PETROBRAS	**TECHNICAL SPECIFICATION**	Nº: I-ET-3010.00-1350-960-P4X-001	
	CLIENT:		SHEET 1 of 27
	JOB:		--
	AREA:		
SRGE	TITLE: **DESIGN REQUIREMENTS - NAVAL ARCHITECTURE**		INTERNAL
			ESUP

MICROSOFT WORD / V. 2013 / I-ET-3010.00-1350-960-P4X-001_C.DOCX

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	ADDITION ON TANK ARRANGEMENT & SECOND ORDER REQUIREMENTS
B	UPDATE OF DEFINITIONS FOR TANK INSPECTION'S LOADING CONDITIONS & NORMAL OPERATION CONDITION
C	UPDATE OF SECOND ORDER CALCULATION REQUIREMENTS & MAXIMUM HEEL AND TRIM ANGLES CALCULATION

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	MAR/08/22	JUN/24/22	AGO/12/22	DEC/08/2022					
DESIGN	ESUP	ESUP	ESUP	ESUP					
EXECUTION	HRC0	HRC0	HRC0	NTX1					
CHECK	CYEM	CYEM	UPG6	UPG7					
APPROVAL	UPDM	UPDM	UPDM	CYEL					

1 DEFINITIONS AND LIST OF ACRONYMS

1.1 Definitions

Definitions considered in this report are based in GENERAL TECHNICAL TERMS [10].

1.2 List Of Acronyms

CS : Classification Society

DEC : Design Extreme Conditions

DOC : Design Operation Conditions

D.O.F. : Degree of Freedom

FEED : Front End Engineering Design

EDP : Engineering Detailed Phase

FPSO : Floating Production Storage and Offloading

Hs : Significant Wave Height

RAO : Response Amplitude Operator

Tp : Peak Period

KG_{fluid} : The height of the vertical center of gravity (from base line), including free surface effects

MWS : Marine Warranty Surveyor

2 INTRODUCTION

This document presents the minimum PETROBRAS requirements concerning Naval Architecture discipline.

This specification, associated with others Basic Design documents, is the main guide for naval architecture analyses to be used in the Engineering Detail Phase (EDP) by HULL CONTRACTOR. Unit's stability, motion, mooring and towing design shall be completed and in full accordance with the requirements of this document.

The basic criteria presented here shall be complied with in all phases of design. Special cases such as revision of standards, doubts regarding points not defined in the Basic Design, or modifications intended to upgrade the project shall be presented for analysis and approval by PETROBRAS.

3 REFERENCES DOCUMENTS

3.1 Design Documents

Reference documents without code herein mentioned varies for each project. Therefore, one shall consider proper documentation based on their names, presented below and in project DOCUMENT LIST.

In case of any lack of consistency between document's titles, PETROBRAS shall be contacted for clarification.

[1] I-ET-…: METOCEAN DATA

[2] I-ET-3000.00-1300-960-P4X-001 – WEIGHT CONTROL PROCEDURES

[3] I-DE-…: CAPACITY PLAN

[4] I-DE-…: FREEBOARD PLAN

[5] I-RL-…: MOTION ANALYSIS

[6] I-RL-…: PRELIMINARY TRIM AND STABILITY BOOKLET

[7] I-RL-…: MAXIMUM KG CALCULATION

[8] I-DE-…: MOORING LINES ARRANGEMENT

[9] I-ET-…: TOPSIDES STRUCTURAL REQUIREMENTS

[10] I-ET-…: GENERAL TECHNICAL TERMS

[11] I-RL-…: TOWING & BOLLARD PULL CALCULATION

[12] I-DE-…: TOWING ARRANGEMENT

3.2 Industry Standards

[13] ISO 19901-7 - STATIONKEEPING SYSTEMS FOR FLOATING OFFSHORE STRUCTURES AND MOBILE UNITS

4 ADMINISTRATION AND CLASSIFICATION SOCIETY APPLICABLE CODES AND AMENDMENDS

The vessel shall comply with the following, where applicable:

- Latest Classification Society Rules for Building and Classing Mobile Offshore Drilling Units, FPSO Units and correlated rules;
- MARPOL 73/78;
- International Conference on Load Lines (ICLL) 1966 rules amended by 1988 protocol;
- IMO MOBILE OFFSHORE DRILING UNITS (MODU) CODE 2009;
- IMO IS CODE 2008;
- SOLAS 1974 Convention with latest amendments;
- IACS unified requirements S26;
- IACS unified requirements S27.

