PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-3010.2Q-1351-140-P4X-001	
	CLIENT: MARLIM LESTE E SUL		SHEET: 1 of 33
	PROGRAM: BASIC DESIGN – REVIT I		
	AREA: MARLIM LESTE E SUL		ESUP
	TITLE: **HULL STRUCTURAL REQUIREMENTS**		INTERNAL

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INDEX OF REVISION

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	REVISED WHERE IT IS MARKED
B	REVISED ITEMS 3.8 AND 4.1

	REV. 0	RE V. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	MAY/09/24	JUN/20/24	JUL/22/24						
EXECUTION	U3ZY	U3ZY	UPC6						
CHECK	B3NE	B3NE	B3NE						
APPROVAL	CYEL	CYEL	CYEL						

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1 INTRODUCTION

This document establishes BUYER mandatory requirements to be followed by SELLER for the structural analysis, design and construction of the hull structures for PETROBRAS Basic Design - REVIT 1 - *Marlim Leste e Sul* - Floating Production Storage and Offloading System (FPSO), as part of engineering design development at DETAILED ENGINEERING PHASE.

HULL SUPPLIER shall carry out the DETAILED ENGINEERING PHASE based on PETROBRAS Basic Design - REVIT 1 - *Marlim Leste e Sul*.

HULL SUPPLIER shall define a Classification Society (CS) to classify the structural DETAILED ENGINEERING PHASE. HULL SUPPLIER shall use the latest CS rules and standards versions, statutory requirements and document guidelines. PETROBRAS requirements presented in this document shall be followed and, in case of conflict, the most restrictive requirement shall prevail.

In case of rules, requirements and statutory requirements update until keel laying event, it is HULL SUPPLIER scope to immediately inform PETROBRAS to verify the impacts of the necessary changes in the design and construction.

Under PETROBRAS and CS previous approval, HULL SUPPLIER may consider additional relevant criteria, based on its experience.

Fabrication and tolerance requirements specified by basic design shall be followed by HULL SUPPLIER during the DETAILED DESIGN PHASE.

HULL SUPPLIER shall issue a “Hull Structures Design Premises” document based on the present document. The document shall include additional requirements for assembly and construction, shall detail the scope of supply, and shall be submitted to PETROBRAS and CS approval. This document shall present the methodology and computational tools to be adopted during the DETAILED ENGINEERING PHASE. This document shall be revised whenever it is needed during the DETAILED ENGINEERING PHASE or during the CONSTRUCTION.

HULL SUPPLIER shall submit to PETROBRAS:

- All structural design reports and drawings in pdf and in editable version. The 2D and 3D drawings shall be provided in system formats compatible with contractual software;
- All computer structural analysis models containing the geometry, mesh, load conditions, load cases and boundary conditions (the input files shall be in accordance to the format defined in the contract EXHIBIT 03);
- The hull block master plan and all structural block shop drawings in editable and pdf format;
- All blocks weld maps (containing each weld seam identification) in editable and pdf file format;

The pdf files shall have search capability.

HULL SUPPLIER shall submit in due time to PETROBRAS and CS approval, the structural design reports and drawings, containing the files as described previously. It is HULL SUPPLIER's responsibility to reply and incorporate all CS comments.

It is HULL SUPPLIER's ´s responsibility to update the 3D model in order to reflect all structural modification.

During DETAILED ENGINEERING PHASE, changes in hull structural design shall be in accordance with item 7 of EXHIBIT III – DIRECTIVES FOR ENGINEERING EXECUTION (Definition of Flexibility of Documentation complying with Brazilian LAW 13,303).

2 RULES, CODES, STANDARDS AND REFERENCES

2.1 Rules, Codes and Standards

The structural DETAILED ENGINEERING PHASE shall use the latest CS rules and standards, as well as the latest rules and regulations from Flag Administration and Brazilian Statutory Administration.

Additionally, HULL SUPPLIER shall follow the requirements of the standards listed below.

[1] IACS – Common Structural Rules for Bulk Carriers and Oil Tankers – Jan. 2018;

[2] AISC 335-89 – Specification For Structural Steel Building – Allowable Stress Design and Plastic Design, 9th Ed.;

[3] API RP 2A – WSD – 23st Ed. – Recommended Practices for Planning, Designing and Constructing Fixed Offshore Structures – Working Stress Design – Errata and Supplement 3, Oct. 2007;

[4] API Spec 2C, Specification for Offshore Mounted Cranes, 7th Edition, Mar. 2012 – Errata 1 Mar. 2013;

[5] ANSI/AISC 360-16 – Specification for Structural Steel Buildings – Load and Resistance Factor Design - 2016;

[6] API RP 2A – LRFD – Planning, Designing and Constructing Fixed Offshore Structures – Load and Resistance Factor Design - 2019;

[7] API-RP-2FPS – Planning, Designing and Constructing Floating Production Systems – 2011, Reaffirmed 2020;

[8] NORSOK N-003, Actions and Action Effect, Sep. 2017;

[9] NORSOK N-004, Design of Steel Structures, Rev. 2, Oct. 2004;

[10] NR-12, Segurança no Trabalho em Máquinas e Equipamentos, Dec. 2019, in portuguese language;

[11] IACS Unified Interpretations for the application of MODU Code Chapter 2 paragraphs 2.1, 2.2, 2.3, 2.4 and revised technical provisions for means of access for inspections (resolution MSC.158(78)), Jun. 2016;

[12] NORMAM-223, Normas da Autoridade Marítima para Homologação de Helideques Instalados em Embarcações e em Plataformas Marítimas, in portuguese language.

[13] I-ET-3010.00-1350-960-PPC-001 – GUIDELINE FOR FPSO GREEN WATER ANALYSIS

[14] On the slamming of ships - Development of an approximate slamming prediction method, Delft University of Technology, 2018;

[15] ABS GUIDE FOR MEANS OF ACCESS TO TANKS AND HOLDS FOR INSPECTION., 2021.

If there are differences between the standards above, CS rules, Flag Administration and Brazilian Statutory Administration, the most restrictive one shall be considered.

2.2 Structural Basic Design 3D Model and Documents

The documents listed in I-LD-3010.2E-1200-940-P4X-002 shall be used as reference, as well as the 3D model resulted from basic design.

2.3 System of Units

HULL SUPPLIER documents, including numerical models input data and analyses results, quantitative information released in calculation notes, drawings or any other document shall consider the International System of Units (SI), as per Table 1.

Table 1 – Project Standard Units

Description or structural characteristic	Unit
Length	mm
Angles	degrees
Forces	kN
Moments	kN.m
Distributed loads	kN/m² or kN/m
Masses	kg or metric tons (t)
Member stress	N/mm² (MPa)
Time	s (second)
Temperature	°C

3 GENERAL DESIGN REQUIREMENTS

All structural analyses and documents shall fulfill PETROBRAS' requirements, CS rules and standards, flag's requirements, Brazilian laws and regulations

3.1 Design Life

SELLER shall design and build the hull structure considering 30 years of uninterrupted operation period without dry-docking necessity.

3.2 Environmental Data

Environmental parameters for structural analyses shall be obtained from I-ET-3000.00-1000-941-PPC-001 - METOCEAN DATA (CAMPOS BASIN). HULL SUPPLIER shall take into account the transportation condition considering the route from shipyard location to integration site and from integration site sheltered waters in Brazil. The period of return for the transportation analysis shall be 10 years.

3.3 Software

The following computer software are acceptable for analysis execution:

- Hydrodynamics, for the definition of wave loads on floating structures:
  - SESAM-WADAM
  - PRECAL
  - WAMIT
  - AQWA
- For hull's local structural analyses:
  - SESAM
  - ANSYS
  - NASTRAN
  - ABAQUS
- Analyses of space frame structures:
  - SACS
  - SAP 2000
  - GTSTRUDL
  - SESAM/GENIE
- For hull's global structural analyses:
  - NAUTICUS HULL / SESAM
  - EAGLE FPSO / NASTRAN
  - VERISTAR HULL
- Non-linear analyses:
  - ABAQUS
  - ANSYS
  - NASTRAN / LSDYNA
  - USFOS

Computational systems other than those listed shall be used only under previous PETROBRAS approval. All numerical models shall be submitted to PETROBRAS and in a format in accordance with the format defined in the contract EXHIBIT 03

3.4 Structural Materials

Material specification shall correspond to that defined in basic design. Any modification shall be approved by PETROBRAS and CS.

