The environmental conditions required are defined in 3-2-3/1.1 and 3-2-3/1.3 and the environmental criteria required for these design conditions are defined in Section 3-2-4. Additionally, the TLP is to be designed for all operations in pre-service conditions such as loadout, transportation and installation. The environmental conditions for loadout and installation are to be specified by the designers or Owners. The environmental condition for transportation is to be of a 10-year return event of the selected transit route, unless a weather routing plan is to be implemented for the voyage.

In the design of the TLP in-service and pre-service strength, the following environmental conditions are to be considered:

Design Environmental Conditions (DEC). Please refer to 3-2-3/1.1. For structural strength design, environmental conditions that produce the responses having a minimum return period of 100 years are to be used.

Design Operating Conditions (DOC). Please refer to 3-2-3/1.3. For structural design, environmental conditions that produce TLP responses having a minimum return period of 1 year are to be used.

Reduced Extreme Conditions (REC). Environmental conditions that have a low probability of being exceeded when the hull is damaged or a tendon is removed/flooded. For structural strength design, joint statistics may be used to determine a return period which, combined with the probability of damage, produces a risk level equal to that of the Design Environmental Conditions (DEC).

Calm Conditions. Environmental conditions such that the effects of wind, waves and current are insignificant and can be ignored. Where such a situation exists, the design case is permitted to use calm conditions.

In assessing the minimum tendon tension and topside deck clearance the following environmental condition should be considered:

Survival Environmental Conditions (SEC). Environmental conditions that produce TLP responses having a minimum return period of 1000 years.

7 Global Performance Analyses

7.1 General

Global performance analyses of the TLP are aimed at determining the global effects of environmental loads on the overall platform and its components, such as tendons, risers, etc. The key function of the analyses is to establish that the TLP meets all of the pre-service and in-service requirements. It is suggested that global response analysis be performed for each of the most critical design phases. The following aspects are to be included in TLP global performance analyses:

i) Platform motions in six degrees of freedom

ii) Tendon tensions, including the maximum and minimum tensions and tendon fatigue loads for tendon design

iii) Equivalent design wave heights and periods for the global structural analysis

iv) Hull hydrodynamic pressure loads for global structural analysis

v) Platform accelerations for the determination of inertia loads

Global analyses with various loading conditions are required because complex motion characteristics of the TLP will have different impacts on different structural components. Therefore, the deck, hull, tendons and risers are to be included in these analyses. Several analytical methods with varying degrees of complexity may be used to achieve this goal. Loading and response predictions for the deck and hull, and those for the tendons and risers can be performed either separately or in an integrated form. Methods and models employed in the analyses are to account for the relevant nonlinear and motion coupling effects. Due to numerical efficiency and limitations of each method, frequency domain analyses are usually performed for all of the load cases. For those cases that are determined to be critical to the TLP global performance or to have highly nonlinear effects, a time-domain analysis should be performed. For the detailed discussion of various available global analysis methods of TLP, refer to API RP 2T.

7.3 Frequency Domain Analyses

Frequency domain analyses include the wave frequency analysis in six degrees of freedom of the TLP system, and the low frequency analysis in surge, sway and yaw of the TLP system.

In order to evaluate the first-order platform and tendon responses, linear wave theory is usually employed in the wave frequency analysis. However, an alternative method may be applied to evaluate the effects of finite amplitude waves. In case where second-order sum-frequency effects are determined to be significant, the high frequency springing analyses are to be carried out to evaluate the springing responses of the platform and tendons. The low frequency analysis is also to be carried out to evaluate the slow drift effects caused by wind and wave drift. The damping levels used in the above analyses are to be properly determined and documented.

7.5 Time Domain Analyses

Time domain analysis is a preferable approach to evaluate the nonlinear effects in global response analyses of the TLP. These nonlinear effects include hull drag forces, finite wave amplitude effects, nonlinear restoring forces from tendons and risers, ringing (the high frequency vertical vibration of a TLP excited by impulsive loading) and springing (the high frequency vertical vibration of the TLP excited by cyclic loading at or near the resonant periods), and coupling effects of hull, tendons and risers in deep waters. In time domain analysis, a relevant wave spectrum is to be transferred to random time series for simulating irregular wave elevations and kinematics.

For deepwater applications, a time domain analysis of fully coupled motions of platform, tendons and risers may be required and documented for the load cases that are shown to govern the TLP global performance. When strong nonlinear responses are expected, a time domain ringing response analysis is to be performed and submitted for review.

In areas with a strong current extending deep into the ocean, possible VIV effects are to be assessed and documented.

7.7 Deck Clearance *(1 September 2007)*

A clearance meeting the following criteria is recommended to be maintained between the underside of the topside deck and the wave crest:

i) 5 ft minimum in Design Environmental Conditions (DEC).

ii) A reasonable clearance in Survival Environmental Conditions.

The deck clearance is normally determined by an appropriate model test. Alternatively, the deck clearance can also be determined by a detailed hydrodynamic analysis that accounts for relative motions between the TLP and waves. The following items are to be considered to determine the deck clearance:

i) Various environmental headings

ii) Offset due to wind, waves and current

iii) Nonlinearity of wave profile

iv) Wave diffraction, run-up

v) Platform set-down

vi) Tide and water level effects

vii) Seabed subsidence

Deck clearance is also to be checked at various points on the underside of the topside deck.

Unless the recommended deck clearance can be maintained to avoid impact, the TLP including topside deck, hull, tendons and foundations should be designed for the anticipated local and global wave forces (including slamming) and resulting responses. Structures and equipment on the topside deck, which may subject to wave run-up or green water, should also be designed for the associated forces.

7.9 Model Testing

Model testing for deriving some of the design parameters, such as deck clearance and nonlinear effects, is recommended as the final check of TLP designs if innovative components emerge in the design. Relevant environmental conditions are to be covered in the model testing. The primary objectives of model tests are listed below:

i) To determine the responses of a particular design, such as to calibrate factors for ringing and springing.

ii) To verify analysis tools for prediction of system responses or simply to correlate the analysis results.

iii) To derive design information as a substitute for numerical analysis.

9 Corrosion Protection and Control

A corrosion protection and control system utilizing anodes and coating in accordance with the recognized industry standards such as API and NACE is to be provided. The design life of the corrosion protection and control system is to be the design life of the TLP. In the splash zone, corrosion allowance is to be added to the external shell plating.

PART
5B

CHAPTER 2 Tension Leg Platforms

SECTION 2 Stability

1 Stability

1.1 Intact and Damaged Stability *(1 July 2012)*

Stability during wet tow to location is to comply with Coastal and Flag State requirements. If personnel will be on board during the tow, the stability is to meet the criteria for column-stabilized units in the ABS *MODU Rules* at all transit drafts in association with wind speeds to be agreed with ABS based on the environmental parameters and procedures associated with the tow route.

During the installation phase (ballasting and deballasting for tendon connection), the installation is to have a positive metacentric height (GM) after correction for free surface effects. When evaluating GM, the effect of free surface from partially filled tanks during the ballasting/deballasting sequence is to be considered.

Under in-place conditions, positive tendon tension is to be maintained to ensure integrity of the platform and tendons, and account for tendon slacking. The intact condition is to include the full range of possible center of gravity variations permitted by acceptable operating procedures during severe conditions.

The TLP is to maintain positive tendon tension in Design Operating Condition (DOC) after sustaining any one of the following flooding scenarios:

i) Any one compartment at or below the still water line, or

ii) Damage is assumed to be 3 m (10 ft) wide and 3 m (10 ft) high with a horizontal penetration of 1.5 m (5 ft) inboard of the hull plating. This extent of damage is to be considered at all levels between 3 m (10 ft) below to 5 m (16.4 ft) above the waterline in consideration. No vertical bulkhead needs to be considered damaged unless the nearest vertical bulkhead is placed closer than $^1/_8$ of the perimeter of the column at the waterline or 3 m (10 ft), whichever is less, or

iii) Any one tendon compartment.

The environmental condition is to be assumed as Design Operating Condition at the time of flooding. Positive tendon tension is to be demonstrated through analysis. Ballast pump capacity is to meet API RP 2T specifications.

The ability to compensate for damage incurred, by pumping out or ballasting other compartments, is not to be considered when determining whether positive tendon tension can be maintained.

1.3 Weight Control *(1 July 2012)*

An inclining test is to be conducted to accurately determine the platform weight and the position of the center of gravity. If integration of topsides takes place offshore, an alternative procedure may be applied using an inclining test or lightweight survey of the hull combined with weighing of the topside components to be installed.

A global weight verification plan is to be submitted. Procedures for the lightweight survey, each weighing, and permanent ballast measurement are to be submitted for approval and are to include estimates of weight and center of gravity. An ABS surveyor is to attend each activity.

When weighing components, these parts are to be as complete as possible with not more than 2% of the weight of the component remaining to be incorporated.

The result of each weight verification activity is to be compared to the estimated weight. When the measured weight is within ±1% of the estimated weight, the vertical center of gravity is to be the estimated value in the calculation. When it is outside the 1% tolerance, the vertical center of gravity is to be computed by taking the difference between the estimated and the measured weight and placing it at an indisputably conservative location.

Changes of onboard load conditions after the inclining test and during service are to be carefully accounted for. The operations manual is to provide guidance for the maintenance of a weight change log and periodical correlation between calculated and measured tendon tension. The weight log and the records of the periodical correlations are to be kept onboard.

3 Watertight/Weathertight Integrity *(1 September 2007)*

A plan, identifying the disposition (open or closed) of all non-automatic closing devices and locations of all watertight and weathertight closures, and unprotected openings is to be submitted for review prior to the installation's delivery. Upon satisfactory review the plan is to be incorporated into the Operating Manual.

3.1 Weathertight Integrity

External closing appliances are to be in accordance with the requirement of the 1966 International Convention on Load Lines.

In all cases, external openings whose lower edges are below the levels to which weathertight integrity is to be ensured are to have weathertight closing appliances.

Openings fitted with appliances to ensure weathertight integrity are to effectively resist the ingress of water due to intermittent immersion of the closure.

3.3 Watertight Integrity *(1 July 2012)*

All internal and external openings whose lower edges are below the levels to which watertight integrity is to be ensured, as shown by the diagrams submitted in accordance with 5B-3-2/3, are to be fitted with appliances to ensure watertight integrity.

3.3.1 Internal Openings

Internal openings fitted with appliances to ensure watertight integrity are to comply with the following.

3.3.1(a) Doors and hatches are to be of the quick-acting type and an indicating system (e.g., light signals) is to be provided showing personnel, both locally and at a normally manned central position, whether the doors or hatches in question are open or secured closed. In addition, a sign is to be posted near the opening to the effect that the closing appliance is to be secured closed and opened only during actual use. If sliding doors are fitted they are to be capable of being remotely controlled from a normally manned central position as well as being operable locally from both sides of the bulkhead.

3.3.1(b) Manholes fitted with bolted covers need not be dealt with as under 5B-2-2/3.3.1(a).

3.3.1(c) The closing appliances are to have strength, tightness and means for securing which are sufficient to maintain watertightness under the water pressure of the watertight boundary under consideration.

3.3.2 External Openings

External openings are to comply with the following.

3.3.2(a) The lower edges of all openings, including air pipes, ventilators, ventilation intakes and outlets (regardless of closing appliances), non-watertight hatches and weathertight doors, are to be above the levels to which watertight integrity is to be ensured.

3.3.2(b) Manholes fitted with bolted covers need not be dealt with as under 5B-2-2/3.3.2(a).

3.3.2(c) External openings fitted with appliances to ensure watertight integrity are normally to be secured closed and are to comply with the requirements of 5B-2-2/3.3.1.

3.5 Penetrations *(1 July 2013)*

Where watertight bulkheads and flats are necessary for damage stability, they are to be made watertight throughout. Where individual lines, ducts or piping systems serve more than one compartment or are within the extent of damage, satisfactory arrangements are to be provided to preclude the possibility of progressive flooding through the system. Valves fitted at watertight boundaries are to be operable from above the top of the hull.

Cable penetrations are to be installed in accordance with the manufacturer's specifications and procedures. Evidence of prototype testing at the water pressure of the watertight boundary under consideration is to be provided.

During installation of deck and bulkhead watertight and fire-rated cable penetrations, the attending Surveyor is to confirm that the installer is familiar with and has access to the manufacturer's installation procedures for stuffing tubes, transit devices or pourable materials.

After installation, all watertight and fire-rated cable penetrations are to be visually examined. Watertight cable penetrations are to be tested as required by 3-7-1/Table 1 of the *Steel Vessel Rules*.

PART

5B

CHAPTER 2 Tension Leg Platforms

SECTION 3 Hull and Primary Structures

1 Structural Design

1.1 General

The design of the TLP is to be based on the applicable portions of the *MODU Rules*. Where the conditions at the installation site are less than those for full ocean service that are the basis of the *MODU Rules*, the design criteria for various components of the TLP may be reduced to reflect these differences. However, when the installation site conditions produce more arduous demands, it is mandatory that the design criteria be increased appropriately. The TLP strength can be obtained by initially designing each component's scantlings for local load effects and, subsequently, verifying the initial scantlings for the global load effects.

This subsection provides requirements for the designs of initial scantlings and secondary structures. 5B-2-3/5 of these Rules provides requirements for verification of the initial scantlings.

1.3 Hull Scantlings

Scantlings of TLP structural components, including columns and pontoons, are to be designed in accordance with 5B-2-3/3.

1.5 Modules and Buildings on the Topside Deck

The structural design of modules and buildings on the topside deck is to be in accordance with 5B-2-3/5.3, wherever applicable. The relative deformations among module and building supports are to be included in the analysis if their effects on the module are significant.

The module and building supporting structures on the topside deck are to be analyzed and shown explicitly on the drawings so that the construction of the module and building supports can be consistent with those assumed in the structural analysis. Means are to be provided to verify that the module and building design reactions and conditions are identical with those used in the topside deck design.

The structural fire protection aspects of the design of topsides modules and buildings, including the arrangement of the hydrocarbon process area, are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules.*

The designs of piping system on the topside deck are to comply with Part 4, Chapter 2 of the *MODU Rules* and applicable requirements of the *Facilities Rules.*

1.7 Helicopter Deck

The design of the helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules* and 3-8/9.9 of the *Facilities Rules*.

1.9 Protection of Openings on Top of Columns

All openings of the top of columns are to comply with Section 3-2-15 of the *Steel Vessel Rules*.

1.11 Guards and Rails

Guards and rails are to comply with the requirements of 5-3-1/5 of the *MODU Rules*. The above mentioned section is to be used for the perimeters of the TLP. Alternative arrangements, such as a minimum 42-inch high and two tiers evenly spaced handrail with a kickboard, may be considered by the Bureau, provided they are also acceptable to local authorities.

1.13 Machinery and Equipment Foundations

Foundations for machinery or equipment subject to high concentrated or cyclic loading, such as drilling facilities, cranes, tendon porches, riser porches, if applicable, are to be designed to provide satisfactory strength and fatigue resistance for the reaction forces specified by the manufacturer or the maximum anticipated loads during the design life of the TLP, in accordance with safety factors outlined in 5B-2-3/5.1. The global load effects, TLP motion-induced inertia loads are also to be considered in addition to the reaction forces. The backup structures, reinforcements on hull or topside deck, are also to be designed for the same loads and safety factors, as a minimum.

1.15 Appurtenances

Main appurtenances attached to the exterior of the hull are to be evaluated, taking into account the effects of both local drag and inertia loads. Responses resulting from these loads, together with any appropriate consideration of global action of the TLP, are to be considered with respect to yield, buckling and fatigue strength. The backup structures are also to be designed for the same loads and safety factors, as a minimum.

1.17 Temporary Structures

Structures built for temporary use in the pre-service conditions are not subjected to ABS review. However, the arrangements and details of these structures are to be submitted for reference to verify the adequacy of the local and global strength of the hull and topside deck to support these temporary structures during operation in the pre-service condition. The backup structures are to be designed for the safety factors outlined in 5B-2-3/5.1.

3 Scantling Design of the Hull Structure

The initial scantling design of the hull is to be based on the applicable portions of the *MODU Rules* and the *Steel Vessel Rules*. The aspects that are not covered by these Rules are to be based on the recognized codes and standards. For curved shells, the minimum scantlings of shell girders are to be determined on the basis of established shell analysis methods, using the heads given in 5B-2-3/3.1 and safety factors appropriate to the method employed. As a minimum, a detailed local analysis is to be performed, with failure modes meeting the criteria in 5B-2-3/5.1.6.

3.1 Hull – Pontoons and Columns

Pontoons and columns may be considered either as framed or unframed shells. Ring stiffeners, bulkheads or other suitable diaphragms which are used are to be adequate to maintain shape and stiffness under all anticipated loadings in association with established shell analysis methods.

3.1.1 Scantlings of Framed Shells

Where the components of columns or pontoons incorporate stiffened plating, the minimum scantlings of plating, framing, girders, etc., for shells and interior boundary bulkheads and flats may be determined in accordance with the requirements for tanks, as given in 5B-2-3/3.5, in association with the following.

3.1.1(a) Tank Space. Where the internal space is a tank, the head, *h*, is to be taken to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, or to a point 0.91 m (3 ft) above the top of the tank, whichever is greater. For tanks intended to carry contents with a specific gravity in excess of 1.05, the head is to be suitably increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.1(b) Void Compartment Spaces. Where the internal space is a void compartment, the head is to be taken to the maximum permissible draft of the unit in service.

3.1.1(c) Areas Subject to Wave Immersion. For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

3.1.1(d) Minimum Scantlings. In general, the scantlings of boundaries are not to be less than those required by 5B-2-3/3.3, in association with a head to the maximum damaged waterline.

3.1.2 Scantlings of Unframed Shells

Where columns or pontoons do not incorporate framing members, the minimum scantlings of shell plating and ring stiffeners are to be determined on the basis of established shell analysis methods using the heads given in 5B-2-3/3.1.1 and safety factors appropriate to the methods employed. Interior boundary bulkheads and flats are to be considered on the basis of framed shells, as given in 5B-2-3/3.1.1.

3.1.3 Additional Structural Requirements for Scantlings

Scantlings of columns and pontoons as determined above are minimum requirements for hydrostatic loads. Where wave and current loadings are superimposed, the scantlings of the local structure of the shell are to be increased as necessary, to meet the strength requirements of 5B-2-3/5.1.6.

3.3 Watertight Boundary Formula

3.3.1 Plating

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

$$t = sk\sqrt{qh}\,/290 + 1.5 \text{ mm} \qquad t = sk\sqrt{qh}\,/525 + 0.06 \text{ in.}$$

but not less than 6 mm (0.24 in.) or s/200 + 2.5 mm (s/200 + 0.10 in.), whichever is greater.

where

t = thickness in mm (in.)

s = spacing of stiffeners in mm (in.)

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

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

q = 235/Y (24/Y, 34,000/Y)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)

h = distance, in m (ft), from the lower edge of the plating to a point defined in 5B-2-3/3.1

3.3.2 Stiffeners and Beams

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

$$SM = Q\,f\,c\,h\,s\,\ell^2 \quad \text{cm}^3\ (\text{in}^3)$$

$$Q = 49.92/(Y + 2U/3) \qquad \text{(SI Units)}$$

$$Q = 70900/(Y + 2U/3) \qquad \text{(US Units)}$$

where

f = 7.8 (0.0041)

c = 0.56 for stiffeners with ends attached

= 0.60 for stiffeners with no end attachment

h = distance, in m (ft), from the middle of ℓ to a point defined in 5B-2-3/3.1

s = the spacing of stiffeners, in m (ft)

ℓ = the length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 3-2-2/Table 2 of the *MODU Rules*, the length of ℓ maybe measured to a point on the bracket equal to 25% of the length of the bracket.

Y = specified minimum yield strength, in kgf/mm^2 (psi)

U = specified minimum tensile strength of the higher-strength material, in kgf/mm^2 (psi)

3.3.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = Q f h s \ell^2 \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

f = 4.7 (0.0025)

h = distances, in m (ft), from the middle of the area supported to a point defined in 5B-2-3/3.1

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-2-3/3.3.2

3.5 Tank Boundary Formula

3.5.1 Plating

Plating is to be the thickness derived from the following equation:

$$t = sk\sqrt{qh}/254 + 2.5 \text{ mm} \qquad t = sk\sqrt{qh}/460 + 0.10 \text{ in.}$$

but not less than 6.5 mm (0.25 in.) or s/150 + 2.5 mm (s/150 + 0.10 in.), whichever is greater.

where

t = thickness, in mm (in.)

s = spacing of stiffeners, in mm (in.)

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

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

q = 235/Y (24/Y, 34,000/Y)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)

h = distance, in m (ft), from the lower edge of the plating to a point defined in 5B-2-3/3.1

When the specific gravity of the liquid contents of a tank is greater than 1.05, the head, h, specified above is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.5.2 Stiffeners and Beams

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

$$SM = Q f c h s \ell^2 \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

f = 7.8 (0.0041)

c = 0.9 for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders

= 1.0 for stiffeners supported at both ends by girders

h = distance, in m (ft), from the middle of ℓ to a point defined in 5B-2-3/3.1

s = spacing of stiffeners, in m (ft)

ℓ = length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-2-3/3.3.2

3.5.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = Q f c h s \ell^2 \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

f = 4.74 (0.0025)

c = 1.5

h = distances, in m (ft), from the middle of the area supported to a point defined in 5B-2-3/3.1

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-2-3/3.3.2

5 Structural Strength Analysis and Design of Primary Structures

5.1 Hull, Integrated Deck and Top Column Frame

5.1.1 General

Documents necessary to verify the structural strength, including yielding, buckling and fatigue of the hull, integrated deck, column top frame and main intersections of primary structures are to be submitted for review. The criteria in this subsection relate to the analyses required to verify the scantlings selected in the basic design in 5B-2-3/3. Except as provided in the *MODU Rules*, the results of analyses that are required in this subsection cannot be used to reduce the scantlings established from 5B-2-3/3 of these Rules.

Depending on the specific features of the TLP, additional analyses to verify and help design other portions of the TLP structural components will be required. Such additional analyses include the hull interfaces with tendons, riser systems, machinery/equipment foundations and appurtenances. Analysis criteria for these additional hull structural components are given in 5B-2-4/5.

5.1.2 Global Strength Analysis

The primary structures of the hull, integrated deck and column top frame are to be analyzed using the loading and environmental conditions stipulated below. Conditions representing all modes of operation are to be considered to determine the critical cases. Calculations for critical conditions are to be submitted for review. The analyses are to be performed using recognized calculation methods and fully documented and referenced.

5B-2-3/Table 1 below shows the required environmental events and safety factors to be considered for each design condition in the global strength analysis:

TABLE 1
Required Environmental Events and Safety Factors

Design Conditions	*Environmental Events*	*Safety Factors*
Loadout	Calm or specified by designer or Owner	1.67
Ocean Transit (Dry Tow)	10 year return storm for the selected route condition or specified by designer or Owner if weather routing plan is to be implemented for the voyage	1.25
Field Transit (Wet Tow)	1 year return storm for the selected route condition or specified by designer or Owner	1.25
Deck Installation	Calm or specified by designer or Owner	1.67
In-place Design Operating	1 year return storm (minimum)	1.67
In-place Design Environmental	100 year return storm	1.25
In-place Damaged	1-year return storm	1.25

5.1.2(a) Critical Responses for Global Strength. The global strength of the hull is to be designed to withstand the responses induced by the loads specified in 5B-2-1/5.1. The responses of the hull induced by these loads that control the hull strength design are prying/squeezing loads, inertia loads and torsional moments. The responses that control the topside deck strength design are the accelerations induced by the waves in addition to those responses that control the hull. As indicated in 5B-2-3/Table 1, the in-place intact strength is to be designed for these responses with a 100-year return period in the Design Environmental Condition (DEC).

The highest wave may not always produce the most critical responses. To ensure that the most critical responses are captured, a sufficient number of design cases are to be used, considering the following permutations:

i) Variation in environmental conditions and headings

ii) Variation in variables (deck payloads)

iii) Variation in ballasting distributions

iv) Variation in riser arrangements

5.1.3 Major Joint Analysis – Analysis for Main Intersections of Primary Structures

Since the details of the main intersections are difficult to adequately capture in the global strength model, local FEM analyses are to be used, as required, to design these areas. These main intersections include connections of pontoon to pontoon, column to pontoon, column to topside deck, column to column top frame, and joints of column top frame and topside deck structures.

5.1.4 Fatigue Analysis

Fatigue analysis is to be performed to ensure adequate strength against fatigue failure within the TLP's design life. The fatigue analysis is to consider all loading history of the TLP including transport and in-place conditions. Special attention is to be given to the major joints mentioned above.

Attention is also to be given to the designs of structural notches, cutouts, attachments and abrupt changes of structural sections where they are prone to fatigue damages.

5.1.5 Structural Redundancy Analysis

Redundancy analysis is required to ensure that there is adequate redistribution of stress in the damaged conditions defined in 5B-2-3/Table 1. The damaged conditions are also to consider loss of buoyancy in one compartment or removal of one tendon.

5.1.6 Acceptance Criteria

The total assessment of the structure and details is to be performed against the design conditions specified in 5B-2-3/Table 1 and failure modes of material yielding, buckling, ultimate strength and fatigue. The acceptance criteria of each mode are given as follows.

5.1.6(a) Material Yielding (1 July 2012). For the hull, integrated deck and column top frame, the yielding criteria indicated in 3-2-1/3 of the *MODU Rules* is to be used. The safety factors in 5B-2-3/Table 1 of these Rules are to be used for bar and beam elements. For plated structures the allowable von Mises equivalent stress is to be 0.7 of the yield strength for the Design Operating, Loadout and Deck Installation Conditions, and 0.9 of the yield strength for the Design Environmental, Transit and Damaged Conditions.

The yield strength is to be based on the specified minimum yield point or yield stress, as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for higher strength material.

5.1.6(b) Buckling and Ultimate Strength. For the hull, integrated deck and column top frame, the buckling criteria in API Bulletin 2V and 2U or other recognized standards are to be used. The safety factors are to be based on 5B-2-3/Table 1 of these Rules.

5.1.6(c) Fatigue. For the hull, including the main intersections defined in 5B-2-3/5.1.3, the fatigue damages can be calculated using the ABS Offshore S-N curves for environment in air, in seawater with cathodic protection and free corrosion, as specified in Section 3 of the ABS *Guide for the Fatigue Assessment of Offshore Structures*. The S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm ($^7/_8$ in.). For members of greater thickness, thickness correction is to be applied with an exponent of 0.25. Other recognized standards equivalent to ABS requirements are also acceptable.

For integrated deck and column top frame, ABS Offshore S-N curves and AWS S-N curves can be used.

The fatigue life is determined by safety factors and the design life of the TLP. Safety factors depend on the inspectability, repairability, redundancy, the ability to predict failure damage, as well as the consequence of failure of the structure. Minimum safety factor requirements are listed in 5B-2-3/Table 2.

TABLE 2
Safety Factors for Fatigue Life of Hull, Integrated Deck and Column Top Frame

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	3	5
Critical	5	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

5.3 Non-integrated Deck

5.3.1 General

The designs of non-integrated deck structural members, such as deck girders, columns, beams, braces, stiffeners, deck plating, etc., are to be based on the applicable sections of the *Offshore Installation Rules*. To this end, the loads on the structure, as indicated in 5B-2-3/5.3.2, as applicable, are to be determined, and the resulting structural responses are not to exceed the safety criteria given in 5B-2-3/5.3.4.

The use of design methods and associated safety criteria, other than those specifically covered in this section, is permitted where it can be demonstrated that the use of such alternative methods will result in a structure possessing a level of safety equivalent to or greater than that provided by the direct application of these requirements.

5.3.2 Loading Conditions

Loadings which produce the most unfavorable effects on the non-integrated deck structure for the pre-service and in-service conditions are to be considered. The environmental conditions and applicable loads described in 5B-2-1/5 are to be used to establish the design load cases for the in-service and pre-service conditions. The environmental events included in 5B-2-3/Table 1 are also to be considered for the deck design. For a given topside payload, the most critical responses for the topside deck may be the accelerations induced by the TLP's motions and the inclination-induced loads.

5.3.3 Structural Analysis

A space frame analysis of the deck structure is to be performed to obtain the structural response. The structural model can be either the overall TLP with a detailed deck model or a standalone deck structural model. In the latter case, the boundary conditions of the model are to be properly simulated in the analysis. In modeling the deck structures, all relevant structural components are to be included. The nature of loads and loading combinations, as well as the local environmental conditions, are to be taken into consideration in the selection of design methods. Methods of analysis and their associated assumptions are to be compatible with the overall design principles. Linear, elastic methods (working stress methods) are generally employed in design and analysis. For the use of other methods, reference is to be made to 3/4.7 of the *Offshore Installations Rules*.

5.3.4 Allowable Stresses

The safety criteria are to be expressed in terms of appropriate basic allowable stresses, in accordance with requirements specified below:

5.3.4(a) For tubular members, stress limits are to be in accordance with the API RP 2A. The basic allowable stresses for the other type of members are to be obtained using the American Institute of Steel Construction (AISC) *Manual of Steel Construction, ASD*. For plated structures, the design is to be in accordance with API RP 2U and API RP 2V or other recognized industry standards.

5.3.4(b) Where stresses in members described in 5B-2-3/5.3.4(a) are shown to be due to forces imposed by the Design Environmental Condition (DEC) acting in combination with dead and live loads, the basic allowable stresses cited in 5B-2-3/5.3.4(a) may be increased by one-third, provided the resulting structural member sizes are not less than those required for the operating environment loading combined with dead and live loads without the one-third increase in allowable stresses.

5.3.4(c) (1 July 2009) The allowable stresses specified in 5B-2-3/5.3.4(b) are to be regarded as the limits for stresses in all structural parts for the marine operations covered in 5B-2-1/5.1, except for lifting, where the one-third increase in the basic allowable stress is not permitted. The one-third increase in the basic allowable stress is also not permitted in loadout operations. The lifting analysis is to adequately account for equipment and fabrication weight increase with dynamic amplification factors recommended in API RP 2A. Other lift analysis methods can be considered on a case-by-case basis.

5.3.4(d) (1 July 2012) For any two- or three-dimensional stress field within the scope of the working stress formulation, the equivalent stress (e.g., the von Mises stress intensity) is to be used in the design. The allowable von Mises stress is to be 0.7 of the yield strength for the Design Operating Condition (DOC) and 0.9 of the yield strength for the Design Environmental Condition (DEC). For highly localized areas, local yielding of the structure may be accepted, provided it can be demonstrated that such yielding does not lead to progressive collapse of the overall structure and that the general structural stability is maintained.

5.3.4(e) Whenever elastic instability, overall or local, may occur before the stresses reach their basic allowable levels, appropriate allowable buckling stresses govern.

5.3.5 Fatigue Assessment

A detailed fatigue analysis is to be performed for deck structures. Rational fatigue analysis methods are acceptable if the forces and member stresses can be properly represented. The dynamic effects are to be taken into consideration if they are significant to the structural response. For the frame members of the deck, the S-N curves specified in the ABS *Guide for the Fatigue Assessment of Offshore Structures* and API RP 2A are recommended. The Stress Concentration Factors (SCFs) for tubular joints can be calculated based on applicable empirical formulas. For the complex critical connections, the SCFs should be calculated by means of a fine mesh finite element analysis.

The results of the assessment are to indicate a minimum expected fatigue life of three times the design life of the structure where sufficient structural redundancy exists to prevent catastrophic failure of the structure of the member or connection under consideration. Where such redundancy does not exist or where the desirable degree of redundancy is significantly reduced as a result of fatigue damage, the result of a fatigue assessment is to indicate a minimum expected fatigue life of three or more times the design life of the structure. 5B-2-3/Table 3 provides general safety factor requirements for fatigue life. For the deck to hull connections, see 5B-2-3/5.1.6(c).

TABLE 3
Safety Factors for Fatigue Life of Topside Deck Structures *(1 July 2012)*

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	2	5
Critical	3	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

5.3.6 Stresses in Connections *(1 July 2009)*

Connections of structural members are to be developed to ensure effective load transmission between connected members, to minimize stress concentration and to prevent excessive punching shear. Connection details are also to be designed to minimize undue constraints against overall ductile behavior and to minimize the effects of post-weld shrinkage. Undue concentration of welding is to be avoided. The design of tubular joints is to be in accordance with the API RP 2A, including pinching shear. AISC *Manual of Steel Construction, ASD* can be used for the design of non-tubular joints.

PART
5B

CHAPTER 2 Tension Leg Platforms

SECTION 4 Other Structures

1 Tendon System Design

1.1 General

The tendon system provides a vertical mooring system to the TLP by linking the TLP hull to the foundation system. The tendon system provides axial stiffness to control the heave natural period of the TLP and also provides sufficient axial strength to restrain the TLP motions under the environmental loading.

The tendon system may consist of a different number of tendons, depending on the platform configuration, loading conditions, intended service life requirement and redundancy requirement specified by the Owner. Generally, the design life of the tendon is to be taken as the service life of the TLP. In special situations, the tendons may also be designed to be removable for maintenance and/or inspections.

Each tendon consists of a top section for attaching the tendon to the TLP hull-mounted tendon porches, a tendon main body to span the water column and a tendon bottom termination assembly for attaching the tendon to the foundation system. The main body of the tendon is generally made up of steel tubulars. Any other form of tendons such as solid rods, bars or wire ropes and any other materials such as non-metallic materials and composites that meet the service requirements may also be specially considered.

The tendon main body may consist of a number of tendon elements connected by tendon connectors. Tendon connectors can be mechanical couplings, welded joints or any other form of structural connection that meets the service requirements. The tendons may also have special components such as corrosion protection system components, tendon load and performance monitoring devices and VIV suppression devices. The term "tendon", as used here, refers to all of the components of the tendon system between the hull porch and the foundation system.

1.3 Loading Conditions

Loading conditions which produce the most unfavorable effects on the tendons for pre-service and in-service conditions are to be considered. The in-service condition analyses are to consider TLP intact and damaged conditions. The TLP intact condition analyses are to consider different TLP configurations such as drilling with rig, production with or without rig, different number of risers attached to the TLP, etc. TLP damaged condition analyses are to consider accidental flooding of a compartment in the platform or tendon and tendon removed condition. The environmental conditions described in 5B-2-1/5 are to be used in these analyses. TLP analyses, as a minimum, are to consider loading conditions associated with the following:

i) Maximum tension

ii) Minimum tension

iii) Largest flex element rotational angle

iv) Lifetime fatigue conditions

v) Hydrostatic collapse

1.5 Tendon Analysis Procedure

Tendon static loads may be determined from the equilibrium condition of the TLP. Tendon static loads arise from pretension, tide, platform offset due to wind and current and due to foundation installation position errors.

Tendon dynamic loads arise from platform motions under hydrodynamic loads and seismic motions and direct hydrodynamic forces acting on the tendons. Tendon dynamic loads may be determined by TLP global performance analysis described in 5B-2-1/7 if the analysis is coupled, that is, the transverse (bending) response of the tendon is calculated simultaneously with the platform response. If the global performance analysis is uncoupled, that is, the tendons are represented by springs, then separate tendon analysis is to be carried out to evaluate the tendon responses along the length of the tendon. Procedures described in API RP 2T can be used for detailed tendon analysis.

