PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-3A50.00-1350-940-P56-001	
	CLIENT: E&P - AGUP	SHEET: 1 de 55	
	PROGRAM: Atapu Field Development – Module 2	-	
	AREA: Atapu	-	
SUB/ES	TITLE: FPSO Structures and Facilities for Riser System	PUBLIC	
		PSUB	

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR AFFECTED PAGES
0	ORIGINAL
A	CHANGE OF SUPPLY SCOPE OF THE TEMPORARY PLR PIPEWORK CONNECTION FOR GAS EXPORT PRE-COMMISSIONING

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	01/07/2022	14/12/2022							
DESIGN	PSUB	PSUB							
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APPROVAL	Eduardo Bacellar	BF6I							

CONTENTS

1 INTRODUCTION

1.1 Project Description

PETROBRAS, as operator, intends to develop a portion of the offshore Atapu Field — located in Santos Basin, offshore Brazil, at water depths ranging from 2000m to 2350m.

The development consists of one purpose-built vessel-based spread-moored System (SMS) Floating Production Storage and Offloading Unit (FPSO) — also called “the Unit” or FPU in this document, connected to the subsea facilities via a coupled riser system, and moored at circa of 2300m WD.

Their subsea production systems will include rigid (Base Case) or flexible gathering sealines for oil production and injection of gas and water, rigid and flexible sealines for gas-lift/service and gas transfer, and umbilical lines (STU) for various functions.

FPU construction project will comply with the FPSO-SMS basic design developed by PETROBRAS (“HIGH CAPACITY FPSO”), and will be able to operate with three types of satellite wells, as follows:

- Production well, which will require two risers, one exclusively for oil production, and the other for gas-lift/service operations.
- Gas and/or Water Injection well: usually injection wells will be arranged on WAG Loops of two wells, therefore with one riser for each well, operating with gas injection and water injection alternately, at any time.
- Production well with flexibility to be converted to injection well (called PWAG), which will require two risers, one for oil production or water injection, and the other allowing for operation with gas-lift (service line) or gas injection.

1.2 Scope of Document

The purpose of this specification and documents referenced hereafter is to provide the SUPPLIER with general information of intended risers, minimum requirements for the detailed engineering and construction of the essential parts of the Riser Balcony in respect to the hang-off structures and connections of the riser system, and aspects of main related installation activities on FPSO. Topics include, but are not limited to:

- Riser Balcony Support Structures
- Riser hard pipes / top spools connections
- Riser Pull-in/Pull-out (Overview)
- Diving & ROV activities
- Riser integrity monitoring systems
- Control and monitoring of TSUDL and BSDL diverless functions

The intention is not to provide full and detailed description of data and conditions, but rather to state the main capabilities and functionalities, to present scope of major items and the specifications to which the FPSO riser balcony and pull-in facilities and structures shall comply, and also to provide considerations for the design and arrangement of the associated systems.

This specification has to be read in conjunction with referred project specifications and general technical specifications (see sec. 3.1 and sec. 3.2), as well as other contract documents describing the related FPSO facilities and interfacing equipment, or presenting design features or requirements concerning riser balcony and pull-in platform structures. All these documents will give input to this specification regarding scope of detailed design and supply, construction requirements, pressure classes, onshore site integration, detailed testing, commissioning, etc.

2 DEFINITIONS

For the purpose of this Specification the following definitions shall apply.

2.1 Organizations

PETROBRAS	PETROBRAS – Petróleo Brasileiro S.A.
BIDDER	The Organization tendering the construction phase of the FPSO to PETROBRAS
SUPPLIER	The Organization in charge of detailed engineering, supply and construction phase of the FPSO, under contract to PETROBRAS
SURFCONTR	The Organization providing the construction and installation of the subsea facilities, under contract to PETROBRAS
SUB-SUPPLIERS	The party that manufactures and/or supplies equipment, materials, goods, and/or services for the project through SUPPLIER Purchase Order
Work	All work to be performed by the SUPPLIER and/or SUB-SUPPLIERS under the construction phase of the FPSO, including all duties and obligations of the construction Contract.

2.2 General Definitions

May	Is used where alternatives are equally acceptable.
Shall	Is used where a provision is mandatory.
Should	Is used where a provision is preferred.

2.3 Technical Definitions

BELLMOUTH	Locking Device for the Bend stiffener of a Flexible or Umbilical Riser, coupled to the base of its Lower I-Tube.

BEND STIFFENER	Component of a Flexible or Umbilical Riser, consisting of a molded plastic conical shape around the flexible structure, to sustain the transverse loads and associated high bending moments in a transition to a rigid connection point.
DIRECT APPROACH PULL-IN	This definition is used in this document for the Pull-in of Risers approaching from eastern sector (Portside-facing risers)
END FITTING	End component of a flexible pipe or umbilical that makes the transition from its flexible part to a rigid connection point.
HANG–OFF STRUCTURE	Hull Structure welded to the Lower Riser Balcony (LRB) or Upper Balcony (URB), and where a Riser top assembly part will be locked or seated.
HARD PIPE / HARDPIPING	Pipework attached to the FPSO hullside, extending from Rigid Riser termination at LRB to the URB.
HANG-OFF ADAPTOR	Assembly that promotes interface between the Rigid Riser Top Joint and Support Tube.
INSTALLATION	All activities carried out by the FPSO for the riser installation: riser pull-in; connection of riser termination to ESDV; assistance to sealine pre-commissioning; connection of riser integrity monitoring system to Topsides etc.
LOWER I-TUBE	Pipe Guide (*hang-off structure*) section located in the LRB, including the *Bellmouth* fitted on its base to accommodate the Bend stiffener of the Flexible or Umbilical Riser.
MOCKUP	Dummy insert that fits Riser support and replicates azimuth, departure angle, and flange position of riser top assembly.
SUPPORT TUBE (TSUDL)	Special Tube for structural connection of Rigid riser at Starboard direction
TOP (INTERFACE) SPOOL	Piping at URB connecting Topside SDV´s with Flexible Riser Connector or Hard Pipe of Rigid Riser
UPPER I-TUBE	Pipe Guide (*hang-off structure*) section located in the URB, which provides the support for the Flexible or Umbilical Riser.
RISER	Subsea Riser: Rigid; Flexible; Umbilical.
(RIGID) RISER TOP JOINT	Is used in this document to refer to the two options of end joints of the Rigid Riser, enabling its interfacing with the FPU: the Flexible Joint and the Tapered Stress Joint.
TWO-FOLD POSITION	Position that may connect a Rigid Riser or a Flexible Riser
“SEALINE”	Is used in this document as a general term to refer to the risers and related flowlines (rigid or flexible) attached to FPU.
“GATHERING SEALINE”	Is used in this document to refer to the riser and related flowline (rigid or flexible) piping subsea wellhead to FPU.

“GATHERING SYSTEM” — Is used in this document to refer to all subsea facilities (risers, flowlines, tie-in systems, umbilicals etc.) linking the WCTs to the FPU.

2.4 Abbreviations

A&R	Abandonment and Recovery (acronym related to pipelay)
BSDL-SI	Diverless Bellmouth - standard interface (Portuguese acronym)
CMM	Coordinate Measure Machine
CP	Cathodic Protection
FAT	Factory Acceptance Test
FPSO	Floating Production, Storage and Offloading
FPU	Floating Production Unit
FXJ	Flexible joint
HOA	Hang-off Adaptor
GE, GI, GL, GT	Gas Export, Gas Injection, Gas-lift, Gas Transfer
HP	Hardpiping section(s)
ID, OD	Inside Diameter, Outside Diameter
LRB	Lower Riser Balcony
MSGL	Gas-lift Subsea Manifold
NA	Not Applicable
PLET	Pipeline End Termination
P&ID	Piping & Instrumentation Diagram
PLV	Pipelay Vessel
PRM	Permanent Reservoir Monitoring
PWAG	Used in this document to refer to Prod. Well convertible to GI / WI
RRMS	Rigid Riser Monitoring System
RAO	Response Amplitude Operator
ROV	Remotely Operated Vehicle for Underwater Activities
SCR, SLWR	Steel Catenary Free Hanging Riser, Steel Lazy Wave Riser
SDV, SSDV	Shutdown Valve, Subsea Shutdown Valve
S-SCR	Shaped Steel Catenary Riser
SDV	Shut-down Valve
SDU	Subsea Distribution Unit
SMS	Spread Mooring System
STU, TPU	Steel Tube Umbilical, Thermoplastic Umbilical
SURF	Subsea Umbilicals, Risers and Flowlines
TBD	To be Defined
TEC	Thermal Exchange Coefficient (W/m.K)
TSJ	Tapered (Titanium) Stress Joint
TSUDL	Unified Diverless Support Tube (Portuguese acronym)

URB	Upper Riser Balcony
WAG, WI	Water Alternate Gas, Water Injection
WCT	Wet Christmas tree (satellite wellhead equipment)
WD	Water Depth

3 REFERENCE DOCUMENTS

3.1 FPSO Project Specifications

Ref.#	Doc. No.	Doc. Title
\1\	I-ET-3010.2E-1351-140-P4X-001	Hull Structural Requirements
\2\	I-ET-3010.2D-5268-968-P4X-001	Riser Pull-in and Pull-out System
\3\	I-ET-3010.2D-1200-200-P4X-010	Technical Specification for Hard Pipe
\4\	TBD	Riser Monitoring Systems Block Diagram