To prevent lamellar tearing, steel with Z quality (through thickness strength) shall be used in locations with significant through thickness tension (TTT), as per CS rules specification.

Steel design properties shall be taken as:

- Young's Modulus (E) = 210000 N/mm²
- Shear Modulus (G) = 80000 N/mm²
- Poisson's Ratio (ν) = 0.3
- Density (ρ) = 7850 kg/m³
- Coefficient of thermal expansion (α) = 12.0 x 10^{-6}/ºC

Creep curves and heat effects need to be assessed for special applications (e.g.: flare tower).

3.5 Structural Categorization

All areas of the structures shall be categorized according to the importance in terms of the application and consequence of an eventual failure, to be included in specific structural drawings. The information is used as guidance for material grade and quality choice, fabrication and weld inspection requirements.

Along the FPSO hull structure, it may be found regions with structural behavior similar to that of typical offshore production units, mainly where structures associated with production are attached, and other regions with behavior similar to that of typical ship structures, not affected by loads from those structures.

The design area categorization shall follow the document recommendations from CS rules and take into account the typical ship areas and offshore areas. Table 2 presents a general definition to be applied to offshore areas of the hull structure.

Document I-DE-3010.2Q-1351-140-P4X-007 – STEEL GRADES AND STRUCTURAL AREAS CLASSIFICATION PLAN presents the structural categorization considered in basic design. The structural categorization document shall be updated during DETAILED ENGINEERING PHASE to include the structures detailed during this stage of the design. The updated document shall be submitted to PETROBRAS and CS approval.

Any difference between material grade information among documents I-DE-3010.3Q-1351-140-P4X-007 – STEEL GRADES AND STRUCTURAL AREAS CLASSIFICATION PLAN, structural drawings and 3D model, the most restrictive information shall prevail.

Table 2 - Structural Categorization for Offshore Areas of the Hull

Structural Category	Typical Locations
Special Design Area	Regions of the Primary Structure that are critical for the load transfer and may be subject to critical stress concentrations; comprise highly stressed elements (usage factor larger than 0.85 for yielding/buckling verifications) in way of main supporting structures of heavy substructures and equipment; to be assigned to regions in general up to 1 m from stress concentration peaks in all directions. Examples for hull are regions of: support and foundations of heavily loaded topside modules columns; risers and pull-in supports and foundation; fairlead support and foundation; crane pedestal and foundation; flare tower foundation; support of chain stoppers; support of offloading riser; supporting structure for winches, lifting padeyes, davits, hawser brackets for shuttle tanker and towing brackets.
Primary Design Area	Structural elements essential to the overall unit integrity, but less critical than a special design area; comprise non-highly-stressed elements in way of main supporting structures mentioned above; regions of supports and foundations of modules columns not heavily loaded; pipe rack stanchions; heavy equipment substructure support girder, when not classified as special design area.
Secondary Design Area	Structural elements of minor importance, the failure of which is unlikely to affect the unit integrity. This class is represented in hull by walkways, stairs, handrails, piping supports, attachments and others, except when classified in categories above.

Notes:
1 - Stiffeners, brackets, tripping brackets, flat bars and other elements in special design areas belong to special design area classification, if not otherwise specified.
2 - Stiffeners, brackets, tripping brackets, flat bars and other elements in primary design areas belong to secondary design area classification, if not otherwise specified.

3.6 Welding

Welds shall be properly designed for all load conditions in accordance with CS rules and requirements. HULL SUPPLIER shall follow at least the minimum requirements presented on the document I-DE-3010.2Q-1351-140-P4X-001 - HULL GENERAL NOTES AND TYPICAL DETAILS.

Weld grinding procedure shall be submitted for PETROBRAS approval.

3.7 Hull Construction

HULL SUPPLIER shall guarantee the adequate construction techniques in order to ensure requested design alignment and CS requirements.

All structural elements shall be constructed and assembled in accordance with the fabrication tolerances defined by CS rules.
Misalignments above tolerance limits shall be analyzed and reported to CS and PETROBRAS. The corrective actions, if necessary, shall be submitted for CS and PETROBRAS approval. Imperfections can be accepted only within CS rules.

Distorted members in special and primary design areas shall be straightened according to procedure approved by PETROBRAS and CS.

Dimensional control reports of all structural blocks from hull structure and from offshore structures shall be submitted to PETROBRAS and CS.

Painting schemes shall be in accordance to I-ET-3010.00-1200-956-P4X-002 – GENERAL PAINTING.

3.8 Hull Outfitting

Hull outfitting shall be in accordance with Brazilian Authorities and CS requirements. For exposed areas, the handrail presented in document I-DE-3010.00-1400-140-P4X-003 – STANDARD – STEEL GUARDRAIL – TYPICAL DETAILS may be used as a guideline.

The requirements presented on the chapter are valid for all tanks of the Hull. For outside the tanks, the Ergonomic Requirements shall be followed. However, the next two paragraphs are valid for internal and outside of tanks.

For vertical ladders, with height equal or greater than 5.0m, defined as routine use or as escape routes in emergency situations, a guided fall arrester or a retractable fall arrester shall be installed. For guided type fall arrester, a vertical cable or rail shall be installed. For retractable fall arrester an anchorage is required.

A guardrail extension shall be provided as requested on ABS GUIDE FOR MEANS OF ACCESS TO TANKS AND HOLDS FOR INSPECTION (see [15]). The extension shall be provided, in all directions, where the horizontal distance is lesser than 1830 mm. The extension shall be in a way that the free gap between top ladder (or safety cage bottom) cannot be higher than 760 mm (Figure 3).

Permanent means of access, including accesses inside tanks, shall follow the requirements:

- Permanent means of access shall follow the requirements contained in reference [7] and [8], CS rules and the applicable statutory requirements;

- DETAILED ENGINEERING PHASE outfitting philosophy shall be based on basic design document I-DE-3010.2Q-1351-140-P4X-015 - HULL STANDARD OUTFITTING;

- Walkways, platforms, ramps and stairs shall have handrails to protect against falling. Handrails shall be designed to withstand the adequate loads. Handrail shall be built in steel and any other material shall have previous approval from PETROBRAS and CS;

- Walkways, platforms and ramps shall have, at least, 0.6 meter width. Requirements from safety, arrangement or architecture disciplines shall also be taken into account and the most restrictive dimension shall be adopted.

- Walkways, platforms, ramps, stairs and vertical ladders shall be designed to withstand the adequate loads;

- Ramps shall not have inclination angles greater than 20 degrees. Whenever the ramps have angles greater than 10 degrees, it is mandatory to weld transverse pieces spaced of 0.4 meters in order to avoid slippery condition;

- Outfittings shall be design to avoid any risk of man falling;

- Stairs without risers shall follow the requirements (nomenclature in Figure 1) presented hereafter:

  a) Minimum width of 0.6 meter;
  b) Minimum tread length of 0.15 meter;
  c) Maximum height between treads shall not exceed 0.25 meter and shall be kept uniform along the flight of stairs;
  d) The treads shall be leveled and free from protrusions;
  e) The flight of stairs height shall not exceed 3 meters;
  f) The platform, between flight of stairs, shall have at least 0.6 meter width and 0.6 meter length;
  g) The tread projection over the next tread shall be at least 0.01 meter;
  h) The tread length and height shall obey the relationship $600 \leq g + 2h \leq 660$.