1.7 Tendon Loads *(1 September 2007)*

For each loading condition, the maximum and minimum tendon tensions are to be evaluated. In general, the following factors are to be considered in the evaluation of the maximum and minimum tendon tensions.

i) Design pretension at mean water level

ii) Variation in tendon tension due to tide and storm surge

iii) Variation in tendon tension due to variations in load and ballast condition

iv) Tension due to overturning moment from wind and current forces

v) Tension due to set down and slowly varying offset caused by wind, wave drift and current

vi) Tension due to wave forces and wave-induced platform motions about the mean offset

vii) Tension due to high frequency heave, pitch and roll oscillations (ringing and springing)

viii) Tension due to vortex-induced responses.

For special situations, tendon loads arising from other sources such as thermal stresses may have to be considered.

Tendon loads include axial, bending, shear, torque, radial and hoop loads. While the tendon loads are primarily axial, other types of loads should also be evaluated, as appropriate, to assure adequacy of the design. Axial and bending stresses are to be combined in the evaluation of the maximum stresses in the tendon. Axial, bending and hoop stresses are to be considered in the evaluation of the adequacy of the tendons to withstand hydrostatic loads.

The minimum tendon bottom tension is to be positive for all intact conditions. For damage conditions, if the tendon minimum bottom tension is less than zero, both scenarios of tendon buckling and downstroke of the bottom flex element connector are to be evaluated. In addition, the tendon stresses resulting from reengagement of the bottom connector are to be evaluated. A static overload analysis may be required to show that the TLP does not rotate or heave to unlatch the tendons when a small overload is applied.

The tendon tension requirements under platform damaged conditions due to different flooding scenarios are described in 5B-2-2/1.

1.9 Tendon Components

The adequacy of the tendon components such as top and bottom connectors, couplings, flex element, etc., are to be verified by detailed finite element analysis (FEA) and testing, where necessary, to support and validate the FEA. The loads for the finite element analyses are to be obtained from the tendon global analysis. Worst case analyses are to be run to quantify the effects of fabrication tolerances on fit-up and component stresses. Axisymmetric modeling may be used for FEA. Three-dimensional modeling is to be used to quantify three-dimensional effects in critically stressed areas, where appropriate. Von Mises equivalent stresses of net section stress and local bending stress are to be evaluated for critical sections. Peak stresses are to be evaluated for fatigue analysis of the components.

1.11 Installation Analyses

The effects which may be induced in the tendons during transportation, lifting and installation are to be considered in the design. If the tendons are pre-installed, analysis is to be carried out for the freestanding condition to verify structural stability and tendon interference.

1.13 Allowable Stresses

The allowable stresses of the tendons are to be in accordance with API RP 2T. The interaction between the net section stresses and local bending stresses is to be considered, where applicable.

The allowable stresses against hydrostatic buckling are to be in accordance with API RP 2A.

1.15 Fatigue Analysis

Fatigue damage calculations are to be carried out to verify the adequacy of the fatigue life of the tendon. The fatigue calculations are to consider all of the sea states expected over the lifetime of the tendons and any fatigue damage due to vortex-induced vibrations during the in-place and installation conditions.

Frequency domain or time domain analysis may be used to evaluate the tendon loads. The tendon fatigue loading is to consider total tendon stresses, including axial and bending stresses, due to wave frequency, low frequency and high frequency loads. Appropriate material S-N curves based on the lower bound of a two-sided 95 percent prediction interval are to be selected according to the material, welding detail and workmanship, level of quality control and level of cathodic protection. For the use of different S-N curves, please refer to the ABS *Guide for the Fatigue Assessment of Offshore Structures*. Appropriate stress concentration factors (SCF) for tendon pipe and components are to be determined based on parametric formulas or local finite element analyses considering local mismatch tolerances, geometry and loading.

For tendon receptacles and other components attached to the pile while it is driven, fatigue damage due to pile driving is also to be considered. Fatigue damage is to be accumulated using the linear Palmgren-Miner rule.

The minimum fatigue life of the tendon is to be ten (10) times the tendon service life.

1.17 Fracture Mechanics Calculations

The tendons are to have sufficient fracture toughness to prevent fracture unstable crack growth from surface, sub-surface or through-wall flaws under extreme design loads within a period less than five (5) times the tendon service life or tendon inspection period, whichever is less. Fracture mechanics analyses are to be performed in accordance with BS7910 or other equivalent standard to demonstrate that the smallest reliably detectable initial flaws will not grow by fatigue to a critical size for fracture failure within this period, where the preferred critical flaw is a through-thickness fatigue crack rather than a surface or sub-surface fatigue crack. Initial flaws of various aspect ratios and no threshold for fatigue crack growth ($\Delta K_{th} = 0$) are to be considered in these analyses.

1.19 Corrosion Protection *(1 July 2009)*

The tendons are to be protected from the effects of corrosion by the use of coatings and cathodic protection. The system is to be effective from the time the structure is initially installed. When the sea environment contains unusual contaminants, any special corrosive effects of such contaminants are also to be considered. For the design of coatings and cathodic protection systems, reference is to be made to the appropriate National Association of Corrosion Engineers (NACE) standards, such as SP0108 or SP0176 or other recognized standards.

3 Foundation

3.1 General

The primary function of the foundation system is to anchor the tendons to the seafloor. TLP foundation system may consist of individual piles directly attached to the tendons or template structures anchored by piles or a gravity base. TLP foundation design and site investigation requirements in general are to be in accordance with Part 3, Section 6 of the *Offshore Installation Rules*. Detailed geological surveys, seafloor and sub-bottom geophysical surveys and geotechnical investigations are to be carried out for each TLP site. Special design considerations for foundation systems subject to tensile loading and in deepwater sites are given in the following sections. Fabrication, transportation, installation and materials of foundation systems are also to be in accordance with *Offshore Installation Rules*.

3.3 Site Investigations

Requirements for site investigations are to be guided by the quality of data from prior site surveys and the consequence of foundation failure. For soil samples obtained from deep water sites, the measured properties under laboratory conditions may be different from in-situ values due to relief of hydrostatic pore pressure and its associated effects on dissolved gases. Therefore, in-situ or special laboratory testing is required to determine soil properties for deepwater sites. Since installation sites may be distant from areas for which extensive site data are available, regional and local site studies are to be carried out to adequately establish soil characteristics. A less extensive site investigation may be acceptable, provided that previous site investigation and experience are available.

TLP foundations experience upward static and dynamic loadings that are different from those typically experienced by the foundations of a jacket-type structure. In order to predict soil-structure interaction due to cyclic loading, soil tests are to be carried out to define the dynamic and cyclic behavior of the soil. In addition, TLP foundations are subject to sustained tensile loads together with cyclic tensile load components, which can result in tensile creep of the foundation. Therefore, additional tests are to be carried out to determine long-term soil-pile response when subjected to these loadings. Consideration should be given to the performance of permeability and consolidation tests to assist in the evaluation of the soil-pile setup.

3.5 Foundation Design

The loadings used for the foundation design are to be obtained from the tendon analyses. The loads resulting from the extreme, normal, platform or tendon damaged and tendon removed conditions are to be considered in the foundation design. The application of the loads to the foundation system should also consider the foundation installation tolerances, as applicable.

The design of the foundation systems consisting of driven piles, in general, is to be in accordance with ABS *Offshore Installation Rules*. The axial capacity of piles subject to tension is to be equal to skin friction alone. In the evaluation of the axial capacity, consideration should be given to cyclic degradation about a sustained tension load, axial flexibility of the pile, the effects of sustained tension loading such as creep, group effects and the potential of near surface axial capacity reduction from gapping caused by lateral deflection, scouring or liquefaction.

Pile set-up analyses are to be carried out to evaluate the time required for the piles to gain the ultimate strength. The pile design penetration is to be determined based on the pile axial capacity at the completion of TLP installation. For the duration between the tendon hook up and completion of TLP installation, the adequacy of the piles capacity will be determined based on the project specifications.

TLP piles are subject to cyclic tensile loads during the life of the structure. Therefore, for TLP foundation systems, a fatigue analysis is to be carried out to evaluate the fatigue life. The fatigue analysis is to consider fatigue damage due to in-place loading, as well as fatigue damage during pile driving.

Pile installation analyses are to be carried out in accordance with API RP 2A. The effect of ocean currents on the freestanding portion of the pile and hammer are to be considered in these analyses.

The analysis of piled template structures and gravity-based structures is to be in accordance with ABS *Offshore Installation Rules*, API RP 2T and API RP 2A.

The safety factors for TLP foundations are specified in 5B-2-4/Table 1.

TABLE 1
Safety Factors for Pile Foundation Design

Description	*Safety Factors*
Design Operating Condition	3.0
Design Environmental Condition	2.25
Tendon Removed with Reduced Extreme Condition	2.25
Foundation Fatigue Life w.r.t. Design Service Life	10

5 Analysis and Design of Other Major Structures

The analysis and criteria to be applied to the other pertinent features of the TLP structural design are to conform to recognized practices acceptable to the Bureau. For TLPs, there will be a need to consider in the hull and topside deck design: the interface between the tendon system and the hull, the interface between the riser system and the hull and the effects of structural support reactions from deck modules. The criteria to be applied for these cases are presented below.

5.1 Hull Interface with Riser System (Riser Porches, Supports and Guides)

The riser porches, guides and supports, including the hull backup structures (the reinforcements for the hull), are to be designed for the maximum anticipated riser loads with a safety factor of 1.25 in the Design Environmental Condition and with a safety factor of 1.67 in the Design Operating Condition.

Fatigue strength is to be designed to meet the requirements in 5B-2-3/5.1.6(c), taking into account the effects of both local drag and inertia loads on the risers and the global motions of the TLP.

5.3 Hull Interface with Tendons (Tendon Porches)

The tendon porches, including the hull backup structures, are to be designed for the maximum anticipated tendon loads with a safety factor of 1.25 in the Design Environmental Condition and with a safety factor of 1.67 in the Design Operating Condition.

Fatigue strength is to be designed to meet the requirements in 5B-2-3/5.1.6(c), taking into account the effects of both local drag and inertia loads on the tendons and the global motions of the TLP.

5.5 Topside Deck Interface with Deck Modules

The topside deck may require reinforcements to resist the reaction forces from equipment/machinery foundations or deck modules. The reinforcements of the topside deck are referred to as backup structures. The forces to be resisted by the backup structures of the topside deck are to be designed for the maximum anticipated load together with the inertia loads induced by the TLP motions with a safety factor of 1.25 in the Design Environmental Condition and with a safety factor of 1.67 in the Design Operating Condition. If deemed necessary, the fatigue strength is to meet the requirements of 5B-2-3/5.1.6(c).

PART

5B

CHAPTER 2 Tension Leg Platforms

SECTION 5 Materials and Welding

1 Materials and Welding

1.1 Hull Including Integrated Deck Structures

Sections 3-2-6 and 3-2-7 of the *MODU Rules* are to be used to establish the welding requirements for the hull. The weld type and sizing are to be shown on the scantling drawings or in the form of a welding schedule, and are to comply with the Rules that govern the steel selection. Special attention is to be given to the weld details for fatigue sensitive areas, if necessary. Weld improvements by means of toe grinding and weld profiling are to be used if required by fatigue analysis results.

Section 3-1-3 of the *MODU Rules* is to be used for the material selections for the hull including integrated deck. The TLP hull structures are grouped into the following material application categories for the purpose of material grade selection:

Special Application Structure	• External shell structure in way of main intersections of columns, topside deck, pontoons, column top frame, tendon porches and riser porches • Portions of topside deck which receive major concentrated loads • Intersections of topside deck main truss members • External brackets, portions of bulkheads, flats and frames which receive concentrated loads at main intersections of columns, topside deck, pontoons, column top frame, tendon porches and riser porches • "Through" material used at main intersections of columns, topside deck, pontoons, column top frame, tendon porches and riser porches, which provide proper alignment and adequate load transfer
Primary Application Structure	• External shell structure of columns, pontoons, column top frame, tendon porches and riser porches • Integrated topside deck main truss members • Bulkheads, flats and framing which provide local reinforcement or continuity of structure in way of main intersections, except where the structure is considered special application • Bulkhead girders, decks that are designed to provide global strength to the TLP
Secondary Application Structure	• Internal structure, including bulkheads and girders in columns, integrated topside deck, pontoons and top column frame, except where the structure is considered primary or special applications • Decks of topside deck, except where the structure is considered primary or special applications

1.3 Non-integrated Deck Structures

Part 2 of the *Offshore Installation Rules* can be used to establish the material selections and welding requirements for the truss deck of the topside. The deck structures are categorized into the following four groups, in association with the Charpy toughness test described in Table 2/1.3 of the *Offshore Installation Rules*:

i) Deck lifting points, deck-to-hull cans

ii) Major truss row girders, major truss row columns, major truss row bracing

iii) Intermediate girders, intermediate bracing

iv) Deck stringer beams, deck plating

Alternatively, Section 3-1-3 of the *MODU Rules* may be used for material selections.

Note: Items such as handrails, walkways, access platforms do not require the above material requirements.

PART

5B

CHAPTER 2 Tension Leg Platforms

SECTION 6 Machinery and Systems

1 Marine Piping Systems

Marine piping systems are those systems that are required for maintaining the normal operations of a floating unit (such as power generation, bilge, ballast, tank vent and sounding, etc.). Subsection 4-2-1/3 of the *MODU Rules* lists these systems. Systems installed in the hull are to be designed to minimize the requirements for equipment and machinery to be installed in hull compartments and to limit as much as possible systems requiring piping or cable runs in the TLP hull.

Marine piping systems are to be in accordance with the requirements of the *MODU Rules*, except as modified herein.

1.1 Bilge System

The design of bilge systems is to meet applicable requirements of Section 4-2-4 of the *MODU Rules*. For the bilge suction sizing purposes, column-stabilized units and self-elevating units sizing criteria listed in 4-2-4/9.3 of the *MODU Rules* are applicable.

1.3 Ballast System

The system fitted is to provide the capability to ballast and deballast all ballast tanks. All pumps and valves are to be fitted with a remote means of operation situated above the uppermost watertight deck. The capabilities of the pumping system are to meet the requirements of API RP 2T. The normal or emergency operation of the ballast system is not to introduce a greater risk of progressive flooding due to the opening of hatches, manholes etc. in watertight boundaries.

1.3.1 Pumping Systems

Where ballast systems powered by pumping systems are installed, at least two ballast pumps are to be provided, one of which is to be permanently connected to the installation's ballast system. The second pump may be a spare held in reserve or an eductor type arrangement permanently connected to the system. If submersible ballast pumps are installed in each ballast tank, one spare pump must be stored onboard at all times.

1.3.2 Compressed Air Systems

Where ballast systems powered by compressed air are installed, a satisfactory quantity of compressed air is to be available to the system at all times. If two compressors are installed, one compressor is to be powered by either the emergency switchboard or a dedicated engine. Each compressor is to be capable of providing 100% of the required capacity of compressed air, as defined in 5B-2-6/1.3.2(a). If only one compressor is provided, this compressor is to be powered by either the emergency switchboard or a dedicated engine, and a quantity of stored compressed air equivalent to the required capacity called out in 5B-2-6/1.3.2(a) is to be provided.

1.3.2(a) Quantity of Compressed Air. A quantity of air capable of bringing the installation from its worst case damage or accidental flooding condition, as defined by 5B-2-2/1.1, to normal operating tension.

1.5 Vents and Sounds

Except for comparatively small compartments that are not fitted with a fixed means of drainage, vent pipes are to be fitted on all tanks, cofferdams, voids, tunnels and compartments which are not fitted with other ventilation arrangements.

The requirements for sounding are to comply with the *MODU Rules*. However, to prevent duplication of pipe runs, it would be acceptable to sound the void spaces through the vent lines. In the case of a sealed vent, a sounding plug would need to be provided to permit void space sounding.

1.7 Hydrocarbon Storage in Hull Tanks

If the TLP is designed to store hydrocarbons in hull tanks, criteria for hull storage of hydrocarbons are to meet flag and coastal state requirements and applicable international requirements. The designs for scantlings and strength for such storage tanks are to be in accordance with 5B-2-3/3 and 5B-2-3/5. See 3-5/5.9 of the *Facilities Rules* for the storage facility arrangement requirements.

3 Electrical Systems

The design criteria of electrical systems associated with marine systems (and drilling systems) are to be in accordance with applicable requirements described in Part 4, Chapters 1 and 3 of the *MODU Rules*.

The design criteria of electrical systems strictly devoted to the hydrocarbon processing facilities are to be in accordance with applicable requirements described in Chapter 3 of the *Facilities Rules*.

The design criteria of electrical systems associated with both marine systems and hydrocarbon processing facilities are to be in accordance with the applicable requirements described in Part 4, Chapters 1 and 3 of the *MODU Rules*.

5 Fire Fighting Systems and Equipment

The fire fighting systems and equipment for the TLP service functions not associated with the process facilities are to be in accordance with Part 5, Chapter 2 of the *MODU Rules*. Fire fighting systems and equipment for protection of hydrocarbon process and associated systems, including fire pumps, are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*.

7 Machinery and Equipment

Machinery and equipment not associated with the process facilities are to be in accordance with the applicable requirements of Part 4, Chapter 1 of the *MODU Rules*. Machinery and equipment forming a part of the hydrocarbon processing facilities are to be in accordance with the applicable requirements of Chapter 3, Section 3 of the *Facilities Rules*. Machinery and equipment forming a part of the permanent drilling facility are to be in accordance with Part 4, Chapter 1 of the *MODU Rules*.

PART

5B

CHAPTER 3 Spar Installations

CONTENTS

PART

5B

CHAPTER 3 Spar Installations

SECTION 1 General Requirements

1 General

A Spar is a deep draft installation consisting of a hull and a topside deck, where the topside deck sits on top of the hull. The hull can be divided into upper hull, mid-section and lower hull, as described in the following Subsection. The topside deck is a space frame truss deck that provides space for the production equipment, workover or drilling rig (if any), accommodations and marine support systems, and supports the loads of this equipment, including operational loads.

The design and construction of the hull are to be based on all applicable requirements of the *MODU Rules*. The design and construction of topside deck are to be based on the *Offshore Installation Rules*. However, the structural performance and demand of a Mobile Offshore Drilling Unit (MODU) in ocean service are different from those of a Spar positioned at a particular site on a long-term basis. Therefore, the design criteria given in *the MODU Rules* can be modified to reflect the differences. In addition, in the absence of equivalent Coastal State requirements, the applicable criteria contained in the Load Line, SOLAS and MARPOL Conventions issued by the International Maritime Organization (IMO) may be considered. It is further suggested that the local authorities having jurisdiction where the installation is to operate be contacted to obtain any further criteria that are applicable to the Spar installations.

3 Definitions

3.1 Upper Hull – Hard Tank

The *Upper Hull* is also known as the *Hard Tank*, which serves to provide buoyancy to support the topside deck and provide spaces for variable ballast and in some cases for diesel oil, drill water, or methanol storage. The Spar Deck is the uppermost deck of the hard tank.

3.3 Mid-section – Truss Space Frame with Heave Plates or Free Flooded Cylindrical Column

The *Mid-section* connects the upper hull with the lower hull. The mid-section can be a truss space frame with heave plates or a cylindrical column. Normally, the cylindrical column mid-section is free flooded and the truss space frame is buoyant. The heave plates are a series of horizontal decks between each bay of the truss space frame that trap water mass providing added mass and hydrodynamic damping to limit heave motions and act as guides for the risers.

3.5 Lower Hull – Soft Tank (or Keel Tank)

The *Lower Hull*, also known as the *Soft Tank* (or *Keel Tank*), normally consists of a fixed ballast tank and, in the case of a truss Spar, a flotation tank. The fixed ballast tank provides temporary buoyancy during a horizontal wet tow and provides the needed ballast in upending by flooding the tank. After upending, the ballast water may be replaced by fixed ballast (a substance with a density higher than water) to lower the Spar center of gravity. The ballast in the fixed ballast tank results in a vertical center of gravity well below the center of buoyancy, which provides Spar with sound stability, as well as motion characteristics. The flotation tank is located adjacent to the fixed ballast tank to provide additional buoyancy for wet tow and ballast in upending.

5 Loading Criteria

5.1 Loads

The Spar's modes of operation in pre-service (load-out, transportation, installation) and in-service (in-place) conditions are to be investigated using anticipated loads, including gravity loads together with relevant environmental loads due to the effects of wind, waves, current and other phenomena such as earthquake, temperature, fouling, ice, etc., depending upon the specific installation site.

The Spar is to be designed for the loading conditions that produce the most severe local and global effects on the structure, as determined by the most severe operational or installation requirements. Applied loading combinations considered for structural design are to include, as applicable, but not limited to the following loads:

i) *Environmental Loads.* Loads due to wind, waves and current are to be considered. Directionality of wind, waves and current may be considered if accurate data is available. Where there is no accurate data available, the directionality of wind, waves and current that generates the most severe local and global load effects are to be used for design. Adequate headings for the environment are to be analyzed such that the most critical heading for the environment has been covered.

ii) *Hydrostatic Pressures and Buoyancy.* Hydrostatic pressures and buoyancy are to be considered for all submerged structural members.

iii) *Gravity and Inclination Induced Loads.* Gravity with appropriate components due to Spar heeling and trimming is to be considered.

iv) *Inertia Loads.* Inertia Loads due to motions of the Spar are to be considered.

v) *Operational Loads.* Loads induced by operations of drilling, production, storage and offloading, as applicable, are to be considered.

vi) *Mooring and Riser Loads.* Loads due to mooring and riser systems are to be considered.

vii) *Marine Operation Loads.* Loads encountered during transportation and installation are to be taken into account in the design. These loads include loads exposed during transport (wet or dry), launch or float-off, upending, and during ballasting and deballasting operations when the deck is being installed.

viii) *VIV Loads.* Vortex-Induced-Vibration (VIV) is incurred by vortex shedding behind slender bodies and the Spar hull itself in current. Loads and fatigue strength are to be fully assessed for structures and the mooring system subject to VIV effects.

ix) *Green Water Loads on Spar Deck.* Green water effects are to be considered for the strength of affected structures on the top of the hull, as applicable.

x) *Slamming.* Wave slamming loads are to be considered for members subject to wave slamming during transportation and operation.

5.3 Environmental Conditions

The Spar is to be designed to withstand a specified extreme storm in the Design Environmental Condition and operate in the Design Operating Condition. The environmental conditions required for these conditions are defined in 3-2-3/1.1 and 3-2-3/1.3 and the environmental criteria required for these design conditions are defined in Section 3-2-4. Additionally, the spar is also to be designed for all operations in pre-service conditions such as load out, transportation and installation. The environmental conditions for load out and installation are to be specified by the designers or Owners. The environmental conditions for transportation is to be of a 10-year return event of the selected transit route, unless a weather routing plan is implemented for the voyage.

In the design of the Spar in-service and pre-service strength, the following environmental conditions are to be considered:

Design Environmental Conditions (DEC). Please refer to 3-2-3/1.1. For structural strength design, environmental conditions that produce the responses having a minimum return period of 100 years are to be used.

Design Operating Conditions (DOC). Please refer to 3-2-3/1.3. For structural design, environmental conditions that produce the responses having a minimum return period of 1 year are to be used.

Reduced Extreme Conditions (REC). Environmental conditions that have a low probability of being exceeded when the hull is damaged. For structural strength design, joint statistics may be used to determine a return period which, combined with the probability of damage, produces a risk level equal to that of the Design Environmental Conditions (DEC).

Calm Conditions. Environmental conditions such that the effects of wind, waves and current are insignificant and can be ignored. Where such a situation exists, the design case is permitted to use calm conditions.

7 Global Performance Analyses

7.1 General

Global performance analyses of a Spar are aimed at determining the global effects of environmental loads on the overall platform and its components. The principal scope of the analyses includes calculation of external loads for global structural analysis for in-place condition and critical pre-service conditions, as well as analysis/confirmation of:

i) Hydrodynamic loads, shear forces and bending moments for global strength analyses

ii) The Spar in-place motions and accelerations, including those for the structural design of the deck structure and topside modules, hull appurtenances, and those for risers and mooring lines

iii) The Spar freeboard and deck clearance

The hydrodynamic models used in the global performance analysis may include:

i) Diffraction equation or simulated diffraction equation using Morison members for cylindrical sections

ii) Morison equation for truss element and external hull appurtenances (with well documented drag coefficients C_d and inertia coefficients C_m)

iii) Computational fluid dynamics, diffraction theory, and/or model test of multiple heave plate, or simulated using Morison members with C_d and C_m computed by CFD/Diffraction theory

Global motions of a Spar are quite different from traditional offshore floating structures due to the deep draft of the Spar. The vertical modes of motions, i.e., pitch, roll and heave of the Spar are important design parameters for deriving inertia loads and are to be included in the mooring analysis due to the increased line tensions induced by vertical motions of the Spar. Among these, the effects due to rotational modes are more pronounced. The static rotational modes of motions are due to the mean loads of wind, current and waves, while the low frequency rotational modes of motions are induced by the slowly varying low frequency waves, wind and current excitations. The motion responses of the Spar in six degrees of freedom are usually solved in a time domain analysis for the nonlinear effects described below. Hydrodynamic coefficients, except the drag coefficients used in a time-domain analysis, are usually taken from frequency domain wave diffraction/radiation calculations. For classic spars, C_d for heave will significantly impact the heave motions and needs to be carefully chosen, accounting for the potential damping, drag from the bottom as well as from the strakes and other hull appurtenances. Both industry-recognized software and in-house software may be used for the analyses. In-house software needs to be adequately calibrated against model tests or industry-recognized software.

7.3 Frequency Domain Analyses

Frequency domain analyses include the six degrees of freedom analysis of a Spar system in wave frequency range for motion Response Amplitude Operators (RAOs) and hydrodynamic coefficients such as wave exciting forces and moments, added masses and moments of inertia, and radiation damping. The hydrodynamic coefficients are to be passed to time domain analysis for the prediction of installation motions and mooring line tensions with the combined effects of wave frequency and low frequency excitations.

7.5 Time Domain Analyses

For a Spar, due to nonlinear effects and large displacements in surge/sway and pitch/roll motions, a time domain analysis is generally required in order to obtain more accurate loads and global motion responses for the design.

The nonlinear effects include hull drag forces, finite wave amplitude effects, nonlinear restoring forces from mooring lines and risers, Vortex-Induced Motions (VIM), dynamics of heave plates and coupling effects. For deepwater applications, a time domain analysis of fully coupled motions of the Spar hull, mooring lines and risers is desirable. The most probable maximum response is to be predicted using adequate simulations and appropriate distribution curves fitted to the simulation results or other recognized statistical techniques. The most critical SCR and/or TTR cases are to be included in the loading conditions of the analysis. Typically, it is recommended that at least five simulations with different seeds for a storm duration of three hours each are to be conducted. In the time domain analysis, relevant wave and wind spectra are to be transferred to random time series in order to simulate irregular wave elevations and wind gustiness.

7.6 Maximum Inclination *(1 July 2012)*

The maximum angles of inclination in the storm survival, operating, and damage conditions in applicable DOC or DEC environment (see 5B-3-1/1.5.1) are to be established with consideration of the following:

i) Static and dynamic inclination limits of equipment and machinery on board the installation

ii) Strength of the mooring system, risers and umbilicals

Inclinations may be determined based on model tests or analytical methods.

7.7 Deck Clearance

A clearance is to be maintained between the lowest point of the topside deck and the highest point on the wave surface. The clearance can be determined by an appropriate model test or a detailed hydrodynamic analysis that accounts for relative motions between the Spar and wave surfaces. The analysis is to be performed for various environmental headings and to include static heeling due to mean wind, wave, current loads (including long period oscillations), mooring and riser loads, nonlinearity of wave profile, wave diffraction, wave run-up, hull set down and tide elevation effects. The clearance is to be checked at various points on the underside of the topside deck for all of the relevant environmental conditions.

If wave impact on the underside of the lower deck is anticipated, local strengthening of these members is required. Structures and equipment subject to wave run-up or green water are to be designed for the associated forces.

7.9 Model Testing

Model testing can be used to calibrate analytical tools. It may also be an alternative for analytical tools. Whenever analytical tools have difficulties or a significant level of uncertainty in determining hydrodynamic properties such as wind and current drag force coefficients (C_d), heeling moments, etc., wind tunnel tests are preferred. In addition, wave basin testing may be carried out to evaluate the Spar performance, including deck clearance, in-place motion and mooring responses, VIM effects, horizontal tow, upending and vertical tow.

Adequate heading angles and wind profiles are to be considered in wind tunnel testing. For wave basin tests, a calibration analysis may be required to correlate the results obtained from the model tests with the software being used for different analyses.

9 Corrosion Protection and Control

A corrosion protection and control system utilizing anodes and coating, in accordance with the recognized industry standards such as API and NACE, is to be provided. The design life of the corrosion protection and control system is to be the design life of the Spar. In the splash zone, a corrosion allowance is to be added to the external shell plating.

PART
5B

CHAPTER **3 Spar Installations**

SECTION **2 Stability**

1 Stability *(1 July 2012)*

1.1 Wet Tow

Stability during wet tow to location is to comply with Coastal State requirements.

1.3 Installation

After the upending and during the installation phase, the installation is to have a positive metacentric height (GM). If the installation is to accommodate personnel during the installation and commissioning the installation's stability are to fully comply with in-service stability specified on 5B-3-2/1.5. The installation analysis is to be submitted for review.

1.5 In-Service Stability

The stability calculations are to reflect the actual configuration of the spar while afloat. Free flooding compartments are not accounted for in assessment of the installation's stability. In case the permanent ballast is installed in a free flooding compartment, the net weight of the permanent ballast (using the in-water density) is to be included in the loading calculation.

1.5.1 Environmental Loads

Installations are to comply with the intact and damage stability criteria presented below, using the site-specific wind or 50 knots (25.7 m/s), whichever is greater. Height profile is to be taken from the *MODU Rules* or other recognized standard.

i) *Wind speed for normal operations* V_n – the 1-year, 1-minute average wind in the DOC as defined in 5B-3-1/5.3

ii) *Wind speed for storm survival* V_s – the 100-year, 1-minute average wind in the DOC as defined in 5B-3-1/5.3

iii) *Wind speed for survival after damage* V_d – the 1-year 1-minute average wind in the DOC as defined in 5B-3-1/5.3

iv) *Current Speed* – The current at surface associated with the adopted wind speed as defined above.

The design wind and current velocities are to be selected by the designer and submitted with the design documentation.

1.5.2 Heeling Moment

Heeling moments represent an idealization of the total environmental force on the installation. For purposes of stability calculations they are taken as the moments, which result from wind forces on the installation at the speeds specified in 5B-3-2/1.5.1 and calculated in accordance with 3-2-4/7.1.

For each draft of the designated range of operating drafts, the wind heeling moment is to be calculated assuming the installation in the upright position for all directions. The critical wind direction is the direction that produces the greatest wind heeling moment. The analysis will assume this determined critical wind heeling moment acting in all directions and constant over the range of inclination angles.

The lever for the heeling moment is to consider the wind center of pressure and the attachment point of the mooring lines. In case that the current force increases the heeling moment, the adverse effect of the current is to be considered in the heeling moment lever calculation. The current force on the hull is to be calculated as shown in 3-2-4/5.

Heeling force and center of pressure derived from wind tunnel tests on a representative model of the installation may be considered alternatively. The wind profile to be adopted for wind tunnel tests is defined on 3-2-4/7.1 or a more conservative profile.

1.5.3 Stability Criteria

The installation is to meet stability requirements of this subparagraph for each mode of operation at all drafts in design. Other standards may be acceptable during abnormal operations, with due consideration to the hazards associated with the operation. Such operations and standards are to be submitted for approval.

The installation is to have positive metacentric height (GM) in calm water equilibrium position and the vertical center of buoyancy is to be above the height of center of gravity in all conditions.

1.5.3(a) Intact Stability Criteria. The area under the righting moment curve at 30 degrees is to reach a value of not less than 30% in excess of the area under the overturning moment curve to the same limiting angle. In all cases, the righting moment curve is to be positive over the entire range of angles from upright and all downflooding angles are to be greater than 30 degrees.

1.5.3(b) Damage Stability Criteria. After damage by collision or accidental flooding as described in 5B-3-2/1.5.3(b)i) and 5B-3-2/1.5.3(b)ii) respectively, the unit is to meet the following criteria:

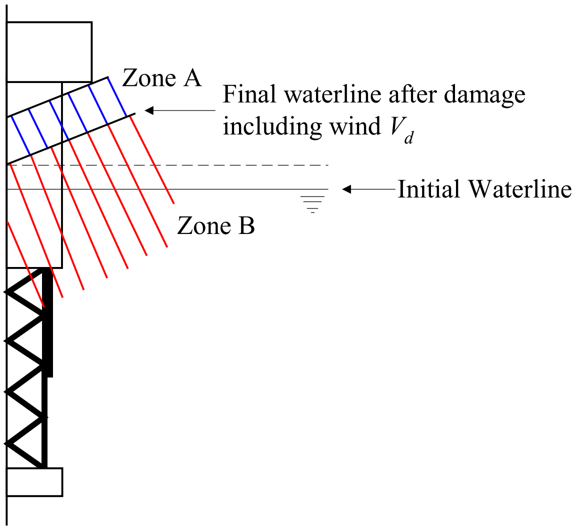
The final waterline, after damage with a wind speed V_d, is not to exceed the level of watertight integrity and is to be 1.5 m (5 ft) below any unprotected opening that could lead to further flooding of the hull or the lowest point of the hull upper deck, whichever is lower.

i) *Collision Damage.* Damage is assumed to be 3 m (10 ft) wide and 3 m (10 ft) high with a horizontal penetration of 1.5 m (5 ft) inboard of the hull plating. This extent of damage is to be considered at all levels between 3 m (10 ft) below to 5 m (16.4 ft) above the waterline in consideration.

Where a watertight flat is located within this zone, the damage is to be assumed to have occurred in both compartments above and below the watertight flat in question.

The distance between effective watertight bulkheads or their nearest stepped portions which are positioned within the assumed extent of horizontal penetration is to be not be less than 3.0 m (10 ft). Where there is a lesser distance, one or more of the adjacent bulkheads are to be disregarded.

FIGURE 1
Zones of Weathertight and Watertight Integrity *(1 September 2007)*



Zone A: (Minimum 1.5 m (5 ft) above final waterline after damage with wind V_d) - Zone of weathertight integrity

Zone B: (Below final waterline after damage with wind V_d) - Zone of watertight integrity

ii) *Accidental Flooding.* Any compartment at or below the waterline in consideration is to be assumed independently flooded, regardless of exposure and source of the assumed flooding.

When access openings are fitted on watertight divisions between compartments to provide access to one or more compartments, the compartments are to be assumed flooded simultaneously. Multiple compartment flooding may be dispensed, provided the following measures are taken to avoid operations that can result in the accidental flooding of such compartments when the covers are removed:

- Warning (or Notice) plates, e.g., "Watertight Door (or Hatch) – Keep closed" are placed on the access opening covers.
- Instructions and warnings are provided in the operations manual.
- System locks are available to prevent unintentional ballasting operations, where either compartment designed for ballast tank.
- The compartment can be pumped or blown dry without removal of the access cover.

The operations manual is to include guidance for operating personnel in determining the cause of unexpected inclination or draft changes and assessing the potential effects of corrective measures on stability and buoyancy.

1.7 Lightweight and Center of Gravity

The lightweight and center of gravity of the installation are to be established by a combination of a hull lightweight survey, measurement of permanent ballast and weighing of the major components. There are to be at least two (2) separate measures of the permanent ballast.