3.2 PETROBRAS General Technical Specifications

Ref.#	Doc. No.	Doc. Title
\5\	I-ET-3010.00-1519-140-P56-001	Unified Diverless Support Tube (TSUDL) Specification
\6\	I-ET-3010.00-1519-140-P56-002	Unified Diverless Support Tube (TSUDL) Factory Acceptance Test Procedure
\7\	I-LI-3010.00-1300-270-P56-001	Unified Diverless Support Tube (TSUDL) Parts List
\8\	I-DE-3010.00-1300-279-PEK-004	Lateral Support Module - MTL
\9\	I-ET-3010.00-1519-140-PPC-001	Wear Bushing for Riser Unified Diverless Support Tubes
\10\	I-ET-3010.00-1300-279-PPC-350	Diverless Bellmouth Standard Interface Supply Specification
\11\	I-LI-3010.00-1300-279-PPC-350	BSDL-SI Part List
\12\	I-ET-3010.00-1300-850-PEK-001	Control and Monitoring System for Riser Supports
\13\	I-DE-3010.00-1300-850-PEK-001	Riser Supports P&ID
\14\	I-DE-3010.00-1300-279-PEK-003	5K Hydraulic Actuator Assembly for BSDL-SI
\15\	I-ET-3010.00-1300-850-PEK-002	Hull side Umbilical for Riser Systems
\16\	I-DE-0000.00-0000-140-P56-002	Riser Top Connector Mockup for TSUDL - Conceptual Drawing
\17\	I-ET-3010.00-1500-274-PLR-001	Riser Top Interface Loads Analysis
\18\	I-ET-3000.00-5529-850-PEK-005	Rigid Riser Monitoring System (RRMS) - Umbilical Hullside Solution
\19\	I-ET-3010.00-5529-854-PEK-001	MODA (Flexible) Riser Monitoring System – FPU Scope (Spread Mooring)
\20\	I-ET-3010.00-5529-812-PAZ-001	Flexible Riser – Annulus Pressure Monitoring and Relief System
\21\	I-ET-3000.00-1300-941-PEH-002	Diving System for Risers, Mooring, Hull, and Jacket of Offhore Production Units
\22\	I-ET-3000.00-1500-251-PEK-001	High-Strength Low-Alloy Steel Fasteners for Subsea Applications
\23\	I-ET-3000.00-1200-940-P4X-001	Tagging Procedure for Production Units Design
\24\	I-ET-0000.00-0000-290-P9U-005	Titanium Pull in Tube Specification

3.3 PETROBRAS Interface Data Documentation

3.3.1 for BIDDER

Ref.#	Doc. No.	Doc. Title
\25\	I-DE-3A50.00-1500-941-P56-001	Riser Supports Arrangement Conceptual Design - FPSO Balcony

3.3.2 for SUPPLIER

Ref.#	Doc. No.	Doc. Title
\26\	I-DE-3A50.00-1500-941-P56-001	Riser Supports Arrangement Conceptual Design - FPSO Balcony
\27\	TBD	Riser Top Assembly Data

4 GENERAL OVERVIEW

4.1 Riser System Summary

The riser system of the Unit will encompass a number of **56** risers, according to Tables 4-1 and 4-2. Regarded information will be ratified in the Notice to Proceed.

Table 4-1 – Sealine Risers Summary.

Production System	Line Function	Riser Size (ID)	no.	Comments
PROD.: Oil Production Wells (9 off.)	**Oil Production**	6,5-in or 8-in	9	Rigid as Base Case. Flexible as alternative.
	Service & GL	4-in, (Flex)	9	Flexible.
WAG Injection Wells (7 pairs)	**Water & Gas Injection**	6,5-in (Rigid)	14	Rigid as Base Case. Flexible as alternative. - Riser able to inject water or gas alternately at any time.
PWAG Flex: Oil Prod. Wells convertible to Injection Wells (5 off.)	**Production / Water or Gas Injection**	8-in/6,5-in	5	Rigid as Base Case. Flexible as alternative. - Riser able to operate as producer or water injector. - Conversion from Prod. to WI/GI can be implemented at any time without building work on FPSO.
	Service & GL	4-in (GL) (Flex.)	5	Flexible as base case. A small ID **Flexible** Riser (only for service & GL) is likely to be employed until the well conversion
GE: Gas Export (1 off.)	**Gas Export**	7-in or 8-in (Rigid) / 9,13-in (Flex.)	1	Rigid as Base Case. Flexible as alternative.
		TOTAL	**43 RISERS**	

All relevant information regarding the riser configurations is available in APPENDIX A – RISER CONFIGURATION DATA.

Table 4-2 – Umbilical Risers Summary.

Application	Line Composition	Umbilical Structure	no.	Comments
Umbilicals for wells, via SDU or satellite	Steel tubes and electrical cables	STU 9F+CE/12F+CE/15F+CE	8	
Umbilical for Sysmic monitoring	PRM	(TBD)	3	(TBD)
Umbilicals for electric power supply	Power Cable	(TBD)	1	(TBD)
Umbilicals for ESDV control	Thermoplastic hoses and electrical cables	UEH 5F+CE	1	Integrated fiber optic for IT.
		TOTAL	**13 UMBILICAL POSITIONS**	

The sequence of risers and diameters, for each riser-slot, will be defined at the Notice to Proceed.

4.2 Riser System Layout

Risers are attached along Portside of the FPSO.

Platform approach will include risers at both eastern and western sectors.

Riser system layout will be defined at the project kickoff meeting.

4.3 Riser Balcony

Riser Balcony of the Unit is located on the Portside of the vessel.

There are 56 available positions at riser balcony frames, from which 56 positions (see sec. 5.3) will be required (see ref. \25\).

SUPPLIER shall design, supply, fabricate, install and integrate the riser balcony structures and facilities according to project specifications, including but not limited to the following:

- Riser support systems including all their connection devices and interfaces, for both definite, optional, alternative and spare risers, on all required Riser-Slots.
- The required hardpiping and interface spools for risers connections to process plant (battery limits at topside SDVs and risers connectors).
- The required hydraulic, electrical and optical lines and connections between URB and LRB for diverless supports actuation and monitoring (TSUDL and BSDL), and RRMS infrastructure up to the battery limit with SURFCONTR scope.

- The required outfittings on hull, not only for permanent structures related to connection systems abovementioned but for installation devices and to support all installation activities.
- The complete pull-in system facilities.
- The handling equipment and installation devices to support pull-in, pull-out and offshore installation activities.

5 RISER BALCONY MAIN FEATURES

This section introduces the Riser Balcony concept for the "HIGH CAPACITY ALL ELECTRIC FPSO" in terms of main structures and piping. Emphasis is placed on the support systems that attach the risers to the hull structure.

The Riser Balcony comprises two riser support sections, one below minimum draft (LRB), and another close to deck level (URB), with 56 available locations for positioning of Riser-Slots.

Different riser support structures are required, appropriate for Flexible/Umbilical Risers (hang-off on URB) and for Rigid Risers.

5.1 Support Systems

Flexible and Umbilical Risers will be fitted to the hull through the Upper and Lower Balcony sections, the LRB and the URB (see figure 1).

Rigid risers can be supported in two different ways, depending on the type of riser interface used (TiPT or HOA). They can be directly connected to the Lower Balcony section (LRB) using Support Tubes as hang-off system (HOA case) or can be fitted to the hull through the LRB and the URB (TiPT case) (see figure 2).

Another feature of the Riser Balcony is that support positions expected for Rigid Risers shall also consider the possibility of connecting Flexible Risers in place of them (see sec. 5.1.2.

5.1.1 Support Structures for Flexible and Umbilical Risers

Flexible and Umbilical Risers will be connected to the hull through lower and upper I-Tubes attached to balcony sections, as shown in figure 1. The top I-Tube will anchor the riser axial loads on URB, and the lower I-Tube arranged will incorporate a diverless bellmouth (BSDL-SI) to support the riser bend stiffener.

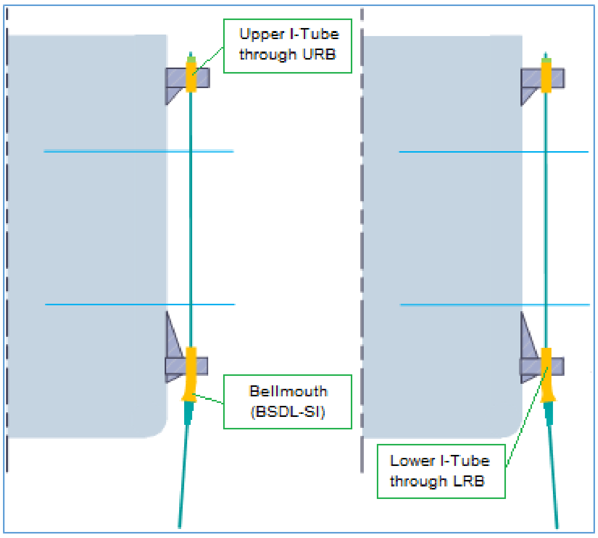


Figure 1 – I-Tube Assembly with two I-Tube Sections.

5.1.2 Support Structures for Two-Fold Positions

Specific supports on LRB will connect the Rigid Risers to the Hull.

A balcony support position for a Rigid Riser will comprise its Support Tube (TSUDL) on a single layer of the LRB, together with an upper I-Tube section at the URB (see figure 2).

- The TSUDL will suppress and replace the Lower I-Tube/bellmouth set for the related Flexible Riser.

The TSUDL is able to perform the structural connection of the Rigid Riser to the LRB, as well as to perform the same functions of a Lower I-Tube/bellmouth for the connection of a Flexible Riser to the URB.

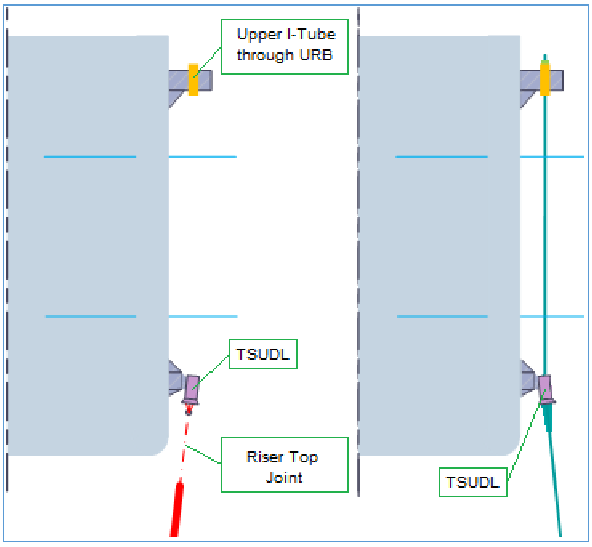


Figure 2 – Riser Support Tube Assembly (TSUDL & Upper I-Tube) (Illustrative).