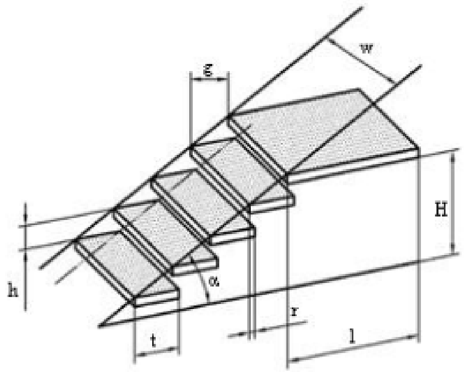

Figure 1 – Stairs nomenclature

- Stairs with risers shall follow the requirements (nomenclature in Figure 1) presented hereafter:

  a) Minimum width of 0.6 meter;
  b) The minimum tread length shall be 0.2 meter;
  c) The steps shall be uniforms, leveled and free from protrusions;

d) The height between treads shall be in the minimum 0.2 meter and in the maximum 0.25 meter;
e) The platform, between flight of stairs, shall have at least 0.6 meter width and 0.6 meter length;
f) The flight of stairs height shall not exceed 3 meters.

- Vertical ladders shall follow the requirements presented hereafter:

a) Minimum width is 0.4 meter and the maximum width is 0.6 meter;
b) Whenever the vertical ladder height exceeds 3.0 meters, it shall have a safety cage. The safety cage shall be installed 2.0 meters above the floor level up to 1.2 meter above the upper vertical ladder level. The safety cage internal diameter shall be in the minimum 0.65 meter and in the maximum 0.8 meter. The safety cage maximum distance between the horizontal bars shall not be greater than 1.5 meter and the maximum distance between vertical bars shall exceed 0.3 meter. Figure 2 presents some details of the safety cage;

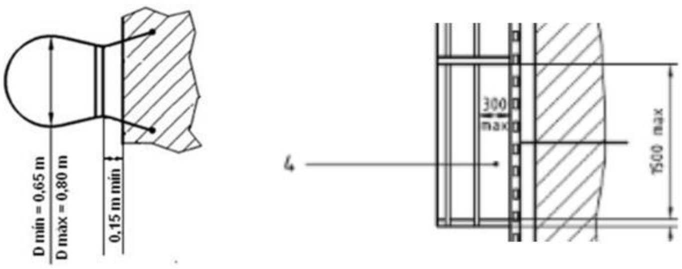

Figure 2 – Safety cage minimum dimensions

c) Vertical ladder shall have a ladder extension of 1.2 meter above the upper ladder level;
d) Maximum vertical ladder height between two platforms shall not exceed 5 meters;
e) Spacing between the vertical ladders horizontal bars shall be between 0.25 meter and 0.3 meter;
f) Minimum distance between two vertical ladders at the platform shall be, at least, 0.7 meter;
g) Figure 3 presents vertical ladders requirements details.

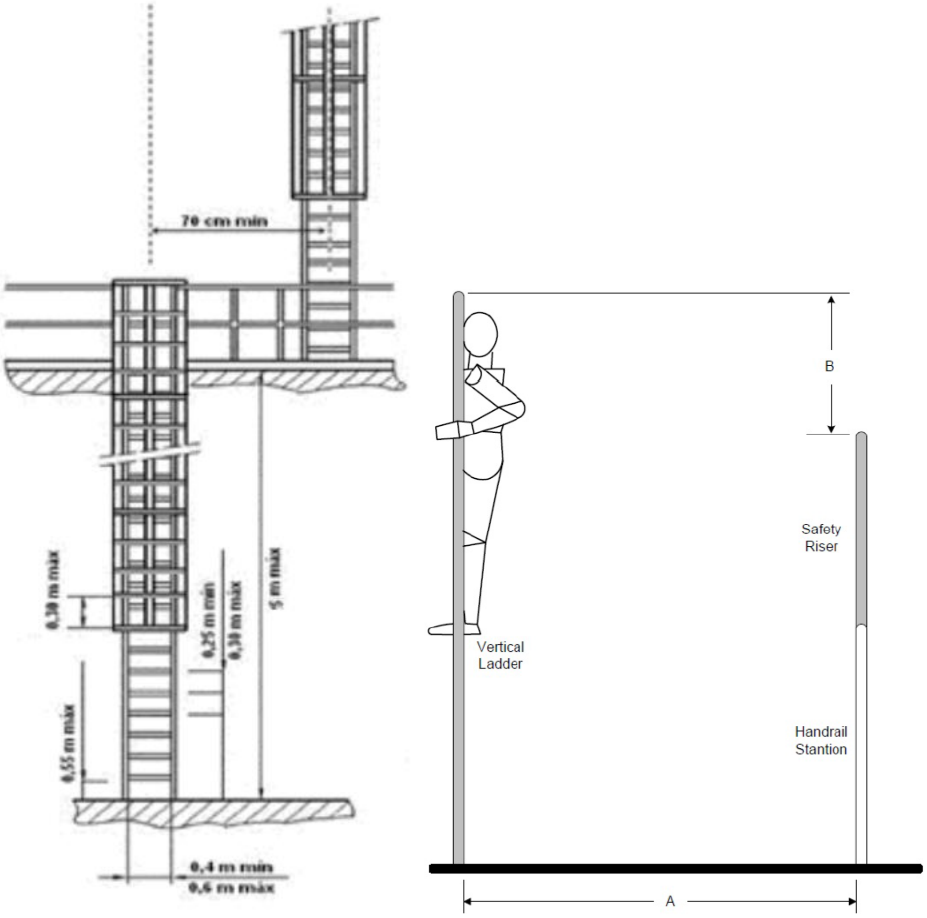

Figure 3 – Vertical ladders requirements

3.9 Hull Deflection

HULL SUPPLIER shall issue a “Hull Global Deflections” report, containing the deflections in cargo region to design any structures supported in it. This document shall be based in I-ET-3010.00-1351-140-P4X-001 – HULL GLOBAL DEFLECTIONS, attached below, and shall be submitted for PETROBRAS and CS approval.

I-ET-3010.00-1351-14
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3.10 Inspection

Welds NDT extension shall be in accordance to I-DE-3010.2Q-1351-140-P4X-001 - HULL GENERAL NOTES AND TYPICAL DETAILS.

Inspection plan containing all structural regions subject to inspections, as well as the respective acceptance criteria, shall be issued in accordance with CS requirements. This document shall clearly indicate the weld seams to be inspected, the weld seam length to be inspected in accordance with the structural category and the type of inspection.

Access for external inspection of mooring lines guides and of pad eyes for service vessels mooring shall be provided. In case such accesses are submerged during UNIT operation, handrails shall be provided in order to allow the correct subsea inspection activities.

Access for in-service inspection of all main joints in special areas below deck shall be provided, without the need for assembling additional scaffolding.

Internal access to void spaces in UNIT shall be provided.

For structural tanks, the following requirements shall be considered:

a) Cargo tanks, ballast tanks, void spaces, cofferdams, slop tanks and other tanks:
   a. Means for permanent access to transverse bulkheads, at the reinforcements side, shall be provided;
   b. At least a permanent longitudinal access in each side of the tank, at a minimum distance of 1.6 m and maximum distance of 3 m, in relation to the bottom part of the deck plate;
   c. Access between arrangements above in a and b shall be provided;
   d. Means for permanent access on the longitudinal bulkhead to the upper regions of the web frames shall be provided. The permanent access shall be integrated to a structural element. Pad eyes that allows access for inspection by climbers/rope access shall be disposed at deck transverse and on deck longitudinal;
   e. Permanent access to cross-ties in tanks shall be provided;
   f. Alternative means for access, such as by pad eyes, may be provided for tanks with height less than 17 m;
   g. Tanks with height less than 6 m may have pad eyes that allow the assembling of scaffolding for inspection in lieu of permanent means.

b) AFT and FWD peak tanks:
   a. For tanks with height larger than 6 m at the center line, at the collision bulkhead, means to access to critical areas, as the tank ceiling, stringers (horizontal girders), collision bulkhead and side shell shall be provided.

Lifeboat decks shall have extensions at bow and stern regions of each life boat in order to allow for safe access to their slings.

3.11 Structural Verifications

All structural elements shall be designed and verified using yielding, buckling and fatigue criteria according to CS Rules.

Helideck, Lifesaving Platform, Pull In, M09 and pipe racks structures shall be evaluated by LRFD Method. Hull Structures shall be evaluated by WSD Method.

All structural design reports shall present detailed listing of results as well as summary of the results with comments and solutions.