HULL CONTRACTOR shall consider the latest amendments submitted for mentioned rules.

5 COORDINATE SYSTEM

All documents issued by HULL CONTRACTOR shall consider the reference coordinate system presented in basic design documentation.

6 NAVAL ARCHITECTURE ARRANGEMENTS

6.1 Design And Arrangement of Structural Tanks

Preliminary CAPACITY PLAN is provided by PETROBRAS (see reference [3]) and shall be updated by HULL CONTRACTOR.

There shall not be any intersection between cargo tanks and the rooms located at hull's Forecastle, i.e., HULL CONTRACTOR shall propose tank arrangement solutions to avoid this issue (see an example in **Figure 6-1**) and submit for CS and PETROBRAS approval.

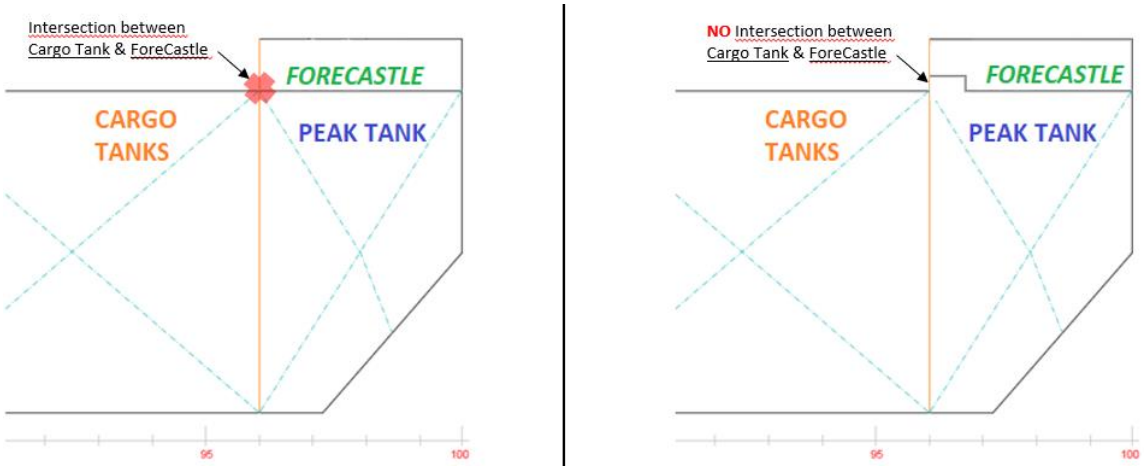

Figure 6-1 Example of solution to avoid intersection between Cargo tanks & Forecastle

6.2 Design And Arrangement of Openings

Preliminary FREEBOARD PLAN is provided by PETROBRAS (see reference [4]) and shall be updated by HULL CONTRACTOR.

Design and arrangement of openings and closing appliances are to be according to International Conference on Load Lines and Classification Society requirements. In case of inconsistence between the mentioned rules and PETROBRAS requirements, the most restrictive requirement shall be adopted.

HULL CONTRACTOR shall provide and install watertight access hatches for all the tanks of the vessel.

Hatches, ventilators and air pipes fitted on the forward quarter of the vessel shall comply with additional strength requirements as outlined by IACS UR S26 & S27.

6.2.1 Openings at Cargo Zone/Portside

At cargo zone, whenever escape route might clash with air vent pipe (e.g. elevated escape route, Figure 6-2), HULL CONTRACTOR shall route air vent pipe leading the weathertight valve towards hull's center line.

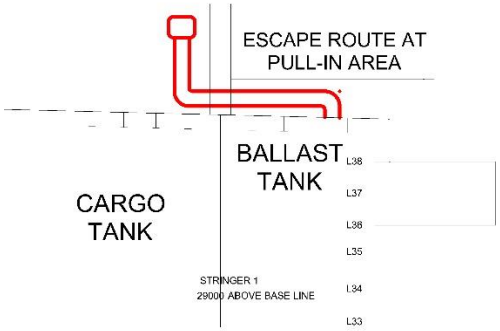

Figure 6-2 Air Vent Pipes Routing in Cargo Zone/PS

In the same region, hatch coamings for tank access might be reduced or omitted entirely, in accordance with rules mentioned in Chapter 4 and Classification Society requirements. HULL CONTRACTOR shall submit these coaming heights for PETROBRAS and CS approval, during detail engineering design phase.