NOTE: Figure 2 illustrates one TSUDL configuration for both Rigid (Starboard aproach) and Flexible Risers (direct approach). Nevertheless, TSUDL can be used for direct and starboard approach of any type of riser (rigid or flexible) (see sec. 16).

5.1.3 Support Systems (definitions)

As described above, two kinds of riser support systems are required: one is for Flexible and Umbilical Risers connection, while the other system is for Rigid Riser or alternative Flexible Riser:

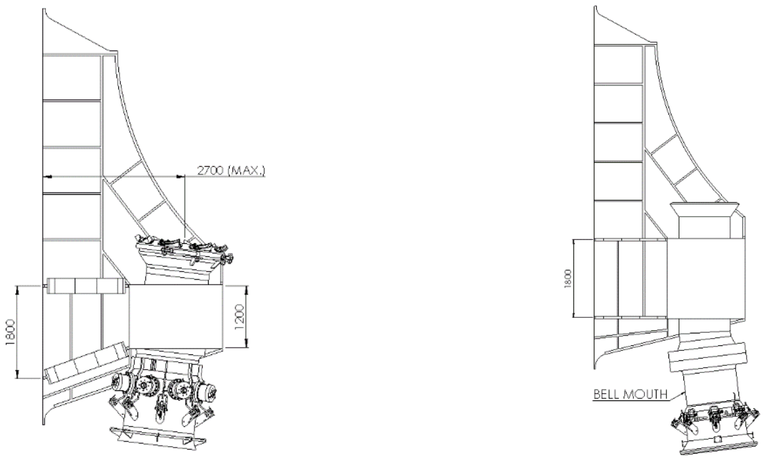
System "F" – I-Tube Assembly for Flexible/ Umbilical Riser.

System "T" – (i) TSUDL, for Rigid Riser (HOA case) as a Hang-off system; for Rigid Riser (TiPT case) or Flexible Riser as a bellmouth.

(ii) Upper I-Tube, for both Rigid (TiPT case) and Flexible riser, as a Hang-off.

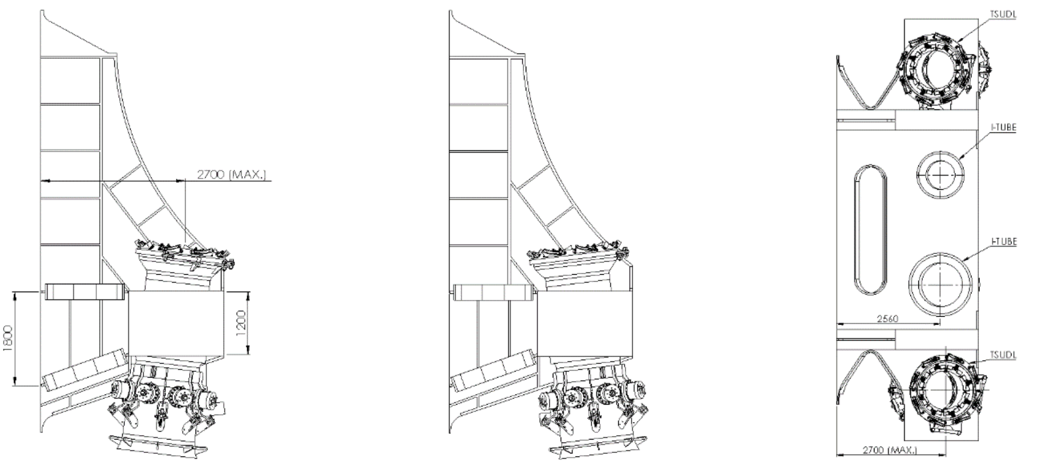
5.2 Lower Riser Balcony Porch Configurations

The Lower Riser Balcony arrangement will consist of modularized contiguous balcony segments, comprising four support positions (risers) each. Figure 3 and Figure 4 show the configuration for the hull porch structures.



(a) Porch for TSUDL. (b) Porch for I-Tubes.

Figure 3 – Comparison of Hull Porch Configurations.



(a) TSUDL – Starboard Configuration. (b) TSUDL – Direct Approach Configuration. (c) Configuration with I-Tubes.

Figure 4 – LRB Arrangement for Porch Modules with TSUDL(s) (illustrative).

5.3 Riser-Slots Composition

The document I-DE-3A50.00-1500-941-P56-001 (ref. \25\) shall be considered as a base case for the balcony design and for the analysis to be carried out during bidding phase by BIDDER.

Nevertheless, the final support type for each riser-slot will be defined at the Notice to Proceed among one of the following options:

- System “F” (portside/starboard direction)
- System “T” (portside/starboard direction)

The amount and type of balcony features associated to the above mentioned support structures, such as LRB porch modules (see sec. 5.2) and hardpiping / top spools (see sec. 5.4) will vary accordingly, as well as other demands on elements (and infrastructure) for automation capabilities of diverless support structures (TSUDLs and BSDLs) and riser integrity monitoring, described hereafter.

Exception is made to the support structures for the umbilical risers (13 off.), whose riser-slot support type is System “F”. For the other 43 off. risers, as described in section 4.1, related support types and equivalent hardpiping / top spools will be confirmed at Notice to Proceed.

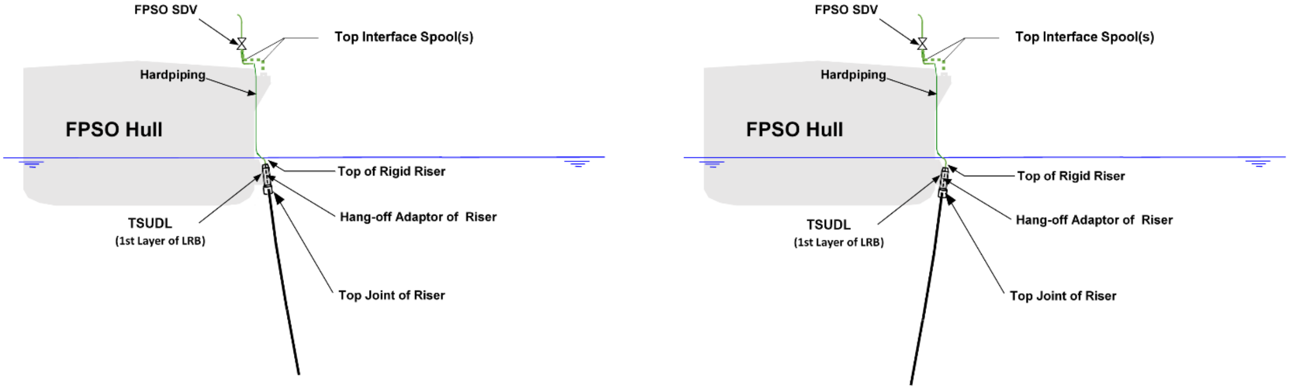
Riser Hardpiping and Top Interface Spool(s) Connections at FPSO Risers can be supported in two different ways, depending on the type of riser interface used (TiPT or HOA).

5.4 Riser Hardpiping and Top Interface Spool(s) Connections at FPSO

As stated in section 5.1 Rigid risers can be supported in two different ways, depending on the type of riser interface used (TiPT or HOA). When a HOA is used as interface, Rigid Risers have to be connected to the FPSO piping above the URB through Hard Pipes and associated Top Interface Spool on URB, provided by SUPPLIER. For the TiPT case, rigid risers will be supported at URB and have to be connected to the FPSO piping through a Top Interface Spool on URB, provided by SUPPLIER.

Flexible risers will be supported at upper riser balcony and have to be connected to the FPSO piping through a Top Interface Spool on URB, provided by SUPPLIER.

Figure 5 shows sketches of Hardpiping and top interface spools for positions related to Rigid Risers (interface spool for flex. riser also indicated).



(a): Risers from Direct Approach – Rigid attached to TSUDL (b): Risers from Starboard direction – Rigid attached to TSUDL

Figure 5 – Hardpiping & Top Interface Spool(s) for Rigid Riser positions (illustrative).

NOTE: Flexible risers and Rigid risers with TiPT interface are always supported in the upper riser balcony hang-off structure, and therefore will require only top interface spools for connection with SDV.

Figure 6 illustrates the composition of hard pipes and interface spools as described above. The Figure shows connection at LRB to a portside-facing rigid riser. General configuration (hard pipe sections) is basically the same for connection to a starboard-facing rigid riser.

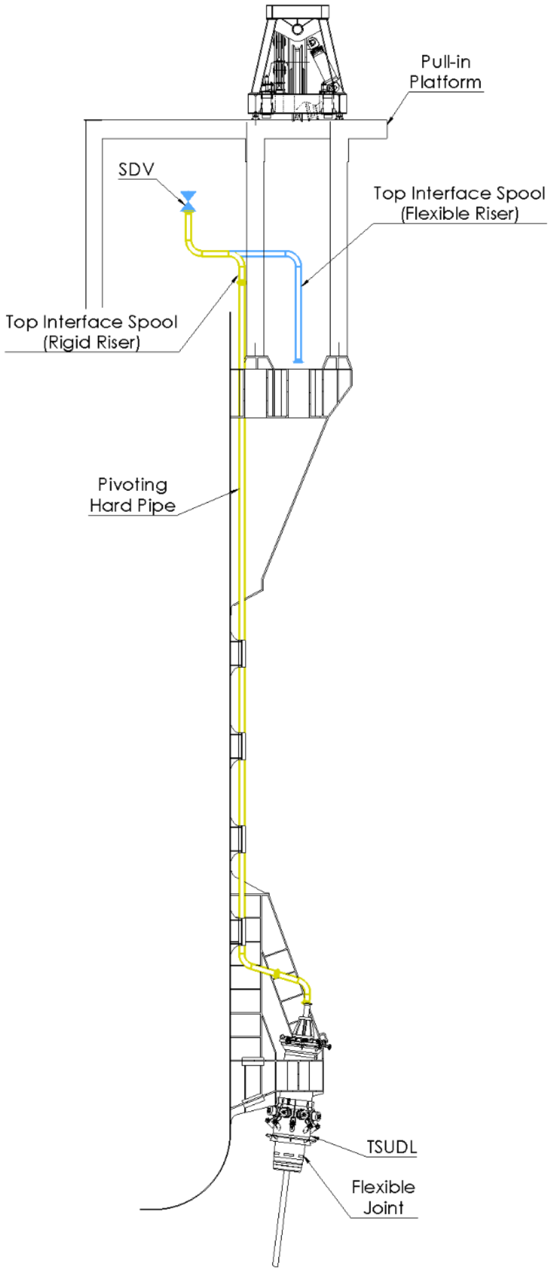


Figure 6 – Pivoting Hardpiping / Top Interface Spool(s) compositions (illustrative) (risers are not represented).