All FEM structural models (global and local) shall be submitted to PETROBRAS. Models shall be in electronic format in accordance to contract EXHIBIT 03, considering all the necessary inputs for the analysis (including geometry, loads, boundary conditions, properties, materials, mesh, etc).

For the purpose of structural analysis, the material design temperature shall be 0° C. The material selection shall be in accordance with the document I-DE-3010.2Q-1351-140-P4X-007, "STEEL GRADES AND STRUCTURAL AREAS CLASSIFICATION PLAN" or structural drawings or 3D model.

3.11.1 Yielding Design Requirements

Yielding analysis shall follow CS requirements. The applicable references from section 2.1 shall also be taken into account whenever it is relevant.

3.11.2 Buckling Design Requirements

Buckling analysis shall follow CS requirements. The applicable references from section 2.1 shall also be taken into account whenever it is relevant.

3.11.3 Fatigue Design Requirements

In addition to the requirements of this document, fatigue analysis shall follow CS requirements. The applicable references from section 2.1 shall also be taken into account whenever it is relevant.

The distribution of stress ranges to evaluate fatigue damage may be obtained by simplified and stochastic methods. Stresses shall be obtained through hot spot stress approach where recommended by CS and where nominal stress approach is not clearly applicable. Stress concentration factors shall be obtained through parametric equations, where applicable, or finite element method (FEM) model. Dynamic amplification shall be considered when relevant for the analysis.

For the hull structure fatigue analysis and verification, besides global FEM model at cargo region required by CS, with proper extent, tank filling patterns and other loads, a complete hull FEM model shall be generated and analyzed by stochastic approach. Definition of levels of mesh refinement for models and submodels and relevant representative details to be addressed shall be according to CS rules, recommendations and guidelines. The minimum requirements for the submodels structures that shall be calculated are:

- Web Frames considering high stressed areas (areas higher that 0.8 of yield stresses)
- Bottom longitudinals connections with web frames
- Main deck longitudinals with Web Frames
- Side shell connection with riser balcony

- Main deck with longitudinals and transversals supporting the topside columns (included)

For the stochastic approach:

- The model will be used both for design calculations and associated with the in service hull stress monitoring system (HSHMS), to be implemented according to I-ET-3010.00-1351-140-P4X-002, “DIGITAL TWIN FOR HULL STRUCTURAL INTEGRITY MANAGEMENT”.
- The calculation report of the stochastic fatigue analysis shall be approved by the same CS of the HULL.
- Hydrodynamic and mass models for load transfer shall be generated for all loading conditions, following CS requirements.
- The reference distribution of occurrence of loading conditions is based on 5 (five) increasing vessel drafts, associated with percentages of occurrence of 5% (11.2 m, minimum, ballast), 25% (13.2 m), 40% (16.1 m, intermediate), 25% (19.6 m) and 5% (23.8 m, maximum, fully loaded), respectively, according to I-RL-3010.2Q-1350-960-P4X-002, "MOTION ANALYSIS". The number of drafts for fatigue calculations shall be according to CS requirements and/or HSHMS Vendor recommendations, with a minimum of 3 (three) properly spaced vessel drafts, adapting the percentages of occurrence, subject to PETROBRAS approval. Intermediate draft for fatigue calculations shall be chosen around the vertical position of the strain gauges defined by HSHMS inside ballast tanks at the side shell with a tolerance of 1 m.
- Besides fatigue evaluation of hot spots, stress RAOs shall also be generated and provided in the documentation for specific points free from stress concentration, called cold spots, according to requirements for HSHMS, at the location of the strain gauge sensors (ballast tanks and main deck).
- RAOs shall be generated for all loading conditions, with headings spaced with a maximum of 30 deg and proper number of wave frequencies in order to represent structural response peaks and valleys.

For simplified fatigue assessment:

- HULL SUPPLIER shall consider the number of drafts required by Classification Society.
- The long term mean wave period to obtain the number of cycles shall be calculated based on CS rules or 6.3 seconds may be adopted.

For both high cycle and low cycle fatigue, damage calculations shall consider the number of cycles correspondent to the design life indicated in section 3.1.

Low frequency cyclic effects due to cargo tanks loading/unloading shall be considered assuming 1 cycle every four days during the whole design life, what leads to 2740 cycles.

Design fatigue factors (DFF) from Table 3 and Table 4 shall be used as PETROBRAS minimum requirements. The DFF shall be applied after calculating the fatigue damage and cannot be applied different DFFs for the same structural detail design.

Table 3 - Minimum design fatigue factors (DFFs)

Classification of structural components based on consequence of failure	Accessibility for inspection and repair		
	Accessible		Not accessible (2)
	Above minimum operational draft	Internal hull areas below minimum operational draft	
Critical(3)	3	5	10
Non-Critical(3)	2	3(1)	5

(1) DFF = 2 Internal structure, accessible and not welded directly to the submerged part (applicable only to ballast tanks and void spaces).

(2) Includes, but not limited to, areas that may be inspected in dry or submerged conditions, but requires dry docking for repair and areas at the splash zone. For external areas of hull below minimum draft (drive for in-service diving to be minimized) to be DFF = 10.0

(3) "Critical" implies that failure of these structures would result in the rapid loss of structural integrity and/or produce an event of unacceptable consequence

Specific safety factors for fatigue design of some structural components and connections shall be in accordance to Table 4.

Table 4 – Specific minimum design fatigue factors (DFFs)

Structural components (except for non-accessible joints)	Design Fatigue Factors (DFF)
Main deck and side shell region above minimum draft, plate and longitudinal	2.0
Side shell region below minimum draft, double bottom plating and longitudinal	3.0
Bulkheads, plating and longitudinal and transverse stiffeners	2.0
Web frames, beams and girders	2.0
Foundations in hull for stools, for riser balcony and for mooring supports (internal hull structure)	3.0
Connections hull to columns that support topside multicolumn structure, including pipe racks	2.0
All elements inside vessel tanks, except for locations where higher safety factors are required	2.0
Mooring balconies, above and below minimum draft, respectively	3.0/5.0
Brackets connecting fairleads to side shell	10.0
Bilge keel	10.0
Lower riser support, external balcony	10.0
Upper riser support, external balcony	5.0
Support stools	2.0
Cranes and their foundation in hull	2.0
Flare tower and its connections to hull	2.0
Flare tower connections to hull if it is not accessible (or if a side is not accessible)	10.0
Pipe rack and piping support in general	2.0
Pull-in equipment support structure	2.0
Offloading hose support (above minimum draft)	2.0

Structural components (except for non-accessible joints)	Design Fatigue Factors (DFF)
Support for Casings and Caissons (e.g. for sea water in-take), including defense structures, above splash zone/at splash zone/ below minimum draft	2.0/5.0/10.0
Elements in secondary design areas, except those classified above.	2.0
Non-critical external elements: at the splash zone/below minimum draft (to be considered as non-inspectable)	5.0/10.0

3.12 Loads

Structural analysis shall consider loads for the FPSO considering static load condition, design operational condition, design extreme condition and transportation condition. Major loads that shall be applied on each structural model is presented in this topic, but are not restricted to them. HULL SUPPLIER shall analyze each model to evaluate if any other load application is required.

3.12.1 Hull Global Load Cases

Hull global structure shall be verified in accordance with CS rules. Global load cases considering tank filling patterns, sea pressure and bending moment and shear force adjustment shall be used for structural evaluation as well as input for other structural analysis.

Loads during temporary phases, such as transportation and construction, shall also be considered and shall be in accordance with planned operations. The correspondent structural analysis for the temporary conditions shall be sent for PETROBRAS verification.

3.12.2 Environmental Loads

Environmental loads shall follow CS rules. For environmental data, see section 3.2.

3.12.3 Green Water Loads

Green water occurrence and effects on hull and offshores structures shall be addressed. The corresponding loads may be obtained by computational fluid dynamic software (CFD), model test or, as a minimum, prescribed loading from CS rules may be used. Green water shall be applied in accordance with GUIDELINE FOR FPSO GREEN WATER ANALYSIS [13].