A global weight verification plan is to be submitted. Procedures for the lightweight survey, each weighing, and permanent ballast measurement are to be submitted for approval and are to include estimates of weight and center of gravity. An ABS surveyor is to attend each activity.

When weighing components, these parts are to be as complete as possible with not more than 2% of the weight of the component remaining to be incorporated.

The result of each weight verification activity is to be compared to the estimated weight. When the measured weight is within ±1% of the estimated weight, the vertical center of gravity is to be the estimated value in the calculation. When it is outside the 1% tolerance, the vertical center of gravity is to be computed by taking the difference between the estimated and the measured weight and placing it at an indisputably conservative location.

Reports of the results of each weight verification activity are to be submitted for review. An overall lightweight calculation, considering all individual approved lightweight components, is to be submitted for review.

Alterations in the lightweight data during service (e.g., new equipment, structural modifications) are to be recorded in the operation manual and be taken into account in daily operation.

3 Watertight/Weathertight Integrity *(1 July 2012)*

A plan, identifying the disposition (open or closed) of all non-automatic closing devices and locations of all watertight and weathertight closures, and unprotected openings is to be submitted for review prior to the unit's delivery. Upon satisfactory review the plan is to be incorporated into the Operating Manual.

3.1 Weathertight Integrity

External openings whose lower edges are below the levels to which weathertight integrity is to be ensured are to have weathertight closing appliances.

Openings fitted with appliances to ensure weathertight integrity are to effectively resist the ingress of water due to intermittent immersion of the closure.

3.3 Watertight Integrity

All internal and external openings whose lower edges are below the levels to which watertight integrity is to be ensured, as shown by the diagrams submitted in accordance with 5B-3-2/3, are to be fitted with appliances to ensure watertight integrity.

3.3.1 Internal Openings

Internal openings fitted with appliances to ensure watertight integrity are to comply with the following.

3.3.1(a) Doors and hatches are to be of the quick-acting type and an indicating system (e.g., light signals) is to be provided showing personnel, both locally and at a normally manned central position, whether the doors or hatches in question are open or secured closed. In addition, a sign is to be posted near the opening to the effect that the closing appliance is to be secured closed and opened only during actual use. If sliding doors are fitted they are to be capable of being remotely controlled from a normally manned central position as well as being operable locally from both sides of the bulkhead.

3.3.1(b) Manholes fitted with bolted covers need not be dealt with as under 5B-3-2/3.3.1(a).

3.3.1(c) The closing appliances are to have strength, tightness and means for securing which are sufficient to maintain watertightness under the water pressure of the watertight boundary under consideration.

3.3.2 External Openings

External openings are to comply with the following.

3.3.2(a) The lower edges of all openings, including air pipes, ventilators, ventilation intakes and outlets (regardless of closing appliances), non-watertight hatches and weathertight doors, are to be above the levels to which watertight integrity is to be ensured.

3.3.2(b) Manholes fitted with bolted covers need not be dealt with as under 5B-3-2/3.3.2(a).

3.3.2(c) External openings fitted with appliances to ensure watertight integrity are normally to be secured closed and are to comply with the requirements of 5B-3-2/3.3.1.

3.5 Penetrations *(1 July 2013)*

Where watertight bulkheads and flats are necessary for damage stability, they are to be made watertight throughout. Where individual lines, ducts or piping systems serve more than one compartment or are within the extent of damage, satisfactory arrangements are to be provided to preclude the possibility of progressive flooding through the system. Valves fitted at watertight boundaries are to be operable from above the top of the spar hull.

Cable penetrations are to be installed in accordance with the manufacturer's specifications and procedures. Evidence of prototype testing at the water pressure of the watertight boundary under consideration is to be provided.

During installation of deck and bulkhead watertight and fire-rated cable penetrations, the attending Surveyor is to confirm that the installer is familiar with and has access to the manufacturer's installation procedures for stuffing tubes, transit devices or pourable materials.

After installation, all watertight and fire-rated cable penetrations are to be visually examined. Watertight cable penetrations are to be tested as required by 3-7-1/Table 1 of the *Steel Vessel Rules*.

PART

5B

CHAPTER 3 Spar Installations

SECTION 3 Hull and Primary Structures

1 Structural Design

1.1 Scantlings

The design of the Spar is to be based on the applicable portions of the *MODU Rules*. Where the conditions at the installation site are less than those for full ocean service that are the basis of the *MODU Rules*, the design criteria for various components of the Spar may be reduced to reflect these differences. However, when the installation site conditions produce more arduous demands, it is mandatory that the design criteria be increased appropriately. The Spar strength can be obtained by initially designing each component's scantlings for local load effects and subsequently verifying the initial scantlings for the global load effects.

This subsection provides requirements for the designs of initial scantlings and secondary structures. 5B-3-3/5 of these Rules provides requirements for verification of the initial scantlings.

1.3 Scantling Design of the Hull Structure

Scantlings of the hull are to be designed in accordance with 5B-3-3/3.

1.5 Modules and Buildings on the Topside Deck

The structural design of modules and buildings on the topside deck is to be in accordance with 5B-3-3/5.3, wherever applicable. The relative deformations among module and building supports are to be included in the analysis if their effects on the module are significant.

The module and building supporting structures on the topside deck are to be analyzed and shown explicitly on the drawings so that the construction of the module and building supports can be consistent with those assumed in the structural analysis. Means are to be provided to verify that the module and building design reactions and conditions are identical with those used in the topside deck design.

The structural fire protection aspects of the design of topsides modules and buildings, including the arrangement of the hydrocarbon process area, are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*

The designs of the piping system on the topside deck are to comply with Part 4, Chapter 2 of the *MODU Rules* and applicable requirements of the *Facilities Rules*.

1.7 Helicopter Deck

The design of the helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules* and 3-8/9.9 of the *Facilities Rules*.

1.9 Protection of Spar Deck Openings

All openings on the Spar deck are to comply with 3-2-15 of the *Steel Vessel Rules*.

1.11 Guards and Rails

Guards and rails are to comply with the requirements of 5-3-1/5 of the *MODU Rules*. The above mentioned section is to be used for the perimeters of the Spar, including the hull, topside deck and center well on the Spar deck. Alternative arrangements, such as a minimum 42-inch high and two tier evenly spaced handrail with a kickboard, may be considered by ABS, provided they are also acceptable to the local authority.

1.13 Machinery and Equipment Foundations

Foundations for machinery or equipment subject to high concentrated or cyclic loading, such as mooring winches, fairleads, chain stoppers, riser guides, riser tensioner supports, crane and drilling facilities, if applicable, are to be designed to provide satisfactory strength and fatigue resistance for the reaction forces specified by the manufacturer or the maximum anticipated loads during the entire service life of the Spar, in accordance with safety factors outlined in 5B-3-3/5.1. The global load effects and Spar motion-induced inertia loads are also to be considered in addition to the reaction forces. The backup structures and reinforcement on hull or topside deck are also to be designed for the same loads and safety factors, as a minimum.

1.15 Vortex Shedding Strakes

Vortex shedding strakes are designed to reduce the VIM effects on the Spar hull. Yield, buckling and fatigue strengths of vortex shedding strakes are to be checked, taking into account the effects of local drag and inertia loads together with the effects of global motions.

1.17 Appurtenances

Main appurtenances attached to the exterior of the hull are to be evaluated, taking into account the effects of local drag and inertia loads together with any appropriate consideration of global action of the Spar and the VIM effect. The backup structures are also to be designed for the same loads and safety factors, as a minimum.

1.19 Temporary Structures

Structures built for temporary use in the pre-service conditions are not subjected to ABS review. However, the arrangements and details of these structures are to be submitted for reference to verify the adequacy of the local and global strength of the hull and topside deck to support these temporary structures during operation in the pre-service condition. The backup structures are to be designed for the safety factors outlined in 5B-3-3/5.1.

3 Scantling Design of the Hull Structure

The initial scantling design of the hull is to be based on the applicable portions of the *MODU Rules* and the *Steel Vessel Rules*. The aspects that are not covered by these Rules are to be based on the recognized codes and standards. For curved shells, the minimum scantlings of shell girders are to be determined on the basis of established shell analysis methods, using the heads given in 5B-3-3/3.1 and safety factors appropriate to the method employed. As a minimum, a detailed local analysis is to be performed, with failure modes meeting the criteria in 5B-3-3/5.1.6.

3.1 Hull Structure

3.1.1 Upper Hull – Hard Tank

Where the external components of the hard tank, such as external shell, center well bulkheads and top (Spar deck) and bottom decks, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc. may be determined in accordance with the requirements for tanks as given in 5B-3-3/3.1.5, in association with the following heads:

3.1.1(a) Tank Spaces. Where the internal space is a tank space, the head, *h*, is to be taken:

i) To a point located at two-thirds of the distance from the top of the tank to the top of the overflow,

ii) To a point 0.91 m (3 ft) above the top of the tank, or

iii) To a point representing the maximum permissible operating draft, including offset operation draft.

For tanks intended to carry contents with a specific gravity in excess of 1.05, the head, *h*, is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.1(b) Void Compartment Spaces. Where the internal space is a void compartment or a tank without liquid in it, the head is to be taken to a point representing the maximum permissible operating draft.

i) *Areas Subject to Wave Immersion.* For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

ii) *Minimum Scantlings.* The scantlings of the external boundary are also to be designed as watertight boundary using 5B-3-3/3.1.4, in association with

- A head to the maximum damaged waterline, or
- A head to a point representing the installation draft.

Where the interior boundaries of the hard tank, such as radial bulkheads and other bulkheads and flats that separate two tank spaces, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc. may be determined in accordance with the requirements for the tank spaces of the hard tank, as given in 5B-3-3/3.1.5.

Where the interior boundaries of the hard tank, such as radial bulkheads and other bulkheads and flats that separate two void spaces, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., may be determined in accordance with the requirements for watertight bulkheads and flats, as given in 5B-3-3/3.1.4, in association with a head to the maximum damaged waterline.

3.1.2 Mid-Section – Free Flooded Column and Truss Space Frame with Heave Plates

3.1.2(a) Free Flooded Column. Where the external components of the mid-section incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc. may be determined in accordance with the requirements for tank bulkheads and flats as given 5B-3-3/3.1.5, in association with the maximum anticipated hydrostatic and hydrodynamic pressures during the wet tow and in the in-place conditions.

3.1.2(b) Truss Space Frame with Heave Plates. The scantlings of the chords and braces of the truss frame may be initially determined in accordance with API RP 2A for the hydrostatic collapse requirements, in association with the installation and maximum operating drafts.

Where the components of the heave plates incorporate stiffened plating, the minimum scantlings of plating, framing, girders, etc., may be determined in accordance with the requirements for tank bulkheads and flats, as given in 5B-3-3/3.1.5, in association with the maximum anticipated pressures in wet tow, upending and in the in-place conditions.

3.1.3 Lower Hull – Fixed Ballast and Flotation Tank

Where the components of the fixed ballast and flotation tanks incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., may be determined in accordance with the requirements for tank bulkheads and flats, as given in 5B-3-3/3.1.5, in association with the following:

i) The maximum anticipated hydrostatic pressures in wet tow and upending, and

ii) Equivalent hydrostatic head due to fixed ballast weight.

3.1.4 Watertight Boundary Formula

3.1.4(a) Plating. The plating thickness of watertight boundaries is not to be less than that obtained from the following equation:

$t = sk\sqrt{qh}\,/290 + 1.5$ mm $\qquad$ $t = sk\sqrt{qh}\,/525 + 0.06$ in.

but not less than 6 mm (0.24 in.) or $s/200 + 2.5$ mm ($s/200 + 0.10$ in.), whichever is greater.

where

t = thickness, in mm (in.)

s = spacing of stiffeners, in mm (in.)

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

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

q = $235/Y$ ($24/Y$, $34{,}000/Y$)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)

h = distance, in m (ft), from the lower edge of the plating to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3

3.1.4(b) Stiffeners and Beams. The section modulus, *SM*, of each bulkhead stiffener or beam on a watertight flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$SM = Q f c h s \ell^2$ cm^3 (in^3)

$Q = 49.92/(Y + 2U/3)$ (SI Units)

$Q = 70900/(Y + 2U/3)$ (US Units)

where

f = 7.8 (0.0041)

c = 0.56 for stiffeners with ends attached

= 0.60 for stiffeners with no end attachment

h = distance, in m (ft), from the middle of ℓ to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3

s = spacing of stiffeners, in m (ft)

ℓ = length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 3-2-2/Table 2 of the *MODU Rules*, the length of ℓ maybe measured to a point on the bracket equal to 25% of the length of the bracket.

Y = specified minimum yield strength, in kgf/mm^2 (psi)

U = specified minimum tensile strength of the higher-strength material, in kgf/mm^2 (psi)

3.1.4(c) Girders and Webs. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$SM = Q f h s \ell^2$ cm^3 (in^3)

where

f = 4.7 (0.0025)

h = distances, in m (ft), from the middle of the area supported to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-3-3/3.1.4(b)

3.1.5 Tank Boundary Formula

3.1.5(a) Plating. Plating is to be the thickness derived from the following equation:

$t = sk\sqrt{qh}/254 + 2.5$ mm $\qquad t = sk\sqrt{qh}/460 + 0.10$ in.

but not less than 6.5 mm (0.25 in.) or $s/150 + 2.5$ mm ($s/150 + 0.10$ in.), whichever is greater.

where

t	=	thickness, in mm (in.)	
s	=	spacing of stiffeners in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	for $1 \le \alpha \le 2$
	=	1.0	for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
q	=	$235/Y$ ($24/Y$, $34{,}000/Y$)	
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)	
h	=	distance, in m (ft), from the lower edge of the plating to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3	

When the specific gravity of the liquid contents of a tank is greater than 1.05, the head, h, specified above, is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.5(b) Stiffeners and Beams. The section modulus, *SM*, of each bulkhead stiffener or beam on a flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$SM = Q\,f\,c\,h\,s\,\ell^2$ cm^3 (in^3)

where

f	=	7.8 (0.0041)	
c	=	0.9	for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders
	=	1.0	for stiffeners supported at both ends by girders
h	=	distance, in m (ft), from the middle of ℓ to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3	
s	=	spacing of stiffeners, in m (ft)	
ℓ	=	length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.	
Q	=	factor defined in 5B-3-3/3.1.4(b)	

3.1.5(c) Girders and Webs. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$SM = Q\,f\,c\,h\,s\,\ell^2$ cm^3 (in^3)

where

f	=	4.74 (0.0025)
c	=	1.5

h = distances, in m (ft), from the middle of the area supported to a point defined in 5B-3-3/3.1.1 through 5B-3-3/3.1.3

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length in m (ft), between supports, where brackets are fitted at shell, deck, or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Q = factor defined in 5B-3-3/3.1.4(b)

5 Structural Analysis and Design of Primary Structures

5.1 Hull Structure

5.1.1 General

Documents necessary to verify the structural strength, including yielding, buckling and fatigue of the hull are to be submitted for review. The criteria in this subsection relate to the analyses required to verify the scantlings selected in the basic design in 5B-3-3/3. Except as provided in the *MODU Rules*, the results of analyses that are required in this subsection cannot be used to reduce the scantlings established from 5B-3-3/3 of these Rules.

Depending on the specific features of the spar, additional analyses to verify and help design other portions of the Spar structural components will be required. Such additional analyses include the hull interfaces with the topside deck, position mooring and riser systems. Analysis criteria for these additional structural components are given in 5B-3-4/1.

5.1.2 Global Strength Analysis

Global strength analysis is to be performed in accordance with the design conditions and required safety factors outlined in this Subparagraph. The objective is to verify the scantlings selected in the basic design in 5B-3-3/3 against the global stresses induced by the global motions, environmental loads and gravity loads.

The global strength analysis is to be performed for the in-service and pre-service conditions, ensuring that the strength of the hull is adequate. The environmental conditions and loads described in 5B-3-1/5 are to be used to establish the design load cases for the in-service and pre-service conditions.

The in-service condition includes in-place intact and in-place damaged conditions. The in-place intact condition includes Design Operating Conditions (DOC) and Design Environmental Conditions (DEC), as defined in 5B-3-1/5.3. The in-place damaged condition includes design cases such as loss of one mooring line or one compartment flooded.

The pre-service condition includes load out, transportation (both wet and dry tows) and installation (topside deck mating and hull upending) conditions. Some structural component design could be governed by transport, upending and installation loads.

5B-3-3/Table 1 below shows the required environmental events and safety factors to be considered for each design condition in the global strength analysis:

TABLE 1
Required Environmental Events and Safety Factors

Design Conditions	*Environmental Events*	*Safety Factors*
Loadout	Calm or specified by designer or Owner	1.67
Ocean Transit (Dry Tow)	10 year return storm for the selected route condition or specified by designer or Owner if a weather routing plan is implemented for the voyage	1.25
Field Transit (Wet Tow)	1 year return storm for the selected route condition or specified by designer of Owner	1.25
Upending	Calm or specified by designer or Owner	1.67
Topsides Installation	Calm or specified by designer or Owner	1.67
In-place Design Operating	1 year return storm (minimum)	1.67
In-place Design Environmental	100 year return storm	1.25
In-place Damaged	1 year return storm	1.25

5.1.2(a) Critical Responses for Global Strength. The global strength of the hull is to be designed to withstand the responses induced by the loads specified in 5B-3-1/5.1. The responses of the hull induced by these loads that control the hull strength design are the global bending moments and shears. As indicated in 5B-3-3/Table 1, the in-place intact strength is to be designed for responses with a 100-year return period in the Design Environmental Condition.

Special attention is to be given to the low frequency loads and the heeling and trimming induced loads in calculating these responses.

The highest wave may not always produce the most critical responses. To ensure that the most critical responses are captured, a sufficient number of design cases is to be used considering the following permutations:

i) Variation in environmental conditions and headings

ii) Variation in variables (topside deck payloads)

iii) Variation in ballasting distributions

iv) Variation in riser arrangements

5.1.3 Main Intersections (Major Joints)

The details of the main intersections are difficult to adequately capture in the global strength model. To design these areas, local FEM analyses are to be used, as required. These main intersections include connections of hard tank to topside legs, hard tank to truss and truss to soft tank (or keel tank). For the truss space frame of the mid-section, the design of unstiffened tubular joints, stiffened tubular joints and transition joints is to comply with Section 3/4 of the *Offshore Installations Rules* or API RP 2A.

5.1.4 Fatigue

Fatigue analysis is to be performed to ensure adequate strength against fatigue failure within the Spar's design life. The fatigue analysis is to consider all loading history of the Spar, including transport and in-place conditions.

Attention is to be given to the low frequency loads and global motions induced by these loads, which are important to fatigue damages at the main intersections of connections between topside deck to hard tank, hard tank to mid-section, mid-section to soft tank (or keel tank) and truss joints.

Attention is also to be given to the designs of structural notches, cutouts, attachments and abrupt changes of structural sections which are prone to fatigue damages.

5.1.5 Structural Redundancy Analysis

Redundancy analysis is required to ensure that there is adequate redistribution of stress in the damaged conditions defined in 5B-3-3/Table 1. The damaged conditions are to consider loss of one compartment buoyancy or one mooring line.

5.1.6 Acceptance Criteria

The total assessment of the structure and details is to be performed against the design conditions specified in 5B-3-3/Table 1 and failure modes of material yielding, buckling and ultimate strength, and fatigue. The acceptance criteria of each mode are given as follows.

5.1.6(a) Material Yielding (1 July 2012). For the hull, the yielding criteria indicated in 3-2-1/3 of the *MODU Rules* are to be used. For the truss space frame of the mid-section, the yielding criteria in Chapter 3 of API RP 2A are to be used. The safety factors in 5B-3-3/Table 1 of these Rules are to be used for bar and beam elements. For plated structures the allowable von Mises equivalent stress is to be 0.7 of the yield strength for the Design Operating, Loadout, Upending and Topsides Installation Conditions, and 0.9 of the yield strength for the Design Environmental, Transit and Damaged Conditions.

The yield strength is to be based on the specified minimum yield point or yield stress, as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for higher strength material.

5.1.6(b) Buckling and Ultimate Strength. For the hull, the buckling criteria in API Bulletin 2V and 2U or other recognized standards are to be used. For the truss space frame of the mid-section, the buckling criteria in Chapter 3 of API RP 2A are to be used. The factors of safety are to be based on 5B-3-3/Table 1 of these Rules.

5.1.6(c) Fatigue. For the hull, including the hard tank connections to the truss space frame mid-section, the topside deck legs and the soft tank (or keel tank) connections to the truss space frame mid-section, the fatigue damages can be calculated using ABS Offshore S-N curves for environment in air, in seawater with cathodic protection and in seawater free corrosion, as specified in the ABS *Guide for the Fatigue Assessment of Offshore Structures*. The S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm ($^7/_8$ in.). For members of greater thickness, thickness correction is required with an exponent of 0.25. Other recognized standards equivalent to ABS requirements are also acceptable.

For the truss space frame mid-section, the API RP 2A S-N curves can be used.

The fatigue life is determined by safety factors and the design life of the Spar. Safety factors depend on the inspectability, reparability, redundancy, the ability to predict failure damage, as well as the consequence of failure of the structure. Minimum safety factor requirements are listed in 5B-3-3/Table 2.

TABLE 2
Safety Factors for Fatigue Life of Hull Structures

Importance	*Inspectable and Repairable*	
	Yes	*No*
Non-critical	3	5
Critical	5	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

5.3 Topside Deck

5.3.1 General

The designs of topside deck structural members such as deck girders, columns, beams, braces, stiffeners, deck plating, etc., are to be based on the applicable portions of the *Offshore Installation Rules*. To this end, the loads on the structure, as indicated in 5B-3-3/5.3.2, as applicable, are to be determined, and the resulting structural responses are not to exceed the safety criteria given in 5B-3-3/5.3.4.

The use of design methods and associated safety criteria, other than those specifically covered in this section, is permitted where it can be demonstrated that the use of such alternative methods will result in a structure possessing a level of safety equivalent to or greater than that provided by the direct application of these requirements.

5.3.2 Loading Conditions

Loadings which produce the most unfavorable effects on the topside deck structure for the pre-service and in-service conditions are to be considered. The environmental conditions and applicable loads described in 5B-3-1/5 are to be used to establish the design load cases for the in-service and pre-service conditions. The environmental events included in 5B-3-3/Table 1 are also to be considered for the deck design. For a given topside payload, the most critical responses for the topside deck may be the accelerations induced by the Spar's motions and the inclination-induced loads.

5.3.3 Structural Analysis

A space frame analysis of the deck structure is to be performed to obtain the structural response. The structural model can be either the overall Spar with a detailed deck model or a standalone deck structural model. In the latter case, the boundary conditions of the model are to be properly simulated in the analysis. In modeling the deck structures, all relevant structural components are to be included. The nature of loads and loading combinations, as well as the local environmental conditions, are to be taken into consideration in the selection of design methods. Methods of analysis and their associated assumptions are to be compatible with the overall design principles. Linear, elastic methods (working stress methods) are generally employed in design and analysis. For the use of other methods, reference is to be made to 3/4.7 of the *Offshore Installations Rules*.

5.3.4 Allowable Stresses

The safety criteria are to be expressed in terms of appropriate basic allowable stresses in accordance with requirements specified below:

5.3.4(a) For tubular members, stress limits are to be in accordance with the API RP 2A. The basic allowable stresses for the other type of members are to be obtained using the American Institute of Steel Construction (AISC) *Manual of Steel Construction, ASD*. For plated structures, the design is to be in accordance with API RP 2U and API RP 2V or other recognized industry standards.

5.3.4(b) Where stresses in members described in 5B-3-3/5.3.4(a) are shown to be due to forces imposed by the Design Environmental Condition (DEC) acting in combination with dead and live loads, the basic allowable stresses cited in 5B-3-3/5.3.4(a) may be increased by one-third, provided the resulting structural member sizes are not less than those required for the operating environment loading combined with dead and live loads without the one-third increase in allowable stresses.

5.3.4(c) (1 July 2009) The allowable stresses specified in 5B-3-3/5.3.4(b) are to be regarded as the limits for stresses in all structural parts for the marine operations covered in 5B-3-1/5.1, except for lifting, where the one-third increase in the basic allowable stress is not permitted. The one-third increase in the basic allowable stress is also not permitted in loadout operations. The lifting analysis is to adequately account for equipment and fabrication weight increase with dynamic amplification factors recommended in API RP 2A. Other lift analysis methods can be considered on a case by case basis.

5.3.4(d) (1 July 2012) For any two- or three-dimensional stress field within the scope of the working stress formulation, the equivalent stress (e.g., the von Mises stress intensity) is to be used in the design. The allowable von Mises stress is to be 0.7 of the yield strength for the Design Operating Condition (DOC) and 0.9 of the yield strength for the Design Environmental Condition (DEC). For highly localized areas, local yielding of the structure may be accepted, provided it can be demonstrated that such yielding does not lead to progressive collapse of the overall structure and that the general structural stability is maintained.

5.3.4(e) Whenever elastic instability, overall or local, may occur before the stresses reach their basic allowable levels, appropriate allowable buckling stresses govern.

5.3.5 Fatigue Assessment

A detailed fatigue analysis is to be performed for deck structures. Rational fatigue analysis methods are acceptable if the forces and member stresses can be properly represented. The dynamic effects are to be taken into consideration if they are significant to the structural response. For the frame members of the deck, the S-N curves specified in the ABS *Guide for the Fatigue Assessment of Offshore Structures* and API RP 2A are recommended. The Stress Concentration Factors (SCFs) for tubular joints can be calculated based on applicable empirical formulas. For the complex critical connections, the SCFs should be calculated by means of a fine mesh finite element analysis.

The results of the assessment are to indicate a minimum expected fatigue life of two or more times of the design life of the structure where sufficient structural redundancy exists to prevent catastrophic failure of the structure of the member or connection under consideration. Where such redundancy does not exist or where the desirable degree of redundancy is significantly reduced as a result of fatigue damage, the result of a fatigue assessment is to indicate a minimum expected fatigue life of three or more times the design life of the structure. 5B-3-3/Table 3 provides general safety factor requirements for fatigue life. For the deck to hull connections, see 5B-3-3/5.1.6(c).

TABLE 3
Safety Factors for Fatigue Life of Topside Deck Structures

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	2	5
Critical	3	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

5.3.6 Stresses in Connections *(1 July 2009)*

Connections of structural members are to be developed to insure effective load transmission between connected members to minimize stress concentration and to prevent excessive punching shear. Connection details are also to be designed to minimize undue constraints against overall ductile behavior and to minimize the effects of post-weld shrinkage. Undue concentration of welding is to be avoided. The design of tubular joints is to be in accordance with the API RP 2A, including pinching shear. AISC *Manual of Steel Construction, ASD* can be used for the design of non-tubular joints.

PART

5B

CHAPTER 3 Spar Installations

SECTION 4 Other Structures

1 Analysis and Design of Other Major Structures

The analysis and criteria to be applied to the other pertinent features of the Spar structural design are to conform to recognized practices acceptable to ABS. For Spars, the following needs to be considered in the Spar structural design: the interface between the position mooring system and hull, and the interface between hull and the riser system. The criteria to be applied for these cases are presented below.

1.1 Hull Interface with Mooring System (Fairlead, Chain Stopper and Winch Foundations)

Each individual foundation and back-up structure of the fairlead, chain jack and winch is to be designed for the breaking strength of the mooring line with a safety factor of 1.25. The foundation and back-up structure for multiple fairleads, chain jacks or winches is to be designed for the maximum anticipated mooring loads with a safety factor of 1.25 in the Design Environmental Condition (DEC) and with a safety factor of 1.67 in the Design Operating Condition (DOC).

Fatigue strength is to be designed to meet the requirements in 5B-3-3/5.1.6(c), taking into account the effects of both local drag and inertia loads on the mooring lines and the global motions of the Spar.

1.3 Hull Interface with Riser System (Riser Guides and Riser Supports)

The riser foundation and guide and back-up structures are to be designed for the maximum anticipated riser loads with a safety factor of 1.25 in the Design Environmental Condition (DEC) and with a safety factor of 1.67 in the Design Operating Condition (DOC).

Contacts between hull and riser buoyancy components may cause cyclic impact loads to the hull. Fatigue due to the cyclic impacts is to be adequately considered in the design.

3 Mooring and Foundation System

3.1 Mooring System

Design of the mooring system is to meet the requirements in Sections 6-1-1 and 6-1-3 of these Rules, and applicable requirements in API RP 2SK. In particular, strength and fatigue damage of mooring lines due to vortex-induced motions of the Spar itself are to be fully assessed.

3.3 Foundation System

The design criteria of the foundation system are to be in accordance with the requirements described in Sections 6-1-1 and 6-1-3 of these Rules.

PART
5B

CHAPTER 3 Spar Installations

SECTION 5 Materials and Welding

1 Hull Structures

Sections 3-2-6 and 3-2-7 of the *MODU Rules* are to be used to establish the welding requirements for the hull. The weld type and sizing are to be shown on the scantling drawings or in the form of a welding schedule and are to comply with the Rules that govern the steel selection. Special attention is to be given to the weld details for fatigue-sensitive areas. Weld improvements by means of toe grinding and weld profiling are to be used, if required by fatigue analysis results.

Section 3-1-3 of the *MODU Rules* is to be used for the material selections for the hull. The Spar hull structures are grouped into the following material application categories for the purpose of material grade selection:

Special Application Structure	• Hard tank-to-topside deck leg connection • Hard tank-to-truss connection • Truss-to-soft tank (or keel tank) connection • Heave plate-to-truss connection • Truss tubular joint cans • Chain jack foundation structure • Fairlead foundation structure • Riser support foundation structure • Riser guide-to-hull connection
Primary Application Structure	• All inner and outer hull shell plating • Hull top deck and bottom deck, including main girders • All radial hull bulkheads • All hull ring frames and longitudinal girders • All truss chords and braces • Heave plate plating and girders • Soft tank (or keel tank) plating and girders • All struts
Secondary Application Structure	• All hull, heave plate and soft tank (or keel tank) stiffeners • All internal hull flats • All internal bulkheads in soft tank (or keel tank) • All other structures

3 Topside Deck Structures

Part 2 of the *Offshore Installation Rules* can be used to establish the material selections and welding requirements for the truss deck of the topside. The deck structures are categorized into the following four groups, in association with the Charpy toughness test described in Table 2/1.3 of the *Offshore Installation Rules*:

i) Deck lifting points, deck-to-hull cans

ii) Major truss row girders, major truss row columns, major truss row bracing

iii) Intermediate girders, intermediate bracing

iv) Deck stringer beams, deck plating

Alternatively, Section 3-1-3 of the *MODU Rules* may be used for material selections.

Note: Items such as handrails, walkways and access platforms do not require the above material requirements.

PART

5B

CHAPTER 3 Spar Installations

SECTION 6 Machinery and Systems

1 Marine Piping Systems

Marine piping systems are those systems that are required for maintaining the normal operations of a floating unit (such as power generation, bilge, ballast, tank vent and sounding, etc.). Subsection 4-2-1/3 of the *MODU Rules* lists these systems. Systems installed in the hull are to be designed to minimize the requirements for equipment and machinery to be installed in hull compartments and to limit as much as possible systems requiring piping or cable runs in the Spar hull.

Marine support systems are to be in accordance with the requirements of the *MODU Rules*, except as modified herein.

1.1 Bilge System

It is acceptable to omit a fixed bilge pumping system, as required by 4-2-4/1.1 of the *MODU Rules*, for void spaces in the Spar hull and to use portable pumps lowered into spaces through manholes for bilge pumping capabilities. At least two (2) portable pumps with hoses and accessories, capable of draining any void space, are to be available onboard at all times. For the bilge suction sizing purposes, column-stabilized units and self-elevating units sizing criteria listed in 4-2-4/9.3 of the *MODU Rules* are applicable.

1.3 Ballast System

The system fitted is to provide the capability to ballast and deballast all ballast tanks when the unit is upright or listed up to five degrees in any direction. All pumps and valves are to be fitted with a remote means of operation situated above the uppermost watertight deck. The normal or emergency operation of the ballast system is not to introduce a greater risk of progressive flooding due to the opening of hatches, manholes, etc., in watertight boundaries.

1.3.1 Pumping Systems

Where ballast systems powered by pumping systems are installed, at least two ballast pumps are to be provided, one of which is to permanently connected to the installation's ballast system. The second pump may be a spare held in reserve or an eductor type arrangement permanently connected to the system. If submersible ballast pumps are installed in each ballast tank, one spare pump must be stored onboard at all times.

1.3.2 Compressed Air Systems

Where ballast systems powered by compressed air are installed, a satisfactory quantity of compressed air is to be available to the system at all times. If two compressors are installed, one compressor is to be powered by either the emergency switchboard or a dedicated engine. Each compressor is to be capable of providing 100% of the required capacity of compressed air, as defined in 5B-3-6/1.3.2(a). If only one compressor is provided, this compressor is to be powered by either the emergency switchboard or a dedicated engine, and a quantity of stored compressed air equivalent to the required capacity called out in 5B-3-6/1.3.2(a) is to be provided.

1.3.2(a) Quantity of Compressed Air. A quantity of air capable of bringing the installation from its worst case damage or accidental flooding condition, as defined by 5B-3-2/1.5.3(b), to normal operating draft and inclination is to be provided.

1.5 Vents and Sounds

Except for comparatively small compartments that are not fitted with a fixed means of drainage, vent pipes are to be fitted on all tanks, cofferdams, voids, tunnels and compartments which are not fitted with other ventilation arrangements. The vent opening for a hull void space on a Spar hull may be normally sealed off at the spar deck level by means of a blank, provided the venting arrangement of the Spar hull satisfies the conditions listed below:

i) The hull void spaces are below the waterline under all operating conditions. Above waterline void spaces may be considered if they are designed for pressure fluctuations due to thermal load and if fitted with a rupture disk. The set pressure of the rupture disk is to be lower than the void design pressure

ii) The hull void space is not classified as a hazardous area. Hazardous voids may be considered if they are designed for pressure fluctuations due to thermal load and fitted with a rupture disk. The set pressure of the rupture disk is to be lower than the void design pressure. Areas around vents fitted with rupture disks are to comply with appropriate hazardous area requirements.

iii) The hull void space is not fitted with a permanently installed bilge or drainage system.

iv) Each void space is fitted with a high bilge water level alarm or a high pressure alarm.

v) The blank is to be installed after commissioning the Spar hull below the water line and after giving due consideration for temperature stabilization of the void space atmosphere with outside.

vi) The blank is installed in readily accessible position so that the same can be removed for ventilation purposes during routine inspection and/or de-watering period.

vii) The hull void space does not contain pressurized piping. When pressurized pipe must be routed through the void space, a burst disk designed to rupture at pressure/vacuum not exceeding the void space's design pressure/vacuum will be installed at the vent pipe outlet instead of a blank. For such instances, a blind flange or similar device is not acceptable as a blanking device. Additionally, the vent terminal will be provided with a gooseneck and fitted with a ball check valve (or equivalent).

The requirements for sounding are to comply with the *MODU Rules.* However, to prevent duplication of pipe runs, it would be acceptable to sound the void spaces through the vent lines. In the case of a sealed vent, a sounding plug would need to be provided to permit void space sounding.

1.7 Hydrocarbon Storage in Hull Tanks

If the Spar is designed to store hydrocarbons in hull tanks, criteria for hull storage of hydrocarbons are to meet flag and coastal state requirements and applicable international requirements. The designs for scantlings and strength for such storage tanks are to be in accordance with 5B-3-3/3 and 5B-3-3/5. See 3-5/5.9 of the *Facilities Rules* for the storage facility arrangement requirements.