5.4.1 Composition of Hardpiping and Top Interface Spools

The amounts and types of hard pipes and top interface spools under SUPPLIER´s scope of detailed design, fabrication, assembly, fit-up and testing, from battery limit with topsides piping to battery limit with Riser connection point, will vary accordingly with the final support type for each riser-slot (see sec.5.3), from the following:

- System “F” – Top Interface Spool
- System “T” – Pipework Assembly including Pivoting HP & associated Top Interface Spool (for HOA case) **plus** a specific Top Interface Spool (for TiPT case or flexible riser).

Final quantities related to each riser function, diameter and associated risers positions will be defined at the Notice to Proceed.

NOTE: Initial and Future Risers will be defined at the Notice to Proceed. Depending on this definition, interface spools with risers on upper balcony have to be dismounted after fit-up testing and preserved onboard or kept in position with appropriate locking and corrosion protection devices.

General requirements for the battery limits with risers as well as for the scope of supply and services related to hardpiping system and top interface spools, and special construction works to assure compatibility with riser connection points and supports, are further described in this specification.

6 HANG-OFF SYSTEMS

6.1 General Requirements

SUPPLIER shall design, fabricate, install and integrate the riser balcony hang-off structures, in accordance with riser system arrangement and related input data to be provided by PETROBRAS for the contract execution. Reference is made to sec. 3.3, Interface Data Documentation for SUPPLIER.

The support structures on LRB, for each support system abovementioned, shall be precisely aligned with respective riser azimuth planes and top angles at each riser location. Maximum construction tolerances of these support systems on LRB shall be ± 0.5 deg for both the top angles and azimuths. The inspection method will typically utilize coordinate measuring machine (CMM) technology and the procedure shall be submitted for review and approval.

SUPPLIER shall inform the as-built coordinates, top angle and azimuth angle for all riser supports at URB level (hang-off) and LRB level (bellmouths/TSUDLs). All these structures shall be identified regarding their numbering of Riser-slot position on Balcony arrangement according to ref. \23\. Markings shall be performed in three points (top and sides of support), in an indelible form and painted in a contrasting color. Characters shall be visible and identifiable by divers and by ROV. The choice of the positions for these markings shall be sent to PETROBRAS approval.

SUPPLIER shall provide as-built drawings for each support along with inspection reports performed during fabrication. The drawings shall inform azimuth angles and top angles, dimensions and tolerances on contact surfaces, which have to take the coating thickness into account.

6.2 Unified Diverless Support Tubes (TSUDL)

SUPPLIER shall design, fabricate and integrate diverless support tubes (TSUDLs).

The TSUDL is a hybrid support as it incorporates features to connect both rigid risers and flexible risers, for the intended sealines.

Figure 7 illustrates the TSUDL integration to the hull porch structure through its box structure.

Reference is made to PETROBRAS specifications ref. \5\ and ref. \6\, and Part List ref. \7\, for TSUDL design and supply.

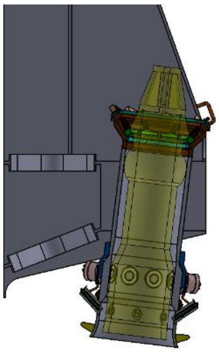


Figure 7 – Unified Support Tube (TSUDL) for Hang-off of Positions for Rigid risers (starboard directions).

Care shall be taken regarding electrical connections between the TSUDL main body and its moving parts in order to guarantee continuous cathodic protection from the FPSO.

TSUDL will require automation capabilities for diverless pull-in and pull-out operations, as well as for CP monitoring, fully integrated to the Topside. Reference is made to PETROBRAS Specifications ref. \12\ and ref. \15\, and drawing ref.\13\. See also sec. 19.

All materials will be SUPPLIER's responsibility. The operational procedure shall be submitted for PETROBRAS.

SUPPLIER shall design, fabricate, perform operational tests and install the TSUDLs (fully integrated with their automation system).

TSUDLs require sacrificial protection against abrasion (wear bushing) due to the contact and movements of the main wire rope during pull-in / pull-out operations. The design of this protection will be confirmed through full scale load tests to be performed by SUPPLIER. (see PETROBRAS Specification ref. \9\)

The TSUDL design shall be configured to include the transition plates with LRB section welded on the factory before final machining (see PETROBRAS specification ref. \5\), to avoid distortion inside the TSUDL. Furthermore, checking of internal profile with dummy HOA (see Figure 8 and ref. \7\) is required during the FAT of each TSUDL (see PETROBRAS specification and ref. \6\) and, whenever PETROBRAS deems it necessary, after the assembly of the TSUDLs on LRB modules.

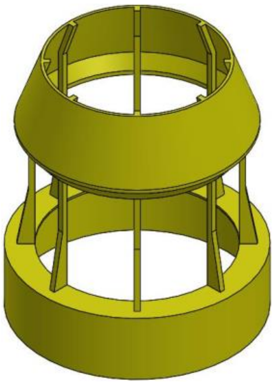


Figure 8 – Dummy HOA.

SUPPLIER shall supply spare parts of the TSUDLs for use in case replacement is needed (see sec. 21.2).

6.2.1 TSUDL Hang-off Interfaces for Rigid Risers

For HOA interface cases, Rigid risers will incorporate a transition piece (HOA) integrated to the Riser Top Joint, to make the connection to their support-tubes (TSUDLs) at the LRB, as shown in Figure 7.

- The Top Joint / HOA assembly allows both riser structural connection with TSUDL and piping connection with the HP.
- Although the HOA assembly is scope of SURFCONTR, SUPPLIER shall regard its geometry and tolerances on both design and functional testing of the TSUDL to ensure the adequacy of this hang-off system for the intended application.

The TSUDL comprises a top cone featuring locking wedges to support rigid riser axial loads, and a cylindrical body presenting a lateral locking system at its base to suppress radial gaps with the transition piece (HOA) of the rigid riser, in order to avoid relative rotations which could adversely affect the integrity of hang-off interfaces and hullside hardpiping.

6.2.2 TSUDL Locking Interface for Flexible Risers

TSUDL fulfills the same functions of a Lower I-Tube/Bellmouth for the pull-in of the flexible riser and attachment of its bend stiffener to the LRB. Moreover, TSUDL employs interface mechanisms and automation features equivalent to BSDL-SI features, to achieve diverless capabilities during pull-in/ pull-out.

Figure 9 presents a sketch of the bend stiffener coupled on TSUDL by means of its metallic extension (see Appendix A).

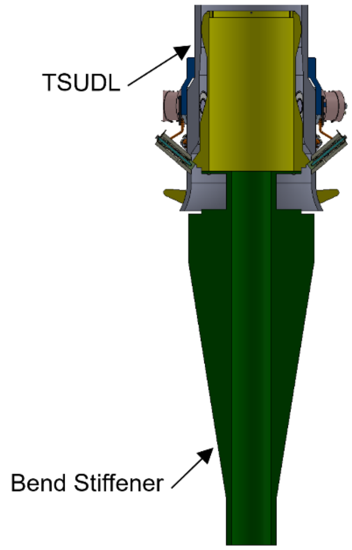


Figure 9 – Bend Stiffener coupling with TSUDL.

6.3 I-Tube Assemblies for Flexible Risers and Umbilicals

The Flexible risers and Umbilicals will be attached to both URB and LRB through I-Tube assemblies having a bellmouth (BSDL) at the base, to hold in place the bend stiffeners, sustaining their transverse loads and associated bending moments and reacting with LRB, and a hang-off split collar (under SURFCONTR scope) around the end fitting and coupled to the top of upper I-Tube to anchor their axial loads on the URB.

The I-Tube assemblies shall be split into upper and lower parts in order to allow risers inspection.

SUPPLIER shall define the required wall thickness for the upper and lower I-Tubes.

The upper I-Tubes shall end in MSS SP-44-2010 FFWN #300 seat flanges matching the respective riser hang-off split collars. These flanges shall be in an elevation high enough above the URB level to allow the provision of three evenly spaced windows (150 mm height x 150 mm width), in order to enable inspection of the flexible riser end-fittings. This elevation shall not exceed 500 mm. Removable caps shall be installed on the upper I-Tubes flanges and inspection windows.

The upper and lower I-Tubes intermediate ends shall be flared to a conical shape with smooth internal edges. Protection for the exposed parts of the risers shall be designed if indicated by the required safety studies.

The lower I-Tubes shall also end in flanges, with the respective nominal top angles and azimuths and matching the respective bellmouth flanges.

The required I-Tube diameters are indicated in Table 6-2.

Table 6-1 – I-Tubes Sizes.

Function	Nominal Diameter [in]	
	Lower Balcony	Upper Balcony
Oil Production	48	48
Oil Prod./ Water or Gas Injection		
Gas Injection		
WAG Injection		
Service (Gas lift); Gas Transfer		
Umbilicals	32	32

6.3.1 Bellmouths

Bellmouths will be connected to the lower I-Tubes, close to FPSO keel level, and will sustain the flexible risers bend-stiffeners.