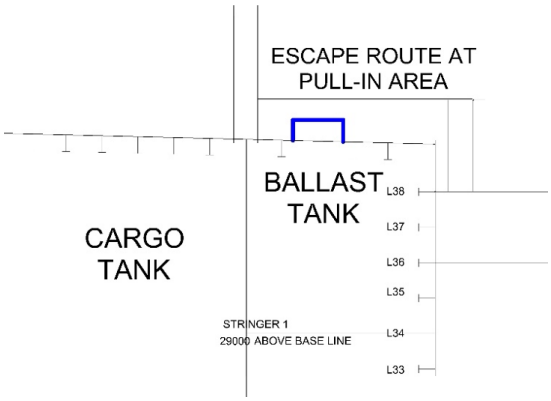

Figure 6-3 Access Hatches in Cargo Zone/PS

7 ENVIRONMENTAL CONDITIONS

The environmental data, described in METOCEAN DATA [1], shall be considered for the site of the FPSO. In addition, the FPSO shall be verified to withstand the environmental conditions, for the specified route during transportation from the construction site to final offshore location. For the Design Operational Condition (DOC), the 1-year return period shall be verified and for the Design Extreme Condition (DEC), the 100-year return period shall be verified.

8 LOADING CONDITIONS

The description of the loading conditions shall be divided in two main parts:

- Lightweight
- Deadweight

Final loading conditions shall incorporate Lightweight characteristics determined by the administration and CS approved Inclining Test.

During the Basic Design, FEED, EDP and fabrication, HULL CONTRACTOR shall perform a weight control according to WEIGHT CONTROL PROCEDURES [2].

HULL CONTRACTOR shall present for every loading condition, as a minimum, the following items:

- % of filling for each tank;
- Fore, midship and aft drafts (PortSide & StarBoard);
- Trim;
- Longitudinal Centre of Gravity (LCG);
- Transversal Centre of Gravity (TCG);
- Vertical Centre of Gravity (KG);
- Free Surface Effect correction (FSE);
- KG corrected by FSE (KG_{fluid});
- Metacentric Height (GM).

At least one of the following Loading Conditions Classes shall be considered by HULL CONTRACTOR, concerning stability, motion, mooring analyses:

1. Standard Loading Conditions: transit to location and daily operation where all hull structural tanks are available for loading;
2. Loading Conditions For Tank Inspection: daily operation where any single ballast, cargo, slop, offspec, settling or produced water tank is empty and available for survey;

3. Additional Loading Conditions: extraordinary conditions, such as structural repair operations.

From mentioned classes, HULL CONTRACTOR shall perform a set of loading conditions:

- Transit condition(s) to location;
- Minimum loaded draft;
- 20 % loaded;
- 40 % loaded;
- 60 % loaded;
- 80 % loaded; and
- 100 % (full) loaded.

REMARKS:

1) Different intermediate % loaded conditions may be proposed by HULL CONTRACTOR and subjected to PETROBRAS approval;
2) Cargo tank in the totally full condition shall be considered filled up to maximum 90% of its capacity. Cargo tank in the totally empty condition shall be considered with less than 1% of its capacity;
3) Slop Tanks may be considered in any filled condition, from totally full to totally empty. A constant amount of 50% each may be accepted, subjected to CS approval, for all Loading Conditions.

The maximum allowable trim (% of ship length between perpendiculars) shall be, for any Loading Condition, according to the following:

- Standard and Tank Inspection Loading Conditions:
  . Maximum trim = 0.0 % towards bow;
  . Maximum trim = 2.0 % towards stern.

- Additional Loading Conditions:
  . Maximum trim = 0.6 % towards bow;
  . Maximum trim = 2.0 % towards stern.

9 OPERATIONAL LIMITS

9.1 Essential Equipment

These equipment are defined according to CS requirements, comprising of special equipment, such as emergency category, life safety, telecommunication, etc.

All essential equipment shall be able to operate under the following conditions:

. Heel angle : 22.5^0

. Trim angle : 10.0^0

Angles less restrictive than specified above might be accepeted, based on rules mentioned in Chapter 4. HULL CONTRACTOR shall submitt such values for PETROBRAS approval.