3 Electrical Systems

The design criteria of electrical systems associated with marine systems (and drilling systems) are to be in accordance with applicable requirements described in Part 4, Chapters 1 and 3 of the *MODU Rules*.

The design criteria of electrical systems strictly devoted to the hydrocarbon processing facilities are to be in accordance with applicable requirements described in Chapter 3 of the *Facilities Rules*.

The design criteria of electrical systems associated with both marine systems and hydrocarbon processing facilities are to be in accordance with the applicable requirements described in Part 4, Chapters 1 and 3 of the *MODU Rules*.

5 Fire Fighting Systems and Equipment

The fire fighting systems and equipment for the Spar service functions not associated with the process facilities are to be in accordance with Part 5, Chapter 2 of the *MODU Rules*. Fire fighting systems and equipment for protection of hydrocarbon process and associated systems, including fire pumps, are to be in accordance with Chapter 3, Section 8 of the *Facilities Rules*.

7 Machinery and Equipment

Machinery and equipment not associated with the process facilities are to be in accordance with the applicable requirements of Part 4, Chapter 1 of the *MODU Rules*. Machinery and equipment forming a part of the hydrocarbon processing facilities are to be in accordance with the applicable requirements of Chapter 3, Section 3 of the *Facilities Rules*. Machinery and equipment forming a part of the permanent drilling facility are to be in accordance with Part 4, Chapter 1 of the *MODU Rules*.

PART

5B

APPENDIX 1 Wave Impact Criteria *(1 July 2009)*

CONTENTS

PART
5B

APPENDIX 1 Wave Impact Criteria *(1 July 2009)*

1 Application and Scope

Wave impact is referred to in several locations in these Rules; see 5B-1-1/5.1 for a Column Stabilized Vessel, 5B-2-1/5.1 for a TLP, and 5B-3-1/5.1 for a Spar vessel. The criteria given herein are mandatory for the Classification of a non-ship type FPI. For a ship-type FPI, wave impacts in the form of bow and bottom slamming are considered in 5A-3-2/13.

These criteria consider wave breaking loads on the hull and topside deck of an FPI, such as a Column Stabilized Vessel, a TLP and a Spar, for in-service and pre-service conditions. Wave impact is considered a solitary and unusual load that is resisted by local structural components, possibly into the post yield range of their strength. Therefore criteria are included so that the needed post yield strength is available (i.e., member 'compactness' and detailing criteria are provided).

3 Impact Load

3.1 Column, Pontoon and Hard Tank

Where the column or pontoon of a column stabilized vessel or a TLP or the hard tank of a Spar is subjected to wave impact, the scantlings of the plating, stiffeners and girders of the framed shell are to be determined using the following wave impact pressure, p_s:

$$p_s = kf_sH_s \quad \text{kN/m}^2 \ (\text{T/m}^2, \text{lbf/ft}^2)$$

where

k	=	37.84 (3.858, 240.9)	
f_s	=	1.0	for plate panels between stiffeners, and the stiffeners themselves
	=	0.656	for girders in a stiffened shell having a rectangular cross section
	=	0.492	for girders in a stiffened shell having a circular cross-section
H_s	=	significant wave height in meters (feet) of the design sea state having a 100 year return period. Where the structure is subjected to wave impact during its transit to the installation site, H_s, for the critical sea state during transit is also to be considered.	

3.3 Other Members

The main bracing members of a Column Stabilized Vessel or a TLP between the columns or between columns and the topside deck, and the members of an open-truss in a topside deck of a Column Stabilized Vessel, TLP or Spar are small diameter tubular members. The p_s determined above for plating (i.e., f_s = 1.0) can be divided by 1.9 and multiplied by the member's width to obtain the impact force per unit length along the member.

5 Areas of Wave Impact

5.1 General

The wave impact zone is the region in which structural elements will be subject to wave impact loads. The wave impact zone is the vertical distance from the SWL to the crest elevation of the maximum wave associated with the design sea state.

The horizontal extent of the wave impact zone is all of the outward facing portions of the hull. For example, a circular corner leg column of a TLP will have a 270 degree arc of its surface exposed to wave impact. The shielding from impact provided by adjacent structural members may be considered where justification is provided.

5.3 Column, Pontoon and Hard Tank

Wave impact areas are used to determine the design loads on individual members. The areas that will be subjected to wave impact are as follows:

- For individual plate panels between stiffeners, the wave impact pressure is considered to act uniformly over the entire panel.
- For an individual plate stiffener with its associated shell plating, the pressure is considered to act uniformly along the length of the stiffener. The area on which the pressure acts for the stiffener has a width equal to the spacing between stiffeners and a height that is the length of the stiffener. Even if only a portion of a stiffener is in the wave impact zone, the entire stiffener length is to be considered loaded by the specified pressure.
- For girders in the wave impact zone, the area over which the pressure is applied is as follows:
  - For horizontal members (e.g., girders, decks and flats) the loaded area is:

    Vertically: The lesser of the sum of one-half the plate stiffener spans above and below the horizontal member, or $0.62H_s$

    Horizontally: The length of the horizontal member between points of effective flexural support.
  - For vertical girders and similar structural members (e.g., vertical webs and bulkheads) the loaded area is:

    Vertically: The lesser of the distance between points of effective flexural support, or $0.62H_s$

    Horizontally: The sum of one-half the distance on either side of the web to the next vertical girder or bulkhead.

  (Where the actual framing is other than the conventional orthotropic plate framing system envisioned, modification of the specified areas will be considered in consultation with ABS.)

5.5 Other Members

- Portions of a main brace exposed to wave impact will need sufficient flexural and shear strength to resist the impact load. The impact load per unit of length along the brace extends from the SWL to the crest elevation of the maximum wave associated with the design sea state.
- Additionally all portions of the brace in the impact zone are to be able to resist the local pressure given in 5B-A1/3.1 divided by 1.9.

7 Structural Strength

7.1 General

Individual structural elements in the wave impact zone are to satisfy the criteria given below. As mentioned previously wave impact is considered a solitary local load. Typically, it is envisioned that structural elements will be initially designed considering the scantling requirements and the global strength requirements for the specified in-service and pre-service conditions in the *FPI Rules*. The parts of the FPI structure in the wave impact zone, will then be assessed for their resistance to wave impact. As needed, the design of an element is to be suitably increased using the criteria given below to account for wave impact. Since some of the affected structural elements will need to mobilize post yield behavior to resist the wave impact load it is important that both the strength criteria given below and the 'Compactness and Detailing' criteria given in the next subsection are satisfied.

7.3 Shell Plating

The thickness of shell plating, t, in the wave impact zone is not to be less than the following.

$$t = \frac{sk}{70.7}\sqrt{\frac{p_s}{Y}} + 1.5 \quad \text{mm} \qquad\qquad t = \frac{sk}{26.8}\sqrt{\frac{p_s}{Y}} + 0.06 \quad \text{in.}$$

where

t	=	thickness, in mm (in.)
p_s	=	pressure from 5B-A1/3.1, in kN/m^2 (T/m^2, lbf/ft^2)
s	=	spacing of stiffeners, in mm (in.)
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$
	=	1.0 for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)
Y	=	specified minimum yield point or strength, in N/mm^2 (kgf/mm^2, psi)

7.5 Stiffener

The *plastic* section modulus, Z, of plate stiffeners with their associated shell plating is not to be less than the following

$$Z = 125 c p_s s \ell^2 / Y \quad \text{cm}^3 \qquad\qquad Z = 3\, c p_s s \ell^2 / 2Y \quad \text{in}^3$$

where

s	=	stiffener spacing, in m (ft)	
p_s	=	pressure from 5B-A1/3.1, in kN/m^2 (T/m^2, lbf/ft^2)	
ℓ	=	length of stiffener, in m (ft), between supports; where brackets are fitted in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.	
Y	=	specified minimum yield point, in N/mm^2 (kgf/mm^2, psi)	
c	=	0.5	when both ends of the stiffener have effective end brackets
	=	0.67	when one end has effective end bracket and other end is continuous into the next stiffened panel
	=	0.8	when both ends of a stiffener are continuous into the next stiffened panel
	=	1.0	for a single span stiffener without effective flexural restraint at ends.

The plastic section modulus, Z, may be obtained from the following equations, where b_f, t_f, d_w, t_w, b_p, and t_p are as indicated in 5B-A1/Figure 1, in cm (in.):

$$Z = b_f t_f (d_w + \alpha + t_f/2) + d_w t_w (d_w/2 + \alpha) + b_p(\alpha^2 - \alpha t_p + t_p^2/2) \qquad \text{when } b_p t_p > b_f t_f + d_w t_w$$

$$Z = b_f t_f (d_w - \beta + t_f/2) + t_w(\beta^2 - \beta d_w + d_w^2/2) + b_p t_p(\beta + t_p/2) \qquad \text{when } b_p t_p \le b_f t_f + d_w t_w$$

where

α = $0.5(b_p t_p - d_w t_w - b_f t_f)/b_p$

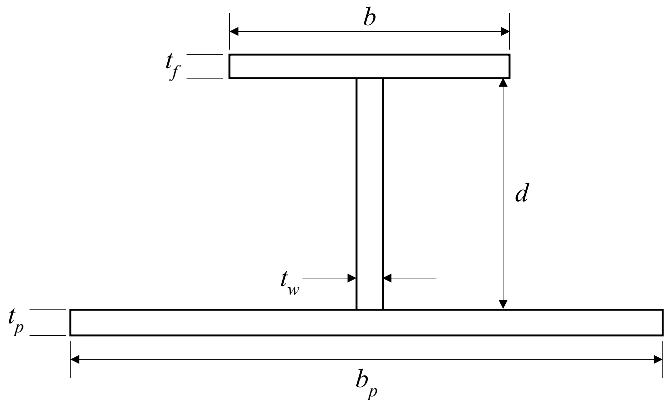
β = $0.5(d_w t_w + b_f t_f - b_p t_p)/t_w$

The shear area of the stiffener, A_w, is not to be less than:

$A_w = p_s s\ell/0.12Y$ cm^2 $\qquad$ $A_w = p_s s\ell/1.2Y$ in^2

where p_s, s, ℓ, and Y are as defined above.

FIGURE 1
Stiffener Section *(1 July 2009)*



7.7 Girder

The *elastic* section modulus, SM, of a girder supporting stiffeners on flat plating, including the associated shell plating is not to be less than:

$SM = 91.0 p_s b\ell^2/Y$ cm^3 $\qquad$ $SM = p_s b\ell^2/0.92Y$ in^3

where

p_s = pressure from 5B-A1/3.1, in kN/m^2 (T/m^2, lbf/ft^2)

ℓ = length of girder, in m (ft), between supports. The ends of girders should have flexural restraint either from being continuous with adjacent structure or the provision of brackets in accordance with 3-2-2/Table 2 of the *MODU Rules.* In the latter case, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.

b = dimension of the loaded area perpendicular to the length, in m (ft)

Y = specified minimum yield point, in N/mm^2 (kgf/mm^2, psi)

The shear area of the girder, A_w, is not to be less than:

$A_w = p_s b\ell/0.108Y$ cm^2 $\qquad$ $A_w = p_s b\ell/1.08Y$ in^2

where p_s, b, ℓ, and Y are as defined above.

Where the stiffened shell is curved, the girder scantlings are to be determined based on an established shell analysis method. The scantlings of the curved girder are to be based on linear elastic behavior where the maximum bending stress due to wave impact is limited to the yield stress.

For a vertical girder whose length is not completely in the wave impact zone, adjustment to the above calculated section modulus and web area can be made using an appropriate method based on linear elastic behavior.

7.9 Other Members

For a smaller diameter member (e.g. a brace that can be appropriately analyzed as a single or system of 'beam-column' elements) a structural calculation is to be performed to demonstrate the adequacy of the member to resist the impact load (acting alone) along its length as determined from 5B-A1/5.5. The calculation should appropriately account for the support at the ends of the member. Permissible stresses are those given in 3-2-1/3.7 of the *MODU Rules* for 'combined loadings'; or alternatively the pertinent member strength and allowable stress criteria of the API-RP2A can be used, where the basic allowable stress is increased by one-third.

The adequacy of the member's local strength subjected to direct wave impact is to be demonstrated. A brace segment composed of a stiffened plate is to satisfy the criteria given above in 5B-A1/7.3 and 5B-A1/7.5, as applicable. Brace segments which are circular shell structures are to satisfy the applicable criteria given in the Section 4 of ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*, where gross member properties may be used; alternatively API-RP2A, may be used. The local impact pressure on the cylindrical shell can be considered as a uniform hoop stress; increased allowable stresses are permitted.

7.11 Deck, Flat, and Bulkhead

When the main support to a plate stiffener is not a flexural element (such as a girder), it may be a deck, flat or bulkhead. In such a case the in-plane strength and buckling resistance of the deck, flat or bulkhead should be sufficient to assure that the stiffener's supports and boundary conditions will perform as intended in design. The ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures* is to be used in the assessment of stiffened panels comprising affected decks, flats and bulkheads.

9 Compactness and Detailing

The following criteria are to be satisfied for structural elements subjected to wave impact.

- The web of a plate stiffener or girder is to be continuously welded to the shell plate and the flange.
- An attached flange should preferably be symmetric with respect to webs (e.g., T-section).
- For an unsupported element (e.g., projection of flange from a web) the ratio of outstand (b) to thickness (t) is not to exceed $0.4(E/Y)^{0.5}$, where E and Y are, respectively, the modulus of elasticity and yield strength of the material in the same units of measure.
- For a supported element (e.g. web of a flanged stiffener) the ratio of web depth (d) to its thickness (t) is not to exceed $1.5(E/Y)^{0.5}$.
- It is to be shown, using an appropriate method, that the unsupported length of the stiffener's flange is less than that for which the stiffener will be subject to torsional instability. For example refer to Section 3.5.3 of the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*, where gross member properties can be used.
- Tripping brackets, arranged to support the flanges of the girders, are generally to be fitted at intervals of about 3 m (10 ft), close to any changes of section, and in line with the flanges of struts.
- The web depth of a girder is to be at least 2.5 times the depth of the largest stiffener cut-out opening.
- The load paths between all elements, including welds, are to be reviewed to verifythat all supporting members and their connections will have sufficient strength and buckling resistance so that element support and boundary conditions will behave as intended.

PART

6

Mooring Systems

CONTENTS

PART
6

CHAPTER 1 Position Mooring Systems

CONTENTS

PART

6

CHAPTER 1 Position Mooring Systems

SECTION 1 Mooring System

The position mooring system includes the mooring, anchoring and dynamic positioning (if any) systems. The purpose of the position mooring system is to keep the Floating Installation on station at a specific site.

Typically, there are two types of position mooring systems: conventional spread mooring and single point mooring, as defined in 3-1-4/3 and 3-1-4/5. Thruster-assisted systems are defined in 3-1-4/7. For mooring systems incorporating fiber ropes, additional design considerations are defined in ABS *Guidance Notes on the Application of Fiber Rope for Offshore Mooring*.

1 System Conditions

The various conditions of a Floating Installation which are important for the designer to consider are as follows.

1.1 Intact Design

A condition with all components of the system intact and exposed to an environment as described by the design environmental condition (DEC).

1.3 Damaged Case with One Broken Mooring Line

A condition with any one mooring line broken at the design environmental condition (DEC) that would cause maximum mooring line load for the system. The mooring line subjected to the maximum load in intact extreme conditions when broken might not lead to the worst broken mooring line case. The designer should determine the worst case by analyzing several cases of broken mooring line, including lead line broken and adjacent line broken cases. For a disconnectable mooring system with quick release system, the mooring analysis for a broken line case may not be required. For unusual (non-symmetric) mooring pattern, mooring analysis for the broken line case for the disconnectable environmental condition may be required.

For a system utilizing the SALM concept, the case with one broken mooring line is not relevant. A case considering loss of buoyancy due to damage of a compartment of the SALM structure should be analyzed for position mooring capability.

The loss of thruster power or mechanical failure on thruster-assisted position mooring systems will be considered on a case-by-case basis.

1.5 Transient Condition with One Broken Mooring Line

A condition with one mooring line broken (usually the lead line) in which the moored installation exhibits transient motions (overshooting) before it settles at a new equilibrium position. The transient condition can be an important consideration when proper clearance is to be maintained between the moored installation and nearby structures. An analysis for this condition under the design environmental condition (DEC) is required. The effect of increased line tensions due to overshoot upon failure of one mooring line (or thruster or propeller if mooring is power-assisted) should also be considered.

3 Mooring Analysis

The analysis of a mooring system of a Floating Installation includes the determination of mean environmental forces and the extreme response of the installation in the DEC (design environmental condition, see 3-2-4/3) and the corresponding mooring line tension. A moored system is a dynamic system that is subjected to steady forces of wind, current and mean wave drift force, as well as wind and wave-induced dynamic forces. Calculations of the maximum mooring system loading are to consider various relative directions of the wind, wave and current forces.

Depending on the level of sophistication and analysis objectives, quasi-static (see API RP 2SK), quasi-dynamic (begins with calculating the low-frequency responses of the moored installation followed by superposition of the wave-frequency motions) and dynamic analysis methods (see API RP 2SK) may be used. Both frequency and time domain approaches are acceptable. The designer should determine the extreme installation offset and line tension in a manner consistent with the chosen method of analysis. For the final design of a permanent mooring system, the dynamic analysis method is to be employed to account for mooring line dynamics. For deepwater operations with large numbers of production risers, the mooring system analysis should take into account the riser loads, stiffness and damping due to significant interactions between the installation/mooring system and riser system.

3.1 Mean Environmental Forces and Moments

The calculation of steady forces and yawing moments due to wind and current are outlined in Part 3, Chapter 2. The available methods of calculating hydrodynamic characteristics and hydrodynamic loading are also indicated. The drift forces and yawing moments on a moored installation consist of a mean wave drift force, along with the slowly varying oscillatory drift force at or near the natural period of the spring-mass system of the moored installation. The mean and oscillatory low frequency drift forces may be determined by model tests or using hydrodynamic computer programs benchmarked against model test results or other data.

Designers may use API RP 2SK for estimating purposes, if applicable, that provides mean drift force charts for ship-type installations with lengths from 122 m (400 feet) to 165 m (540 ft) and less general information for column-stabilized installations. Installation-specific information is to be provided based on appropriate analysis or model testing or both.

3.3 Maximum Offset and Yaw Angle of the Installation

The wave-induced vessel dynamic responses can be calculated by the methods outlined in 3-2-4/9.3. The maximum offset consists of static offset due to wind, current and wave (steady drift), and both wave and wind-induced dynamic motions (high and low frequency). The maximum responses of surge, sway and yaw are to be determined, as follows, in accordance with API RP 2SK:

$$S_{\max} = S_{mean} + S_{\ell f(\max)} + S_{wf(sig)} \quad \text{or}$$

$$S_{\max} = S_{mean} + S_{\ell f(sig)} + S_{wf(\max)}; \quad \text{whichever is greater}$$

where

S_{mean} = mean installation offset due to wind, current and mean (steady) drift force

$S_{\ell f(sig)}$ = significant single amplitude low frequency motion

$S_{wf(sig)}$ = significant single amplitude wave frequency motion

Alternatively, the maximum excursion can be determined through model tests.

The maximum values of low frequency motion, $S_{\ell f(\max)}$, and wave frequency motion, $S_{wf(\max)}$, are typically calculated by multiplying the corresponding significant single amplitude values by a factor C that is to be calculated as follows:

$$C = \tfrac{1}{2}\sqrt{2 \ln N}$$

$$N = \frac{T}{T_a}$$

where

T = specified storm duration (seconds), minimum of 10,800 seconds (i.e., 3 hours). For areas with longer storm duration (e.g., a monsoon area), a higher value of T may need to be considered.

T_a = average response zero up-crossing period (seconds).

For low frequency components, T_a can be taken as the natural period, T_n, of the installation with mooring system. T_n can be estimated from the installation mass (or mass moment of inertia for yaw motion), m (including added mass or mass moment of inertia for yaw motion), and mooring system stiffness, k, for lateral and yaw motions at the installation's mean position and equilibrium heading as follows:

$$T_n = 2\pi\sqrt{\frac{m}{k}}$$

The quantities m and k are to be in consistent units.

Note: The above formula may not be applicable for C for estimating either wave frequency or low frequency motions. See API RP 2SK for statistical limits on the value of C and alternative analysis methods.

Other parameters affecting the low frequency motions, such as system stiffness and damping forces, are to be calibrated and the supporting data submitted to ABS for review.

3.5 Maximum Line Tension

The mean tension in a mooring line corresponds to the mean offset and equilibrium heading of the installation. The design (maximum) mooring line tension, $T_{\max}$, is to be determined as outlined in API RP 2SK and is summarized below:

$$T_{\max} = T_{mean} + T_{\ell f(\max)} + T_{wf(sig)} \qquad \text{or}$$

$$T_{\max} = T_{mean} + T_{\ell f(sig)} + T_{wf(\max)} \qquad \text{whichever is greater.}$$

where

T_{mean} = mean mooring line tension due to wind, current and mean (steady) drift force.

$T_{\ell f(sig)}$ = significant single amplitude low frequency tension.

$T_{wf(sig)}$ = significant single amplitude wave frequency tension.

The maximum values of low frequency tension, $T_{\ell f(\max)}$, and wave frequency tension, $T_{wf(\max)}$, are to be calculated in the same procedure as that of obtaining the motions at wave frequency and low frequency described in 6-1-1/3.3.

3.7 Mooring Line Fatigue Analysis

The fatigue life of mooring lines is to be assessed using the *T-N* approach, using a *T-N* curve that gives the number of cycles, N, to failure for a specific tension range, T. The fatigue damage ratio, D_i, for a particular sea state, i, is estimated in accordance with the Miner's Rule, as follows:

$$D_i = \frac{n_i}{N_i}$$

where

n_i = number of cycles within the tension range interval, i, for a given sea state.

N_i = number of cycles to failure at tension range, i, as given by the appropriate *T-N* curve.

The cumulative fatigue damage, D, for all of the expected number of sea states, NN (identified in a wave scatter diagram), is to be calculated as follows:

$$D = \sum_{i=1}^{NN} D_i$$

D is not to exceed unity for the design life, which is the field service life multiplied by a factor of safety, as specified in 6-1-1/Table 1.

It is recommended that a detailed fatigue analysis following the procedure outlined in API RP 2SK be performed for the permanent mooring system.

The fatigue life of each mooring line component is to be considered. *T-N* curves for various line components are to be based on fatigue test data and a regression analysis.

5 Mooring Line Design

The mooring lines are to be designed with the factors of safety specified in 6-1-1/Table 1 with respect to the breaking strength and fatigue characteristics of mooring lines. These factors of safety are dependent on the design conditions of the system, as well as the level of analyses. Allowances for corrosion and abrasion of a mooring line should also be taken into consideration. See API RP 2SK for detailed recommendations.

TABLE 1
Factor of Safety for Anchoring Lines

		Factor of Safety
All Intact		
Dynamic Analysis	(DEC)	1.67
Quasi-Static	(DEC)	2.00
One broken Line (at New Equilibrium Position)		
Dynamic Analysis	(DEC)	1.25
Quasi-Static	(DEC)	1.43
One broken Line (Transient)		
Dynamic Analysis	(DEC)	1.05
Quasi-Static	(DEC)	1.18
Mooring Component Fatigue Life w.r.t. Design Service Life		
Inspectable areas		3.00
Non-inspectable and Critical Areas		10.00

7 Hawser Loads

Hawsers that are used to temporarily secure installations to the component which is permanently anchored to the seabed are to meet the requirements of the *Single Point Mooring Rules*.

9 Dynamic Positioning Systems

Dynamic positioning systems installed for position mooring purposes will be subject to approval in accordance with the requirements of the ABS *Guide for Dynamic Positioning Systems*.

11 Thruster Assisted Mooring Systems

Where Floating Installations are equipped with thrusters to assist the mooring system, the thrusters are subject to approval in accordance with Section 4-3-5 of the *Steel Vessel Rules*. The contribution of the thrusters in the mooring system design will be reviewed on a case-by-case basis.

13 Mooring Equipment *(2014)*

13.1 General

Mooring equipment for Floating Installations includes winches, windlasses, chain, wire rope, in-line buoys and fairleads. Anchors and single point mooring mechanical systems are addressed elsewhere in this Chapter.

For the review of mooring equipment, ABS will apply the published ABS requirements for such equipment. In instances where ABS does not have published requirements, the equipment will be reviewed for compliance with applicable recognized industry standards. The applicable references to ABS publications and industry standards are listed below:

- *Buoyancy Tanks* — ASME Boiler and Pressure Vessel Code
- *Chain* — ABS *Offshore Mooring Chain Guide*
- *Fiber Ropes* — ABS *Fiber Ropes Guidance Notes*
- *Wire Rope* — API Spec 9A and RP 9B

For a winch intended for mooring line hook-up and future retensioning activities, the equipment needs to be in compliance with recognized industry standards. The manufacturer needs to submit details to demonstrate compliance with the industry standards, either in the form of certificates issued by recognized certification bodies or by submitting details and calculations to ABS for review and approval.

Complete details and supporting calculations, including fatigue analysis, of the structural and mechanical components used in position mooring systems (e.g., connecting links, shackles, chain stoppers, fairleads, etc.), which transmit the mooring loads, are to be submitted.

In general, the structural and mechanical components used in position mooring systems (e.g., connecting links, shackles, chain stoppers, fairleads, etc.), which transmit the mooring loads, are to be designed to the Minimum Breaking Load (MBL) of the mooring line. The computed stress obtained from FE analysis is to be limited to minimum specified yield strength. Local stress due to large contact pressure obtained from FE analysis is to be limited to 3 times the minimum specified yield strength.

The fatigue life for inspectable and repairable structural and mechanical components used in position mooring systems is not to be less than 3 times the service life. For those that cannot be readily inspected and repaired, the fatigue life is to be at least 10 times the service life.

The attachments to the hull or structure are to be such as to withstand the stresses imposed when the mooring line is loaded the Minimum Breaking Load (MBL) of the mooring line. Allowable stress is to comply with 5A-1-4/5.1.1 of this Guide.

13.3 Chain Stoppers

The chain stoppers are to be so designed that additional bending of the individual link does not occur and the links are evenly supported.

The strength analysis is to include the most unfavourable direction of the mooring line.

The chain stoppers are to be function tested at the specified proof load to the satisfaction of the attending Surveyor.

Position mooring systems without chain stoppers will be specially considered.

13.5 Fairleads and Sheaves

Fairleads and sheaves are to be designed to prevent excessive bending and wear of the mooring lines. Sharp edges at the interface structures with the mooring line are to be avoided.

Fairleads used in position mooring system are to be provided with sheave to rope diameter ratio of 40-60 to minimize tension-bending fatigue. 7 to 9 pocket wildcat sheaves are recommended for chain. Other constructions which provide similar or better support may be considered.

The strength analysis is to include the most unfavourable direction of the mooring line.

Corrosion allowance or suitable cathodic protection is to be considered for underwater fairleads.

The fairleads are to be function tested at the specified proof load to the satisfaction of the attending Surveyor.

PART

6

CHAPTER 1 Position Mooring Systems

SECTION 2 Anchor Holding Power

Different types of foundation systems used for floating installations are drag anchors, pile anchors, vertically loaded anchors (VLAs) and suction piles. Gravity boxes, grouted piles, templates, etc., may also be used and are considered to be within the scope of classification.

1 Drag Anchor

For a mooring system with drag anchors, the mooring line length should be sufficiently long such that there is no angle between the mooring line and the seabed at any design condition, as described in 3-2-3/1. For soft clay (in Gulf of Mexico) condition, a small angle for the damaged case with one broken line may be considered by ABS on a case-by-case basis.

Drag anchor holding power depends on the anchor type, as well as the condition of the anchor deployed in regard to penetration of the flukes, opening of the flukes, depth of burial, stability of the anchor during dragging, soil behavior of the flukes, etc. The designer should submit to ABS the performance data for the specific anchor type and the site-specific soil conditions for the estimation of the ultimate holding capacity (UHC) of an anchor design. Because of uncertainties and the wide variation of anchor characteristics, exact holding power is to be determined after the anchor is deployed and test loaded.

The maximum load at anchor, F_{anchor}, is to be calculated, in consistent units, as follows:

$$F_{anchor} = P_{line} - W_{sub}WD - F_{friction}$$

$$F_{friction} = f_{s\ell}L_{bed}W_{sub}$$

where

P_{line}	=	maximum mooring line tension
WD	=	water depth
$f_{s\ell}$	=	frictional coefficient of mooring line on sea bed at sliding
L_{bed}	=	length of mooring line on seabed at the design storm condition, not to exceed 20 percent of the total length of a mooring line
W_{sub}	=	submerged unit weight of mooring line

Note: The above equation for F_{anchor} is strictly correct only for a single line of constant, W_{sub}, without buoys or clump weights. Appropriate adjustments will be required for other cases.

The coefficient of friction $f_{s\ell}$ depends on the soil condition and the type of mooring line. For soft mud, sand and clay, the following values (from API RP 2SK) of $f_{s\ell}$ along with the coefficient of friction at start f_{st} for wire rope and chain may be considered representative:

	Coefficient of Friction, f	
	Starting (f_{st})	*Sliding ($f_{s\ell}$)*
Chain	1.00	0.70
Wire Rope	0.60	0.25

3 Conventional Pile

Conventional pile anchors are capable of withstanding uplift and lateral forces at the same time. Analysis of the pile as a beam column on an elastic foundation is to be submitted to ABS for review. The analyses for different kinds of soil using representative soil resistance and deflection (*p*-*y*) curves are described in the ABS *Offshore Installations Rules*, API RP2A and API RP 2T, as applicable. The fatigue analysis of the pile should be submitted for review.

5 Vertically Loaded Drag Anchors (VLA)

VLAs can be used in a taut leg mooring system with approximately a 35 to 45 degree angle between the seabed and the mooring lines. These anchors are designed to withstand both the vertical and horizontal loads imposed by the mooring line. The structural and geotechnical holding capacity design of the VLA are to be submitted for review. This is to include the ultimate holding capacity and the anchor's burial depth beneath the seabed. Additionally, the fatigue analysis of the anchor and the connectors joining the VLA to the mooring line should be submitted for review.

The safety factors of VLA anchors' holding capacity are specified in 6-1-2/Table 1.

TABLE 1
Factor of Safety for Anchor Holding Capacities*

		Factor of Safety
Drag Anchors		
Intact Design	(DEC)	1.50
Broken Line Extreme	(DEC)	1.00
Vertically Loaded Anchors (VLAs)		
Intact Design	(DEC)	2.00
Broken Line Extreme	(DEC)	1.50
One broken Line (Transient)		
Dynamic Analysis	(DEC)	1.05
Quasi-Static	(DEC)	1.18
Pile Anchors		
Refer to API RP 2A, API RP 2T as applicable		
Suction Piles		
Intact Design	(DEC)	1.5 to 2.0*
Broken Line Extreme	(DEC)	1.2 to 1.5*

* The safety factor to be used in the design should be based on the extent of the geotechnical investigation, confidence in the prediction of soil-pile behavior, experience in the design and behavior of suction piles in the area of interest, and the inclination of the mooring line load.

7 Suction Piles

Suction pile anchors are caisson foundations that are penetrated to the target depth by pumping out the water inside of the pile to create underpressure within the pile. They may typically consist of a stiffened cylindrical shell with a cover plate at the top and an open bottom and generally have larger diameters and are shorter in length than conventional piles. These piles can be designed to have a permanent top or a retrievable top depending on the required vertical holding capacity. The padeye for the mooring line connection can be at the top or at an intermediate level depending on the application of the suction pile.

Suction pile anchors are capable of withstanding uplift and lateral forces. Due to the geometry of the suction piles, the failure modes of the soils may be different than what are applicable for long slender conventional piles. The safety factors for the suction piles' holding capacity are specified in 6-1-2/Table 1.

Geotechnical holding capacity and structural analyses for the suction piles are to be submitted to verify the adequacy of the suction piles to withstand the in-service and installation loads. Additionally, fatigue analysis of the suction piles are to be submitted to verify the adequacy of the fatigue life of the critical locations.

Installation analyses are to be submitted to verify that the suction piles can be penetrated to the design penetration and that the suction piles can be retrieved, if necessary. It is suggested that a ratio of at least 1.5 between the force that would cause uplift of the soil-plug inside of the pile and the effective pile installation force be considered in the penetration analysis.

9 Factor of Safety

The factors of safety for anchor holding capacity in the design of drag anchors, VLAs and suction piles are specified in 6-1-2/Table 1. The required ultimate holding capacity should be determined based on mooring line loads derived from a dynamic analysis to account for mooring line dynamics. Conventional pile anchors should meet the recommended factors of safety as specified in the ABS *Offshore Installations Rules*, API RP2A, and API RP2T, as applicable.

PART

6

CHAPTER 1 Position Mooring Systems

SECTION 3 Field Test

After the mooring system is deployed, each mooring line will be required to be pull-tested. During the test, each mooring line will be pulled to the maximum design load determined by dynamic analysis for the intact design condition and held at that load for 30 minutes. For certain high efficiency drag anchors in soft clay, the test load may be reduced to not less than 80 percent of the maximum intact design load. For all types of anchors, the attainment of design-required minimum soil penetration depth is to be verified at the site.

ABS will determine the necessity of a maximum intact design tension pull test depending on the extent of the geotechnical investigation, the magnitude of loading, analytical methods used for the geotechnical design and the experience with the soils in the area of interest. For suction piles, ABS will also review the pile installation records to verify the agreement between the calculated suction pressures and the suction pressure used to install the suction piles. For conventional piles, ABS will review the pile installation records to verify the agreement between the calculated pile driving blow counts and the actual blow counts required to drive the piles to the design penetration.

If the maximum intact design tension pull tests are waived, ABS will require preloading each anchor to a load that is necessary to develop the ultimate holding capacity of the anchor, but not less than the mean intact design tension, and to ensure the integrity and alignment of the mooring line.

For a disconnectable mooring system, the pull test load will be the greater of the following two values:

i) Maximum design load for "DISconnecting Environmental Condition (DISEC)", i.e., the limiting extreme environmental condition at which the installation is to be disconnected.

ii) Maximum design load of mooring line for the "Design Environmental Condition (DEC)" without the installation, i.e., the disconnected mooring system alone.

PART
6

CHAPTER 2 Single Point Mooring Systems

CONTENTS

PART

6

CHAPTER 2 Single Point Mooring Systems

SECTION 1 CALMs, SALMs, Turrets and Yokes

1 Design Loadings

The design of structural and mechanical components is to consider the most adverse combination of loads, including, but not limited to, those listed below, and is to be submitted for review.

1. Dead Loads
2. Dynamic Loads due to motions
3. Mooring Loads
4. Fatigue Loads

3 Structural Components

In general, structural components are to be designed to a recognized code or standard. The structural and buoyancy elements of CALMs and SALMs are to comply with the requirements of the *Single Point Mooring Rules*. Minimum mooring turret and yoke arm scantlings are to comply with 3-2-4/5 of the *MODU Rules*. (Also see 5A-1-4/3 of these Rules for single point mooring foundation strength criteria.)