3.12.4 Slamming Loads

Slamming is a different phenomenon than Wave Slap. Inspired on [14], Slamming Load is the pressure load due to the Hull's entrance into the seawater or with the combined effect between Hull movement and water wave movement in a low inclined structure (<= 45°), while Wave Slap is the pressure load due to the wave impact into the Hull in a high inclined surface (> 45°).

Fairlead support structures, mooring balconies, riser balconies, aft hull structures and other attached structures subject to wave slamming loads and/or wave slap loads shall be designed and positioned in a way to avoid or minimize the effects of wave slamming and/or wave slap. Sufficiently inclined flat plates at the bottom of each of these structures and/or more transparent concepts shall be employed.

Structures that are potentially subjected to wave slamming loads shall be analyzed considering the slamming and/or wave slap pressure combined with other environmental loads for a period of return of 100 years for yield and buckling analysis. Significance of effects on onboard comfort, as well as on stresses in hull and vibrations (whipping) in the hull girder are also to be addressed.

Slamming and/or wave slap loads loads can be calculated considering CFD software, model tests or by approximations as described in DNVGL-RP-C205 – “Environmental Conditions and Environmental Loads” or ABS Guide for Slamming Loads and Strength Assessment for Vessels.

As from the Slamming phenomenon or Wave Slap, shall be calculated the long-term probability of occurrence for each part of the Hull considering the wave scatter presented on Metocean Data, based on the relative velocity between the Hull and wave particle higher than the threshold velocity. If this long-term probability of occurrence of slamming and wave slap, for any part of the Hull individually, is higher than 0.01%, the fatigue for structure detail shall be considered with the whipping effect whenever the Hull Girder Natural Frequency and the Structure under design are closer than 20%.

The threshold velocity is expressed as:

$$V_{THRESHOLD}(m/s) = 0.1\sqrt{g(m/s^2) * L_{PP}(m)}$$

For each sea state presented on Metocean shall be calculated the probability of slamming occurrence based on reference velocity higher than threshold velocity:

$$Prob(V_R \geq V_{THRESHOLD}) = e^{-\left(\frac{V_{THRESHOLD}^2}{2m_0}\right)}$$

Where m_0 is the square root of reference velocity RMS from hydrodynamics model.

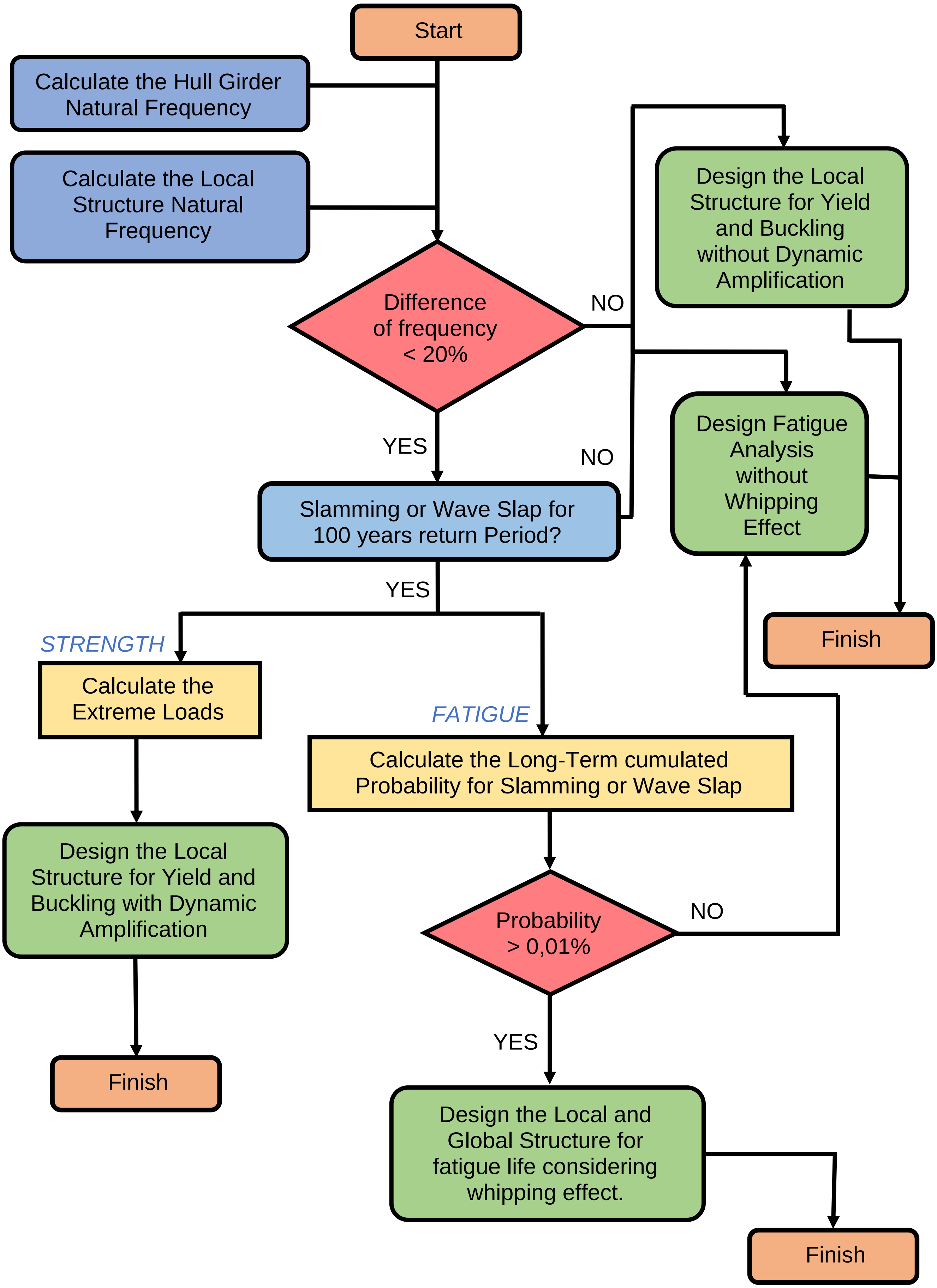
The number of occurrences of slamming per 3-hours sea state is:

$$N_S = Prob_{SLAMMING} * 10800 * \frac{1}{2\pi}\sqrt{\frac{m_2}{m_0}}$$

Where m_2 is the second moment of area of the reference velocity response spectrum from hydrodynamics model.

The long-term probability of occurrence of slamming and wave slap shall be calculated considering the 30 years of operation.

Flowchart presented below detail the logical sequence of the slamming consideration for the yield, buckling and fatigue analysis for the structure design.


Start
Calculate the Hull Girder Natural Frequency
Calculate the Local Structure Natural Frequency
Difference of frequency < 20%
NO
Design the Local Structure for Yield and Buckling without Dynamic Amplification
Design Fatigue Analysis without Whipping Effect
YES
NO
Slamming or Wave Slap for 100 years return Period?
YES
Finish
STRENGTH
Calculate the Extreme Loads
FATIGUE
Calculate the Long-Term cumulated Probability for Slamming or Wave Slap
Design the Local Structure for Yield and Buckling with Dynamic Amplification
Probability > 0,01%
NO
YES
Finish
Design the Local and Global Structure for fatigue life considering whipping effect.
Finish

3.12.5 Functional Loads

Functional loads shall consider as minimum input load contingencies in accordance with the last HULL SUPPLIER Weight Control Report Data revision.

Structural design of deck areas shall consider the variable functional loads based on the values shown in Table 5. Structure deadweight itself is not included in Table 5 and shall be combined with the appropriate variable loads for structural analysis purposes.

Besides the vertical axis, the variable functional loads shall be applied also in the longitudinal and transversal directions adjusted by the correspondent longitudinal and transversal acceleration values, with gravity effects.