REMARKS:

1) In the case of essential equipment, the manufacturer shall guarantee adequate functioning, without loss of performance, after the ship returns to its even keel position (without heel or trim), in the case of a damage or flooding event;
2) Angles not occurring at the same time;
3) Life Saving Appliances and launching devices should be in accordance with SOLAS 1974 Convention with latest amendments;
4) The whole draft range shall be considered, as defined in Chapter 8.

9.2 Process Plant & Utility Systems

9.2.1 Normal Operation Condition

The Unit shall be designed to operate normally up to DEC condition, according to results presented in updated MOTION ANALYSIS (see reference [5]). HULL CONTRACTOR shall consider “to operate normally” as a state in which all systems and processes on the Unit can be started or kept running without tripping alarms or safety shut-down or endangering equipment and personnel involved. This includes, but not limited to, the oil collecting

system, utility systems, vessel systems, as well as oil transfer to/from cargo tanks. In addition, process facilities shall be designed to ensure the efficiency of separation and treatment and transfer of oil, gas and water.

HULL CONTRACTOR might propose less restrictive environmental conditions threshold, for the normal operation of a specific process plant equipment, upon PETROBRAS approval concerning the proposed operation limits.

REMARKS:

1) Horizontal and vertical accelerations also to be considered (including gravity effects).
2) The process plant shall be able to operate normally in all Loading Conditions, defined in Chapter 8.

HULL CONTRACTOR shall consider as Utility Systems all facilities employed to provide power generation, water for cooling, compressed air and HVAC to keep the vessel operating even with process plant under shutdown condition.

All utility systems shall be able to operate under the conditions presented in MOTION ANALYSIS, considering 100-year return period (see reference [5]).

REMARKS:

5) Horizontal and vertical dynamic accelerations also to be considered (including gravity effects);
6) The utility systems shall be able to operate normally in all conditions defined in Chapter 8;
7) This requirement is also applied for the towing condition, from shipyard to final location.

9.3 Pull-in Operation

Only intact mooring system analyses shall be considered, for pull-in operation, at transit loading condition (see chapter 8).

Regarding environmental combinations, 1-year return period aligned waves and winds associated with 1-year return period current profiles (return period defined as per METOCEAN DATA [1]). Current and wind/waves shall be misaligned up to 45 degrees (stepped by 15 degrees), as shown in Figure 9-1.

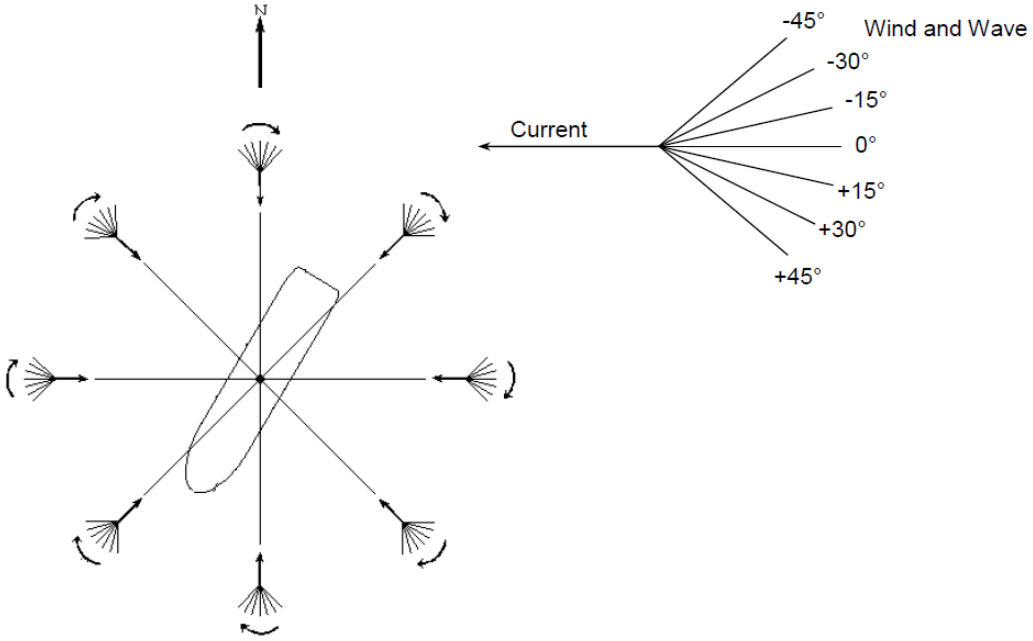

Figure 9-1 Environmental Combination (Wind, Wave and Current) pattern.