Reference is made to BSDL-SI Supply Specification, ref. \10\, and Part List for BSDL-SI, ref. \11\.

BSDL will require automation capabilities for diverless pull-in and pull-out operations, as well as for CP monitoring. Reference is made to PETROBRAS Specifications ref. \12\ and ref. \15\, and drawings ref. \13\ and ref. \14\. See also sec. 19.

Figure 10 presents a sketch of the bend stiffener coupled on BSDL by means of its metallic extension (see Appendix A).

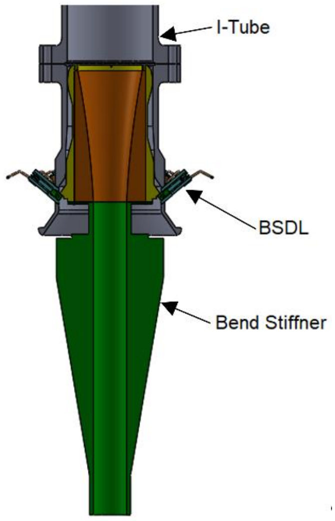


Figure 10 – Bend Stiffener coupling with BSDL.

More information regarding geometries of bend stiffeners are presented in Appendix A.

SUPPLIER shall design the bellmouths and the bottom section of Lower I-Tube beneath the box beam in such a way that offshore replacement by divers is possible. All materials will be SUPPLIER's responsibility. The operational procedure shall be submitted for PETROBRAS.

All weld surfaces inside the bellmouths shall be grinded down to an even and smooth profile, to avoid interference with the bend-stiffener locking devices. Care shall be taken regarding electrical connections between the bellmouth flanges and moving parts in order to guarantee continuous cathodic protection from the FPSO.

SUPPLIER shall fabricate dummy caps to perform interference checking after bellmouths are bolted and tightened to the lower I-Tubes, according to BSDL documentation.

SUPPLIER shall supply spare parts of the BSDLs for use in case replacement is needed. (see sec. 21.2)

SUPPLIER shall supply all BSDLs already bolted in their positions, and fully integrated with their automation system.

7 RISER TOP ASSEMBLY BASIC DATA

This section provides primary information about Rigid Risers end connectors, as well as for Flexible and Umbilical Risers end fittings.

For further details about dimensions on terminations of the rigid risers, reference is made to PETROBRAS interface document ref. \27\ to be issued during contract execution. Related Key input data will be provided at the Notice to Proceed.

7.1 Rigid Risers Top Flanges

7.1.1 Hang-off adaptor Interface Flange

The flanges of risers top terminations (HOA) for support tubes (TSUDLs) will comply with Table 7-2.

Table 7-1 – Top Flanges of HOA for Support Tubes (TSUDLs).

Rigid Riser	**RISER ID [inch]**	FLANGE CHARACTERISTICS **(HOA)**			
		Nominal Size (inch)	Bore (inch)	Specification(1)	Ring Number(1)
Production; WAG Injection	6,5	11(4)	6(3)	API 15000 psi, 6BX	BX-158
Gas Export	7	11(4)	7(3)	API 15000 psi, 6BX	BX-158
Production	8	11(4)	8	API 15000 psi, 6BX	BX-158

(1) Bore, face and sealing flange surfaces cladded with CRA UNS6625 overlay, and ring gasket of the same material.
(2) Connection with swivel flange at FPSO side.
(3) ID transition (see sec. 7.2.1) in case of HP for related risers presents larger ID.
(4) To be confirmed

HOA top flanges will be provided with N_2/He test ports.

The HP Lower Spool Piece Termination connection (lower spool flange that interfaces with riser) shall follow API17D type API17SV with bore compatible with the riser termination flange on HOA (see sec. 7.2.2).

- API 15000 psi swivel flanges will require customized design.

7.2 ID Transitions for Rigid Risers

7.2.1 HOA Top Assembly (on Support Tubes)

For TSUDL Top assembly, ID Transitions between Risers and Hardpiping shall consider the following:

- Whenever hardpiping presents bore larger than the risers, the ID transition should be located on HOA Top flange (beneath its face).
- Whenever hardpiping presents bore smaller than the risers, the ID transition shall be performed inside the hardpiping or on its interface flange with riser (see. sec. 11.2).

7.3 End Fittings of Flexible Risers, Umbilicals and TiPT

The specification and dimensions of interface flanges for flexible risers and umbilical end fittings are depicted in Table 7-3 and Figure 11.

Table 7-2 – Flexible risers and umbilicals interface flanges.

Riser ID [in]	Riser Top Connector Flange	FPSO Spool Flange	ID [mm]	Dimension A (Fig. 15) [mm]
4	7 1/16" API 10,000 psi 6BX BX-156	7 1/16" API 10,000 psi 17SV BX-156	101.60	810.0 ± 2.5
6	7 1/16" API 6BX 10.000 psi BX-156	7 1/16" API 10,000 psi 17SV BX-156	152.4	810.0 ± 2.5
8	9" API 10,000 psi 6BX BX-157	9" API 10,000 psi 17SV BX-157	203.20	960.0 ± 2.5
9,13	11" API 17SS 5000 psi BX-158	11" API 17SV 5000 psi BX-158	231.78	960 ± 2,50
UEH	9" API 6B 2,000 psi flat face	-	-	600.0 ± 2.5

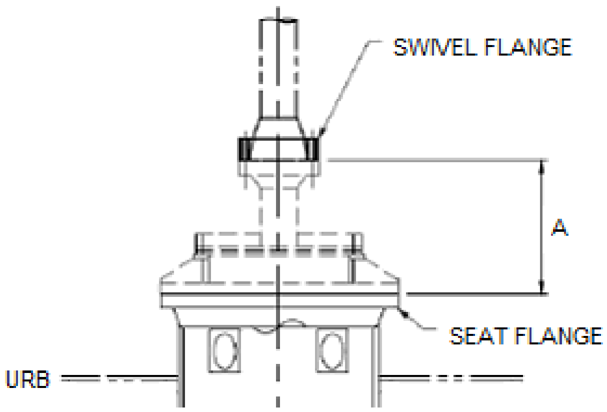


Figure 11 – Hang-off detail of Flexible / Umbilical riser end fitting (Flange Elevation "A").

SUPPLIER shall issue detailed drawing of upper I-Tube end for PETROBRAS approval.

The Flexible Riser Hang-off split collar will be supplied by SURFCONTR.

The Flexible Riser top connector flanges will be provided with N_2/He test ports.

The Flexible Riser end-fittings will be provided with a gas bleed-off connection for depressurization in case of gas leakages: SUPPLIER shall design the venting system in accordance with I-ET-ANNULUS PRESSURE MONITORING AND RELIEF SYSTEM, ref. \20\ (see sec. 18).

7.4 TiPT-Hang-off Electrical Insulation

TiPT top flange shall be electrically insulated from hang-off system according to ref. \24\.

8 HARDPIPING & URB INTERFACE SPOOLS ADJUSTMENTS

SUPPLIER shall provide Mockups adequate to riser sizes, hang-off systems employed, height and flange configuration for the terminations of the Rigid & Flexible Risers, to perform piping fit-up from the Unit to the riser interface flange. Each Mockup shall present seal test port for N_2/He leak testing, required during onshore site fit-up tests of hard pipes and top interface spools.

Mockup drawings shall be submitted for PETROBRAS comments.

8.1 Support Tubes

SUPPLIER shall design and fabricate the HOA termination Mockups to enable proper fit-up test at shipyard, in order to guarantee the correct dimensioning of spool pieces connecting the FPSO piping and HOA top flanges.

Reference is made to PETROBRAS drawing ref. \16\.

The design solution shall enable the insertion and locking of the Mockup assembly from the top of the support tube, taking into account the ID restriction on the top cone due to the sacrificial protection abovementioned. Figure 12 brings an example for this kind of solution.

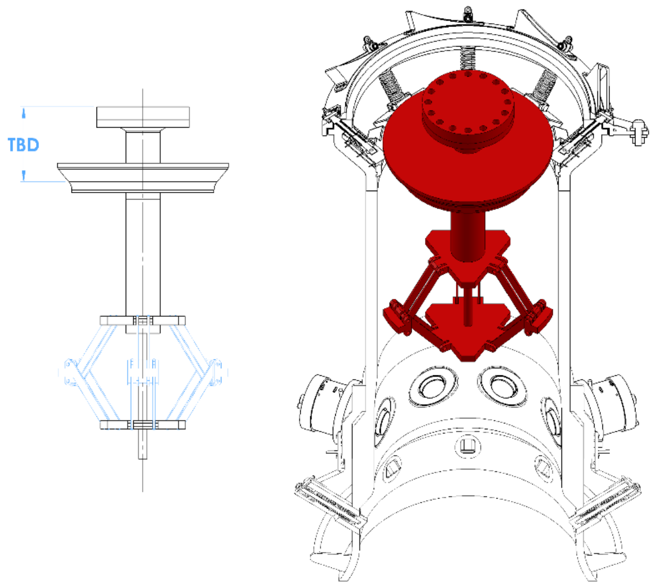


Figure 12 – Mockup of HOA Termination (Reference Only).

Target for the above dimension TBD (Figure 12) will be defined by PETROBRAS at the project kickoff meeting.

8.2 Flexible Risers

SUPPLIER shall design and fabricate the Mockups for the end fittings of the Flexible Risers assembled on their hang-offs to enable proper fit-up test at shipyard, in order to guarantee the correct dimensioning of spool pieces connecting the FPSO piping and flexible risers top flanges.

9 CONTROL UMBILICAL CONNECTION ARRANGEMENT

SUPPLIER shall supply and install TUTU plates for connection of hydraulic and chemical injection lines from umbilical risers with lines from the HPUs and chemical injection units, as well as the junction boxes for the electrical cables. Configuration and number of hydraulic and chemical lines as well as junctions boxes will be defined at Notice to Proceed.

These interfaces shall be installed alongside the umbilical hang-off on the URB, at a distance compatible with umbilical pigtails, which will have length of 1.5 m.