Table 5 - Variable functional loads on deck areas

Area	Local Design		Primary Design	Global Design
	Distributed load [kN/m²]	Point Load [kN] (2)	Distributed Load [kN/m²]	Distributed Load [kN/m²]
Storage	Q=Max(γ x H; 13)	1.5q	q	q
Laydown area	40	40	30	30
Lifeboat platform	9	9	9	May be ignored
Free surrounding area between equipment	5	5	5	May be ignored
Walkways, ladders and platforms	4	4	4	May be ignored
Walkways and ladders for inspection and escape routes	3	3	3	3 for Escape Routes 0 for others
Process(1)(4)	9	9	7	7
Utilities(1)(4)	7.5	7.5	6	6
Accommodation	4	4	4	May be ignored
Diving station	25	25	15	15
Deposit, workshop	15	15	15	May be ignored
Helideck	2	P(3)	2	May be ignored
Roofs (6)	2.5	2.5	2.5	May be ignored
Compass deck	5.0	5.0	5.0	2.5

Notes:

- Local Design is used in the local analysis of plates and beams;
- Primary Design is used in the structural design of the primary and secondary structures;
- Global Design is used in the structural design of foundations;
- γ = specific weight of storage material; H= storage height;

(1) For equipment loads, the worst-case scenario between
(2) Table 5 or the equipment weight plus structural weight plus 5 kN / m² applied over a surrounding free area shall be considered. See Figure 4;

(3) Point loads shall be applied to an area of maximum 100 mm x 100 mm and at the most critical position, but need not be increased by wheel loads nor distributed loads. For laydown area with wooden deck, the point loads shall be applied on an area 220 x 220 mm. For floor grating (steel or pultruded material), the point loads shall be applied on an area 200 x 200 mm;

(4) P to be defined according to the largest helicopter to land;

(5) Process variable load refers to working load on platforms and modules at the process plant region of the UNIT. Utilities variable load refers to working load at the region of the UNIT outside the process plant region, e.g. machinery room, area between accommodation, utilities room.

(6) For roofs with no access, 2.5kN/m² shall be applied. For roofs with access, the free area value shall be applied;

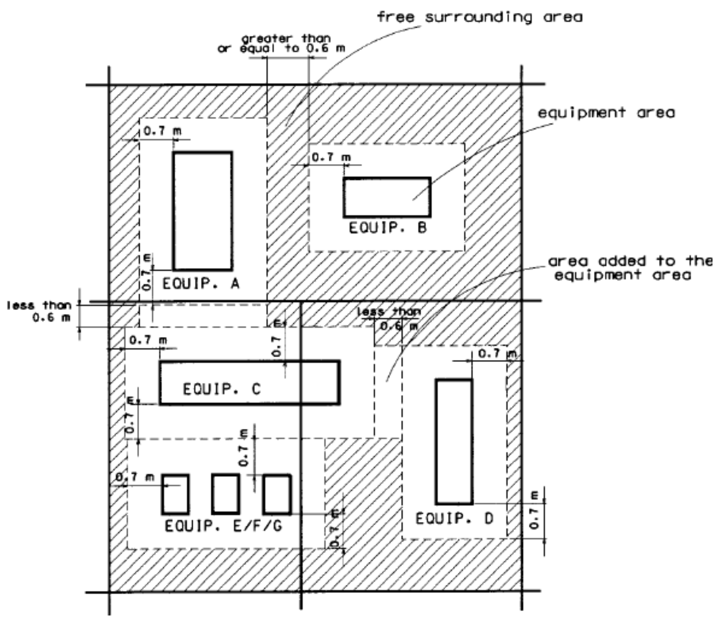


Figure 4 - Example area for variable load application

Dynamic loads from equipment and machinery shall be sought from the equipment vendor. In the absence of specific vendor data, local detailed design shall consider dynamic amplification forces as an increase in static loads of 25% for rotatory and 50% for reciprocating equipment. If equipment vibration frequency is close to the natural frequency of the supporting structure, then a dynamic analysis shall be carried out. Equipment manufacturer shall provide the minimum operation requirements that are mandatory for the structural design. Loads shall take into consideration the existence of anti-vibration mounts (AVM), provided for significant rotating and reciprocating equipment, in accordance with supplier specification.

Test loads for specific structures and equipment shall be considered on an individual basis and will not take part of the global analysis. Special consideration shall be given to system testing involving multiple equipment items on a single skid.

Piping and equipment support shall be designed considering the temperature load due to an occasional operation shutdown.

3.12.6 Topside Reaction

During DETAILED ENGINEERING PHASE early stages, topside reactions and weight from basic design shall be used. During project evolution, these values and models shall be updated to ensure structural integrity.

In addition, loading combinations shall be calibrated by WSD (Working Stress Design) criteria, since the topsides structure elements are designed for LRFD (Load And Resistance Factor Design) factors.

3.13 Corrosion Margins

Corrosion margin values to be considered in the structural design of the hull, for 30 years' service life, are presented in Table 6. Minimum required thickness and substantial corrosion thickness shall be presented, according to Classification Society Rules. In case of different information between Table 6 and Classification Society Rules, the most restrictive value shall be adopted.

Corrosion margin for bilge keel shall be the same value applicable to side shell longitudinal at ballast tank. For lower riser balcony, side shell plate corrosion margin shall be applied.

At each region of the structure prone to present corrosion due to erosion, such as cargo pumps inlet, bell mouth for ballast lines, drop lines, balance lines in slop tanks, sounding tubes, etc, a double plate shall be installed, with thickness, size and position defined by marine system discipline. Examples of these double plates are presented in documents I-DE-3010.2Q-1350-944-P4X-002 – PIPING AND INSTRUMENT DIAGRAM LOADING SYSTEM and I-DE-3010.2Q-5335-944-P4X-001 – PIPING AND INSTRUMENT DIAGRAM BALLAST SYSTEM (FWD).

Boundary plates between tanks with different purposes (e.g. longitudinal bulkhead dividing ballast tank and cargo tank) shall adopt the most conservative margin for corrosion among those applicable.

The structural elements of the offspec produced water tanks, offspec oil tanks and settling tanks shall use the corrosion margins applicable to the correspondent slop tanks structural elements.

Table 6 - Corrosion margin

LOCAL	ITEM	CORROSION MARGINS [mm]			
		Cargo Tanks	Ballast Tanks	Slop Tanks	Void Spaces
LONGITUDINAL ELEMENTS	Main Deck Plate	3.75	3.75	3.75	1.50
	Main Deck Longitudinal Web	2.50	3.13	3.13	1.50
	Main Deck Longitudinal Flange	2.50	3.75	3.75	1.50
	Side Shell Plate	3.75	3.75	3.75	1.50
	Side Shell Longitudinal Web	3.13	3.13	3.13	1.50
	Side Shell Longitudinal Flange	2.50	2.50	2.50	1.50
	Longitudinal Bulkhead Plate	3.75	3.75	3.75	1.50
	Longitudinal Bulkhead Longitudinal Web	3.75	3.75	3.75	1.50
	Longitudinal Bulkhead Longitudinal Flange	3.13	3.13	3.13	1.50
	Bottom Plate	3.75	3.75	3.75	1.50
	Bottom Longitudinal Web	2.50	2.50	3.13	1.50
	Bottom Longitudinal Flange	3.13	3.13	3.75	1.50
WEB FRAMES	Transverse Deck Girder Web	3.13	3.13	3.13	1.50
	Transverse Deck Girder Flange	3.13	3.13	3.13	1.50
	Transverse Bottom Girder Web (Painted)	2.50	2.50	2.50	1.50
	Transverse Bottom Girder Flange (Painted)	2.50	2.50	2.50	1.50
	Transverse Bottom Girder Web (Not Painted)	3.13	NA	NA	1.50
	Transverse Bottom Girder Flange (Not Painted)	3.13	NA	NA	1.50
	Side Shell Vertical Girder Web	3.13	3.13	3.13	1.50
	Side Shell Vertical Girder Flange	3.13	3.13	3.13	1.50
	Longitudinal Bulkhead Vertical Girder Web	3.13	3.13	3.13	1.50
	Longitudinal Bulkhead Vertical Girder Flange	3.13	3.13	3.13	1.50
	Cross-tie Web	2.50	2.50	2.50	1.50
	Cross-tie Face Plate	2.50	2.50	2.50	1.50
TRANSVERSE BULKHEAD	Transverse Bulkhead Plate	3.13	3.13	3.75	1.50
	Vertical Stiffener	2.50	2.50	2.50	1.50
	Horizontal Stringer Plate	3.75	3.75	3.75	1.50
	Horizontal Stringer Face Plate	3.75	3.75	3.75	1.50
	Vertical Girder Web	3.13	3.13	3.13	1.50
	Vertical Girder Flange	3.13	3.13	3.13	1.50

3.14 Structural Protection

3.14.1 Passive Fire Protection

Passive fire protection shall be applied on structural elements at all points subject to fire scenarios that affect the integrity of the structure and critical safety functions. Fire and explosion scenarios that will be used as input data in the passive fire protection design of the structure and firebreak bulkheads shall be identified in the Fire Propagation Study from Topside and Explosion Study from Topside.