9.4 Offloading Operation

The vessel shall be able to keep offloading operations up to the following environmental condition:

- Winds: 50 Knots, 10 minutes average wind speed
- Waves: The waves shall be considered as being aligned with the wind and be limited to: HS = 5 m; Tp = ranging from 6.0 to 19 seconds.
- Currents: 1 (one)-year return period current shall be considered as propagating going to any direction, up to 45 degrees out of alignment with wind and waves

incidence direction (see Figure 9-1). The worst case scenarios shall be accounted for, in the analysis.

REMARKS:

1) The whole draft range shall be considered, as defined in Chapter 8.

10 STABILITY ANALYSIS

Preliminary STABILITY BOOKLET [5] (i.e. FPSO's Loading and Stability Manual) is provided by PETROBRAS and shall be updated by HULL CONTRACTOR.

HULL CONTRACTOR shall issue the STABILITY BOOKLET prior and after the unit's inclining test. It shall comply with the stated in the latest CS Rules for Building and Classing Mobile Offshore Drilling Units, FPSO Units and correlated rules, IMO RESOLUTION A-749, MARPOL and International Conference on Load Lines (ICLL) 1966 rules amended by 1988 protocol.

The STABILITY BOOKLET shall be approved by CS and PETROBRAS.

The intact and damage stability analyses shall be performed for Standard and Tank Inspection Loading Conditions, specified in Chapter 8, regarding at least the following condition cases:

Table 10-1 Minimum Condition Cases to be issued in Stability Booklet

		Standard LC	TK Inspection LC	Additional LC
1	Transit condition(s) to location	**Required**	*Not Required*	*Not Required*
2	Minimum loaded draft	**Required**	**Required**	*Not Required*
3	20 % loaded	**Required**	**Required**	*Not Required*
4	40 % loaded	**Required**	**Required**	*Not Required*
5	60 % loaded	**Required**	**Required**	*Not Required*
6	80 % loaded	**Required**	**Required**	*Not Required*
7	100 % (full) loaded	**Required**	**Required**	*Not Required*

REMARKS:

1) For Transit Condition, there is no need for Marpol 73/78 verification;
2) Different intermediate % loaded conditions may be proposed by HULL CONTRACTOR, subjected to PETROBRAS approval;
3) Shear force and bending moment limits shall be verified for all draughts;
4) Whenever Additional Loading Conditions (as defined in Chapter 8) are requested by CS, HULL CONTRACTOR shall present intermediate conditions, containing the filling/emptying sequence of tanks, showing that the shear force and bending moment curves are within acceptable limits.

HULL CONTRACTOR shall calculate the up-to-date MAXIMUM ALLOWABLE KG CURVE [7], covering unit's trim range, according to CS requirements, and considering actual openings positions and wind forces.

For wind heeling levers, regarding intact stability, 100-year return period, 1-minute sustained wind from METOCEAN DATA [1], might be considered by HULL CONTRACTOR, upon agreement with CS.

For Stability standpoint, the highest possible KG shall be determined for a range of draughts, covering from the minimum to the maximum operational and transit conditions. For each draught, the maximum allowable KG shall be derived among the most restrictive criterion between intact and damage cases, as requested by administration and CS codes.

For any Loading Condition, the respective KG_{fluid} shall be below the threshold of the MAXIMUM ALLOWABLE KG CURVE.

HULL CONTRACTOR shall perform a Maximun Heel and Trim Angle Analysis, considering flooding the compartments according to MODU. In addition, flooding shall occur at full sounding level and consider an additional meter (1.0m) of KG in the total weight.

11 MOTION ANALYSIS

Preliminary MOTION ANALYSIS [5] is provided by PETROBRAS and shall be updated by HULL CONTRACTOR.

Motion analysis results, regarding displacements, velocities and accelerations, shall be used at least for the analysis of the following items:

- Process plant structural design;
- Fairlead and riser support structure/hull interface design (Spread-Mooring);
- Flare boom / tower structural design;
- Helideck structural design;
- Crane foundation structural design;
- Equipment operational limit assessment;
- Offloading operational limit assessment;
- Pull-in / out operational limit assessment.