Figure 13 presents a typical sketch for these connections and battery limits between SUPPLIER and SURFCONTR, regarding both STU and TPU umbilicals.

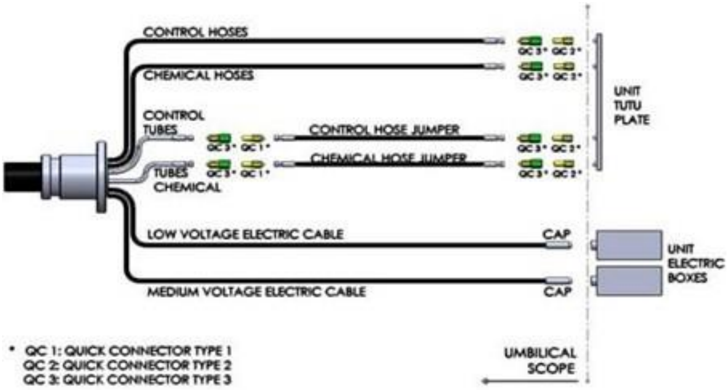


Figure 13 – Typical arrangement for connections of Umbilicals on URB.

NOTE: The TUTU plates shall be supplied with caps to isolate all hydraulic and chemical connections up to the moment of the umbilical connections. Junction boxes shall have removable gland plates for future connections.

10 RISER TOP LOAD ANALYSIS

SUPPLIER shall carry out global analysis of the risers, in order to ensure proper structural dimensioning of the Riser Balcony and pull-in system structure.

Preliminary riser configurations and properties are informed in APPENDIX A – RISER CONFIGURATION DATA. PETROBRAS will provide detailed data at the Notice to Proceed.

The acceptable methodology is described in I-ET-RISER TOP INTERFACE LOADS ANALYSIS, ref. \17\.

- For assessment of fatigue top loads, SUPPLIER should employ closed form solutions with an assumption of a Weibull long term stress range distribution where a shape parameter to the safe side shall be used.

- The mark-up factors to be applied on extreme loads shall be in accordance with ref. \17\, except for the bending moments of Umbilical Risers, that shall employ a mark-up factor of 1.8.

In addition, SUPPLIER shall consider that:

- For flexible risers: bending moments, shear forces and 10% of tension are applied on the Lower Riser Balcony (friction) while 100% of tension is applied on the Upper Riser Balcony
- For rigid risers: bending moments, shear forces and tension are all applied on the LRB.

SUPPLIER shall report the interface loads for the SURFCONTR within 9 months after the project kickoff meeting.

11 HARDPIPING & TOP INTERFACE SPOOLS

Scope of supply for the Hardpiping system and top interface spools includes the detailed mechanical and structural design, manufacturing, development of installation methods, construction, testing, commissioning and preservation, according to project requirements. Items shall fully attend the Project Specification ref. \3\ where applicable.

11.1 General Design Considerations

The design of HP sections and top interface spools shall provide sufficient flexibility to allow for any global and local displacements at the riser connection points with the LRB and URB subjected to Riser Installation, Design Operating (DOC) and Design Environmental (DEC) loading conditions. In addition, the corresponding levels of hull flexing, if relevant, shall be considered.

The hydrodynamic Environmental force on the hardpiping shall be calculated, associated with maximum operational and hydrotest load conditions, considering combined wave and current flow. The calculation of hydrodynamic forces shall consider the increase in overall diameter of the hardpiping due to marine growth, where applicable.

Vortex Induced Vibration (VIV) and wave fatigue shall be verified and avoided.

The effects of the riser stiffness on the hardpiping should be incorporated in the design analysis. Hull piping should be modelled with the TSJ, TSUDL-HOA and sufficient porch structure to ensure the stiffness of the complete structure is captured.

11.2 Piggability Requirements

Hardpiping and top interface spools shall consider the following diameter sizes, and minimum bending and straight lengths dimensions, in order to assure diameter tolerances of pipeline pigs and, in particular, of multi-size intelligent pigs that may be used — with capability for ID variations from 4-in to 8-in.

Table 11-1 – Hardpiping Circuit Dimensional Requirements for Pigging Operations.

Riser Function	Minimum Nominal Diameter: NPS = D [inch]	Minimum Inner Diameter(1) [inch]	Radius for Bends(2) (minimum)	Straight Lengths(3) between adjoining bends
Production	**6**	**4**	**4 x D (24-in)**	**18-in**
Production	**8**	**5.125**	**3 x D (24-in)**	**18-in**

(1) Considering all uncertainties (e.g. ovality, maximum thickness tolerances, possible misalignment)
(2) Referred to piping centerline
(3) Exceptions shall be previously approved by PETROBRAS. Sufficient tangent lengths should be left at each end of a bend to ensure good alignment.

NOTES:

1 - The transitions on ID, between HP flanges and Riser terminations and throughout piping circuit, shall be made with chamfer of maximum 15-deg. slope with reference to the centerline of the pipe.

2 - The internal diameter of the bends shall suit the straight pipe internal diameter: maximum reduction due to ovality at any point around the bend shall be submitted to PETROBRAS approval.

11.3 Construction Adjustments

SUPPLIER is responsible for the dimensional compatibility of the Hardpiping and Interface Spools with the Rigid and Flexible Riser terminations assembled on their respective slots, by means of performing all the necessary piping adjustments (under very stringent connection tolerances) and corresponding fit-up tests at the Lower / Upper Riser Balcony for each location / spool, using the riser termination Mockups.

SUPPLIER shall provide an appropriate number of Mockups to ensure properly adjustments and Fit-Up tests of Hardpiping and Interface Spools on each position of Riser Slot. Fit-Up Procedures shall be submitted to PETROBRAS for approval.

The Hardpiping and interface spools shall be identified in three points, evenly spaced, in bas-relief and painted in a contrasting color. The correlation between piping and subsea wells shall be clearly represented in the installation procedures

11.4 Interface Connections with Risers

SUPPLIER shall provide the hard pipes / top spools for the risers with swivel flanges at the lower end (battery limit with riser connector) compatible with risers flanges and bores specified herein (see sec. 7.1 and 7.3), in accordance with API 6A and API 17D and technical requirements of project documentation (see ref. \3\). The datasheets, including dimensional drawings, shall be submitted for PETROBRAS.

- Flanges shall be coated with Inconel 625 (UNS 6625) overlay through whole sealing areas, achieving a minimum hardness of 220 HB and iron content less than 5% at 0.5 mm depth from the overlay surface.

SUPPLIER shall provide the ring gaskets, stud bolts and nuts for all the interface flanges with risers:

- Sets of ring gaskets, stud bolts and nuts to be supplied shall fully attend the needs for both temporary (e.g., fit-up, testing, preservation) and offshore installation.
- Stud bolts and nuts of underwater flanges shall be made in ASTM A 320 L7 and shall comply with ref. \22\.
- Stud bolts and nuts shall be suitable for hydraulic bolt tensioning.
- The ring gaskets shall be compatible with the flanges and with maximum hardness 190 HB. SBX gaskets are not acceptable.

NOTE: Surfaces where stud bolts and nuts are assembled shall not be coated to assure electrical contact between flanges and stud bolts.

11.5 Hardpiping Handling Features

Hardpiping shall be designed to minimize offshore activities (diving, loads lifting etc.), in order to enhance the safety of the operations involved, and to speed up the final assembly.

SUPPLIER shall design and provide all the handling and lifting systems and rigging required to perform the offshore connections. Reference is made to Hard Pipe Project Specification ref. \3\.

SUPPLIER design shall consider rotary (pivoting) hard pipes to allow continuous piping from the battery limit with rigid riser to the URB, so requiring only one submerged flange connection, and minimize diver activities. Reference is made to Hard Pipe Project Specification ref. \3\. On this configuration, after fabrication, proper adjustment and testing during construction onshore construction, the hard-pipes shall be assembled at the shipyard on their pre-pull-in folded positions, anchored to a cradle support appropriate for sea fastening and long term parking. These folded positions shall not interfere with nor impose restrictions to the pull-in/pull-out operations of nearby risers.

NOTE: SUPPLIER shall develop the handling method and provide all required tools (including spares) and equipment to allow piping rotation and alignment to the riser termination. The procedure should as far as possible be executed from an accessible location at platform operational area.

HP supports clamps located on hull side shall be designed to make installation and adjustment straightforward and economical. Access to bolts for the use of bolt tensioning system shall be considered.

SUPPLIER shall develop and provide the procedure for offshore installation of HP and Top Interface Spools.

11.6 Hardpiping routing

The hard pipes in their pre-pull-in position shall not interfere with nor impose restrictions to the pull-in / pull-out operations of adjacent risers.

The criteria for the final routing and arrangement of the hardpiping sections are basically:

i) Space constrain imposed by permanent surrounding structures.

ii) Space constrain imposed by temporary surrounding structures, like main pull-in wire and hullside umbilicals.

iii) Battery limits of the risers.

iv) Handling issues for lateral (pivoting) and longitudinal (vertical) HP movements required for connection alignment with riser top flange.

v) Handling issues for assemble / disassemble of top interfaces spools.

vi) Handling issues for lowering / raising special tools etc.

11.7 Top Interface Spools Identification

All Top Interface Spool pieces shall be identified regarding their numbering of Riser-slot position on Balcony arrangement according to ref. \23\. Identifications shall be marked in three points, evenly spaced, in an indelible form and painted in a contrasting color.

12 TECHNICAL DATA FOR SUPPLIER

The following input data for detailed design and construction will be provided by PETROBRAS during contract execution.

12.1 Riser Configuration Data

PETROBRAS will confirm configurations and physical properties of the Risers for Top Interface Load Analysis (see sec. 10), based on actual WD, at the project kickoff meeting.

12.2 Riser Top Assembly Data

PETROBRAS will provide Top Assembly interface dimensions for detailed design and construction, at the project kickoff meeting (see ref. \27\).