5 Mechanical Components

Mechanical components of an SPM usually include the Product Distribution Unit (PDU), bearings, driving mechanisms and various types of connectors. The *Single Point Mooring Rules* are generally applicable to these components, and in cases where specific requirements are not addressed in the *Single Point Mooring Rules*, the Bureau will review those components for compliance with the following standards and codes:

Product Distribution Unit	ASME Boiler and Pressure Vessel Code AISC Steel Code ANSI B31.3 (for Pipe Swivels)
Bearings	AFBMA Codes (Anti Friction Bearing Manufacturers Association ASME 77-DE-39
Connectors: driving mechanisms	ASME Boiler and Pressure Vessel Code AISC Steel Code API Standards as applicable

Ancillary mechanical components, such as structural connectors, uni-joints, chain jacks, turret retrieval mechanisms, hoists, winches, quick connect and disconnect devices, are to be designed in accordance with applicable industry standards, codes and published recommended practices.

7 Hazardous Areas and Electrical Installations

Requirements for hazardous areas and electrical installations are in Part 4, Chapter 3 of the *Single Point Mooring Rules*.

9 Fire Fighting Equipment

Fire fighting equipment is to comply with 4-4-1/3 of the *Single Point Mooring Rules*. Additionally, for internal turret mooring arrangement, fire fighting equipment is to comply with the applicable requirements in 3-8/5.15 of the *Facilities Rules*.

11 Product Piping Systems and Floating Hoses

Product piping systems and floating hoses are to comply with the applicable requirements of the *Single Point Mooring Rules* and *Facilities Rules*.

13 Turret Mooring *(December 2008)*

A turret mooring system is one type of station keeping system for a floating installation and can either be installed internally or externally. Both internal and external turret mooring systems will allow the installation to weathervane around the turret. The mooring lines are fixed to the sea bottom by anchors or piles.

For an internal turret system, the turret is supported in the installation by a system of bearings. The loads acting on the turret will pass through the bearing system into the installation. Typically, a roller bearing is located near the installation deck level, and radial sliding bearing is located near the keel of the installation. For an external turret mooring system, the installation is extended to attach the turret mooring system at the end of the installation.

The loads acting on an internal turret system include those basic loads induced by the mooring lines, risers, gravity, buoyancy, inertia and hydrostatic pressure. Other loads, such as wave slam and loads resulting from misalignment and tolerance, that may have effect on the turret should also be considered in the design. In establishing the controlling turret design loads, various combinations of installation loading conditions ranging from the full to minimum storage load conditions, wave directions, and both collinear and non-collinear environments are to be considered. The mooring loads and loads applied to the external turret structure are transferred through its bearing system into the installation. The load range and combinations to be considered and analysis methods are similar to those stated for an internal turret mooring system, with additional consideration of environmentally-induced loads on the turret structure.

A structural analysis using finite element method is required to verify the sufficient strength of the turret structure. The allowable von Mises stress of the turret structure is to be 0.7 of the yield strength for the operational intact mooring design conditions, as specified in 3-2-3/1.3. The von Mises stress allowed for the design storm intact mooring design conditions and for the design storm one-line broken mooring condition are 0.9 and 1.0 of the yield strength, respectively, to verify the turret structure mooring attachment locations and supporting structure.

Note: The yield strength is to be based on the specified minimum yield point or yield stress as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for higher strength material or 72 percent of the specified minimum tensile strength, whichever is the lesser.

The buckling strength check for the turret structures is to be performed using the criteria in Part 5A of these Rules, API RP 2U, 2V or other applicable industry standards. A fatigue evaluation of the turret system using a spectral method or other proven approaches is needed to determine the fatigue lives for the turret components. Fatigue life of the turret should not be less than three times the design life for inspectable areas and 10 times for uninspectable areas.

15 Turret/Installation Structural Interface Loads

The installation structure in the way of the turret mooring system interface is to be capable of withstanding forces (obtained as the maximum of all the design conditions considered) from the systems and is to be suitably reinforced.

Mooring forces transmitted to the installation's supporting structure by the turret mooring system are to be determined by an acceptable engineering analysis. The transmission and dissipation of the resulting mooring forces into the installation's structure are required to be determined by an acceptable engineering method, such as finite element analysis. The loads acting on the installation's supporting structures due to the turret system are mainly transmitted through the upper and lower bearings. The loading conditions are chosen to cause the most unfavorable loads and the load combinations that may occur. The derivation of mooring loads is to be determined as described in 6-2-1/13, "Turret Mooring". The structural model used in the finite element analysis for the installation's supporting structure should extend to a reasonable distance of the installation to minimize the effects due to the boundary conditions.

17 Submerged Buoys Structure *(2014)*

The submerged buoy structure that forms part of the positioning mooring system for a floating installation is to be capable of withstanding the design forces during the following design conditions.

1. Design Environmental Condition (DEC) defined in 3-2-3/1.1
2. DISconnecting Environmental Condition (DISEC) defined in 3-2-3/1.1 (if applicable)
3. Design Installation Condition (DIC) defined in 3-2-3/1.5

The design of the submerged buoy structure is to consider the most adverse combination of loads, including, but not limited to, those listed below.

i) Risers and mooring loads

ii) Swivel stack load

iii) Bearings load

iv) Hook-up or pull-in loads

v) Inertia loads

vi) Loads induced by the holding device and contact points with the hull when connected to the floating installation

vii) Hydrostatic pressure

viii) Accidental flooding of a single compartment when not connected to the floating installation

When the buoy structure is connected to the floating installation, reference should be made to design conditions, as specified in 6-2-1/13.

The fatigue life of the submerged buoy is to be at least 10 times the service life of the unit.

Suitable protective coating with sacrificial anodes is to be provided for the submerged buoy.

17.1 Submerged Condition

The *Submerged Condition* is defined as the condition in which the buoy not connected to the floating installation and is submerged in water with risers and mooring lines hooked-up to the buoy.

For permanently moored unit, the maximum submerged depth of the buoy should be determined considering the dynamic motion induced for the worst anticipated environment during the proposed submerged period prior to hook-up to the floating installation. The selected environment is to be based on the site metocean data and agreed by ABS. The selected environment is not to be lower than that defined for the DIC.

For disconnectable unit, the maximum submerged depth of the buoy should be determined considering the dynamic motion induced for the DEC.

Structural adequacy for accidental flooding condition with single compartment damaged is to be studied. Alternative acceptance criteria for this accidental flooding condition can be considered on a case-by-case basis.

The submerged buoy with accidental flooding of a single compartment is to have sufficient buoyancy for supporting the mooring, riser system and any ballast when not connected to the floating installation. Stability is to comply with Section 3-3-1 of the *Single Point Mooring Rules*, where applicable.

PART

6

CHAPTER 3 Mooring System Surveys

CONTENTS

PART
6

CHAPTER 3 Mooring System Surveys

SECTION 1 Surveys During Construction

Items of equipment to be used in a mooring system are to be examined during the fabrication process, and testing is to be performed to the satisfaction of the attending Surveyor.

Components fabricated by welding are to meet the requirements of Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)* and are to be to the Surveyor's satisfaction. Specifications to be used for chain, wire rope and connecting hardware are to be submitted for review. Physical testing, including break, pull, dimensional and nondestructive testing, is required to be performed in accordance with the submitted specifications to the satisfaction of the attending Surveyor.

PART

7

Surveys

CONTENTS

PART

7

CHAPTER 1 Surveys During Installation and Commissioning

(1 July 2012)

CONTENTS

PART

7

CHAPTER 1 Surveys During Installation and Commissioning

SECTION 1 General

1 General

The requirements in this Chapter apply to the ABS approved procedures and the surveys to be performed on any type of Floating Production Installation (FPI).

Prior to carrying out the on-site installation, the ABS approved installation procedures are to be made available to the Surveyor. The ABS approved installation procedures are to at least cover the following, where applicable.

3 Pre-installation Verification

Pre-installation verification procedures for the seabed condition in way of the installation site and contingency procedures for removing any obstacles found on site.

5 Pile or Anchor and Mooring Line Installation

Pile or anchor and mooring line installation procedures which are to include, but are not limited to, the following:

i) General preparations for installation.

ii) Rigging arrangements for piles, chaser pile and driving hammers.

iii) Work barge setup during the various phases of installation, taking into consideration the prevailing weather conditions.

iv) Anticipated pile driving resistance.

v) Pile penetration acceptance criteria established by design and pile refusal and overdrive contingency procedures.

vi) Procedure for positioning of the pile orientation toward the center of the Position Mooring System and the criteria for allowable deviations of position and orientation.

vii) Procedure for installation of the mooring line and the precautions to be taken in order to prevent any twisting of the mooring chains during installation.

viii) Procedure for installation of anchors, including piggyback anchors, if applicable, and procedure for determining the installed positions and orientations of the anchors. Criteria for allowable deviations in positioning and orientation are also to be included.

7 Tensioning and Proof Load Testing

Tensioning and proof load testing procedures of the anchor piles or anchors and chain system are to include the following:

i) Rigging arrangements for proof load tension testing of the mooring chains, anchor or pile system.

ii) Work barge setup to perform the proof load testing of the chains and anchor or pile system.

iii) Detailed tensioning procedure, including type of tensioning device to be utilized and tensioning operations.

iv) Chain retrieval and abandonment procedures during tensioning.

v) Procedure for chain proof load tensioning by ballasting the FPI, if applicable.

9 Hook-up of the Anchor Chain System

Procedure for hook-up of the anchor chain system to the FPI, which is to include the following:

i) Rigging and towing procedures for positioning of the FPI for hook-up to the mooring system.

ii) Preferred ballast condition of the Floating Installation prior to the hook-up.

iii) Procedure for sequential hook-up of the chains, repositioning of the FPI and tensioning of the chains.

iv) Method of determining the correct tension of the chains and the acceptable design tolerance.

v) Procedure for determining the positioning of the SPM system relative to the PLEM or wellhead and the acceptable design tolerance for the position of the SPM center relative to the PLEM or wellhead.

vi) Method of securing the chain turntable from movement and the overall safety precautions for the entire hook-up installation.

vii) Procedure for chain tensioning by ballasting the Floating Installation, if applicable.

11 Import/Export System Installation

The Import/Export System installation procedure which verifies that all appropriate installation loadings have been considered. The manual is to describe procedures to be employed during the installation of the import/export systems. In addition, the manual is to include a list of allowable environmental limits under which system installation may proceed. Abandonment procedures, retrieval procedures and repair procedures are to be supplied, when deemed necessary.

11.1 Rigid and Flexible Risers

The procedure to hook-up the import/export risers to the FPI is to include the following items, where applicable:

i) Handling and rigging of the rigid and flexible riser during installation.

ii) Positioning of the work barge for the various phases of the installation.

iii) Procedure for installation of the buoyancy tank and arch support and clump weight, if applicable, including steps to avoid riser interference and precautions against damaging the riser during installation.

iv) Tie-in rigging technique for hook-up of both ends of the risers.

v) Procedure for hydrostatic testing of the risers. Hydrotest pressure and test duration are to be in accordance with API or other recognized code of practice.

11.3 Export Vessel Transfer System

The procedures for installing the export system are to include the following items, as applicable:

i) Rigging, handling and make-up of the export hose system and precautions against damage during installation.

ii) Fitting of all the necessary accessory and navigational aids.

iii) Procedure for paying out of the hose string into the sea.

iv) Procedure for filling and testing the hose string. The required design and testing pressure and testing duration are to be provided.

13 Disconnecting Procedure

For disconnectable mooring systems, the procedures for the disconnecting and connecting of the FPI's mooring system are to include the abandonment and retrieval of the import and export systems. (Also see 1-1-4/11 of these Rules for Operating Manual requirements.)

PART
7

CHAPTER 1 Surveys During Installation and Commissioning

SECTION 2 Surveys During Hook-up

1 General

Survey during the hook-up onboard FPIs, whether classed as an FOI or not, is mandatory. Survey during hook-up is to be performed following reviewed procedures and is to include the following, where applicable.

3 Piping Systems

Piping hook-up is to be verified for compliance with the reviewed drawings and procedures. Welds are to be visually inspected and nondestructive testing (NDT) performed as required. Upon completion of hook-up, the affected sections are to be hydrostatically tested to 1.5 times the design working pressure and proven tight.

5 Electrical Systems

Electrical hook-up is to be verified for compliance with the approved drawings and procedures. Proper support for cables and proper sealing of cable entries to equipment are to be verified. Upon completion of the hook-up, the affected sections of the equipment and cabling are to be insulation tested and proven in order. All grounding is also to be verified as being in order.

7 Instrumentation

Instrumentation hook-up is to be verified for compliance with the reviewed drawings and procedures. Tubing supports are to be verified. Upon completion, all systems are to be functionally tested and proven as being in order. The manufacturer's limits on bend radii for any component of the instrumentation system are to be observed.

9 Mechanical Equipment

Mechanical equipment hook-up is to be verified for compliance with the reviewed drawings and procedures, including the grounding of the equipment. Upon completion, all equipment is to be functionally tested and proven as being in order.

PART
7

CHAPTER 1 Surveys During Installation and Commissioning

SECTION 3 Surveys of the Mooring System

1 General

Survey of the mooring system of all type of FPIs, whether classed as an FOI or not, is mandatory. During installation of the FPI's mooring system, the requirements as contained in this Section are to be verified or witnessed, where applicable, by the attending Surveyor.

3 Certification of Components and Transit Damage Survey

All applicable components required to be certified at the manufacturers' facilities have received certification.

All mooring components are to be examined for transit damages prior to installation. Any damages found are to be dealt with to the satisfaction of the attending Surveyor.

5 Survey of the Installation Site

The area at and in the vicinity of the mooring site is to be surveyed by divers or remotely operated vehicles (ROVs) to confirm that there are no obstructions or debris prior to installation.

7 Installation of Anchors/Piles and Mooring Lines

7.1 Anchors or Piles

During the installation of the anchors or anchor piles, the following are to be verified in order, where applicable:

i) Proper locking of all connecting shackles from chains to piles or anchors and chains to chains.

ii) Sealing of all Kenter shackle locking pins.

iii) All complements of anchor chains for correct sizes and lengths.

iv) All anchor pile or anchors are installed in the designed positions and orientations and are within the allowable design tolerance.

7.3 Mooring Lines

During the installation of the mooring lines, the following are to be verified in order, where applicable:

i) The paying out of the anchor chains after the installation of the piles is to be performed in accordance with the approved procedures.

ii) Unless otherwise approved by the attending Surveyor, the first pair of anchor chains to be cross-tensioned is the first pair to be installed.

iii) The cross-tensioning is to be verified to confirm all pretensioning loads are in accordance with the design and there is no movement or pullout of the anchor piles.

iv) Upon successful completion of the pretensioning, the subsequent hooking up of all of the chain legs to the chain stoppers in the turntable is to be verified.

v) During tensioning of the chains for the position mooring system, the relative position of the mooring system's center to the PLEM is to be verified for compliance with the design specifications and tolerance.

vi) Upon completion, the chain tension is to be verified by measuring the catenary angles of the chains for compliance with the design specifications and tolerance. Any excess length of chain above the chain stoppers is to be removed, unless it is designed to be retained in the chain well.

PART
7

CHAPTER 1 Surveys During Installation and Commissioning

SECTION 4 Surveys of the Import/Export System

1 General

Survey of the import/export system is required only if the system is to be classed with ABS and to be recommended with the optional classification notations explained in Section 1-1-2 of these Rules, Where the import/export system is to be classed, during installation of the system, the following items are to be witnessed by the Surveyor, as applicable.

3 Certification of Components and Transit Damage Survey

All applicable components required to be certified at the manufacturers' facilities have received certification.

The riser is to be examined for damage as it is being paid out, and sufficient tension is to be maintained to keep the riser free of deformations or buckles.

5 Buoyancy Tank and Arch Support

The buoyancy tank and arch support are to be verified as being installed in the correct position relative to the water surface end of the riser.

7 Installation of Riser Clamps and End Flanges

The installation of the riser clamps on the buoyancy tank and arch support are to be monitored to verify that the riser is adequately secured and not damaged due to excessive tightening of the clamps.

The installation of the end flanges of the riser is to be monitored for compliance with the approved procedures.

9 Underwater Examination

Upon completion of installation, the entire underwater complement of components is to be generally examined and verified by divers or ROVs for compliance with the reviewed design specifications and configurations. At a site with limited visibility, alternative means of verifying the installation are to be submitted for review and are to be performed to the satisfaction of the attending Surveyor.

11 Hydrostatic Testing

Hydro testing of the import/export system is to be performed in accordance with the approved procedure. The test pressure and duration of the hydro test are to follow the appropriate codes, such as ANSI/ ASME B31.8, API RP 2RD and RP 17B.

13 Floating Hose String

The make-up of the export floating hose string is to be verified for compliance with the approved procedures. Suitable gaskets for the hose flanges, positioning of all navigational aids, correct location of the breakaway couplings and tightening of the flange bolts are also to be verified.

During the paying out of the hose string, verification is to be made that the hose string bend radii are not smaller than the manufacturer's recommended limits.

Upon completion of installation, the entire export hose string is to be hydrostatically tested in accordance with the approved procedure and codes, such as the *OCIMF Guidelines for the Handling, Storage, Inspection, and Testing of Hoses in the Field.*

15 Subsea Control System

Subsea controls, if installed, are to be satisfactorily tested.

17 Navigational Aids

All navigational aids are to be functionally tested and proven in working order.

PART

7

CHAPTER 1 Surveys During Installation and Commissioning

SECTION 5 Surveys of the Disconnectable System

1 General

Survey of the disconnectable mooring system is required only if the system is to be classed with ABS and to be recommended with the optional classification notations explained in Section 1-1-2 of these Rules, Where the disconnectable system is to be classed, the system together with system's capability to disconnect free from its mooring system is to be demonstrated to the satisfaction of the attending Surveyor, in accordance with approved test procedures.

3 Disconnecting Time

During the disconnect operation, the time taken to effectively free the Floating Installation from the mooring system is to be recorded in the operation manual.

PART
7

CHAPTER **1** **Surveys During Installation and Commissioning**

SECTION **6** **Surveys During Commissioning**

1 General

Survey of the start up and commissioning of the production facilities is required only if the FPI's production facilities are to be classed with ABS and to be recommended with the optional classification notations explained in Section 1-1-2 of these Rules.

The start-up and commissioning of hydrocarbon production systems are to be verified by the attending Surveyor in accordance with the procedures reviewed and agreed by the attending Surveyor. The scope of the start-up and commissioning to be verified by the Surveyor is to include the following items:

3 Safety and Operational Readiness

Verify precautions for safety of personnel during commissioning, including checks of operational readiness of all life saving equipment, fire and gas detection systems, fire fighting equipment, emergency shutdown systems and unobstructed escape routes.

5 Communication Procedures

Verify establishment of communication procedures prior to the start of commissioning operations.

7 Emergency Procedures

Verify that emergency procedures are provided to deal with contingencies, such as spillage, fire and other hazards. Drills may have to be performed to demonstrate readiness to these procedures.

9 Start-up and Testing of Production Support Systems

Verify start-up and testing of all support utility systems, including main and auxiliary sources, for the process system prior to commissioning.

11 Hook-up and Testing

Verify proper hook-up and testing of the entire process system prior to commissioning, including the testing of entire system for leaks, the process control functions and emergency shutdown system.

13 Purging of the Production System

Verify purging of the entire production system of oxygen to an acceptable level prior to the introduction of hydrocarbons into the production system.

15 Introduction of Hydrocarbons and Control of Flow

Verify the introduction of hydrocarbon into the process system and the system's capability to control the flow of the well effluent in the system in a stabilized manner without undue control upsets.

17 Start-up of the Flare System (if applicable)

Verify the start-up of the flare system, if applicable, including the necessary precautions taken to eliminate the risk of explosion or fire. The functional capability of the flare system is to be verified.

19 Function of the Post Commissioned System

The post-commissioned process system is to be verified for operating satisfactorily for duration of at least 12 hours.

Equipment required verification but not used during initial start-up and commissioning is to be identified for verification at the next Annual Survey.

PART

7

CHAPTER 2 Surveys After Construction *(1 July 2012)*

CONTENTS

PART

7

CHAPTER 2 Surveys After Construction

SECTION 1 Conditions for Surveys After Construction

1 Application

General requirements regarding conditions for surveys after construction are contained in the ABS *Rules for Survey After Construction (Part 7)* and Part 7 of the *Rules for Building and Classing Mobile Offshore Drilling Units* (*MODU Rules*), as applicable. Additional requirements specific to floating production installations are contained in Part 7, Chapter 2, of these Rules.

3 Definitions

3.1 Ballast Tank

A *Ballast Tank* is a tank which is used primarily for the carriage of salt water ballast. Salt water ballast tanks are coated with a corrosion resistant hard coating such as epoxy or zinc on all structural surfaces that may or may not be supplemented by anodes.

3.3 Corrosion

Active Corrosion means gradual chemical or electrochemical attack on a metal resulting from a reaction with its environment and producing loose scale.

Allowable Corrosion or *Wastage Limit* is the acceptable corrosion limit for the installation's structure in a given area. Also known as the *Allowable Limit*.

Excessive Corrosion is an extent of corrosion that exceeds the allowable limit.

Extensive Area of Corrosion is corrosion of hard and/or loose scale, including pitting, over 70% or more of the plating surface in question, accompanied by evidence of thinning.

Grooving Corrosion is a localized, linear corrosion which occurs at structural intersections where water collects or flows. This corrosion is sometimes referred to as "in line pitting attack" and can also occur on vertical members and flush sides of bulkheads in way of flexing.

Localized Corrosion is by name local in nature and may be caused by a local breakdown in coating from contact damage, insufficient preparation or at areas of stress concentration.

Overall Corrosion appears as an non-protective rust which can uniformly occur on tank internal surfaces that are uncoated, or where coating has totally deteriorated. The rust scale continues to break off, exposing fresh metal to corrosive attack. Thickness cannot be judged visually until excessive loss has occurred.

Pitting Corrosion is a localized corrosion of a metal surface that is confined to a small area and takes the form of cavities called pits.

Substantial Corrosion is an extent of corrosion such that assessment of corrosion pattern indicates wastage in excess of 75% of the allowable corrosion, but within the acceptable limits.

Weld Metal Corrosion is defined as preferential corrosion of weld deposit. The most likely reason for this attack is galvanic action with the base metal which may start as pitting and often occurs on hand welds as opposed to machine welds.

3.5 Corrosion Control System

Corrosion Control System may be achieved by application of hard protective coating (usually epoxy coating or equivalent), impressed current cathodic protection (ICCP) system, sacrificial anodes, etc., provided that they are applied and maintained in compliance with the manufacturer's specification.

Corrosion control system for salt water ballast tanks is to be a corrosion resistant hard coating such as epoxy or zinc on all structural surfaces that may or may not be supplemented by anodes. Where a long retention of salt water ballast is expected, special consideration may be given to the use of inhibitors or sacrificial anodes.

3.7 Critical Structural Areas

Critical Structural Areas are locations which have been identified from calculation to require monitoring or from the service history of the subject unit or from similar sister units to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit.

3.9 Girth Belt/Belt (Transverse Section)

A *Girth Belt* includes the following:

Surface-Type Units: Deck, bottom, side shell and longitudinal bulkhead plating and internal framing.

Column-Stabilized Units: Column and bracing plating and internals as deemed necessary. Deck sides and bottom of lower hulls between columns, including internal stiffeners as deemed necessary.

3.11 In-Service Inspection Program (ISIP)

In-Service Inspection Program (ISIP) is a comprehensive program that outlines the procedures to be followed and the inspection frequency of the hull and mooring system of a floating facility. All Column-Stabilized Units (CSUs), Spars or Tension Leg Platforms (TLPs) are to be surveyed in accordance with an ABS approved ISIP plan. For further details, see Section 7-2-4.

3.13 Lightering Service

Lightering Service is the side-by-side mooring of two installations, either while underway or stationary, for the purpose of transferring petroleum cargo, excluding bunkers, from a installation to be lightered to a service vessel. Both the lightered installation and the service vessel are to be considered in lightering service.

3.15 Panel

Panel is the area between adjacent main frames or girders from stiffener to stiffener.

3.17 Survey

Close-up Survey is a survey where the details of structural components are within close visual inspection range of the Surveyor (i.e., normally within hand reach). In the offshore industry, this may be referred as the Close Visual Inspection (CVI).

Overall Survey is a survey intended to report on the overall condition of the structure and to determine the extent of additional close-up surveys. In the offshore industry, this may be referred as the General Visual Inspection (GVI)

3.19 Representative Spaces/Tanks

Representative Spaces/Tanks are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion preventive systems. When selecting representative spaces, account is to be taken of the service and repair history onboard and identifiable critical and/or Suspect Areas.

3.21 Spaces

Spaces are separate compartments including tanks, cofferdams, machinery spaces, voids and other internal spaces.

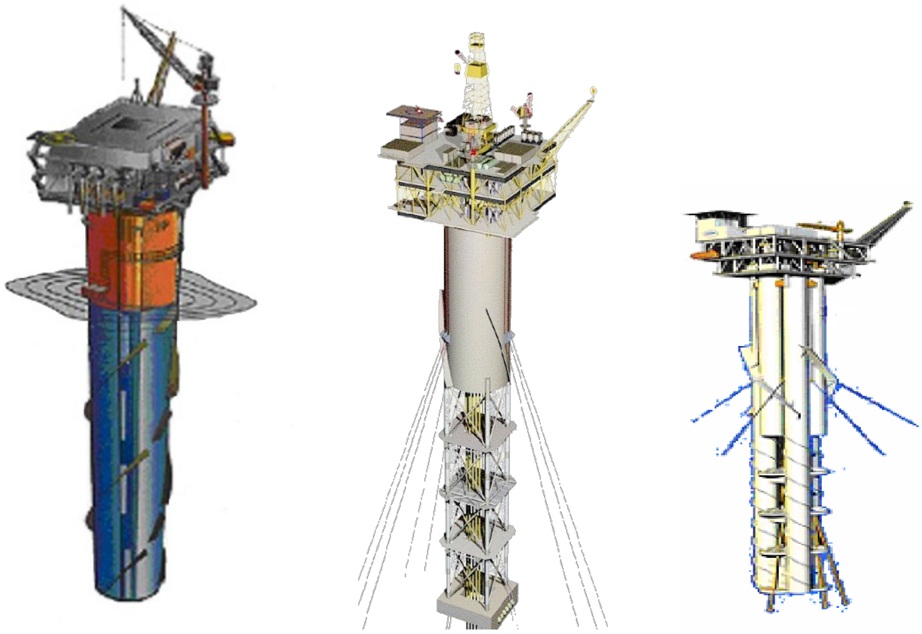
3.23 Spar

Spar is a single column-stabilized production installation that is moored to the seabed with conventional catenary mooring system.

Typical Spar configurations are:

- "Conventional" Spar which has one-piece cylindrical hull.
- "Truss" Spar where the midsection is composed of truss elements connecting the upper buoyant hull (hard tank) with the bottom soft tank containing permanent ballast.
- "Cell" Spar which is built from multiple vertical cylinders.

FIGURE 1
Spar Configurations *(1 July 2012)*



Conventional Spar **Truss Spar** **Cell Spar**

3.25 Splash Zone

Splash Zone on a Tension Leg Platform (TLP) is defined as follows:

- Upper Limit of Splash Zone (above the operating draft) = U1 + U2

  Where U1 = 65% of 1-year storm wave height

  U2 = motion of the installation

- Lower Limit of Splash Zone (below the operating draft) = L1 + L2

  Where L1 = 35% of 1-year storm wave height

  L2 = motion of the installation

Splash Zone on a Column-Stabilized Unit (CSU) or a Spar is defined as follows:

> "Splash Zone" means the external surfaces of the unit that are periodically in and out of the water when the unit is at its operating depth. In general, this zone is between 5m above and 4m below the waterline.

Splash zone of a floating offshore installation is to be defined and recorded for use during visual examinations and hull gauging required during periodical surveys carried out in accordance with these Rules.

3.27 Structural Critical Inspection Point (SCIP)

Structure Critical Inspection Point (SCIP) is a structural point defined in the ISIP (see 9-1-1/13) plan as a critical inspection area as a result of structural assessment using applicable calculations and analysis.

In general, SCIPs are locations with higher stresses and estimated lower fatigue life. These locations are locations which have been identified from calculation to require monitoring or from the service history of the subject unit or from similar sister units to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit.

3.29 Suspect Areas

Suspect Areas are locations showing substantial and/or are considered by the Surveyor to be prone to rapid wastage.

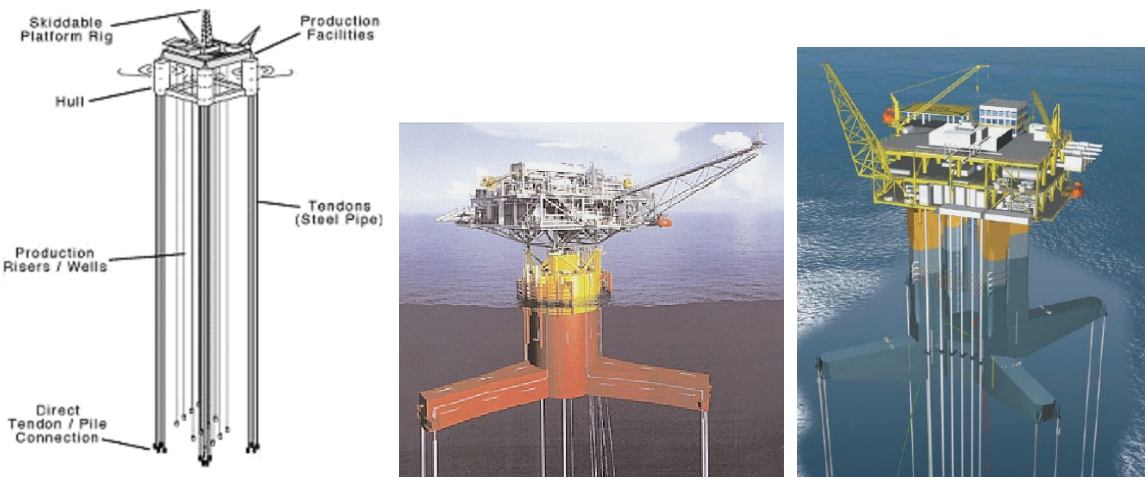
3.31 Tension Leg Platform (TLP)

Tension Leg Platform (TLP) is a floating production installation tethered to the seabed with taut-catenary mooring system in a manner that eliminates most vertical movement of the structure.

Typical TLP configurations are:

- "Conventional" TLP which has four corner columns with a ring pontoon, and has three tendons per corner.
- "Sea-Star" TLP which has one central column with three tendon support structures, and two tendons per support structure. Its mooring system consists of six tendons, top connectors, bottom connectors, top transition joints, bottom transition joints and foundation piles.
- "Moses" TLP which has four inner columns with four tendon support structures, and two tendons per support structure.

FIGURE 2
TLP Configurations *(1 July 2012)*



Conventional TLP **Sea-Star TLP** **Moses TLP**

3.33 Wind and Water Strakes

Wind and Water Strakes on a Column-Stabilized Unit (CSU), Spar and Barge- or Ship-Shaped Unit are the two (2) strakes or equivalent area located in the vicinity of the load waterline, operating draft or operating depth of the unit. For CSUs, this includes portions of columns and bracing members in the vicinity of the operating draft of the unit.

5 Notification and Availability for Survey

The Surveyors are to have access to classed floating production installations at all reasonable times. The Owners or their representatives are to notify the Surveyors on occasions when parts of the structure not ordinarily accessible can be examined.

The Surveyors are to undertake all surveys on classed installations upon request, with adequate notification, of the Owners or their representatives and are to report thereon to ABS. Where the Surveyors find occasion during any survey to recommend repairs or further examination, notification is to be given immediately to the Owners or their representatives in order that appropriate action may be taken. The Surveyors are to avail themselves of every convenient opportunity for performing periodical surveys in conjunction with surveys of damages and repairs in order to avoid duplication of work. See 1-1-8/5 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

7 Damage, Failure, and Repair

7.1 Examination and Repair

Damage, failure, deterioration or repair to the floating production installation or its elements that affects or may affect classification is to be submitted by the Owners or their representatives for examination by the Surveyor at the first opportunity. All repairs found necessary by the Surveyor are to be completed to his satisfaction.

7.3 Repairs

Where repairs to the floating production installation or its elements that may affect classification are planned in advance, a complete repair procedure, including the extent of the proposed repair and the need for the Surveyor's attendance, is to be submitted to and agreed upon by the Surveyor reasonably in advance. Failure to notify ABS in advance of the repairs may result in suspension of the installation's classification until such time as the repair is redone or evidence is submitted to satisfy the Surveyor that the repair was properly completed.

Note: The above applies also to repairs during voyage.

The above is not intended to include maintenance and overhaul to hull, machinery and equipment in accordance with recommended manufacturer's procedures and established marine practice and that does not require ABS approval. Any repair as a result of such maintenance and overhauls that affects or may affect classification is to be noted in the ship's log and submitted to the Surveyors.

7.5 Representation

Nothing contained in this Section or in a rule or regulation of any government or other administration or the issuance of any report or certificate pursuant to this section or such a rule or regulation is to be deemed to enlarge upon the representations expressed in 1-1-1/1 through 1-1-1/7 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*. The issuance and use of any such reports or certificates are to be governed in all respects by 1-1-1/1 through 1-1-1/7 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

7.7 Application of Rules

The applicable ABS Rules to the floating production installation's classification is to be applied to any repair without changing the original design, carried out on the installation's structure, machinery or equipment that affects or may affect classification. Application of the most recent Rules will be specially considered at the Owner's request or otherwise mandated by the current Rules.

9 Alterations/Modifications

No alteration or modification which affect or may affect classification or the assignment of load lines are to be made to the hull or systems of a classed floating production installation unless plans of the proposed alteration or modification are submitted and approved by an ABS Technical Office before the work is commenced, and such work, when approved, is to be performed to the satisfaction of the Surveyor. Nothing contained in this Section or in a rule or regulation of any government or other administration or the issuance of any report or certificate pursuant to this Section or such a rule or regulation is to be deemed to enlarge upon the representations expressed in 1-1-1/1 through 1-1-1/7 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* and the issuance and use of any such reports or certificates are to be governed in all respects by 1-1-1/1 through 1-1-1/7 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

9.1 Application of Rules

The applicable ABS Rules to the floating production installation's classification are to be applied to minor alteration/modification carried out on the unit, including its structure, machinery or equipment, that affects or may affect classification. Application of the most recent Rules will be specially considered at the Owner's request or otherwise mandated by the current Rules.

The following cases may be considered as a major alteration or modification, and therefore require compliance with up-to-date Rules for the section being altered or modified:

- Changing configuration or material of structure that is defined as "Special Application Structure" or "Primary Application Structure" in accordance with these Rules.
- Changing a marine piping system (such as the ballast systems, bilge system, propulsion system, etc.) with all of its components (piping, valves, pumps, etc.).
- Changing a marine electrical system (such as the main power distribution, emergency power distribution, electrical propulsion system, etc.) with all of its components (cabling, electrical motors/pumps, panels, etc.).
- Changing layout and material used in the passive fire protection system, such as more than 10% of deck area alteration or modification to the footprint of the accommodation deckhouse/superstructure or its material used for fire protection.

  Note: Adding another deck on top of an existing accommodation deckhouse is not considered to be a major modification of the entire deckhouse.

- Changing an active fire protection system (such as the fixed-fire fighting system, fire and gas detection system, etc.) with all of its components (piping, pumps, hoses, panels, alarms, detectors, etc.).

11 Welding and Replacement of Materials

11.1 Ordinary and Higher Strength Structural Steels

Welding or other fabrication performed on the structural steels listed in 2-1-2/Table 5 and 2-1-2/Table 5 of the ABS *Rules for Materials and Welding (Part 2)* is to be in accordance with the requirements in Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)*.