Structural analyses shall be carried out considering acting loads for the accidental scenario, as well as the temperature ranges occurred during the different fire scenarios. Those analyses shall take into account physical and geometric nonlinearities and the thermal-structure coupling effects, capturing the stress redistribution caused by the change in the material properties according to temperature level.

Drawings that represent the passive fire protections considered for compliance with structural and safety criteria shall be issued.

3.14.2 Cathodic Protection

Cathodic Protection System shall follow the recommendations defined in I-ET-3010.00-5267-750-P4X-001 - TECHNICAL SPECIFICATION FOR CATHODIC PROTECTION and I-ET-3010.00-5267-750-P4X-002 - TECHNICAL SPECIFICATION FOR GALVANIC ANODES.

Additionally, the anodes position on bottom of cargo, slops, off-spec and produced water tanks shall be placed at the bottom longitudinal web side. The clearance from bottom plate to the galvanic anode lower face shall be maximum 300 millimeters.

3.15 Load Plan

HULL SUPPLIER shall issue a load plan containing the information of loading capacity on all cargo areas for which they were dimensioned.

4 ADDITIONAL REQUIREMENTS

4.1 Fenders and Hull Reinforcement at Supply Vessel Approaching Areas

Platform structure at supply vessel approaching area and nearby areas, subject to collision risk, shall be designed and protected by fenders in order to mitigate the consequences. Criteria and analysis methodology shall follow references [5] and [6], Annex A.3.

Side shell structure at supply vessel approaching area shall withstand an impact energy (collision accidental load) imposed by a 9,000-MT displacement supply vessel, plus added mass, with speed of 2 m/s, for the worst cases of sideways, bow and stern impact scenarios, without causing the rupture of FPSOs cargo tank longitudinal bulkhead and without compromising the global structure.

The maximum space between fenders shall be 2700 mm (center to center).

Side shell structure shall also be designed at the same area to withstand an impact energy imposed by the same 9,000-MT displacement supply vessel, plus added mass, at 0.5 m/s for the worst cases of sideways, bow and stern impact scenarios, combined with normal operation conditions loads, without any rupture to the side shell structure.

In order to prevent contact between supply boat and the UNIT, elastomeric fenders fixed to side shell by steel beams shall be installed. Floating fenders are not allowed. Fenders and fender back structure shall be spaced and dimensioned in a way to absorb the same collision energy as that for normal operating conditions of supply vessel. Reaction forces from fenders may be obtained from vendor catalogs. Longitudinal extent of side shell protection area shall be 30 m aft and 30 m forward from each lifting crane. Vertical extent shall cover distance between maximum draft position plus 3 m and minimum draft position minus 1.5 m.

Other external equipment/structures/piping (e.g. caissons for seawater uptake) connected to side shell at the supply vessel approaching area shall be protected by specific structures, plus elastomeric fenders, using same premises.

SELLER shall design, detail and install the fenders and the respective foundation structural reinforcements inside the hull structure considering the CS rules and BUYER technical requirements.

The nuts used to support the fender rubbers on side shell shall be locked in order to avoid that fender rubber falls down. It is SELLER's scope of work to define the adequate mean to lock the nut and to define the adequate bolt pre-tension in order to keep the fender rubber properly fixed. Contact of dissimilar materials shall be avoided. Transversal bolts shall be considered to fix fender rubber to side shell. Welded perpendicular bolts shall not be considered to fix fender rubber to side shell.

SELLER shall design, detail and install fenders and their foundations in Seawater Caissons region. SELLER shall consider the above fixing criteria to Seawater Caissons region.

4.2 Lifeboats And Rescue Boats Davit Foundations

Lifeboats and rescue boats davits and their support structure shall have their operating conditions checked, taking into account a dynamic factor due to the lifeboat / rescue boat speed reduction when lowered, in accordance with the CS Rules.

Davit and support structures design shall also comply with IMO - International Life-Saving Appliance Code - LSA Code - Chapter VI - Launching and Embarkation Appliances.

Lifeboat Decks shall have an extension in the bow and stern region of each lifeboat to permit a safe access to the lifeboat slings for maintenance.

4.2.1 Damage Condition (Dac)

This condition refers to the structure verification for an accidental event. The structural design for damage condition shall be performed for the following scenarios: (1) Unintended flooding shall be based on the deepest equilibrium waterline in damaged condition obtained from damage Preliminary Trim and Stability Booklet. Damages angles indicated below were used during basic design. The structural design shall be calculated according to the heel and trim angles report to be issued in the detailing phase, associated with 1 year motions and accelerations.

4.3 Helideck

Helideck structural analysis shall consider the following helicopters models Sikorsky S-92, S-61N, AW101 and Eurocopter EC-225 landing loads for the structural design.

Design, construction and installation of the helideck shall be in accordance with the recommendations of NORMAM-223, reference [9], and CS requirements.

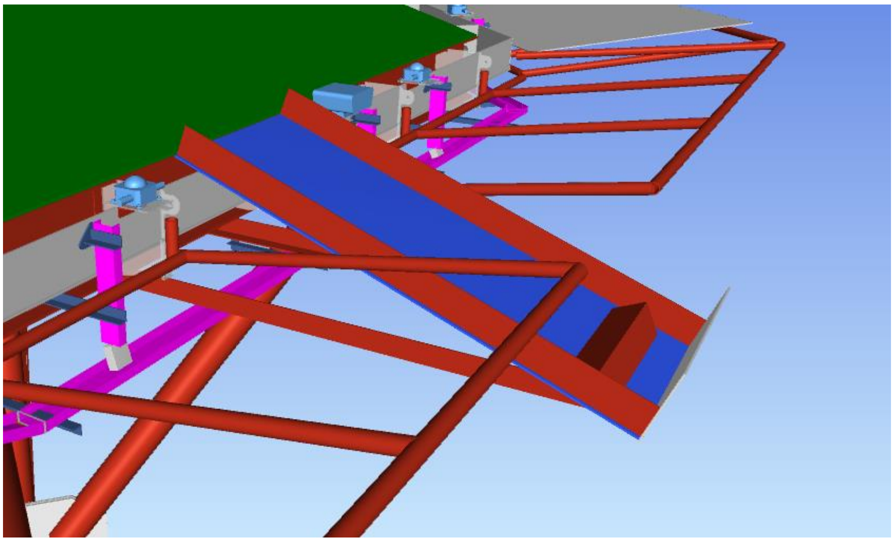
Aluminum structures shall not be used. Helideck structure shall not have a pancake.

The minimum distance of the protection net around the helideck shall be 1.8 meter.

Helideck Structure Natural Frequency shall be calculated considering two scenarios and shall be, at least, 20% away from Natural Frequency of the Hull for all drafts and both scenarios:

- No Helicopter
- Heaviest Helicopter

The helideck shall not have any fire extinguisher ramp positioned to the sea direction, as presented below.



4.4 Flare Tower Foundations

Flare tower foundations, including the necessary hull structural supports and reinforcements, shall be evaluated considering flare tower analysis reactions obtained from WSD criteria. UNIT transport condition from shipyard shall also be considered.

4.5 Risers Supports

Riser balcony design shall consider the operating load of the pull-in during the installation of the risers in combination with proper environmental conditions that limits this operation.

Riser reactions shall be determined from the riser analyses, considering all platform offset positions (near, mean and far).