- For the Rigid Risers, interface data will include Riser Flange Termination manufacturing tolerances for Flexible / Stress Joint. On the other hand, final tolerances on HOA Top Flange elevation and misalignment will depend on detailed design of TSUDL.

12.3 Environmental Conditions

PETROBRAS will provide sea state data (waves and currents) for Top Interface Load Analysis, at the project kickoff meeting.

12.4 Offsets for Extreme Conditions

PETROBRAS will provide the Offsets for Extreme Conditions related to Top Interface Load Analysis, at the project kickoff meeting.

12.5 Riser Balcony Sequence

PETROBRAS will provide the riser sequence distribution for all support positions, with risers functions, diameters, local azimuths and nominal top angles, at the Notice to Proceed (see ref. \26\).

13 PULL-IN / PULL-OUT FACILITIES

SUPPLIER shall design, fabricate and install all the necessary equipment and handling devices to perform the pull-in/pull-out operations and other related installation activities.

Reference is made to Riser Pull-in and Pull-out System Specification (ref. \2\).

The system shall be able to access every riser position and shall not interfere with installed risers.

The pull-in system facilities shall enable the realization of pre- and/or post-pull-in activities (e.g., assembly of spool pieces, pre-commissioning activities, etc.).

❖ Pull-in Philosophy

The following system philosophy is considered for sheave trolley:

1. Main winch is fixed, using one sheave trolley skid system, which travels along the pull-in positions for each riser by dedicated track or rails. The pull-in wires will be routed through sheaves, supports and guides as required.

2. Two service winches (FWD and AFT) integrated to trolley skid, capable to access the vertical of upper I-tubes (simultaneously with main winch) as well as upper balcony hatches.

3. The sheave trolley shall have a vertical longitudinal sheave for the pull-in of flexible and rigid risers and umbilicals, with means to guarantee that the wire rope from main winch will always reach the I-tubes in a vertical and centralized configuration.

Regarding this philosophy, it is important to point out that the pull in/pull-out system maximum capability are the dynamic second end pull in/pull out of rigid and flexible risers, considering the heaviest riser. However, umbilicals are not only lighter structures but also may be installed by first end pull-in, resulting in very low loads, much less the rated main winch pulling capacity.

14 RISER INSTALLATION PROCEDURES

SUPPLIER shall prepare and submit to PETROBRAS approval the pull-in and pull-out procedures for the risers. Two kinds of pull-in/pull-out operations shall be considered:

i) ***First end pull-in:*** The PLV starts the laying from the Unit to a subsea equipment.

ii) ***Second end pull-in:*** The PLV starts the laying from a subsea equipment to the Unit.

The 2nd end pull-in shall be assumed in the procedures for both Flexible Risers and Rigid risers.

For umbilical risers, SUPPLIER shall develop procedures for both 1st and 2nd end pull-in.

The installation and de-installation procedures shall be detailed, step-by-step, starting with the required preparation on the Unit´s pull-in platform and balcony levels in order to perform pull-in and pull-out operations. The procedures shall describe all the necessary steps, including the operations on main winch, the passage of wires through sheaves, steel wire paths required for all rigid risers positions etc.

SUPPLIER shall produce installation (pull-in) and de-installation (pull-out) procedures with all necessary information (e.g. layout plans, three dimensional drawings, details of mechanisms) for a correct understanding of the work and sequence of work (preparation and operation). These procedures shall describe in more detail the pull-in/pull-out activities related to the FPSO.

SUPPLIER shall demonstrate, each at a time, that there is no interference between the pull-in wires and any FPSO structure, topside equipment and piping systems, and other risers in the vicinities.

BIDDER shall bear in mind that the pull-in/pull-out procedures cannot rely merely on the operation of pull-in equipment (winches, trolleys and sheaves), but have to consider the actual characteristics of riser balcony and pull-in structures.

❖ Messenger wires

SUPPLIER shall specify and provide all necessary steel wire rope length for messenger wires (see sec. 21.1), which shall be installed on onshore site in accordance with the installation sequence of the risers. This information shall be checked by SUPPLIER and PETROBRAS and amended if needed, prior the towing the Unit to the offshore site. These wires shall be connected to the topsides by fixed padeyes, using shackles and clips, considering one messenger wire per each guide tube (flexibles and umbilicals) and support tube. The messenger wires shall be easily identified according to the balcony positions and structures.

15 UNDERWATER ACTIVITIES ON RISER BALCONY

PETROBRAS will employ both diver and ROV assistance during pull-in/pull-out operations and other installation activities. All the necessary facilities, protection etc. shall be designed accordingly to ensure divers protection and personal safety.

Given the restricted operational windows required and risks involved, diving activities shall be minimized as much as possible.

Overall design requirements for diving areas are stated in PETROBRAS Specification ref. \21\.

Project documentation presents two diving stations at FPSO portside riser area, with adequate space and utilities supply, positioned to ensure maximum 33.0 meters outreach for diving operations at night within the riser balcony for riser pull-in, pull-out and other installation activities on FPSO side, including the following:

- Pull-in/pull-out preparation (messenger lines installation, main pull-in wire rope handling on support tubes, bellmouths and support tubes inspection, positioning of cameras, etc.).
- Bend-stiffener connection/disconnection at bellmouths, where needed.
- Connection/disconnection to the pull-in/pull-out rigging. (PLV A&R wire connection to transfer rigging for pull-out operations, etc.).
- Bellmouths replacement.
- Replacement of TSUDL Top cone internal parts.

- Replacement of TSUDL MTLs.
- Support of rigid risers pre-commissioning operations. (PLR assembly/disassembly and operation, hoses connection/disconnection, etc).
- Connection/disconnection of Rigid Riser Pull head and underwater PLR used for Rigid Riser testing (HOA case).
- Connection/disconnection of HP Lower flange to the HOA Top flanges (handling, bolts tensioning, seal test, etc.
- Installation of the rigid risers monitoring system. See I-ET-RIGID RISER MONITORING SYSTEM (RRMS), ref. \18\.

In addition to the provisions required in ref. \21\, SUPPLIER shall provide additional free space and utilities (electric power 100 – 240 V alternate current, compressed air and fresh water) in the diving stations to allow use of small electric ROV during pull-in for the wide visual monitoring of Riser Pull Head / Top Joint / HOA on its path toward riser support.

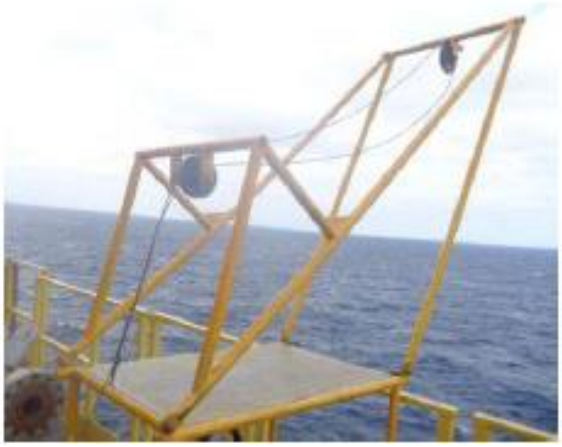
- For ROV launching, a free area of 2000 mm x 2000 mm is required on the portside.
- Area for control and maintenance unit: container 3000 mm x 3000 mm x 2400 mm height, max. weight of 5 mT.

Equipment to be handled (supplied by PETROBRAS or SURFCONTR), is shown in Figure 14.

The LRB and its riser support structures shall be provided with the following ancillary features, required for inspection and maintenance activities with divers, work class ROV or hybrid ROV:

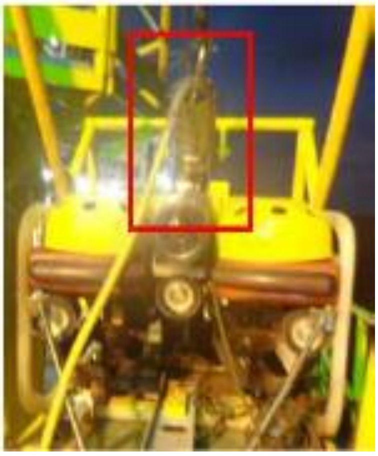
- The underneath of the LRB shall be provided with four padeyes (minimum SWL 15 mT) for each I-Tube/BSDL and TSUDL, and a handrail system in a closed pattern.
- Grab handles shall be provided on the LRB features, for each TSUDL and BSDL, positioned and sized in such a way that the ROV arm can reach and keep taking hold during the intervention. Figure 15 illustrates the arrangement of the grab handles conceived for the TSUDL.
    - **NOTE:** Grab handles shall be designed according to ISO 13628-8 - Petroleum and natural gas industries — Design and operation of subsea production systems — Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems.

(a) ROV model Seaeye Falcon 12249.



(b) A-frame (1 m² footprint, not required removal of guard-rails).

(c) Launching platform + LARS winch (movable).



(d) Lock-latch system.

Figure 14 – LARS System – ROV model Seaeye Falcon 12249 specs.

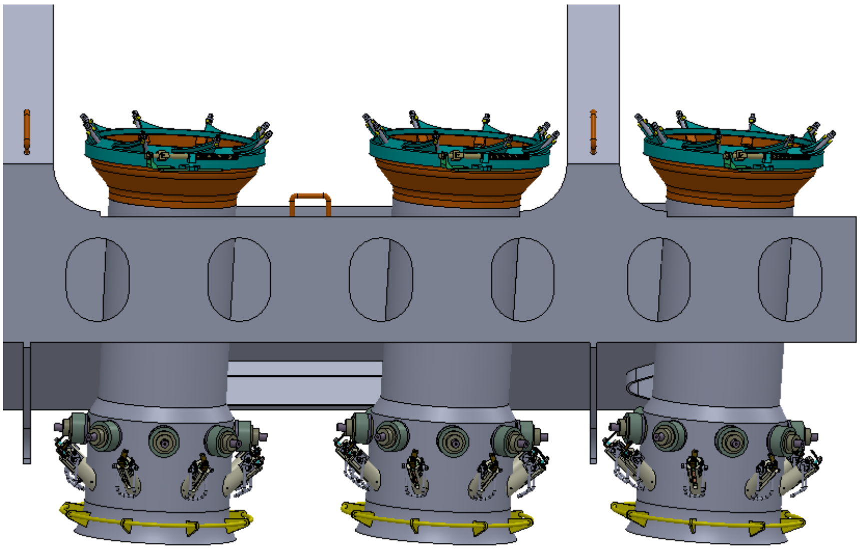


Figure 15 – Grab handles for intervention with ROV on riser support structures; example of LRB with TSUDLs (illustrative).