11.3 Special Materials

Welding or other fabrication performed on other steels of special characteristics or repairs or renewals of such steel or adjacent to such steel is to be accomplished with procedures approved for the special materials involved. The procedures are to be in accordance with the information provided in Section 1-1-6 of the *MODU Rules* Supplement to the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* and Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)*.

11.5 Substitutions and Alterations

Substitutions of steel differing from that originally installed, alteration of original structural configuration or change from bolted to welded joint is not to be made without approval by the ABS Technical Office.

13 Corrosion Prevention System – Ballast Tanks

13.1 Corrosion Prevention System

Corrosion protection system for salt water ballast tanks is to be a corrosion resistant hard coating such as epoxy or zinc on all structural surfaces that may or may not be supplemented by anodes. Where a long retention of salt water ballast is expected, special consideration may be given to the use of inhibitors or sacrificial anodes.

13.3 Coating Conditions

Condition of hard coatings is defined as follows:

GOOD is a condition with only minor spot rusting.

FAIR is a condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20 percent or more of areas under consideration, but less than as defined for POOR condition.

POOR is a condition with general breakdown of coating over 20 percent or hard scale at 10 percent or more of areas under consideration.

13.5 Salt Water Ballast Spaces

In salt water ballast spaces, other than double bottom tanks, where poor coating condition is found and Owners or their representatives elect not to restore the coating, where a soft coating has been applied or a protective coating has not been applied, the ballast tanks are to be internally examined at each subsequent Annual Survey.

Double bottom tanks for the purpose of this requirement are those double bottom tanks separate from topside tanks, side tanks or deep tanks.

15 Requirements for Internal Examinations

The following apply to all internal examinations of any spaces adjacent to shell plating, such as tanks, holds, voids or machinery spaces, and are applicable at Annual, Intermediate or Special Periodical Survey.

15.1 Safety

Precautions are to be taken for safety during inspection. Tanks are to be made safe for entry and work.

15.3 Preparation for Survey

In preparation for survey and to allow for a meaningful examination, all spaces are to be cleaned, including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and illumination is to be provided to reveal corrosion, deformation, fracture, damages or other structural deterioration.

15.5 Safe Access into Spaces with Soft Coatings

Where soft coatings are found, safe access is to be provided for the Surveyor to verify the effectiveness of the coatings and to perform an assessment of the conditions of internal structures that may include spot removal of the coating. Where the soft coatings are found no longer effective, the space shall be treated as an uncoated tank and sufficient cleaning, as required by 7-1-1/15.3, is to be performed prior to survey.

15.7 Extent of Overall Survey

Based on conditions found, thickness gauging and means of access to the upper part of the tank or space may be required. Where significant corrosion or structural damage is found, the extent of the overall examination may be expanded to other spaces. The requirements for Close-up Survey and thickness gauging, per Section 7-3-2 of the ABS *Rules for Survey After Construction (Part 7)*, will be applied to barge- and ship-shaped installations in some cases, as described in 7-2-3/3 of these Rules.

15.9 Examination of Plating and Framing

Casings, ceilings or linings, and loose insulation, where fitted, are to be removed as required by the Surveyor for examination of plating and framing.

15.11 Compositions on Plating

Compositions on plating are to be examined and sounded but need not be disturbed if found adhering satisfactorily to the plating.

17 Surveys Using Risk-Based Inspection (RBI) Techniques

A properly conducted Risk-Based Inspection (RBI) plan or Reliability Centered Maintenance (RCM) plan may be credited as satisfying requirements of Survey After Construction for the corresponding installation. The plan is to be in accordance with the ABS *Guide for Surveys using Risk-Based Inspection for the Offshore Industry* or the ABS *Guide for Surveys using Reliability-Centered Maintenance*.

The application of these Guides does not cover any statutory survey requirements that may apply to the installation being considered. Although ABS is authorized to perform statutory surveys on behalf of some authorities, ABS is not in a position to alter or waive them. The cognizant administration or regulatory body is the final determining body for statutory or regulatory requirements under their jurisdiction. The Owner is responsible in developing the inspection plan, to give due consideration to applicable requirements external to ABS.

19 Incomplete Surveys

When a survey is not completed, the Surveyor is to report immediately upon the work done in order that Owners and ABS may be advised of the parts still to be surveyed.

21 Lay-up and Reactivation

ABS is to be notified by the Owner that an installation has been laid-up. This status will be noted in the *Record*, and surveys falling due during lay-up may then be held in abeyance until the installation reactivates. Lay-up procedures and arrangements for maintenance of conditions during lay-up may be submitted to ABS for review and verification by survey.

In the case of installations that have been laid up for an extended period (i.e., six months or more), the requirements for surveys on reactivation are to be specially considered in each case, with due regard being given to the status of surveys at the time of the commencement of the lay-up period, the length of the period and the conditions under which the installation has been maintained during that period.

Where the lay-up preparations and procedures have been submitted to ABS for review and confirmed by Annual Lay-up Surveys, consideration may be given to deducting part or all of the time in lay-up from the progression of survey intervals.

For installations returning to active service, regardless of whether ABS has been informed previously that the installation has been in lay-up, a Reactivation Survey is required.

23 Onboard Documents and Records

The following documents are to be available onboard at all times.

Note: This is applicable to all drilling units built under a contract, signed between the Builder and the Owner, on or after 1 January 2012.

23.1 ABS Reviewed and Stamped Documents

As a minimum, the following documents reviewed and stamped by ABS are to be available onboard the drilling unit for Surveyor's verification and reference during survey after construction:

i) Operating Manual

ii) In Service Inspection Program (ISIP) Plan

iii) Drawings indicating locations of all "Special", "Primary" and "Secondary" application structures as defined in these Rules

iv) Drawings showing all watertight boundaries and access/closing devices for such boundaries

v) Drawings showing the Fire Protection Systems, clearly indicating all fire rated boundaries and access/closing arrangements for such boundaries, including location of fire dampers for 'A' class divisions

vi) Drawings showing the Fire Extinguishing Systems, clearly indicating layout of all fixed and portable fire extinguishing systems. Minor changes to these drawings may be accepted and endorsed by the attending Surveyor, however the endorsed copy of the drawings are to be submitted to ABS engineering at earliest opportunity for record purposes.

vii) Drawings showing layout of all Hazardous Areas, clearly indicating layout of different class hazardous divisions together with access/closing/ventilation arrangements for such division boundaries, the arrangement of ventilation shutdown and alarms, and a listing of Electrical Equipment in Hazardous Areas.

viii) Drawings showing layout of the Emergency Shutdown Systems

ix) Where the floating production installation is classed with a notation affecting its Automation System (such as **ACC**, **ACCU**, **AMCC**, or **AMCCU**), Automation System Operating Manual

x) Where the floating production installation is classed with a **DPS** notation, the Dynamic Positioning System (DPS) Manual and the Failure Modes and Effects Analysis (FMEA)

xi) Where the topside facilities of the floating production installation is also classed, drawings showing layout of the topside Production Facilities and associated Equipment, and a listing of all equipment and components of the Production, Process, and Support Systems

xii) Where the floating production installation is classed with optional **HIMP** Notation, the Owner's Hull Inspection and Maintenance Program (HIMP) used for hull inspection and maintenance purposes is to be available onboard the installation

Minor changes to the drawings regarding fire protection systems, fire extinguishing systems, and listing of electrical equipment in hazardous areas, may be accepted by the attending Surveyor and revised documents endorsed to show Surveyor's verification, however the endorsed copy of the drawings are to be submitted to ABS engineering at earliest opportunity for record purposes.

23.3 ABS Surveyor Reviewed and Endorsed Documents

As a minimum, the following documents endorsed by an ABS Surveyor are to be available onboard the floating production installation for Surveyor's verification and reference during any survey after construction:

i) Construction Booklet.

ii) ABS Certificates for temporary anchoring gear such as the anchors, chains and/or wires, and associated accessories (such as shackles, links, sockets, etc.) used for self-propelled installations units or installed on installations with the Ⓔ notation.

iii) ABS Certificates for all mooring gear components such as the anchors, piles, chains and/or wires, and associated accessories (such as shackles, links, sockets, etc.), tendons, etc., used for station keeping of the installation at its operational site.

iv) Record of all Nondestructive Testing (NDT) of critical structural areas carried out during each Drydocking Survey (or UWILD) or Special Periodical Survey – Hull.

23.5 Records

As a minimum, the following records are to be available onboard the floating production installation for Surveyor's verification and reference during any survey after construction:

i) All abnormalities found, including associated videos and photographic records

ii) All repairs performed on any abnormalities found and any further repetitive abnormalities found subsequent to the repairs

iii) All corrosion protection system maintenance, including records of all cathodic potential readings taken, records of depletion of all sacrificial anodes, impressed current maintenance records, such as voltage and current demands of the system, coating breaks and the monitoring records of the steel material wastage in way of the coating break areas

iv) Any findings of abnormalities by the crew personnel onboard, including all leakages in bulkheads and piping

PART

7

CHAPTER 2 Surveys After Construction

SECTION 2 Survey Intervals

1 In-Service Inspection Program (ISIP) (see Section 7-2-3)

Unless otherwise requested by the owner, all barge- or ship-shaped floating installations are to be surveyed in accordance with proceeding Subsections of this Section. Application of an ISIP to barge- or ship-shaped installations operating within the Outer Continental Shelf (OCS) of the United States of America (USA), Gulf of Mexico (GOM) is mandatory. Application of an ISIP to barge- or ship-shaped installations operating outside of the Outer Continental Shelf (OCS) of the United States of America (USA), Gulf of Mexico (GOM) is optional, and is to be requested by the Owner.

All Column-Stabilized Units (CSUs), Spars or Tension Leg Platforms (TLPs) are to be surveyed in accordance with an ABS approved plan for In-Service Inspection Program. Applicable class surveys of the floating installation's hull structure and mooring system are to be carried out in accordance with the ABS approved ISIP plan.

Unless otherwise requested by the owner, all installations surveyed in accordance with an ABS approved ISIP, are to be surveyed under Continuous Survey of the Hull and Mooring System. The due dates shown in ABS Survey Status are to be per the "Master Inspection Plan" mentioned in 7-2-3/3.5.2ii).

3 Annual Surveys (see Section 7-2-4)

Annual Surveys are to be carried out within three (3) months before or after each annual anniversary date of the crediting of the previous Special Periodical Survey – Hull or original construction date. For installations on Continuous Survey, all Continuous Survey requirements for those parts (items) due are generally to be completed each year. The Annual Survey will not be credited and the Certificate of Classification will not be endorsed unless Continuous Survey items which are due or overdue at the time of the Annual Survey are either completed or granted an extension.

5 Intermediate Surveys (see Section 7-2-5)

Intermediate Surveys are to be carried out either at the second or third Annual Survey or between these surveys.

7 Special Periodical Surveys (see Section 7-2-6)

A Special Periodical Survey is to be completed within five years after the date of build or after the crediting date of the previous Special Periodical Survey. The interval between Special Periodical Surveys may be reduced by ABS under certain circumstances. If a Special Periodical Survey is not completed at one time, it will be credited as of the completion date of the survey, but not later than five years from date of build or from the date recorded for the previous Special Periodical Survey. If the Special Periodical Survey is completed prematurely but within three months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date.

Special consideration may be given to Special Periodical Survey requirements in the case of floating production installations of unusual design, in lay-up or in unusual circumstances. ABS reserves the right to authorize extensions of Rule-required Special Periodical Surveys under extreme circumstances.

A Special Periodical Survey may be commenced at the fourth Annual Survey and be continued with a view to completion by the due date. In connection with the preparation for the Special Periodical Survey, thickness gauging, as required for the forthcoming Special Periodical Survey, are to be taken to the extent accessible and practical in connection with the fourth Annual Survey.

Where the Special Periodical Survey is commenced prior to the fourth Annual Survey, the entire survey is normally to be completed within 12 months if such work is to be credited to the Special Periodical Survey.

7.1 Continuous Surveys

At the request of the Owner, and upon approval of the proposed arrangements, a system of Continuous Survey may be undertaken whereby the Special Periodical Survey requirements are carried out in regular rotation to complete all requirements of the particular Special Periodical Survey within a five-year period. The completion date will be recorded to agree with the original due date of the cycle. If the Continuous Survey is completed prematurely but within three months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date.

ABS reserves the right to authorize extensions of Rule-required Special Continuous Surveys under extreme circumstances.

Each part (item) surveyed becomes due again for survey approximately five years from the date of the survey. For Continuous Surveys, a suitable notation will be entered in the *Record* and the date of completion of the cycle published. If any defects are found during the survey, they are to be dealt with to the satisfaction of the Surveyor.

At a survey approximately four years after each Continuous Survey of Hull has been credited, all accessible thickness gauging, as required for the forthcoming Special Periodical Survey, are to be taken.

7.3 In-line Surveys

All items required to undergo Special Periodical Surveys, including but not limited to hull, machinery, mooring, topside facilities, and automation, are to be carried out at the same time and interval in order that they are recorded with the same crediting date. In cases where damage has necessitated extensive repairs and examination, the survey thereon may, where approved by ABS, be accepted as equivalent to Special Periodical Survey.

9 Drydocking Surveys or Equivalent (see Section 7-2-7)

For units operating in salt water, a minimum of two Drydocking Surveys is to be carried out two times in each five-year Special Periodical Survey period. One such examination is to be carried out in conjunction with the Special Periodical Survey – Hull. In all cases, the interval between any two Drydocking Surveys is not to exceed thirty-six (36) months.

For units operating in fresh water the interval between Drydocking Surveys is not to exceed five years.

Consideration may be given to special circumstances which may justify an extension of the interval. An underwater inspection by a diver may be required for such extensions.

9.1 Underwater Inspection in Lieu of Drydocking (UWILD) Survey

Underwater inspection by diver equivalent to a Drydocking Survey may be carried out at each Drydocking Survey up to and including Special Periodical Survey No. 4.

For each Drydocking after Special Periodical Survey No. 4, requests to carry out an Underwater Inspection in Lieu of Drydocking in accordance with previously approved plans are to be submitted for consideration well in advance of the proposed survey. Approvals to carry out the Underwater Inspection in Lieu of Drydocking after Special Periodical Survey No. 4 are to be made available onboard for the Surveyor's reference.

11 Tailshaft Surveys (see 7-2-8)

11.1 Water-Lubricated Bearings in Fresh Water Exclusively

Survey interval is five (5) years.

11.3 Water-Lubricated Bearings in Fresh Water and Sea Water

i) *Single Screw* – Survey interval is three (3) years.

ii) *Multiple Screw* – Survey interval is five (5) years.

iii) *Continuous Liner or Equivalent* – Survey interval of five (5) years provided:

a) The tailshaft is protected by a continuous metallic liner, or continuous cladding per 4-3-2/5.17.5 of the *Steel Vessel Rules* or fiberglass reinforced plastic coating between liners installed according to approved procedure per 4-3-2/5.17.4 of the *Steel Vessel Rules* which effectively prevents seawater from contacting the steel shaft, or which have shafts of corrosion-resistant materials.

b) In addition to the propeller hub details given in the 4-3-2/Figure 1 of the *Steel Vessel Rules*, the design includes other features that would further reduce stress concentration in the propeller assembly.

11.5 Oil-Lubricated Bearings

Survey interval is five (5) years.

11.7 Extensions – Water-Lubricated Bearings

i) *Extension up to Three (3) Months.* An extension up to three (3) months may be granted by the Surveyor, when requested by the Owner, provided a survey is carried out in accordance with 7-5-1/5.1.1 of the ABS *Rules for Survey After Construction (Part 7)*.

ii) *Extension up to One (1) Year.* An extension up to one (1) year may be granted by the Surveyor, when requested by the Owner, provided a survey is carried out in accordance with 7-5-1/5.1.2 of the ABS *Rules for Survey After Construction (Part 7)*.

11.9 Extensions – Oil-Lubricated Bearings

i) *Extension up to Three (3) Months.* An extension up to three (3) months may be granted by the Surveyor, when requested by the Owner, provided a survey is carried out in accordance with 7-5-1/5.3.1 of the ABS *Rules for Survey After Construction (Part 7)*.

ii) *Extension up to One (1) Year.* An extension up to one (1) year may be granted by the Surveyor, when requested by the Owner, provided a survey is carried out in accordance with 7-5-1/5.3.2 of the ABS *Rules for Survey After Construction (Part 7)*. An additional extension up to one (1) year may be considered, when requested by the Owner, provided a survey is carried out at the end of the first extension period, in accordance with 7-5-1/5.3.2 of the ABS *Rules for Survey After Construction (Part 7)*. No more than two (2) extensions may be granted.

iii) *Extensions not Exceeding Five (5) Years.* In lieu of 6-2-2/1.11.4(b), an extension not exceeding five (5) years may be granted by the Surveyor, when requested by the Owner, provided a survey is carried out at the fifth year, in accordance with 7-5-1/5.3.3 of the ABS *Rules for Survey After Construction (Part 7)*. Consideration may be given to an additional extension not exceeding five (5) years when requested by the Owner, provided a survey is carried out at the fifth year after the first extension, in accordance with 7-5-1/5.3.3 of the ABS *Rules for Survey After Construction (Part 7)*. No more than two (2) extensions may be granted.

13 Auxiliary Boiler Surveys (see Section 7-2-9)

Waste-heat or fired auxiliary boilers intended for working pressures above 3.4 bar (3.5 kgf/cm^2, 50 psi), a minimum of two surveys are to be carried out during each 5-year Special Periodical Survey period. One such survey is to be carried out in conjunction with the Special Periodical Survey. In all cases, the interval between any two such surveys is not to exceed 36 months.

An extension of the survey up to three (3) months may be granted by the Surveyor in exceptional circumstances*, provided a survey is carried out in accordance with 7-7-1/11 of the ABS *Rules for Survey After Construction (Part 7)*.

In addition, annual examinations are to be carried out in accordance with 7-7-1/13 of the ABS *Rules for Survey After Construction (Part 7)*.

For units on Continuous Survey of Hull, the two surveys are to be carried out during each 5 year cycle and may be aligned with the Drydocking Survey dates as long as the interval between surveys does not exceed 36 months.

* *Note* "Exceptional circumstances" means, e.g., unavailability of repair facilities, unavailability of essential materials, equipment or spare parts, or delays incurred by action taken to avoid severe weather conditions.

PART
7

CHAPTER **2** **Surveys After Construction**

SECTION **3** **Survey Pre-Planning and In-Service Inspection Program (ISIP)**

1 Survey Pre-Planning

Plans and procedures for a Special Periodical Survey, Drydocking Survey, and Underwater Inspection in Lieu of Drydocking (UWILD) are to be made available onboard for the purpose of carrying out an on-board survey pre-planning meeting with the attending Surveyor.

The planning document is intended to identify critical structural areas and to stipulate the minimum extent, location and means of close up inspection, extent and type of NDT, and thickness measurements with respect to the major structural components as well as to nominated areas.

The document is to be worked out by the Owner in co-operation with ABS and submitted for review well in advance of the survey.

The basis for nomination of the critical structural areas is an assessment in consideration of possible deterioration and designated fatigue prone areas where the following elements on a particular unit are taken into account:

- Design feature with relatively low fatigue life.
- Former history available at Owner's or ABS offices with respect to corrosion, cracking, buckling, indents and repairs for the particular installation as well as similar installations
- Installation's service history since last survey (e.g., area of operation, environmental data, water depth, length of time at each location etc.)

1.1 Planning Document

The degree of criticality is to be judged and decided on the basis of the installation's structural and fatigue analyses and recognized principles and practice. The planning document is required to contain the following items:

i) Main particulars

ii) Plans to include details of major brace and column connections on column-stabilized units

iii) Detailed information on NDT methods and locations

iv) List of tanks with information on use, protection and condition of coating

v) Corrosion risk of tank and other major structural members

vi) Design risk nomination of major structure

vii) Nomination of areas for close up surveys and NDT

viii) Nomination of areas of structure for thickness measurement

ix) List of acceptable corrosion allowance of different structures

x) Method and extent of cleaning inspection points

1.3 In-Service Inspection Program (ISIP)

Where the installation is surveyed under an ISIP, the approved ISIP plan is to be used for the purpose of carrying out an on-board survey pre-planning meeting with the attending Surveyor.

All Column-Stabilized Units (CSUs), Spars or Tension Leg Platforms (TLPs) are to be surveyed in accordance with an ABS approved plan for In-Service Inspection Program. Applicable class surveys of the floating installation's hull structure and mooring system are to be carried out in accordance with the ABS approved ISIP plan.

3 In-Service Inspection Program (ISIP)

In-Service Inspection Program (ISIP) is a comprehensive program that outlines the procedures to be followed and the inspection frequency of the hull and mooring system of a Floating Production Installation (FPI).

All Column-Stabilized Unit (CSU), Spar or Tension Leg Platform (TLP) type floating production installations classed by ABS are to be surveyed in accordance with an ABS-approved ISIP plan.

An ISIP is mandatory for ABS class surveys on a non ship-shaped installation that is either classed as a Floating Offshore Installation (FOI) or together with its topside facilities of the CSU, Spar or TLP.

An ISIP is also mandatory for ABS class surveys on a ship-shaped production installation such as a Floating Production Storage and Offloading (FPSO) operating within the United States Outer Continental Shelf (OCS).

3.1 Coastal State Regulations

Compliance with an ISIP may be required by any Coastal State Authority. For example, for installations operating within the United States OCS, the United States Coast Guard (USCG) requires the installations to be inspected in accordance with an ISIP approved by the USCG (refer to the USCG D8(m) Policy Letter 03-2004 dated 03-May-2004). An ISIP plan in compliance with the ABS Rules will provide the basis for the owner's ISIP plan to be submitted to the USCG.

3.3 Contents of an ISIP Plan

Owner's ISIP plan is expected to at least cover the following items of 7-2-3/3.3.1 through 7-2-3/3.3.4 below. Additional documents such as tables, checklists, and procedural lists may be included as an Appendix to the plan.

3.3.1 Introduction and General Information

i) Description of the installation, together with its dimensions, main particulars, and the arrangement of ballast tanks and other spaces.

ii) Description of the installation's hull and special features. This is to include brief explanation of hull scantlings and locations with high stress.

iii) Description of special application structures and Structural Critical Inspection Points (SCIPs). The ISIP plan is to include a copy of the ABS review letter agreeing to the defined Structural Critical Inspection Points. The ISIP plan is also to include a listing of special application structures.

iv) Description and listing of primary and secondary application structures.

v) Description of the corrosion control system used throughout the installation, internally and externally, together with sacrificial anodes and the Impressed Current Cathodic Protection (ICCP) system, as applicable.

vi) Description of the "splash zone" or "wind-and-water strakes" as applicable. The ISIP plan is to include a copy of the ABS review letter agreeing to the defined "splash zone" or "wind-and-water strakes" of the installation.

vii) Arrangement and description of sea chest openings and sea valves.

viii) Arrangement and listing of accessible and inaccessible spaces throughout the installation.

ix) Supplementary drawings or sketches associated with above listed items (to be included in the ISIP plan as an Appendix).

3.3.2 Operational Procedures and Requirements

i) Following inspection procedures are to be included in the ISIP plan:

a) Description of underwater body inspections and internal structural inspection. The plan for UWILD is to be in accordance with applicable ABS Rules, and the ISIP plan is to briefly explain dive operations, safety standards and interaction with diving personnel and NDT specialists.

b) Detailed scope of individual inspections such as;

- Hull thickness gauging
- Examination by Remotely Operated Vehicle (ROV)
- Tank and space entry
- General Visual Inspection (GVI) and Close Visual Inspection (CVI)
- Non-Destructive Testing (NDT)

Special inspection techniques, interval and procedures for the SCIPs are to be included.

ii) An outline of the installation inspection schedule and frequency of all its hull structure and mooring system components are to be included in the ISIP plan. In general, this outline may be called the "Master Inspection Plan" and cover the entire life-cycle of the installation.

iii) Facility component identification

iv) Reporting and documentation, such as;

a) General record keeping procedures for reports and surveys (company policy).

b) Notification and report delivery procedures involving ABS.

c) Specific record-keeping procedures and report contents for each component category identified under 7-2-3/3.3.2iii) above.

d) Record-keeping for dive conducted during inspections of the underwater hull.

v) Damage assessment and repair procedures, such as:

a) Discussion of categories of damage and company procedures to mitigate.

b) Casualty notification procedures following to facility relating to underwater body and hull structure.

c) Specific procedures and methods to investigate damage or potential damage to the hull or internal structures.

d) Procedures to submit proposed methods, for repair of both underwater defects and damage, to ABS.

3.3.3 Structural Critical Inspection Points (SCIPs)

i) Details of structurally critical locations on the hull of the facility. This section is to at least include a listing, details, inspections cycles, and general inspection procedures of SCIPs.

ii) Drawing detailing the crucial or high stress inspection points as determined by ABS.

3.3.4 Post-Hurricane Structural Inspection

Timely and cost effective inspection of an offshore structure following a hurricane (or similar weather conditions such as a cyclone, typhoon, etc.) is critical before the operator safely re-man the unit/facility and brings production back on-line. In areas of the world where hurricane or equivalent weather events are common, an ISIP plan is required to contain owner's above-water and underwater inspection procedures before re-manning the unit/facility.

The API Bulletin "API BULL 2HINS: Guidance for Post-Hurricane Structural Inspection of Offshore Structures" published on 01-May-2009 is applicable to permanent fixed and floating structures in the Gulf of Mexico. In this bulletin, inspection refers to structural inspections only and does not include inspections of production equipment, process piping, electrical and instrumentation or other systems and components of the platform, unless noted otherwise. It provides necessary guidance regarding how a post-hurricane structural inspection needs to be carried out.

3.5 Structural Critical Inspection Point (SCIP)

SCIP is a structural point defined in the ISIP plan as a critical inspection area which has resulted from structural assessment using applicable calculations and analysis. In general, SCIPs are locations with higher stresses and estimated lower fatigue life. SCIPs are locations which have been identified from calculation to require monitoring, or from the service history of the subject unit or from similar sister units to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit. A tabular listing of the SCIPs, indicating the stress and fatigue life of each location is recommended to be included in the ISIP plan submitted to ABS Engineering Office. 7-2-3/Tables 1, 2 and 3 provide a list of typical structural areas/joints that are considered to be most critical and very critical.

TABLE 1
Critical Structures of a CSU *(1 July 2012)*

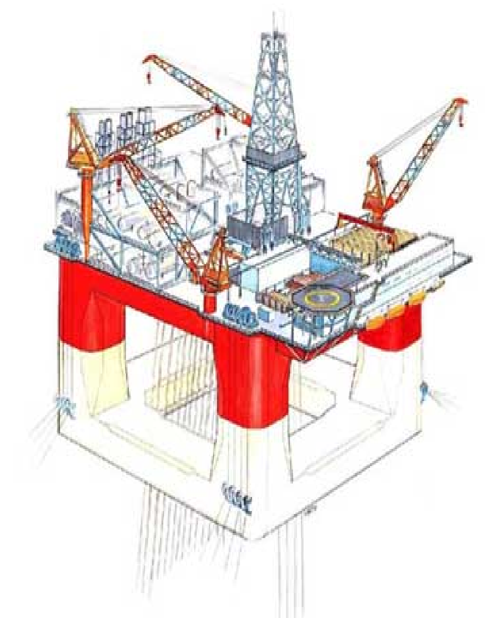
<table>
<tr><td>Special Application Structures (Most Critical)
• Structure in way of main intersections of lower hulls, columns, braces, deck boxes, column top frames and (integrated) deck structures
• Global strength members or portions of integrated deck structure which receive major concentrated loads
• Intersection of column top frame members
• Chain Jack & Fairlead foundations
• Riser porches</td><td rowspan="2"></td></tr>
<tr><td>Primary Application Structures (Very Critical)
• Lower hull shell and bulkheads
• Column shell and bulkheads
• Braces
• Deck box bulkheads which form "box" or "I" beam type structures that contribute to global strength
• Column top frame members
• Integrated deck main truss members and nodes
• Bulkheads, flats and framing which provide local reinforcement or continuity of structure in way of main intersections where not considered special</td></tr>
</table>

TABLE 2
Critical Structures of a Spar *(1 July 2012)*

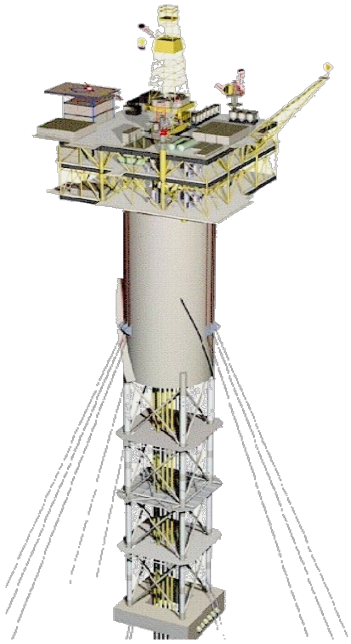
Special Application Structures (Most Critical) • Hard tank – Topside deck leg connection • Hard tank – Truss connection • Truss – Soft tank connection • Heave plate – Truss connection • Truss tubular joint cans • Chain jack & fairlead foundations • Riser guide – Hull connection • Riser porches	
Primary Application Structures (Very Critical) • All inner and outer hull shell plating • Hull top and bottom decks (incl. main girders) • All radial hull bulkheads • All hull ring frames and longitudinal girders • All truss chords and braces • Heave plate plating and girders • Soft tank plating and girders • All struts	

TABLE 3
Critical Structures of a TLP *(1 July 2012)*

Special Application Structures (Most Critical) • Structure in way of main intersections of lower hulls, columns, column top frames and (integrated) deck structures • Global strength members or portions of integrated deck structure which receive major concentrated loads • Intersection of column top frame members • Tendon porches • Riser porches	
Primary Application Structures (Very Critical) • Lower hull shell and bulkheads • Column shell and bulkheads • Column top frame members • Integrated deck main truss members and nodes • Bulkheads, flats and framing which provide local reinforcement or continuity of structure in way of main intersections where not considered special	

PART
7

CHAPTER 2 Surveys After Construction

SECTION 4 Annual Surveys

1 General

The documents and records referenced in 7-2-1/23 of these Rules, as applicable, are to be sighted onboard during Annual Surveys, and the survey is to include the following items of this Section, as applicable.

3 Hull

3.1 Ship-Type Floating Production Installations

For ship-type installations, the weather decks, hull plating and their closing appliances together with watertight penetrations are to be generally examined as far as practicable and placed in satisfactory condition, and the following items are to be verified.

3.1.1 Structure

3.1.1(a) Main structure above waterline.

3.1.1(b) Interface structure between main hull and topside structures, including associated stools and elastomeric bearings, as fitted.

3.1.1(c) Topside main module structures supporting production facilities and supporting systems.

3.1.2 Protection of Openings

3.1.2(a) Hatchways, manholes and scuttles in freeboard and superstructure decks.

3.1.2(b) Machinery casings, fiddley covers, funnel annular spaces, skylights, companionways and deckhouses protecting openings in freeboard or enclosed superstructure decks.

3.1.2(c) Portlights together with deadcovers, cargo ports, bow or stern access, chutes and similar openings in installation's sides or ends below the freeboard deck or in way of enclosed superstructures.

3.1.2(d) Ventilators including closing devices where fitted, air pipes together with flame screens and weld connections to deck plating. All air pipe "closure devices" installed on the exposed decks are to be externally examined, randomly opened out and their condition verified. Scuppers, inlets and overboard discharges are to be externally examined as accessible including their attachment to shell and valves.

3.1.2(e) Watertight bulkheads, bulkhead penetrations, end bulkheads of enclosed superstructures and the operation of any doors in same.

3.1.2(f) Weathertight doors and closing appliances for all of the above including stiffening, dogs, hinges and gaskets. Proper operation of weathertight doors and closing appliances to be confirmed.

3.1.3 Freeing Ports

Freeing ports, together with bars, shutters and hinges.

3.1.4 Protection of Crew

Guard rails, lifelines, gangways and deckhouses accommodating crew.

3.1.5 Loading and Stability Information

Confirmation of loading guidance, stability data and damage control plans, as applicable.

Loading instruments accepted for classification or approved stability computers installed to supplement the Trim and Stability booklet are to be confirmed in working order by use of the approved check conditions, as applicable. The user's instruction manual for the loading instrument or the stability computer is to be confirmed onboard.

3.1.6 Load Line

Confirmation is required that no alterations have been made to the hull or superstructures which would affect the calculation determining the position of the load lines. Record of Conditions of Assignment is to be available onboard for reference. The Load Line marks are to be sighted, found plainly visible, and re-cut and/or painted, as required.

3.3 Column Stabilized Floating Production Installations

For column-stabilized floating production installations, including Spars and TLPs, the exposed parts of the hull, the deck, deck houses, structures attached to the deck, derrick substructure, including supporting structure, accessible internal spaces and their closing appliances together with watertight penetrations are to be generally examined as far as practicable and placed in satisfactory condition, and the following items are to be verified.

3.3.1 Structure

3.3.1(a) Main structure above waterline.

3.3.1(b) Structures attached to the deck, derrick substructure, including supporting structure,

3.3.1(c) Topside main module structures supporting production facilities and supporting systems.

3.3.2 Protection of Openings

3.3.2(a) Hatchways, manholes and scuttles in freeboard and superstructure decks.

3.3.2(b) Machinery casings, fiddley covers, funnel annular spaces, skylights, companionways and deckhouses protecting openings in freeboard or enclosed superstructure decks.

3.3.2(c) Portlights together with deadcovers, cargo ports, bow or stern access, chutes and similar openings in installation's sides or ends below the freeboard deck or in way of enclosed superstructures.

3.3.2(d) Ventilators including closing devices where fitted, air pipes together with flame screens and weld connections to deck plating. All air pipe "closure devices" installed on the exposed decks are to be externally examined, randomly opened out and their condition verified. Scuppers, inlets and overboard discharges are to be externally examined as accessible including their attachment to shell and valves.

3.3.2(e) Watertight bulkheads, bulkhead penetrations, end bulkheads of enclosed superstructures and the operation of any doors in same.

3.3.2(f) Weathertight doors and closing appliances for all of the above including stiffening, dogs, hinges and gaskets. Proper operation of weathertight doors and closing appliances to be confirmed.

3.3.3 Upper Hull Support Structure above Waterline

Columns, diagonals and other parts of the upper hull supporting structure as accessible above the waterline.

3.3.4 Protection of Crew

Guard rails, lifelines, gangways and deckhouses accommodating crew.

3.3.5 Loading and Stability Information

Confirmation of loading guidance, stability data and damage control plans, as applicable.

Loading instruments accepted for classification or approved stability computers installed to supplement the Trim and Stability booklet are to be confirmed in working order by use of the approved check conditions, as applicable. The user's instruction manual for the loading instrument or the stability computer is to be confirmed onboard.

3.3.6 Load Line (where assigned by ABS)

Where Load Line is assigned, confirmation that no alterations have been made to the hull or superstructures which would affect the calculation determining the position of the load lines. Record of Conditions of Assignment is to be available onboard for reference. The Load Line marks are to be sighted, found plainly visible, and recut and/or painted, as required.

3.5 Suspect Areas

Suspect areas of the hull are to be overall examined, including an overall and Close-up Survey of those suspect areas which were identified at the previous surveys.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

Where extensive areas of corrosion are found or when considered necessary by the Surveyor, thickness measurements are to be carried out and renewals and/or repairs made when wastage exceeds allowable margins.