This analysis shall be used mainly to provide DOC and DEC motions and accelerations to be used for Topside structural analysis, in accordance with TOPSIDES STRUCTURAL REQUIREMENTS [9]. In addition, HULL CONTRACTOR shall submit 10-Year return period motions and accelerations results for the items highlighted in bullets above.

HULL CONTRACTOR shall verify probability occurrence of wave slamming loads and green water, according to CS rules. Moreover, HULL CONTRACTOR shall verify whether any wave load exceeds structures ultimate strength limits.

Slamming phenomena shall be assessed at attached structures that might be subject to wave slamming (e.g. Fairlead support structures, mooring balconies, riser balconies, aft hull structures).

Wave loads shall not cause excessive vibrations that can affect slender structures and equipment, if they happen. Structures located in wave splash zones must be designed to prevent vibrations and their consequences from taking place in case of unavoidable wave loads. The structures topology and geometry shall be defined in order to dissipate wave

energy (e.g. design considering slender structures and adopting deadrise angles of 30 through 45 degrees). The efficiency of wave energy dissipation must be demonstrated, whether such solutions are necessary.

HULL CONTRACTOR shall design and install Fairlead support structures in a way to avoid the effects of wave slamming. HULL CONTRACTOR shall place mentioned structures inwards the side shell, inside ballast tanks (except for those strictly necessary to hold the fairlead itself).

Motion Analysis shall be performed for Standard Loading Conditions, specified in Chapter 8, regarding at least the following condition cases:

Table 11-1 Minimum Condition Cases to be issued in Motion Analysis

		Standard LC	TK Inspection LC	Additional LC
1	Transit condition(s) to location	**Required**	*Not Required*	*Not Required*
2	Minimum loaded draft	**Required**	*Not Required*	*Not Required*
3	20 % loaded	**Required**	*Not Required*	*Not Required*
4	40 % loaded	**Required**	*Not Required*	*Not Required*
5	60 % loaded	**Required**	*Not Required*	*Not Required*
6	80 % loaded	**Required**	*Not Required*	*Not Required*
7	100 % (full) loaded	**Required**	*Not Required*	*Not Required*

REMARKS:

1) Different intermediate % loaded conditions may be proposed by HULL CONTRACTOR, subjected to PETROBRAS approval;
2) Full Hs x Tp extreme single peak curves shall be considered in motion analysis (as per METOCEAN DATA [1]);
3) Gravity acceleration components shall be considered to calculate accelerations at desired points;

4) Roll viscous damping data from MOTION DATA [5] shall be considered in Motion Analysis, while results of model tests are not available. HULL CONTRACTOR shall update this according to results from model tests campaign.

5) Accelerations during international transit voyages shall be calculated considering 'Hs' value defined in MOTION DATA [5]. HULL CONTRACTOR might use different value based on updated information, according to CS and Marine Warranty Survey requirements.

The roll RAO curves shall be computed considering roll viscous damping varying according to the significant wave height level:

1) Table 1 → Hs < 2.5m (irregular waves contour curves).

2) Table 2 → 2.5m < Hs < 4.0m (irregular waves contour curves).

3) Table 3 → Hs > 4.0m (irregular waves contour curves).

Motion results shall be computed also considering the following:

- The roll viscous damping shall be derived for each draught, considering stated different significant wave height levels.
- The mooring lines and risers shall be considered only as weight items to compose the loading conditions. No dynamic effect from the lines shall be included in results.
- Excitation frequencies ranging from 0.10 to 3.0 rad/sec.
- The number of calculated frequency components shall be at least 60.
- Around the natural frequency peaks presented in the Roll and Heave RAO amplitude curves, the regular wave frequency discretization in the curves shall correspond to a 0.1s steps within a range of ± 1,0 s around natural period value.
- Regular wave incidences ranging from 0 up to 360 degrees with 7.5 degrees increments, being 0 degree value the "aft", 90 degrees value the "starboard", 180 degrees the "bow".

- RAO and QTF Motion Results shall be referred to the C.O.G. (Center of Gravity of the Unit) for each draught. Therefore, the C.O.G shall be informed together with abovementioned data, apart from respective radius of gyrations about longitudinal, transversal and vertical axes, all of them calculated at C.O.G.