Riser loads shall be provided for static, operational and extreme conditions. Load points shall also be clearly informed for each riser type. Preferably, riser loads due to the offset of the UNIT (2nd order) and due to vessel motions in waves (1st order) shall be informed separately

Riser support structure design shall be carried out in accordance with riser arrangement. In lieu of that information at design phase, most critical riser sequence for riser balcony design shall be considered for all riser balconies segments.

Permanent means of access from vessel main deck to upper riser balcony shall be provided by the shipyard.

Slamming occurrence probability shall be calculated and, in case it is relevant, considered in the structural analysis (see [14]). Slamming load shall be according to section 3.12

4.6 Pull-In

HULL SUPPLIER shall consider the loads and reactions in pull-in structure and in pull-in accessories from the requirements in document I-ET-3010.2Q-5268-968-P4X-001 – RISER PULL-IN AND PULL-OUT SYSTEM. An integrated analysis of the Pull-In and M-09 shall be performed for Petrobras and CS approval.

4.7 Topsides Supports

Loading conditions used to design the foundation structures on hull shall be consistent with loading conditions used to design the module structure. In addition, the load combinations used to obtain the topside reaction shall be calibrated by WSD Criteria.

If the model tests indicates that slamming occurs under frequent wave conditions (<= 1-Year), the modules and flare tower natural frequencies shall be kept away from hull girder natural frequencies.
A minimum of 20% difference for full range of operational drafts (light load up to full load conditions) and in transit condition, in order to avoid large dynamic amplification from hull girder vibration.

When the difference between natural frequencies is less than 20%, then, during DETAILED DESIGN PHASE the HULL SUPPLIER shall perform an integrated analysis, e.g. hull/flare tower model, (including Dynamic effects) to evaluate the flare tower and its foundation integrity, for both strength and fatigue. This analysis shall be also applied for other slender structures, such as topside modules columns, helidecks, vent posts, telecom tower and others.

Topsides connections with hull main deck shall be evaluated considering extreme conditions and main deck displacements as calculated in global analysis calculations.

4.8 Mooring Structures

Global structural design of the mooring structures and their foundations shall consider the operational and extreme loads of the mooring lines combined with the corresponding environmental loads.

For local evaluation, largest MBL (Minimum Breaking Load) among mooring line segments shall be used. This value shall be increased in 25% (with the structure verified by LRFD criteria with resistance factor 1.0) and applied individually to each fairlead at its corresponding position in the mooring support structure.

Mooring chain type to be considered in structural analysis shall be in accordance to I-FD-3010.2Q-1350-962-P4X-001 – MARLIM LESTE E SUL MOORING DATA.

Seven fairleads shall be considered in each mooring balcony calculation. The exact number of fairleads to be used will be informed by PETROBRAS.

Horizontal flat plates on fairlead support balcony structure bottom shall be avoided in order to minimize slamming, and, in consequence, hull girder whipping effect.

Slamming occurrence probability shall be calculated and, in case it is relevant, considered in the structural analysis. Slamming load shall be according to section 3.12.

4.9 Pipe-Racks and Special Pipe Support Structures

Structure shall be designed for the piping flexibility loads. All relevant operational loads due to partial operation and/or maintenance of piping systems (e.g. TCR system and firewater ring) shall be considered for the structural design.

The global hull and environmental loads shall be properly considered and combined with the piping local loads.

4.10 Bilge Keel

Bilge keel shall have, at least, 1.2 meters width to improve roll viscous damping.

Hydrodynamic loads on bilge keel shall be applied considering drag forces.
Drag forces shall be calculated considering velocities from wave and motion. Water particle velocity on bilge keel can be obtained by a hydrodynamic computer model or tank model test pressure probes installed on bilge keels. Alternatively, the following formula shall be used:

$F = ½ \cdot \rho \cdot C_d \cdot V_R^2 \cdot b$

ρ density of seawater = 1.025 t/m^3

C_d drag coefficient (Ikeda formula) = $C_D = \frac{45}{KC} + 2.4$

KC Keulegan-Carpenter number = $KC = \frac{V_R T_{ROLL}}{b}$

V_R relative particle velocity from the hydrodynamics model

b = width of bilge keel = 1.2 meters

This formula results in F expressed as force/length units.

Pressure Loads = $P = \frac{F}{b}$

4.11 Sea Water Lift Caissons

The corrosion margin to be considered for caissons shall be equal to the corrosion margin for the side shell longitudinal in ballast tank.

Hydrodynamic loads shall be applied on caissons structure. Morison equation shall be applied on the tube, while the same methodology of bilge keel shall be applied on the support structure of the tube.

Slamming occurrence probability shall be calculated and, in case it is relevant, considered in the structural analysis. Slamming load shall be according to section 3.12.

A fender structure shall be provided to protect the caissons in accordance to Section 4.1 requirements.

Flange to be designed by SELLER at caisson bottom, if necessary, for filter or blind flange installation, during Shipyard phase, to allow seawater pumps running (quay depth evaluation) and/or preservation.

4.12 Crane Foundation, Pedestal and Boom Rest

Crane foundation and pedestal structure shall be designed for 40 ton crane equipment loads.

The structural analysis shall consider in the minimum the crane loads for 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. The crane reactions shall be combined with correspondent hull and environmental loads for design operational condition with period of return of 1 year.

For fatigue analysis, it shall be considered a deterministic approach considering 63000 cycles with a load of 40 t and a simplified approach considering the extreme condition without 40 t load.

The reference [4] shall be observed to design the pedestal structure.

Boom rest shall be able to withstand crane boom loads in DEC and fatigue condition.

Slamming occurrence probability shall be calculated and, in case it is relevant, considered in the structural analysis. Slamming load shall be according to section 3.12.

4.13 Mini-stools and equipment skids

Equipment skids and mini-stools, if considered in the design, shall have at least 400 mm of height and shall be conceived to facilitate the coating maintenance during UNIT operation lifetime.

In case some support has the height smaller than 400 mm, it is mandatory to be submitted for PETROBRAS approval.

4.14 Connection Between Hull and Topside

Regions connecting both hull and topside shall have similar cross section types in beam design, that is, if beam from hull has an I-shape cross section, topside beam shall have an I-section as well. The same rule applies for other cross section types.

4.15 Other Major Hull and Offshore Structures

All other major hull and offshore structures shall be designed according to relevant loads scenarios. Special attention is required for the presence of green water or slamming loads in every region.

4.16 Hull Girder Natural Frequency

The hull girder natural frequency shall be calculated considering at least 4 drafts (including the minimum and maximum draft). The hull girder shall consider the one of the load conditions and weight distribution presented on the Trim and Stability Booklet for each draft.

Kumai's formula (presented on ABS Guidance Notes on Ship Vibration) can be calculated only to estimate the Hull Girder Natural Frequency, but the calculation shall be performed by a Finite Element Analysis software and consider the correct added mass distribution along the vessel.

MFLUID module from Nastran can be used to calculate the added mass along the vessel. If MFLUID was not considered for added mass calculation, the heave added mass for high frequency is an alternative or any other method that shall be in accordance with Petrobras.

The Hull girder natural frequency shall be calculated considering gross scantlings. The natural frequency can be calculated by a model analysis of a beam element or shell elements. For beam elements model, the length of each beam element shall be the frame spacing.

5 DOCUMENTATION

Every calculation report issued by the HULL SUPPLIER shall provide enough information, so that it is possible to rebuild the exact model from scratch using only the information available in the calculation memory. Reports shall contain, at least, the following items:

- Material properties and coordinate system;
- Documents used as reference (rules, standards and design documents);
- Structural model definitions:
    - Model Extension;
    - Model Properties;
    - Model Materials;
- Design Criteria:
    - Yielding Criteria;
    - Buckling Criteria;
    - Design Life and Fatigue Criteria;
- Detailed Model Loads:

    - Global Loads;
    - Local Loads;
    - Load Cases, including combinations;
- Results:
    - Stress Analysis results, with enough plots to cover all areas of the model;
    - Buckling Analysis results, with enough plots showing all stresses considered in the analysis;
    - Fatigue Analysis results, with enough plots showing all stresses considered in the analysis;
- Numerical models attached in a format in accordance to contract EXHIBIT 03.