Where substantial corrosion is found, additional thickness measurements in accordance with 7-3-2/7 of the ABS *Rules for Survey After Construction (Part 7)*, are to be taken to confirm the extent of substantial corrosion. These extended thickness measurements are to be carried out before the survey is credited as completed.

Where reduced scantlings on the basis of effective corrosion control have been adopted, the results of any measurements are to be evaluated based on the scantlings before reduction.

3.7 Ballast Tanks and Combined Cargo/Ballast Tanks

3.7.1 Installations Over 5 Years of Age

Examination of the following tanks is to be carried out.

i) Ballast tanks and combined cargo/ballast tanks other than double bottom tanks, where the following conditions have been identified at previous surveys.

- A hard protective coating was found in POOR condition, or
- A soft coating has been applied, or
- A hard protective coating has not been applied from the time of construction.

ii) Double bottom ballast tanks, where substantial corrosion was found within the tank, and the following conditions have been identified at previous surveys.

- A hard protective coating was found in POOR condition, or
- A soft coating has been applied, or
- A hard protective coating has not been applied from the time of construction.

3.7.2 Installations Over 15 Years of Age

In addition to the requirements of 7-2-1/3.7.1 of these Rules, the following tanks are also to be examined.

i) Ballast tanks and combined cargo/ballast tanks other than double bottom tanks in way of spaces designated for the carriage of cargo, where FAIR coating conditions were identified at previous surveys, a minimum of three (3) so identified tanks (i.e., one (1) forward, one (1) midship and one (1) aft).

ii) Peak tanks, where FAIR coating conditions were identified at previous surveys.

Where extensive areas of corrosion are found or when considered necessary by the Surveyor, thickness measurements are to be carried out and renewals and/or repairs made when wastage exceeds allowable margins.

Where substantial corrosion is found, additional thickness measurements in accordance with 7-3-2/7 of the ABS *Rules for Survey After Construction (Part 7)* are to be taken to confirm the extent of substantial corrosion. These extended thickness measurements are to be carried out before the survey is credited as completed.

Where reduced scantlings on the basis of effective corrosion control have been adopted, the results of any measurements are to be evaluated based on the scantlings before reduction.

3.9 Helicopter Deck

Where areas of the installation are designated for helicopter operations, the helicopter deck, deck supporting structure, deck surface, deck drainage, tie downs, markings, lighting, wind indicator, securing arrangements where fitted safety netting or equivalent, access arrangements including emergency escape, and access for fire fighting and rescue personnel, are to be examined.

3.11 Floating Production Installations in Lightering Service

In addition to the applicable requirements of 7-2-4/1.1 of these Rules, the Annual Survey is also to include an external examination of hull structures where fenders for lightering operation were located. Where extensive areas of wastage are found, or when considered necessary by the Surveyor, thickness measurements and internal examination, including Close-up Survey, may be required.

3.13 Non Self Propelled Floating Production Installations

Machinery items installed consistent with the services of the installation are subject to a general examination and are to be placed in satisfactory condition.

3.15 Cargo Tanks

Cargo tank openings including gaskets, covers and coamings.

Pressure/vacuum relief valves, flame arrestors and flame screens. Tank vent protective devices are to be examined externally for proper assembly and installation, damage, deterioration or traces of carryover at the outlet. Where deemed suspect, the tank protective device is to be opened for examination.

3.17 Cargo Pump Room

Examination of pump room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangement of all penetrations of bulkheads.

Confirmation that there are no potential sources of ignition in or near the cargo pump room and cargo area and that pump room access ladders are in good condition.

Pump room ventilation system including ducting, dampers and screens.

5 Mooring System

Annual Surveys of the mooring system is mandatory for all types of floating production installations, and are to comply with following requirements of 7-2-3/5.1 or 7-2-3/5.3, as applicable.

5.1 Spread Mooring System

At each Annual Survey, the spread mooring system is to be generally examined so far as can be seen and placed in satisfactory condition as necessary. In addition, the following above water items are to be examined, placed in satisfactory condition and reported upon, where applicable:

i) The anchor chain stopper structural arrangements are to be visually examined, including the structural foundations of all of the stoppers or holders. Tensioning equipment is to be generally examined.

ii) The anchor chain catenary angles are to be measured to verify that the anchor chain tensions are within the design allowable tolerances. Where anchor cables are used, their tensions are to be verified to be within the allowable tensions.

iii) The anchor chains or anchor cables above the water are to be visually examined for wear and tear.

5.3 Single Point Mooring (SPM) Systems

At each Annual Survey, the single point mooring system is to be generally examined insofar as can be seen above water and placed in satisfactory condition as necessary. In addition, the following above water items are to be examined, placed in satisfactory condition and reported upon, where applicable:

i) The anchor chain stopper structural arrangements are to be visually examined, including the structural foundations of all of the stoppers.

ii) The anchor chain's catenary angles are to be measured to verify that the anchor chain tensions are within the design allowable tolerances. Where anchor cables are used, their tensions are to be verified to be within the allowable tensions.

iii) The anchor chains or anchor cables above the water are to be visually examined for wear and tear.

iv) The condition of the bearings is to be verified for continued effectiveness of the lubrication system.

v) The entire assembly of the single point mooring structure above water is to be generally examined for damage, coating breaks and excessive signs of corrosion. This survey is to include all turret wall structures, accessible turret well structures, mooring arms, all structures supporting the disconnectable operations of the mooring system, etc., whichever are applicable.

7 Fire and Safety Systems

Annual Survey of the entire fire and safety systems installed throughout the floating production installation is mandatory for all types of floating production installations.

Following systems are to be verified to confirm no significant changes have been made to any of the systems and that they remain in satisfactory condition.

7.1 Passive Fire Protection Systems

Passive fire protection systems, including the following items are to be generally examined and function tested as necessary:

i) Examination of structural fire protection as well as protection of accommodation spaces, service spaces and control stations, as accessible

ii) Examination and function testing of fire doors

iii) Examination and testing of ventilation fire-dampers

iv) Examination and testing of ventilation system closures and stoppage of power ventilation

v) Examination and testing of shutters or water curtains (where fitted)

7.3 Active Fire Protection – Fixed Systems

Active fire protection fixed systems, including the following items are to be generally examined and function tested as necessary:

i) Examination of all items shown on the fire control plan, and confirmation that no alteration has been made to the ABS endorsed plan

ii) Examination and testing of all fire pumps. Other pumps used for active fire protection are also to be examined. This is to include confirmatory testing of the fire pump capacity, and where installed, testing of relief valves of the fixed fire main system.

iii) Examination and function testing of the fire main system

iv) Examination of all hydrants, hoses, nozzles, and shore connections, and testing of these as necessary

7.5 Active Fire Protection – Additional Fixed Systems

Where installed, active fire protection additional fixed systems, including the following items are to be generally examined and function tested as necessary:

i) Examination and testing of the gas smothering system, including confirmatory examination of the storage of the gas medium, gas alarms, and examination and testing of manual controls

ii) Examination of the high or low expansion foam systems

iii) Examination and function testing of fixed water spraying systems

iv) Protection of helicopter decks with or without refueling capacity

v) Examination of paint and flammable liquid lockers

7.7 Active Fire Protection – Portable Systems

All portable fire-fighting equipment fitted onboard, are to be in accordance with ABS approved plans. In addition, the following items are to be generally examined:

i) Examination of all portable and semi-portable extinguishers

ii) Examination and testing of the firefighter's outfit, as necessary

7.9 Fire Detection and Alarm Systems

Fire detection and alarm systems, as installed, are to be examined and tested as necessary.

7.11 Gas Detection and Alarm Systems

Gas detection and alarm systems, as installed, are to be examined and tested as necessary.

7.13 Outfitting

Outfitting arrangements, including the following items are to be examined and tested as necessary:

i) All escape routes from accommodation spaces, service spaces and control stations, from Category 'A' machinery spaces, from other machinery spaces, deckhouses, together with stairway or ladders in way of any escape route, and the accessibility and access through the routes

ii) Lighting and gratings in way of all escape routes

iii) Guards and rails along floor deck areas and openings, and helicopter landing deck

iv) Contact makers for general alarm system, communication system installed in all emergency control stations

v) Fire precautions taken in all machinery spaces

7.15 Emergency Shutdown Arrangements

Emergency shutdown arrangements provided to disconnect or shutdown, either selectively or simultaneously, of the electrical equipment as outlined in the floating production installation's operating manual, are to be examined and tested.

Services such as the emergency lighting, general alarm system, public address system, distress and safety radio system, that are required to be operable after an emergency shutdown of the installation, are to be verified for their proper operation.

All equipment in exterior locations w*h*ich is capable of operation after an emergency shutdown is to be verified as being suitable for installation in Zone 2 locations.

9 Machinery and Electrical Systems (Marine & Safety Systems)

Annual Survey of machinery and electrical systems servicing the marine and safety systems is mandatory for all types of floating production installations.

9.1 Machinery and Electrical Parts to be Examined

Surveys for ship- or barge-type installations are to comply with applicable requirements of 7-6-2/1 of the ABS *Rules for Survey After Construction (Part 7)*.

Surveys for column-stabilized installations are to comply with applicable requirements of 7-2-4/3 of the *MODU Rules*.

9.3 Self Propelled Installations – Main Propulsion Apparatus

Surveys of self propelled installations is to comply with applicable requirements of 7-6-2/1 of the ABS *Rules for Survey After Construction (Part 7).*

9.3.1 Thrusters (where installed)

Thruster surveys are to comply with the requirements of Section 7-9-6 of the ABS *Rules for Survey After Construction (Part 7)*.

9.5 Preventative Maintenance Techniques

Surveys of machinery that has been accepted for surveys based on preventative maintenance techniques are to comply with the requirements of Appendix 7-A-14 of the ABS *Rules for Survey After Construction (Part 7)*.

9.7 Hazardous Areas

Surveys of hazardous areas and electrical equipment installed in hazardous areas are to comply with applicable requirements of the ABS *Rules for Building and Classing Facilities on Offshore Installations*.

11 Inert Gas Systems (where installed)

Applicable requirements of 7-6-2/1.1.12 of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with.

13 Liquefied Gas Installations (where installed)

The Annual Survey, except First Annual Survey, is to be carried out during a loading or discharging operation, as far as practicable.

In addition to the applicable requirements of 7-2-4/3.17 and 7-2-4/3.19 of these Rules, the Annual Survey is to include the following:

13.1 First Annual Survey

i) *Cargo Containment System.* An Overall Survey is to be made of the cargo containment system including the supporting and positioning arrangements, hatches, access arrangements and penetrations, the secondary barrier where fitted, adjacent hull structure and the insulation, insofar as possible without removing fixed insulation or structural members unless deemed necessary by the attending Surveyor.

ii) *Secondary Barriers.* The secondary barrier is to be checked for its effectiveness by means of a pressure/vacuum test, a visual inspection or some other acceptable method.

iii) *Other Items.* See 7-2-1/13.3 of these Rules for additional items to be included in the first Annual Survey.

13.3 All Annual Surveys

i) *General.* The logbooks are to be examined with regard to correct functioning of the cargo containment and cargo handling systems. The hours per day of the reliquefaction plants or the boil-off rate is to be considered.

ii) *Interbarrier Space Venting System.* The venting system or other arrangements provided for the emergency removal of gas from the interbarrier spaces (i.e., between the primary and secondary barriers) is to be confirmed in satisfactory condition.

iii) *Cargo Tank Venting System.* The venting system for the cargo tanks and hold spaces is to be confirmed in satisfactory operating condition. The vent line drainage arrangement is to be examined.

iv) *Instrumentation and Safety Systems.* Gas leakage detection equipment, including indicators and alarms, is to be confirmed in satisfactory operating conditions. Systems for temperature, pressure and liquid level indication of the cargo, cargo tank, insulation, the hull adjacent to the cargo containment system, and cargo refrigerating installations where fitted, including alarms, are to be confirmed in satisfactory operating condition. The piping of the gas detection system is to be visually examined for corrosion and damage and the integrity of the line between suction points and analyzing units is to be confirmed as far as possible.

The logbooks are to be examined for confirmation that the emergency shutdown system has been tested.

v) *Environmental Control of Hold Spaces.* Inert gas and dry air systems, including indicators and alarms, are to be confirmed in satisfactory operating condition. Means for prevention of backflow of cargo vapor into gas-safe spaces is to be confirmed in satisfactory operating condition. For membrane containment systems, normal operation of the nitrogen control system for insulation and interbarrier spaces shall be confirmed.

vi) *Cargo Handling Piping and Machinery.* All piping, cargo hoses, emergency shut-down valves, remote operating valves, machinery and equipment for loading, unloading, venting, compressing, refrigerating, liquefying, heating or otherwise handling the liquefied gas or vapor is to be examined, as far as possible. Records of stopping of the cargo pumps and compressors upon emergency shut-down of the system is to be verified/confirmed.

Cargo hoses are to be verified, where appropriate, type-approved or marked with date of testing.

vii) *Cargo Tank Tightness.* The tightness of cargo tanks is to be confirmed. For this purpose, the installation's gas leak detectors, micro-flow meters, etc. may be utilized providing that they are first proved to be in good order. The installation's logbooks are also to be reviewed to confirm the tightness of the cargo tanks.

viii) *Heating Coils.* Heating coils and other heating systems which are essential to keep the temperature of the hull structure from falling below the minimum allowable value for the material used are to be proven in satisfactory operating condition.

ix) *Ventilating System.* Examination of the ventilation system is to be made for all gas dangerous spaces and zones, including air locks, cargo pump rooms, cargo compressor rooms, cargo control rooms and spaces used for cargo handling operations. All portable ventilating equipment required for use in the gas dangerous spaces is to be examined. Provision of spares for mechanical ventilation fans for gas dangerous spaces and zones, recommended by manufacturer is to be confirmed.

x) *Spaces in Cargo Areas.* Air locks, cargo pump rooms, cargo compressor rooms, rooms containing electric motors for driving cargo pumps or compressors, cargo control rooms and spaces used for cargo handling operations are to be examined. All accessible gas-tight bulkhead penetrations including gas-tight shaft seals are to be examined. The means for accomplishing gas tightness of the wheelhouse doors and windows is to be examined.

The closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements are to be examined.

All windows and sidescuttles within the area required to be of the fixed type (nonopening) are to be examined for gas tightness.

xi) *Drip Trays.* Portable and fixed drip trays and insulation for the protection of the deck in the event of cargo leakage are to be examined.

xii) *Gas Burning Installations.* Gas burning installations, including instrumentation and safety systems, are to be examined and confirmed in satisfactory operating condition. See also 7-2-1/13.3iv) of these Rules.

xiii) *Sealing Arrangements.* Sealing arrangements on the weather deck in way of openings for the cargo containment system are to be examined.

xiv) *Fire Protection and Fire Extinguishing Equipment.* The fire water main equipment, water spray equipment, dry chemical powder fire extinguishing systems in the cargo area, and fixed inerting and fixed smothering installations in gas-dangerous spaces are to be examined and operationally tested, as far as practicable.

xv) *Electrical Equipment.* Electrical equipment in gas-dangerous spaces or zones is to be examined as far as practicable with particular respect to the following:

- Protective earthing
- Physical condition of electrical cables and supports
- Integrity of enclosures
- Intrinsically safe, explosion proof, or increased safety features of electrical equipment
- Functional testing of pressurized equipment and associated alarms
- Testing systems for de-energizing electrical equipment which is not certified safe for use in gas-hazardous areas but which is located in spaces protected by air-locks (e.g., electrical motor rooms or cargo control rooms)
- Insulation resistance readings of circuits. Where a proper record of testing is maintained, consideration may be given to accepting recent readings.

Note: See also IACS Recommendation No.35 – Inspection and maintenance of electrical equipment installed in hazardous areas.

xvi) *Personnel Protection.* Firemen's outfits, protective clothing, and respiratory protection equipment are to be examined. Decontamination showers and eye wash are to be examined and operationally tested, as far as practicable.

xvii) *Tightness of Hull.* Means for detecting leakage into the hold space through the ship's structure forming the boundary of the hold space are to be examined.

xviii) *Operating Instructions.* Instructions and information material, such as cargo handling plans, loading manual, filling limit information, cooling-down procedure, are to be confirmed as being aboard the installation.

xix) *Relief Valves.* All relief valves in the cargo containment and venting system are to be examined, including protective screens and flame screens, if provided, and seals confirmed intact. Records of opening and closing pressures of relief valves are to be confirmed onboard.

15 Dynamic Positioning Systems (if classed)

Dynamic Positioning Systems are to comply with the requirements of Section 7-9-6 of the ABS *Rules for Survey After Construction (Part 7)*.

17 Automatic and Remote-Control Systems (if classed)

For Shipboard Automatic and Remote-Control System, applicable requirements of Chapter 8 of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with.

19 Production Facilities (if classed)

Where the floating production installation's production facilities are classed, applicable requirements of the ABS *Rules for Building and Classing Facilities on Offshore Installations* are to be complied with.

Maintenance records are to be kept and made available for review by the attending Surveyor. The maintenance records will be reviewed to establish the scope and content of the required Annual and Special Periodical Surveys. During the service life of the facilities, maintenance records are to be updated on a continuing basis. The operator is to inform ABS of any changes to the maintenance procedures and frequencies, as may be caused, for example, by changes or additions to the original equipment. The Surveyor may determine during the periodic survey if the changes are sufficient to warrant review by ABS' technical staff.

21 Import and Export Systems (if classed)

Where the floating production installation's import-export systems are classed, the import and export systems are to be examined as far as can be seen and placed in satisfactory condition as necessary. In addition, the following items are to be examined, placed in satisfactory condition and reported upon where applicable:

i) A general examination is to be performed on all electrical and fluid swivels, flexible risers, floating hoses, cargo piping and valves associated with the import and export systems, expansion joints, seals, etc.

ii) The fluid swivels are to be examined for signs of leaks through their "tell-tale" apertures.

iii) Records of maintenance are to be reviewed, including records of hose hydrostatic testing.

iv) Navigational aids for all floating hoses are to be examined and functionally tested.

v) Riser tensioning arrangements are to be examined for proper functioning order.

vi) All electrical equipment, fitted in hazardous location is to be examined for integrity and suitability for the continued service.

PART
7

CHAPTER 2 Surveys After Construction

SECTION 5 Intermediate Surveys

1 General

The documents and records referenced in 7-2-1/23 of these Rules, as applicable, are to be sighted onboard during Annual Surveys, and the survey is to include the following items of this Section, as applicable.

The Intermediate Survey requirements are in addition to the Annual Survey requirements stated in Section 7-2-4 of these Rules.

3 Hull

3.1 Ship-Type Floating Production Installations

Intermediate Surveys of self-propelled barge- or ship-type installations are to comply with the applicable requirements of 7-3-2/3 of the ABS *Rules for Survey After Construction (Part 7)*.

The scope of the second or third Annual Survey is to be extended to include the following.

3.1.1 Survey Planning Meeting

A survey planning meeting is to be held prior to the commencement of the survey.

3.1.2 Survey of Ballast Tanks

i) *For Installations 5 < Age ≤ 10 years*

Overall Survey of a minimum of three (3) representative ballast tanks selected by the Surveyor is to be carried out. Where a hard protective coating is found in POOR condition, where soft coating has been applied or where a hard protective coating has not been applied from time of construction, the examination is to be extended to other ballast tanks of the same type.

ii) *For Installations Age > 10 years*

Overall Survey of all ballast tanks is to be carried out.

If survey of ballast tanks reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains effective.

3.1.3 Survey of Ballast Tanks and Combined Cargo/Ballast Tanks Other than Double Bottom Tanks

Where provided, the condition of corrosion prevention system of ballast tanks and combined cargo/ballast tanks is to be examined.

Ballast tanks and combined cargo/ballast tanks, other than double bottom tanks, where a hard protective coating is found in POOR condition and Owners or their representatives elect not to restore the coating, where a soft coating has been applied or where a hard protective coating has not been applied from time of construction, the tanks in question are to be internally examined at each subsequent Annual Survey. Thickness measurements are to be carried out as considered necessary by the Surveyor.

3.1.4 Survey of Ballast Tanks in way of Double Bottom

Double bottom ballast tanks, where a hard protective coating is found in POOR condition and Owners or their representatives elect not to restore the coating, where a soft coating has been applied or where a hard protective coating has not been applied from time of construction, the tanks in question are to be internally examined at each subsequent Annual Survey where substantial corrosion is documented. Thickness measurements are to be carried out as required.

3.1.5 Survey of Cargo Tanks

At each Intermediate Survey after Special Periodical Survey No. 2, at least three (3) cargo tanks of integral type: one (1) center, one (1) port wing and one (1) starboard wing tank, are to be examined internally.

3.3 Column Stabilized Floating Production Installations

Intermediate Survey of column stabilized installations is to comply with the requirements of Section 7-2-6 of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units*, applicable to column stabilized units.

3.5 Floating Production Installations in Lightering Service

In addition to the applicable requirements of 7-2-5/3.1, 7-2-5/3.3. 7-2-5/3.7, and 7-2-5/3.9 of these Rules, the Intermediate Survey is to include an external examination and internal Close-up Survey of hull structures, including thickness measurements, where fenders for lightering operation were located.

3.7 Hull Thickness Measurement

When extensive areas of wastage are found, thickness measurements are to be carried out and renewals made where wastage exceeds the allowable margin. Where reduced scantlings on the basis of effective corrosion control have been adopted, the results of any measurements are to be evaluated based on scantlings before reduction.

3.9 Tank Testing

Pressure testing of cargo and ballast tanks is not required unless deemed necessary by the attending Surveyor.

5 Liquefied Gas Installations (where installed)

The Intermediate Survey is preferably to be carried out with the installation in a gas free condition. The extent of the testing required for the Intermediate Survey will normally be such that the survey cannot be carried out during a loading or discharging operation.

In addition to the applicable requirements of 7-3-2/1.13.7 of the ABS *Rules for Survey After Construction (Part 7)*, the Intermediate Survey is also to include the following.

5.1 Instrumentation and Safety Systems

i) The instrumentation of the cargo installation with regard to pressure, temperature and liquid level is to be visually examined and to be tested by changing the pressure, temperature and level, as applicable, and comparing with test instruments. Simulated testing may be accepted for sensors which are not accessible or for sensors located within cargo tanks or inerted hold spaces. The testing is to include testing of the alarm and safety functions.

ii) Gas detectors are to be calibrated or verified with sample gases.

iii) The emergency shutdown system is to be tested, without flow in the pipe lines, to verify that the system will cause the cargo pumps and compressors to stop.

5.3 Gas Burning Installations

The instrumentation and safety systems for gas burning installations are to be examined and tested in accordance with the requirements of 7-2-5/5.1i) of these Rules.

PART

7

CHAPTER 2 Surveys After Construction

SECTION 6 Special Periodical Surveys (SPS)

1 General

The documents and records referenced in 7-2-1/23 of these Rules, as applicable, are to be sighted onboard during Annual Surveys, and the survey is to include the following items of this Section, as applicable.

The Special Periodical Survey requirements are in addition to the Annual Survey and Intermediate Survey requirements stated in Sections 7-2-4 and 7-2-5 of these Rules.

3 Hull

3.1 Ship-Type Floating Production Installations

In addition to the requirements of the Annual Survey – Hull, the SPS – Hull is to include sufficient examination, tests and checks carried out by the Surveyors to satisfy themselves that the hull and its outfitting are in or are placed in satisfactory condition and are fit for the intended purpose for the new period of class of five (5) years to be assigned, subject to proper maintenance and operation and to periodic surveys being carried out at the due dates. Special Periodical Survey is to include the following:

3.1.1 Survey Planning Meeting

A survey planning meeting is to be held prior to the commencement of the survey.

3.1.2 Drydocking Survey (or UWILD)

Drydocking survey is to be carried out in accordance with Section 7-2-7 of these Rules.

3.1.3 Rudder

When the steering gear is maintained operational the rudder is to be examined and, when required, lifted and the gudgeons rebushed. The condition of carrier and steadiment/rudder stock bearings and the effectiveness of stuffing boxes are to be ascertained when the rudder is lifted.

3.1.4 Shell Openings and Their Closures

All openings in the shell including overboard discharges are to be examined.

3.1.5 Decks, Bulkheads and Shell Plating

All decks, watertight bulkheads, and internal and external surfaces of shell plating are to be examined. Plating in way of side shell or superstructure portlights is to be especially examined.

3.1.6 Overall Survey Requirements

3.1.6(a) Spaces. An Overall Survey of all spaces including holds and their tween decks, where fitted; double bottom, deep, ballast, peak and cargo tanks; pump rooms, pipe tunnels, duct keels, machinery spaces, dry spaces, cofferdams and voids, including the plating and framing, bilges and drain wells, sounding, venting, pumping and drainage arrangements.

Internal examination of fuel oil, lube oil and fresh water tanks is to be carried out in accordance with 7-2-6/3.1.6(d) of these Rules.

Where sounding pipes are fitted, the Surveyor is to confirm that a thick steel plate is securely fixed below the sounding pipe for the rod to strike upon.

This examination is to be supplemented by thickness measurement and testing as required to confirm that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

3.1.6(b) Engine Room Spaces. Engine room structure is to be examined. Particular attention is to be given to tank tops, shell plating in way of tank tops, brackets connecting side shell frames and tank tops, and engine room bulkheads in way of tank top and bilge wells. Particular attention is to be given to the sea suction, seawater cooling pipes and overboard discharge valves and their connection to the side shell plating. Where extensive areas of wastage are found, thickness measurements are to be carried out, and renewals and/or repairs made where wastage exceeds allowable margins.

3.1.6(c) Ballast Tanks and Combined Cargo/Ballast Tanks. Where provided, the condition of corrosion prevention system of ballast tanks and combined cargo/ballast tanks is to be examined.

Ballast tanks and combined cargo/ballast tanks other than double bottom tanks, where a hard protective coating is found in POOR condition and Owners or their representatives elect not to restore the coating, where soft coating has been applied or where a hard protective coating has not been applied from time of construction, the tanks in question are to be internally examined at each subsequent Annual Survey. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

When such breakdown of hard protective coating is found in double bottom ballast tanks and Owners or their representatives elect not to restore the coating, where a soft coating has been applied, or where a hard protective coating has not been applied from time of construction, the tanks in question are to be internally examined at each subsequent Annual Survey where substantial corrosion is documented. Thickness measurements are to be carried out as required.

3.1.6(d) Fuel Oil, Lube Oil, Freshwater and Permanent Ballast Tanks. Internal examination requirements will be specially considered for tanks used exclusively for permanent ballast which are fitted with an effective means of corrosion control.

Where tanks of integral structural type, except for peak tanks, are used primarily for heavy fuel oil or exclusively for light oils or fresh water, the internal examination may be specially considered, provided a general external examination and the following internal examinations are carried out.

Minimum requirements for internal examination of fuel oil, lube oil and fresh water tanks at Special Periodical Surveys are as follows.

i) Special Periodical Survey No. 1 (Age ≤ 5 Years)

None

ii) Special Periodical Survey No. 2 (5 < Age ≤ 10 Years)

- One (1) fuel oil tank in the Cargo length area. For installations without a defined cargo area a minimum of one (1) fuel oil tank.
- One (1) freshwater tank

iii) Special Periodical Survey No. 3 (10 < Age ≤ 15 Years)

- One (1) fuel oil tank in way of the engine room
- Two (2) fuel oil tanks in the Cargo length area. For installations without a defined cargo area a minimum of two (2) fuel oil tanks. One (1) deep tank is to be included, if fitted
- All freshwater tanks

iv) *Special Periodical Survey No. 4 and Subsequent Special Periodical Surveys (Age > 15 Years)*

- One (1) fuel oil tank in way of the engine room
- Half of all fuel oil tanks in the Cargo length area, minimum two (2). For installations without a defined cargo area, half of all fuel oil tanks, a minimum of two (2). One (1) deep tank is to be included, if fitted
- One (1) lube oil tank
- All freshwater tanks

Note: If a selection of tanks is accepted for examination, then different tanks are to be examined at each Special Periodical Survey on a rotational basis.

Independent oil tanks in machinery spaces are to be externally examined and, if deemed necessary, tested under a head of liquid.

3.1.7 Protection of Other Openings

3.1.7(a) Tank Protective Devices

i) All tank protective devices, where fitted, are to be examined externally for proper assembly and installation, damage, deterioration or traces of carryover at the outlets.

ii) All pressure-vacuum valves and pressure relief valves are to be opened out, pressure and vacuum valve discs checked for good contact with their respective seats and/or proved by testing.

3.1.7(b) Air Pipes. All air pipes are to be opened out and closing arrangements and flame screens, if fitted, are to be examined both externally and internally. For designs where the inner parts cannot be properly examined from outside, this is to include removal of the head from the air pipe. Particular attention is to be paid to the condition of the zinc coating in heads constructed from galvanized steel.

3.1.7(c) Watertight Bulkheads. Watertight bulkheads, bulkhead penetrations, end bulkheads of enclosed superstructures are to be examined. In addition, watertight doors are to be operationally tested and effectiveness to maintain tightness is to be confirmed.

3.1.8 Close-up Survey Requirements

The requirements for Close-up Survey and thickness gauging, per 7-3-2/5.13 or 7-3-2/5.14 of the ABS *Rules for Survey After Construction (Part 7)*, will be applied to ship- and barge-type installations in the following cases:

i) The ballast tanks are uncoated.

ii) Tank coatings are in FAIR or POOR condition as defined by 7-2-1/13.3 of these Rules

iii) Soft coatings are found to be no longer effective, 7-2-1/15.5 of these Rules

iv) Substantial corrosion is present

Thickness Measurements are to be carried-out as per Section 7-2-5/3.1.2 of these Rules.

3.1.9 Tank Testing

Boundaries of double bottom, deep, ballast, peak and other tanks, including holds adapted for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds, except that cargo tanks on ship-type installations of both single and double hull construction may be tested to the highest point that liquid will rise under service condition. Boundaries of fuel oil, lube oil and fresh water tanks may be tested with a head of liquid to the highest point that liquid will rise under service condition. Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results, provided that representative tanks for fuel oil, lube oil and fresh water are tested.

The testing of double bottoms and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

Stagger testing of bulkheads is acceptable as alternative means of testing.

The Surveyor may require further tank testing, as deemed necessary.

3.1.10 Hull Thickness Measurement (Gauging)

These requirements do not apply to independent cargo tanks.

i) *Special Periodical Survey No. 1 (Age ≤ 5 Years)*

- Suspect areas throughout the installation.

ii) *Special Periodical Survey No. 2 (5 < Age ≤ 10 Years)*

- All main deck plates within the amidships 0.5*L* or cargo tank section, whichever is longer.
- One (1) transverse section within the amidships 0.5*L*.
- Plates in wind-and-water strakes outside the amidships 0.5*L*.
- All complete transverse web frame rings in a ballast wing tank or ballast double hull tank, if any.
- One (1) deck transverse in each of the remaining ballast tanks, if any.
- Both transverse bulkheads including girder system in a ballast wing tank or ballast double hull tank, if any, or a cargo wing tank used primarily for water ballast.
- Lower part of transverse bulkhead including girder system in each remaining ballast tank, one (1) cargo wing tank and two (2) cargo center tanks.
- Internals in forepeak and afterpeak tanks.
- Suspect areas throughout the installation.

iii) *Special Periodical Survey No. 3 (10 < Age ≤ 15 Years)*

- All main deck plates within the amidships 0.5*L* or cargo tank, whichever is longer.
- Two (2) transverse sections within the amidships 0.5*L*.
- Plates in wind-and-water strakes outside the amidships 0.5*L*.
- All complete transverse web frame rings in all ballast tanks and in a cargo wing tank.
- A minimum of 30% of all complete transverse web frame rings in each remaining cargo wing tank. (In calculating the 30% minimum, the number of web frame rings is to be rounded up to the next whole integer.)
- A minimum of 30% of deck and bottom transverse in each cargo center tank. (In calculating the 30% minimum, the number of transverses is to be rounded up to the next whole integer.)
- All transverse bulkheads including girder and stiffener systems in all cargo and ballast tanks.
- Additional complete transverse web frame rings as considered necessary by the Surveyor.
- Internals in forepeak and afterpeak tanks including plating and stiffeners of forepeak and afterpeak tank bulkheads.
- Suspect areas throughout the installation.

iv) *Special Periodical Survey No. 4 and Subsequent Special Periodical Surveys (Age > 15 Years)*

- All exposed main deck plates, full length. Also, exposed first-tier superstructure deck plates (poop bridge and forecastle decks).
- All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space and aft ends of tanks.
- A minimum of three (3) transverse sections within the amidships 0.5*L*.
- All complete transverse web frame rings in all ballast tanks and in a cargo wing tank.
- A minimum of 30% of all complete transverse web frame rings in each remaining cargo wing tank. (In calculating the 30% minimum, the number of web frame rings is to be rounded up to the next whole integer.)
- A minimum of 30% of deck and bottom transverse in each cargo center tank. (In calculating the 30% minimum, the number of transverses is to be rounded up to the next whole integer.)
- All transverse bulkheads including girder and stiffener systems in all cargo and ballast tanks.
- Additional complete transverse web frame rings as considered necessary by the Surveyor.
- Any additional tanks and structure as considered necessary by the Surveyor.
- Internals in forepeak and afterpeak tanks including plating and stiffeners of forepeak and afterpeak tank bulkheads.
- All plates in two (2) wind-and-water strakes, port and starboard full length.
- Suspect areas throughout the installation.
- Plating of seachests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor.

Note: Thickness measurements of any one entire girth belt(s) (transverse section(s)) shall be completed within 15 months from commencement of gaugings of a girth belt (transverse section.)

Thickness measurements review to be carried-out in accordance with 7-A-4/5 of the ABS *Rules for Survey After Construction (Part 7).*

Individual plate and stiffener wastage allowances – Individual plate and stiffener wastage allowances for ship-type floating installations with design life of 20 years are to satisfy Appendix 7-A-4 of the ABS *Rules for Survey After Construction (Part 7)*. Local wastage allowable margins of plates and stiffeners for floating installations with design life longer than 20 years will remain the same as applied to the required 20 year life scantlings to determine minimum scantlings at which renewals are required. Accordingly, based on percent wastage allowance, renewals would be required when scantling were wasted to values as if the installation were a 20 year life installation. The allowable wastage is to be based on the smaller of the percent wastage allowance (see 5A-2-2/Table 1) or the allowable wastage based on local buckling strength.

3.1.11 Application of Requirements for Close-Up Survey and Gauging per ESP Vessels

The requirements for close-up survey and thickness gauging, per 7-3-2/5.13 or 7-3-2/5.14 of the ABS *Rules for Survey After Construction (Part 7)* will be applied to ship- and barge-type installations in the following cases:

i) The ballast tanks are uncoated.

ii) Tank coatings are in POOR condition as defined by 7-2-1/13.3 of these Rules

iii) Soft coatings are found to be no longer effective, 7-2-1/15.5 of these Rules

iv) Substantial corrosion is present.

3.3 Column Stabilized Floating Production Installations

For column-stabilized installations, the following are to be performed, as applicable, the parts examined, placed in satisfactory condition and reported upon:

3.3.1 General Examination

The hull or platform structure, including tanks, watertight bulkheads and decks, cofferdams, void spaces, sponsons, chain locker, deck, keels, helicopter pad, machinery spaces, peak spaces, steering gear spaces and all other internal spaces are to be examined externally and internally for damage, fractures or excessive wastage.