- The waves considered for the roll damping estimation shall be the beam sea condition (irregular waves) that causes the higher motions (higher Hs or wave peak period: Tp equal to the natural period of the roll motion for each specific draft). All roll damping estimation shall be done with no current.

- For Loading Conditions with roll natural periods equal or greater than 17 seconds, considering transit and all operational drafts, second order effects for mean and low-frequency rolling motions must be included in the analysis (in addition to first order results).

- Full second order analysis are required when calculating low-frequency rolling motions, and QTF together with time series for this D.O.F. shall be delivered for every sea state analyzed in MOTION ANALYSIS [5], considering proper seed variation. HULL CONTRACTOR might propose different methodology (such as frequency-domain approximations), upon PETROBRAS approval.

- For roll motion, second order motion assessment based on mean drift approximations are not acceptable. Furthermore, HULL CONTRACTOR shall submit proposed methodology before the submission of the motion analysis report, for PETROBRAS appraisal and approval, presenting evidence that the proposed methodology is feasible.
- For FPSO loading conditions/draughts assessed during model test campaign, the associated reference topside VCG (vertical position of center of gravity) must be taken from the latest Weigh Control Report revision available right before the model tests, considering the respective topside operating weight and its contingency.
- Based on model test outcomes, RAOs for all D.O.F. and 2nd order roll QTFs must be provided for reference topside VCG mentioned above, apart from VCG variations of ± 1.5 meters about the reference value, for all FPSO loading conditions/draughts referred before.

- VCG variations (± 1.5 meters about the reference VCG) are not scope of the model tests.

The reference system and direction conventions shall be included in the Motion Analysis report. The expression that needs to be employed to generate time series for displacements, velocities and accelerations shall be also published by HULL CONTRACTOR.

All numerical output data (RAO curves and tables, added mass coefficients, potential damping coefficients, wave exciting forces and quadratic transfer functions) shall be released in Microsoft Excel file and *.txt format by HULL CONTRACTOR. Different file extensions may be proposed by HULL CONTRACTOR, subjected to PETROBRAS agreement.

11.1 Model Tests

HULL CONTRACTOR shall perform model tests (FPSO motions) during the detail engineering design phase. As minimum scope of work, model tests shall include assessment of predicted FPSO motions, roll viscous damping level in the presence of the bilge keel (for different drafts and wave heights), green water, slamming (occurrence and mitigation options) and induced loads.

HULL CONTRACTOR shall collect roll viscous damping from model test campaign, in order to calibrate numerical analysis properly.

HULL CONTRACTOR shall submit the model test matrix to PETROBRAS for comments/information and carry out the model test program based on agreed matrix.

For Loading Conditions with roll natural periods equal or greater than 17 seconds, considering all operational drafts, second order effects for mean and low-frequency rolling motions must be addressed in the model test scope (in addition to first order motions).

Irregular sea description from METOCEAN DATA [1] shall be considered. In case of lack of information, PETROBRAS shall be contacted for clarification.

Wave basin Unit's model scale shall range from 1: 70 to 1: 100. Different model scale might be proposed by HULL CONTRACTOR, upon PETROBRAS approval.

PETROBRAS shall be informed about the beginning of test campaign, in order to decide to send an observer or not.

12 MOORING ANALISYS

Mooring lines design is PETROBRAS's scope of work. The mooring system is presented in MOORING LINES ARRANGEMENT [8].

HULL CONTRACTOR shall provide, in the beginning of the EDP, lightweight distribution, modules and equipment weight, apart from modules windage areas and all other FPSO characteristics necessary to allow PETROBRAS to update mooring analysis report.

Regarding Mooring System equipment and facilities, HULL CONTRACTOR shall provide:

- Each winch shall be able to operate at least with tension 1.75 times the highest pretension, when the FPSO is at minimum draft, for the set of mooring lines the winch attends. Such factor must be applied in order to incorporate dynamic effects caused by the environmental conditions at Unit's location and other dynamic effects such as friction on the pulleys when installing the mooring system. The minimum chain pull-in speed shall be 1.5 m/min at maximum winch pull-in capacity.

- If chain-stoppers and load cells are not installed on the main deck of the Unit, they shall be installed in places and positions in which they can be inspected and/or dry maintenance (not submerged) can be undergone, without any damage or restriction over normal operation of the Unit.