3.3.2 Examination of Tanks, Compartments and Free-Flooding Spaces

All tanks, compartments and free-flooding spaces throughout the installation are to be examined externally and internally. Internal examinations of lower hull are to be specially considered. Watertight integrity of tanks, bulkheads, hull, bulkhead deck and other compartments are to be verified by visual inspection. Suspect areas may be required to be tested for tightness, nondestructively tested or thickness gauged. Tanks and other normally closed compartments are to be ventilated, gas-freed and cleaned, as necessary, to expose damage and allow for a meaningful examination for excessive wastage. Internal examination and testing of void spaces, compartments filled with foam or corrosion inhibitors and tanks used only for lube oil, light fuel oil, diesel oil or other non-corrosive products may be waived, provided that, upon general examination, the Surveyor considers their condition to be satisfactory. External thickness gauging may be required to confirm corrosion control.

3.3.3 Attachments of Anchor Racks, Fairleads, and Anchorlines

Attachments of anchor racks and anchor cable fairleads are to be examined. Foundations in way of selective anchor line fairlead support structures are to be cleaned and nondestructive examinations performed. Internal support structures in way of these foundations are to be closely examined.

3.3.4 Other Structures

Applicable structures, such as pipe racks, process support structures, deck houses, superstructures, helicopter landing areas and their respective attachments to the deck or hull.

3.3.5 Foundations

Foundations and supporting headers, brackets and stiffeners for process related apparatus, where attached to hull, deck, superstructure or deck house.

3.3.6 Connections of Columns and Diagonals to Upper Hull, etc.

Connections of columns and diagonals to upper hull or platform and lower hull or pontoons. Joints of supporting structure, including diagonals, braces and horizontals, together with gussets and brackets. Internal continuation or back-up structure for the above. Nondestructive testing (NDT) may be required at suspect areas.

3.3.7 Survey of Underwater Parts

Survey of parts of the installation that are underwater and inaccessible to the Surveyor may be accepted on the basis of an examination by a qualified diver, conducted in the presence of the Surveyor. Video or photo records, nondestructive testing and thickness gauging may be required in addition to the diver's report. Refer to Section 7-2-6 of the *MODU Rules*.

Where inspection of underwater joints is required, sufficient cleaning is to be performed in way, and water clarity to be adequate, to permit meaningful visual, video, camera or NDT, as required. Every effort is to be made to avoid cleaning damage to special coatings.

3.3.8 Hull Thickness Measurement

At each Special Periodical Survey, hull thickness measurement (gauging) is to be performed where wastage is evident or suspected. At Special Periodical Survey No. 2 and subsequent Special Periodical Surveys, representative gaugings are required in accordance with 7-2-5/Table 3 of the *MODU Rules*. Special attention is to be given to the splash zones on hulls, columns and ballast tanks, free-flooded spaces and the bottom hulls. The thickness gauging requirements indicated in the table may be reduced or increased, as deemed necessary or appropriate by the Surveyor, in accordance with Notes 2 and 3 of 7-2-5/Table 3 of the *MODU Rules*.

3.5 Floating Production Installations in Lightering Service

In addition to the applicable requirements of 7-2-6/3.1 of these Rules, the Special Periodical Survey is also to include an external examination and internal Close-up Survey of hull structures, including thickness measurements, where fenders for lightering operation were located.

5 Mooring System

SPS of the mooring system is mandatory for all types of floating production installations, and are to comply with following requirements of this Subsection, as applicable.

Since it is impractical to cover all types of mooring systems, the following are provided as guidance to show the basic intent of the requirements. Operators and designers may submit alternative survey requirements based either on service experience or manufacturer's recommendations. Upon ABS review and acceptance, these alternative survey procedures will form the basis for the Special Periodical Survey of the Mooring System.

Typically, the SPS – Mooring System is to include all items listed under the Annual Survey and, in addition, the following are to be performed, where applicable:

i) A Drydocking Survey or equivalent underwater inspection of the SPM system is to be performed. This survey is to include examination of the entire structure of the SPM, the protective coating, cathodic protection system, the chain stoppers and their locking devices.

Any suspect areas where excessive corrosion is evident are to be thickness gauged. Gaugings are to be taken on the structures of the SPM when it has undergone service for 15 years or more.

ii) An examination is to be made on all anchor chains for excessive corrosion and wastage. In particular, the areas to be specially examined are the areas having the most relative movement between the chain links. These areas are normally located in way of the seabed touchdown sections of the catenary part of the chains. The chains are to be inspected for looses studs and link elongations. Sufficient representative locations are to be gauged for wear and wastage. Areas susceptible to corrosion, such as the wind-and-water areas, are to be specially gauged, if considered necessary by the attending Surveyor.

iii) A close examination is to be performed on all mooring components and accessible structural members that carry the mooring loads. These structures include the chain stoppers or cable holders, the structures in way of the chain stoppers or cable holders, structural bearing housing and turret/structural well annulus areas. These structures are to be thoroughly cleaned and examined and any suspect areas are to be nondestructively tested.

iv) A general inspection is also to be carried out on the degree of scour or exposure in way of the anchor or anchor piles to ascertain that these components are not overexposed.

v) An examination is to be performed on the main bearing of the SPM system. This examination is to include visual inspection of bearing, if accessible, for water egress into the structural housing, corrosion, pitting and excessive wear. If the bearing is inaccessible, at least the weardown is to be ascertained and the condition of the bearing seals verified. If disassembled, the bearing rollers and the racer housings are to be examined.

vi) For inaccessible structures, special alternative inspection procedures for inspection of these areas are to be submitted for approval.

vii) The chain tensions are to be checked and where found not in compliance with the specifications are to be readjusted accordingly. Excessive loss of chain or tendon tensions is to be investigated.

viii) Representative areas of the chains are to be examined and checked for excessive wastage. In particular, areas in way of the chain stoppers and the seabed touchdown areas are to be specially examined and measured for excessive wear.

ix) For disconnectable type mooring systems, the disconnect and connect system for the mooring system is to be tested as considered necessary by the attending Surveyor. Alternatively, records of disconnect/connect operations between the credit date of the last Special Periodical Survey and the current due date of same may be reviewed, and if found satisfactory, it may be considered to have been in compliance with this requirement.

7 Fire and Safety Systems

SPS of the entire fire and safety systems installed throughout the floating production installation is mandatory for all types of floating production installations.

Special Periodical Survey – Fire and Safety Systems is to include compliance with the Annual Survey requirements and, in addition, the following requirements as listed below are to be carried out, as applicable, the parts examined, placed in satisfactory condition and reported upon.

Following systems are to be verified to confirm no significant changes have been made to any of the systems and that they remain in satisfactory condition.

7.1 Passive Fire Protection Systems

Passive fire protection systems, including the following items are to be tested:

i) Function testing of all fire doors

ii) Function testing of all ventilation fire-dampers

iii) Function testing of all ventilation system closures and stoppage of power ventilation

iv) Function testing of all shutters or water curtains (where fitted)

7.3 Active Fire Protection – Fixed Systems

Active fire protection fixed systems, including the following items are to be tested:

i) Function testing of all fire pumps. Other pumps used for active fire protection are also to be tested. This is to include confirmatory testing of the fire pump capacity, and where installed, testing of relief valves of the fixed fire main system.

ii) Hydrostatic testing of the fire main system

iii) Hydrostatic testing of fire hoses, as necessary

7.5 Active Fire Protection – Additional Fixed Systems

Where installed, active fire protection additional fixed systems, including the following items are to be tested:

i) Gas smothering system, including confirmatory examination of the storage of the gas medium, gas alarms, and manual controls

ii) Function testing of fixed water spraying systems

7.7 Active Fire Protection – Portable Systems

All portable fire-fighting equipment fitted onboard, are to be in accordance with ABS approved plans. In addition, testing of the firefighter's outfit, as necessary.

7.9 Fire Detection and Alarm Systems

Fire detection and alarm systems, as installed, are to be tested.

7.11 Gas Detection and Alarm Systems

Gas detection and alarm systems, as installed, are to be tested.

7.13 Outfitting

Outfitting arrangements, including the following items are to be tested:

i) Lighting tings in way of all escape routes

ii) Contact makers for general alarm system, communication system installed in all emergency control stations

7.15 Emergency Shutdown Arrangements

Emergency shutdown arrangements provided to disconnect or shutdown, either selectively or simultaneously, of the electrical equipment as outlined in the floating production installation's operating manual, are to be tested.

Services such as the emergency lighting, general alarm system, public address system, distress and safety radio system, that are required to be operable after an emergency shutdown of the installation, are to be verified for their proper operation.

9 Machinery and Electrical Systems (Marine & Safety Systems)

SPS – Machinery and Electrical Systems servicing the marine and safety systems is mandatory for all types of floating production installations.

Special Periodical Survey – Machinery is to include compliance with the Annual Survey requirements and, in addition, the following requirements as listed below are to be carried out, as applicable, the parts examined, placed in satisfactory condition and reported upon.

9.1 Correlation with Special Periodical Survey – Hull

Main and auxiliary engines of all types of installations are to undergo Special Periodical Survey at intervals similar to those for Special Periodical Survey – Hull in order that both may be recorded at approximately the same time. In cases where damage has involved extensive repairs and examination, the survey thereon may be considered as equivalent to a Special Periodical Survey.

9.3 Machinery Parts to be Examined

In addition to the requirements for Annual Survey, at each Special Periodical Survey, special attention is to be given to the following requirements, as applicable.

9.3.1 Openings to the Sea and Fastenings

All openings to the sea, including sanitary and other overboard discharges together with the cocks and valves connected therewith, are to be examined internally and externally while the installation is in drydock or at the time of underwater examination in lieu of drydocking, and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

9.3.2 Pumps and Pumping Arrangements

Pumps and pumping arrangements, including valves, cocks, pipes, and strainers, are to be examined.

9.3.3 Nonmetallic Expansion Pieces

Nonmetallic flexible expansion pieces in the main salt-water circulating system are to be examined internally and externally.

9.3.4 Bilge and Ballast System, and other Systems

The Surveyor is to be satisfied with the operation of the bilge and ballast systems. Other systems are to be tested as considered necessary.

9.3.5 Machinery Foundations

The foundations of machinery, particularly those categorized as "Primary Application Structure" are to be examined.

9.3.6 Pressure Vessels

Heat exchangers and other unfired pressure vessels (except those used solely for drilling operations and complying with a recognized standard) with design pressures over 0.7 bar (7 kgf/cm^2, 100 psi) are to be examined, opened out or thickness gauged and pressure tested as considered necessary, and associated relief valves proven operable. Evaporators that operate with a vacuum on the shell need not be opened, but may be accepted on the basis of satisfactory external examination and operational test or review of operating records.

9.5 Electrical Parts to be Examined

9.5.1 Main Switchboards and Distribution Panels

Fittings and connections on main switchboards and distribution panels are to be examined, and care is to be taken to see that no circuits are over fused.

9.5.2 Cables

Cables are to be examined as far as practicable without undue disturbance of fixtures.

9.5.3 Generator Run

All generators are to be run under load, either separately or in parallel; switches and circuit breakers are to be tested.

9.5.4 Equipment and Circuits

All equipment and circuits are to be inspected for possible development of physical changes or deterioration. The insulation resistance of the circuits is to be measured between conductors and between conductors and ground and these values compared with those previously measured. Any large and abrupt decrease in insulation resistance is to be further investigated and either restored to normal or renewed as indicated by the conditions found.

9.5.5 Electrical Auxiliaries, Generators and Motors

The specified electrical auxiliaries for vital purposes, generators and motors are to be examined and their prime movers opened for inspection. The insulation resistance of each generator and motor is to be measured.

9.5.6 Accumulator Batteries

The accumulator batteries are to be examined, including their maintenance schedule and ABS reviewed procedure of maintenance.

9.5.7 Bilge Alarm (if fitted)

Bilge alarm system, if fitted, is to be tested and proven satisfactory.

9.7 Hazardous Areas

Surveys of hazardous areas and electrical equipment installed in hazardous areas are to comply with applicable requirements of the ABS *Rules for Building and Classing Facilities on Offshore Installations*.

9.9 Preventative Maintenance Techniques

Surveys of machinery that has been accepted for surveys based on preventative maintenance techniques are to comply with the requirements of Appendix 7-A-14 of the ABS *Rules for Survey After Construction (Part 7)*.

9.11 Self Propelled Installations – Main Propulsion Apparatus

On self-propelled installations, in addition to the requirements for Annual Survey and the applicable requirements of 7-2-6/9.3, the main and auxiliary machinery, including pressure vessels, are to be surveyed in accordance with the requirements of the latest edition of the ABS *Rules for Survey After Construction (Part 7)*, as applicable to self-propelled vessels.

Where the installation maintains the optional **AMS** Notation, the windings of generators and motors are to be thoroughly examined and found or made dry and clean. Particular attention is to be paid to the ends of the windings of stator and rotors. After the winding have been cleaned and found dry, they are to be varnished, if necessary, with a standard insulating varnish applied preferably by spraying.

9.11.1 Thrusters (where installed)

Thruster surveys are to comply with the requirements of Section 7-9-6 of the ABS *Rules for Survey After Construction (Part 7)*.

9.13 Major Repairs

On the occasion of major repairs, the coils repaired or renewed are to be subjected to a dielectric strain test, as specified under the applicable parts of Part 4, Chapter 3 of the *MODU Rules*. In addition, the circuits containing the repairs or renewals and coils which have been disturbed during repairs are to be subjected to dielectric strain tests for one minute by application of a potential of 125% of the maximum operating voltage of the circuits to which it is applied. The direct current fields of generators and motors are to be subjected for one minute to a test potential equal to 50% of the value specified under the applicable parts of Part 4, Chapter 3 of the *MODU Rules* and the whole apparatus operated under full-load conditions.

11 Inert Gas Systems (where installed)

Applicable requirements of 7-6-2/3.1.1(o) of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with.

13 Liquefied Gas Installations (where installed)

In addition to the applicable requirements of 7-2-4/1.3.2 and 7-2-4/1.1 of these Rules, the SPS of Liquefied Gas Installations is to include the following:

13.1 SPS No. 1 and No. 2

i) An internal examination is to be made of all cargo tanks (primary containers), after being gas freed, including internal mountings and equipment.

ii) For independent tanks, foundations, chocks, sway braces, keys, anti-flotation arrangements, the secondary barriers or hull plating or both are to be examined, with special attention being given to the cargo tanks and insulation in way of the above. See 7-2-6/13.1vi) for insulation removal. Framing adjacent to the cargo containment system is also to be examined.

Where the arrangement is such that the insulation cannot be examined, the surrounding structures in the wing tanks, double bottom tanks and cofferdams are to be examined for cold spots while the cargo tank is in cold condition, unless sufficient evidence of the integrity of the insulation is available from the voyage records.

iii) Venting systems, relief valves or other arrangements provided for emergency removal of gas from the interbarrier spaces and hold spaces are to be opened, inspected, tested and readjusted as necessary.

iv) Relief valves, liquid-level indicators and venting systems for the primary cargo containment system are to be examined. All relief valves are to be opened, inspected, tested and readjusted as necessary. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced. Liquid-level indicators and alarms are to be proven satisfactory. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination and testing of a representative sampling of valves including each size of each type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since the crediting of the previous Special Periodical Survey. The testing and setting of relief valves may be carried out in place or after removal.

v) All piping, machinery and equipment for loading, unloading, venting, compressing, refrigerating, liquefying, heating or otherwise handling the liquefied gas or vapor and liquid nitrogen, and gas burning installations is to be examined including removal of insulation and opening for examination, as deemed necessary. Where deemed suspect, a hydrostatic test to 1.25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing. All emergency shut-down valves and remote operating valves in the cargo piping systems are to be inspected and proven operable. The pressure relief valves are to be function-tested. A random selection of valves is to be opened for examination and adjusted.

vi) Insulation is to be removed in way of any distorted or otherwise suspect insulation or structural part of the cargo tanks or elsewhere to carry out any of the examinations as required by the Surveyor.

vii) Where there is evidence of corrosion, or where one side of the cargo tank is exposed to possible corrosive atmosphere, the plating of the cargo tanks is to be gauged by nondestructive means to determine the thickness.

viii) All cargo pump tower structures are to be examined including stiffeners, bracings, fasteners and locking devices, spray nozzles, wiring with associated conduits and pipe connections. Where deemed necessary by the Surveyor, dimensional measurements and/or nondestructive testing may be required. See also 7-2-6/13.1x).

ix) The secondary barrier is to be checked for its effectiveness by means of a pressure/vacuum test, a visual inspection or other acceptable method.

x) Nondestructive Testing is to be carried out as follows:

a) Nondestructive testing is to supplement cargo tank inspection with special attention to be given to the integrity of the main structural members, tank shell and highly stressed areas, including welded connections as deemed necessary by the Surveyor. The following items are, inter alia, considered as highly stressed areas:

- Cargo tank supports and anti-rolling/anti pitching devices
- Web frames or stiffening rings
- Y-connections between tank shell and a longitudinal bulkhead of bilobe tanks
- Swash bulkhead boundaries
- Dome and sump connections to the tank shell
- Foundations for pumps, towers, ladders, etc.
- Pipe connections

b) For independent tanks type C, in addition to the requirements of *a)* above, at alternate Special Periodical Surveys, at least 10% of the length of the welded connections in each highly stressed area is to be tested. This testing is to be carried out internally and externally, as applicable. Insulation is to be removed, as necessary, for the required nondestructive testing.

c) For independent tanks type B, the extent of the nondestructive testing is to be in accordance with a planned program specially prepared and approved for the cargo tank design.

xi) Where nondestructive testing, or other evidence such as leakage or distortion, raises doubts as to the structural integrity of a cargo tank, a hydrostatic or hydropneumatic pressure test is to be carried out. For integral tanks and independent tanks type A and B, the test pressure is to be at least MARVS at the top of the tank. For independent tanks type C and pressurized tanks B with MARVS 2.06 bar (2.1 kgf/cm^2, 30 psi) and over, the test pressure is to be 1.25 times MARVS.

xii) Electrical bonding arrangements, including bonding straps where fitted, of the piping systems located within cargo tanks, ballast tanks, pipe tunnels, cofferdams and void spaces bounding cargo tanks are to be examined.

xiii) Systems for removing water or cargo from interbarrier spaces and holds are to be examined and tested as deemed necessary.

xiv) For membrane and semi-membrane tanks systems, inspection and testing are to be carried out in accordance with programs specially prepared in accordance with an approved method for the actual tank system.

xv) All gas-tight bulkheads are to be examined. The effectiveness of gas-tight shaft sealing is to be verified.

xvi) The hoses and spool pieces used for segregation of piping systems for cargo, inert gas and bilge are to be examined.

13.3 SPS No. 3 and Subsequent Special Periodical Surveys

In addition to all of the requirements of Special Periodical Survey No. 1 or 2, the following requirements are to be complied with for Special Periodical Survey No. 3 and all subsequent Special Periodical Surveys.

i) The plating of at least one (1) cargo tank, including membrane tanks and pressure vessels is to be gauged by nondestructive means to determine the thickness. Where only cargoes of a non-corrosive nature are carried, modifications to the extent of thickness measurements may be specially considered.

ii) The plating of metallic secondary barriers which are structural supports for the primary barrier is to be gauged by nondestructive means to determine the thickness.

15 Dynamic Positioning Systems (if classed)

Dynamic Positioning Systems are to comply with the requirements of Section 7-9-6 of the ABS *Rules for Survey After Construction (Part 7)*.

17 Automatic and Remote-Control Systems (if classed)

For Shipboard Automatic and Remote-Control System, applicable requirements of Chapter 8 of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with.

19 Production Facilities (if classed)

Where the floating production installation's production facilities are classed, applicable requirements of the ABS *Rules for Building and Classing Facilities on Offshore Installations* are to be complied with.

Maintenance records are to be kept and made available for review by the attending Surveyor. The maintenance records will be reviewed to establish the scope and content of the required Annual and Special Periodical Surveys. During the service life of the facilities, maintenance records are to be updated on a continuing basis. The operator is to inform ABS of any changes to the maintenance procedures and frequencies, as may be caused, for example, by changes or additions to the original equipment. The Surveyor may determine during the periodic survey if the changes are sufficient to warrant review by ABS' technical staff.

21 Import and Export Systems (if classed)

Since it is impractical to cover all types of import and export systems, the following are provided as guidance to show the basic intent of the requirements. Operators and designers may submit alternative survey requirements based either on service experience or manufacturer's recommendations. Upon review and if found acceptable, these alternative survey procedures will form the basis for the SPS of the Import and Export System.

Typically, the SPS is to include all items listed under the Annual Survey and, in addition, the following are to be performed:

i) Fluid and electrical swivels are to be disassembled, if considered necessary, and examined for wear and tear. The seals are to be examined. Upon completion of the reconditioning, the fluid swivels are to be hydrostatically tested. Similarly, the electrical swivels are to be insulation tested upon reassembly.

ii) During underwater inspection of the SPM system, flexible risers are to be examined, including all arch support buoyancy tanks. Risers are to be inspected for damage in high stress areas, such as areas in way of the end flanges, areas in way of the arch support clamps and the bottom of all looped areas. Spreader bars, if fitted to separate one riser string from another, are to be inspected for wear and tear. Hydrostatic tests may be required to be conducted on the risers, as deemed necessary by the attending Surveyor.

iii) For deep sea applications, riser suspension or support systems are to be examined for deterioration and loss of tension. Support areas in way of the riser are to be closely examined for fretting corrosion, wear, kinks, creases, etc.

iv) Floating export hoses are to be examined for kinks, surface cracks, chafing damages, etc. Hydrostatic and vacuum tests may be required to be conducted on the floating hose string, as deemed necessary by the attending Surveyor.

v) All piping systems are to be opened up for examination. Nondestructive and hydrostatic tests may be required, where considered necessary by the attending Surveyor.

vi) For disconnectable type mooring systems, the disconnect and connect arrangements for the import and export systems are to be tested, as considered necessary by the attending Surveyor. Alternatively, records of disconnect/connect operations between the credit date of the last SPS and the current due date of same may be reviewed, and if found satisfactory, it may be considered to have complied with this requirement.

vii) Hoses designed and manufactured based on OCIMF standards are to be tested in accordance with the OCIMF *Guide for the Handling, Storage, Inspection, and Testing of Hoses in the Field*.

PART

7

CHAPTER **2 Surveys After Construction**

SECTION **7 Drydocking Surveys or Equivalent**

1 Underwater Inspection in Lieu of Drydocking Survey (UWILD)

For site-specific floating production installations, UWILD by a diver and a remotely operated vehicle may be considered equivalent to a Drydocking Survey, provided the UWILD is carried out in accordance with Section 7-2-6 of the *MODU Rules* and ABS approved UWILD procedure. This approved procedure is to be made available onboard. In addition, the procedure is to also consist of the following:

i) Scope of inspection that is not to be less than as noted in 7-2-7/3 of these Rules.

ii) Procedure for divers to identify the exact location at which they are conducting their inspection.

iii) Procedure for cleaning the marine growth for inspection purposes that is to include the extent and location of the underwater cleaning.

iv) Procedure and extent for measuring the cathodic potential readings in way of the structures.

v) Procedure and extent for taking thickness gaugings of the structures and NDT of critical joints.

vi) Qualifications of all divers conducting the inspection, NDT and thickness gaugings.

vii) The type of underwater video and photography, including means of communication, monitoring and recording.

viii) For Underwater Inspections in lieu of Drydocking Surveys (UWILD) associated with Special Periodical Surveys, means are to be provided to permit the opening up of all sea valves and overboard discharges for internal examination. In addition, all Special Periodical Survey items related to the underwater portion of the hull or structure, including the gauging requirements are to be dealt with during the underwater survey.

For each drydocking or equivalent underwater examination after Special Periodical Survey No. 4, requests to conduct an UWILD, in accordance with previously approved plans, are to be submitted for consideration well in advance of the proposed survey. Approvals to conduct the UWILD after Special Periodical Survey No. 4 are to be made available onboard for the Surveyors' reference.

3 Parts to be Examined

3.1 Ship-type and Barge-type Floating Production Installations

For ship-type and barge-type installations, the following items are to be examined, as applicable:

The keel, stem, stern frame, rudder, propeller, and outside of side and bottom plating are to be cleaned as necessary and examined, together with bilge keels, thrusters, exposed parts of the stern bearing and seal assembly, sea chest, rudder pintles and gudgeons, together with their respective securing arrangements. All sea connections and overboard discharge valves and cocks, including their attachments to the hull or sea chests, are to be externally examined. All nonmetallic expansion pieces in the sea-water cooling and circulating systems are to be examined both externally and internally. The stern bearing clearance or weardown and rudder bearing clearances are to be ascertained and reported on.

3.3 Column Stabilized, Tension Leg Platform and Spar Floating Production Installations *(2014)*

For column-stabilized, tension leg platform and spar installations, the Structural Critical Inspection Points (SCIPs) identified in the In Service Inspection Program (ISIP) plan are to be examined. In addition, the following are also to be examined:

i) External surfaces of the upper hull or platform, footings, pontoons or lower hulls, underwater areas of columns, bracing and their connections, as applicable, are to be selectively cleaned and examined. These areas include joints of critical structural members, areas susceptible to damage from supply installations, anchor chains, dropped equipment, corrosion and erosion from loss of coating, or sand scouring and areas of progressed and accumulated wear-and-tear.

ii) Nondestructive testing may be required of areas found to be suspect. Joints of different configurations of major structural members are to be selected, cleaned and magnetic particle inspected. The selection of these joints is to be such that all joints underwater are to be inspected every five years.

iii) Sea chests and strainers are to be cleaned and examined.

iv) External portions of propulsion units are to be examined, if applicable.

v) The type, location and extent of corrosion control (coatings, cathodic protection systems, etc.), as well as effectiveness, and repairs or renewals to same are to be reported in each survey. Particular attention is to be given to corrosion control systems in ballast tanks, free-flooding areas and other locations subjected to sea water from both sides.

vi) All tanks and voids that are to be internally examined are to be thoroughly ventilated and gas freed prior to being entered and are to be carefully monitored for pocketing or emissions of hazardous gases during examination.

vii) In conjunction with Drydocking Surveys (or equivalent), the following ballast spaces are to be internally examined, and the effectiveness of coatings or corrosion control arrangements are to be verified either visually by indicator strips or by thickness gauging (as considered necessary), placed in satisfactory condition, as found necessary, and reported upon:

a) Representative ballast tanks in footings, lower hulls or free-flooding compartments, as accessible

b) At least two ballast tanks in columns or upper hull, if applicable

5 Corrosion Protection System – Underwater Body

In addition to the above requirements, the following are to be to be performed during all of the Drydocking (or equivalent) Surveys:

i) Cathodic potential readings are to be taken from representative positions on the entire underwater body and evaluated to confirm that the cathodic protection system is operating within design limits.

ii) Sacrificial anodes are to be examined for depletion and placed in satisfactory condition, as considered necessary.

iii) Impressed current system anodes and cathodes are to be checked for damage, fouling by marine growth and carbonate deposits. The current and voltage demands of the system are also to be checked to confirm the system is functioning properly.

iv) Additional examinations are to be performed on the wind and water areas of the structures where coating breaks are evident. Thickness measurements in these areas may be required if found necessary by the attending Surveyor.

7 Mooring System

In addition to the above requirements, the following items of the mooring system are to be cleaned and examined, where applicable:

i) The mooring anchor chain or cable tensions are to be measured and the end connections of these components are to be examined. All mooring chains are to be generally examined for their entire lengths.

ii) Anchors, cables and their respective handling means are to be examined.

iii) The buoyancy tanks are to be cleaned and examined, if applicable.

iv) Chain and stopper assemblies are to be cleaned, examined and NDT performed, as considered necessary by the attending Surveyor.

v) Areas of high stress or low fatigue life are to be preselected, cleaned and NDT performed, if considered necessary.

vi) Scour in way of anchors or anchor piles is to be examined.

vii) Cathodic potential readings are to be taken from representative positions on the entire underwater structure of the mooring system to confirm that the cathodic protection system is operating within design limits.

viii) Highly stressed, high wear and tear areas of the mooring chain are to be closely examined and nondestructively tested, if found necessary by the attending Surveyor. These include areas in way of the stoppers and sea bed touchdown areas.

9 Import and Export Systems (if classed)

9.1 Import System

For import systems, the following are to be cleaned and examined, where applicable:

i) The entire riser system.

ii) The arch support buoyancy tanks, their structures and the clamping devices.

iii) The flexible riser, including all end flanges and bolting arrangements and spreader bars, if applicable.

Hoses designed and manufactured based on OCIMF standards are to be tested in accordance with the OCIMF *Guide for the Handling, Storage, Inspection, and Testing of Hoses in the Field.*

9.3 Export System

For export systems, the following are to be cleaned and examined, where applicable:

i) The entire export flexible system is to be examined for damage due to chafing and fatigue fractures.

ii) Hoses designed and manufactured based on OCIMF standards are to be tested in accordance with the OCIMF *Guide for the Handling, Storage, Inspection, and Testing of Hoses in the Field.*

iii) All navigation aids are to be examined and functionally tested.

PART
7

CHAPTER 2 Surveys After Construction

SECTION 8 Tail Shaft and Tube Shaft Surveys

1 Tail Shaft and Tube Shaft Surveys

For Tail Shaft Surveys of self-propelled floating production installations, applicable requirements of Chapter 5 of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with. However, due to low running hours on tail shafts of installations, the interval between tail shaft surveys may be extended based on the following being performed to the satisfaction of the attending Surveyor:

1.1 Parts to be Examined

Following items are to be carried out:

i) Diver's external examination of stern bearing and outboard seal area, including weardown check as far as is possible.

ii) Examination of the shaft area (inboard seals) in propulsion room(s).

iii) Confirmation of lubricating oil records (satisfactory oil loss rate, no evidence of unacceptable contamination).

iv) Shaft seal elements are to be examined/replaced in accordance with seal manufacturer's recommendations.

PART

7

CHAPTER 2 Surveys After Construction

SECTION 9 Boiler Surveys

Boiler Surveys are to comply with the requirements of Chapter 7 of the ABS *Rules for Survey After Construction (Part 7)*.

PART

7

APPENDIX 1 Guidance for the Class Notation, Storage Service

(1 September 2007)

CONTENTS

PART
7

APPENDIX **1** **Guidance for the Class Notation, Storage Service** *(1 September 2007)*

1 Introduction

This guidance clarifies the present ABS policy for treatment of classed oil carriers operating in oil storage service. Under no circumstances is this policy to be used for any other vessel without the specific approval of the Chief Surveyor.

3 Application

This guidance applies to vessels, which are to maintain their current **Oil Carrier** classification or for vessels that have reached their MARPOL phase out date, in such cases these vessels will only be eligible for **Oil Storage Service** notation. The primary class differences between classification as an **FPSO, FSO** or **FOI** and **Oil Carrier, Storage Service** or **Oil Storage Service** classification are as follows:

3.1 FPSO, FSO or FOI Notations

3.1.1

Classed floating production installations (i.e., **FPSO, FSO** or **FOI**) require analysis and certification of the mooring system as part of the class requirements for the particular site.

3.1.2

Those that are classed **Disconnectable** are required to maintain propulsion capability for steaming out of harm's way in an established condition in which the installation is able to safely leave the site before the weather event meets or exceeds the design limits of the fixed mooring system.

3.3 Storage Service Notation

3.3.1

For **Oil Storage Service** vessels the mooring arrangements are the responsibility of the Owner, including compliance with Flag and Coastal State requirements.

3.3.2

In order for a vessel to be classed as:

i) **✠ A1 Oil Carrier, Storage Service**; or

ii) **A1 Oil Carrier, Storage Service**; or

iii) **✠ A1 Oil Storage Service**; or

iv) **A1 Oil Storage Service**, the following is required:

3.3.2(a) Written requirements for the conversion to Oil Storage Service are to be obtained from the Assistant Chief Surveyor-Offshore.

3.3.2(b) The attending Surveyor is to report upon the completion of the requirements and recommend Classification as per 7-A1/3.3.2i), ii), iii) or iv) above, as applicable.

3.3.2(c) The vessel's propulsion machinery must be retained to **AMS** classification requirements.

3.3.3

Vessels classed as **Oil Carrier, Storage Service** or **Oil Storage Service** will be permitted the **Storage Service** Classification only while remaining in storage service.

3.3.3(a) Storage Service, for the purpose of this Class notation, means a vessel that is stationed at a single location, does not transit between ports or different sites and does not carry cargo between ports or sites.

3.3.3(b) The vessel serves only in a storage and offloading capacity at a single designated location that is in sheltered waters or at a location that enables the unit to quickly move away from a severe weather event.

3.3.3(c) When the vessel leaves the designated "storage service" location, other than to take refuge from severe weather, the "storage service" provisions provided herein no longer apply.

3.3.3(d) The vessel is not to transport oil to a port or terminal when taking refuge from weather. It is envisioned that voyages, without cargo, may be necessary for repair works or to a lay-up site when the storage service is seasonal.

3.3.4

For vessels planned for this service where the location is not sheltered or the vessel is not self-propelled, the requirements for **FPSO**, **FSO** or **FOI** will apply.

5 Survey After Construction

5.1 General

Vessels in storage service will be surveyed in accordance with the applicable sections of the ABS *Rules for Survey After Construction (Part 7)* except as noted below:

5.3 Drydocking Surveys

5.3.1

The vessel is to be properly prepared for the extended positioning. The preparation would normally include a complete Special Survey appropriate to the age of the vessel, in accordance with 7-3-2/5.13 of the ABS *Rules for Survey after Construction (Part 7).*and preparation of the underwater parts in accordance with Appendix 7-A-1 of the ABS *Rules for Survey after Construction (Part 7)*. All requirements for Close-up Survey and thickness measurements are to be applied. Drydocking Surveys will continue to be required at the regular rule required intervals (normally twice in a 5 year special survey period). However, Underwater Inspection in Lieu of Drydocking (UWILD) examination may be carried out to meet the Drydocking requirements.

5.3.2

For vessels less than 15 years of age the drydocking requirements for Special Survey and Intermediate survey may be accomplished by UWILD for up to 10 years of storage service. For vessels that are over 15 years of age the Intermediate survey drydocking will be permitted to be accomplished by UWILD, the Special Survey drydocking will be required to be an out of water docking.

5.3.3

For vessels exceeding 15 years of age, the time allowable where UWILD is applied may be extended to a maximum of 10 years in special circumstances where agreed to by the Assistant Chief Surveyor-Offshore.

5.3.4

Upon completion of the storage service the vessel would be required to proceed to drydock for an out of water drydocking survey if the vessel has been in Storage Service for two years or more.

5.5 Special Survey of Hull

Vessels in Storage Service will not be given the **ESP** notation. However, a vessel in Storage Service will be required to carry out the Special Survey of Hull in accordance with ESP requirements except that the requirement for an out of water drydocking in association with a Special Survey may be modified to a UWILD while the vessel is in storage service, at the storage site, provided no conditions were found to exist that would warrant an out of water drydocking. In these cases, gauging of the underwater sections of the vessel can be taken afloat by qualified divers or from inside the vessel.

5.7 Intermediate Hull Surveys

Intermediate Hull Surveys, in accordance with the requirements for non-ESP tankers will apply, as long as the vessel remains in Storage Service.

5.9 Lightering Service

Where transfer of cargo is accomplished by side by side mooring of a shuttle tanker and the Storage Service vessel, the Storage Service vessel will be considered in "Lightering Service". The survey requirements of 7-1-1/19 of the ABS *Rules for Survey After Construction (Part 7)* will apply.