- Sufficient room shall be reserved around chain-stoppers (taking into consideration the room occupied by winches), allowing the access of at least two people for assembling the mooring lines' connections. There shall be enough clearance on each side of the chain-stopper, so that at least 5 mooring links can be laid down on the deck for a safe assembly of connections.

- Top Chain Tension Indicator or Means of Detecting Mooring Line Failure - Chain-stoppers shall be equipped with load cells capable of measuring mooring line tensions, identifying eventual mooring lines failures. Top chain tension signals, obtained by the load cells installed on each chain-stopper, will be transmitted to

FPSO's CCR or any other suitable room in the Unit, for all mooring lines. There shall also be a local tension indicator, as specified in the operating philosophy. Other means of identifying mooring lines failure can be used upon assessment of PETROBRAS's operational departments and upon approval by maritime authority.

- The Unit shall have suitable fairleaders for top chain segments of each mooring line. The fairleaders shall be supplied and installed on the side of the Unit at elevations such that, fairleaders and chains do not represent navigation risks for support vessels that regularly approach to the Unit, when they are under water.

- Chain diameters shall be compatible with equipment available in anchor handling tug supply vessels (AHTS) to be used for installation and maintenance operations of the mooring system. Nominal diameters which PETROBRAS operates up to the date of issue of this document are: 76 mm, 105 mm, 114 mm and 120 mm. If changes ISO-19901-7 [13] take place during project development, larger diameters for top chains may be necessary, requiring compatibility reassessment in systems, devices and equipment which are dependent on top and installation chains diameters;

- In order to provide faster and safer operations for maintenance, diving and monitoring during connection and disconnection of mooring lines, davits and padeyes shall be provided in suitable places.

- Electro-hydraulic chain-jacks (linear winches for chains) shall also be provided and installed for the purpose of doing mooring lines hook-up and tensioning.

- Winches configuration shall be as follows:

  a-) At least, a complete set of chain-jack (electro-hydraulic type) for each group (cluster) of mooring lines. The FPSO shall have four (4) sets of linear winches to meet the following groups (clusters): fore-portside, aft-portside, fore-starboard, aft-starboard.

b-) Winches shall be equipped with handling devices that allow their vertical alignment with the chain-stopper of each mooring line for the respective group the winch attends.

c-) These winches shall be composed by lifting cylinders, chain-stopper pawl cylinder, chain-jack pawl cylinder and electric load cell bolts in the chain stopper.

Notes: “electro-hydraulic type” means a winch powered by hydraulic pressure obtained from an electrically driven Hydraulic Power Unit (HPU).

- For FPSOs with four (4) mooring winches, two (2) Hydraulic Power Units (HPU) must be designed, supplied and installed on the deck of the Unit: one HPU at the bow and another at the stern, so that both HPUs can be operated independently.

- Each HPU must be designed and sized to allow the operation of one (1) linear winch at full power at a time.

- The units shall have controlled sequencing, with proximity switches for chain-stoppers pawls positioning.

- The FPSO shall have fixed or movable chain-lockers near each winch. The chain-locker shall be sized to store chain segments 250 meters long, at least (150 meters of installation chain and 100 meters of top chain).

- The chain-lockers shall be located out the hull (above the main deck or above the mooring balcony, for example), in order to avoid the risk of fire due to sparkings generated by friction between mooring chains and the deck itself.

- Mooring chain handling between the winch and the chain-locker shall be done in a way that human intervention is not required during chains pull-out or pull-in operations. The chain-locker geometry shall be such that the need of intervention to accommodate the mooring chain is unnecessary. In addition, the mooring chain handling between the chain-stopper and the fairlead must occur without obstruction, with enough room to allow free passage and rotation of the mooring chain.

13 TOWING ANALISYS

Preliminary minimum required bollard pull for the towing operation can be found in TOWING & BOLLARD PULL CALCULATION [11].

Preliminary data concerning Safe Working Load (SWL) for towing equipment and their arrangement in FPSO can be seen in TOWING ARRANGEMENT [12].

HULL CONTRACTOR shall update abovementioned documents in detail EDP, according to CS and MWS requirements.

Auxiliary Padeyes shall be included in towing arrangement, for easier handling of towing lines, and shall be submitted for PETROBRAS approval during EDP.