16 RIGID RISER PULL-IN PROCEDURES OVERVIEW

16.1 Riser Pull-in Main Stages

To prepare for pull-in, the main pull-in winch is translated and secured at the appropriate riser position.

The riser may be empty, partially or fully flooded during installation. The main stages involved in direct transfer and pull-in of a rigid riser from the PLV to the FPSO are as follows. For the pull-out, riser is fully flooded of sea water following these stages in reverse order.

- *Stage 1 (Figure 16)*

The main pull-in winch deploys the pull-in wire to a predetermined length. The installation vessel (PLV) takes the pull-in wire. Slack wire rope paid out from FPU is attached to the Rigid riser pull-head.

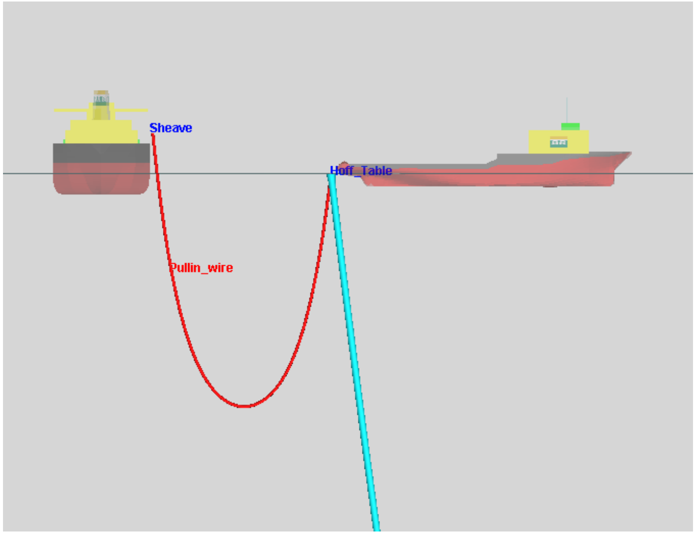


Figure 16 – Direct Approach Pull-in - Start Position.

- *Stage 2 (Figure 17)*

The PLV lowers Rigid Riser on the Abandonment and Recovery (A&R) wire, holding the weight of the riser, while the pull-in wire is pulled slack up to the length defined for load transfer.

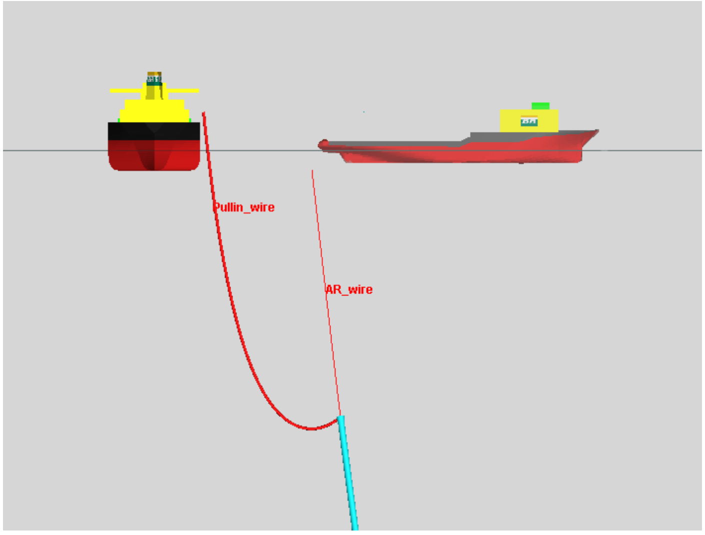
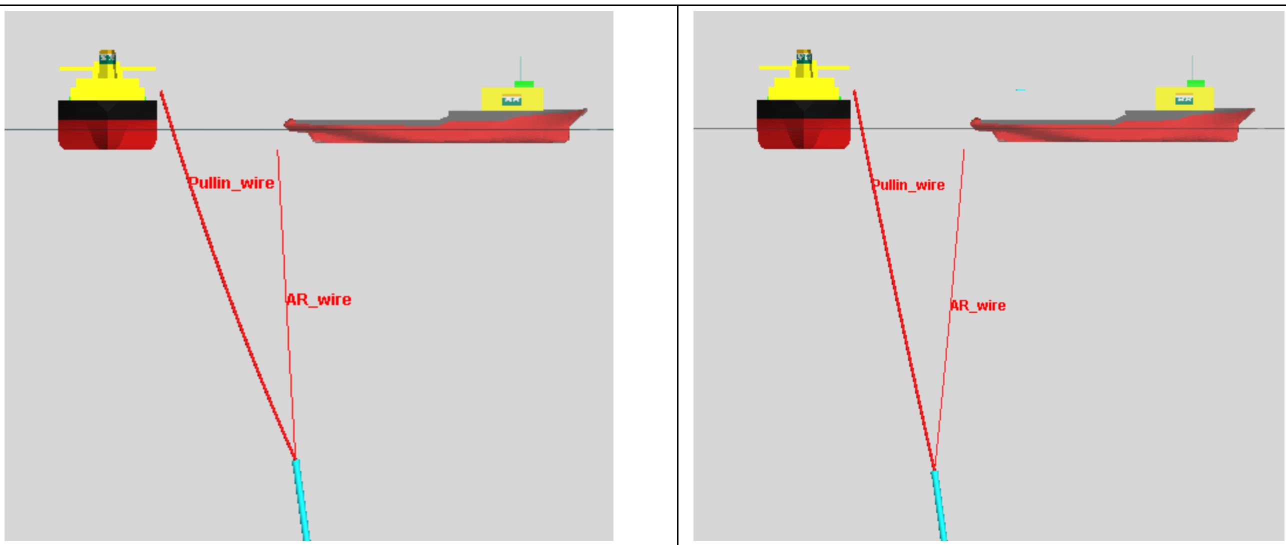


Figure 17 – Direct Approach Pull-in - Lowering Rigid Riser on A&R Wire.

❖ *<u>Stage 3</u> (Figure 18)*

The pull-in wire is held stationary and PLV proceeds lowering SCR on A&R wire, while the riser load is gradually transferred from A&R wire to the pull-in wire.



(a) Start of Load Transfer (maximum Pull-in wire angle).	(b) During Load Transfer.

Figure 18 – Direct Approach Pull-in - Load Transfer.

❖ *<u>Stage 4</u> (Figure 19)*

The pull-in wire from FPU is holding weight of the Rigid Riser. The main pull-in winch commences riser pull-in.

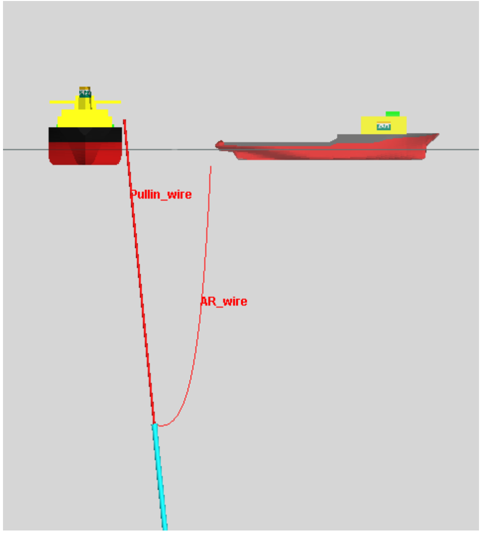


Figure 19: Direct Approach - Rigid Riser Pulling in.

- *Stage 5 (Figure 20)*

The main pull-in winch pulls up the riser until HOA passes through TSUDL top cone, then the pull-in winch lowers the riser slowly seating HOA on top of Top Cone Locking Wedges.

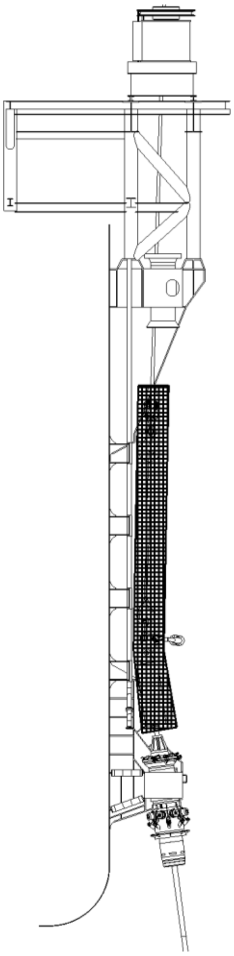


Figure 20 – Direct Approach Pull-in – Installed Position.

16.1.1 Deployed Length of Main Pull-in Wire and Sand-off Distance of PLV.

In order to infer the maximum length of main pull-in wire which can expected to be deployed below the LRB, a Reel Lay PLV with a moonpool-fitted ramp is assumed approaching FPSO starboard side, in alignment with the heading azimuth of the farthest rigid riser position for keelhauling on LRB.

The positioning arrangement during transfer phases for the presumed vessel is shown in Figure 21. A minimum stand-off distance from hull of installation vessel to outer edge of the FPSO is assumed as 65 m, to manage available thrust of the vessel including allowance for weather:

- Vessel approaches FPSO at 45-deg relative heading achieving the minimum stand-off distance as the position for maximum pull-in wire rope length deployment. At this initial step, it is achieved a maximum length around 925 m (worst case) for main wire rope deployed below the Support Tube.
- Then, for this arrangement of PLV with moonpool, the vessel changes its heading and can be positioned paralleled to FPU for the last phase of transfer operation (see sec. 16.2.2).

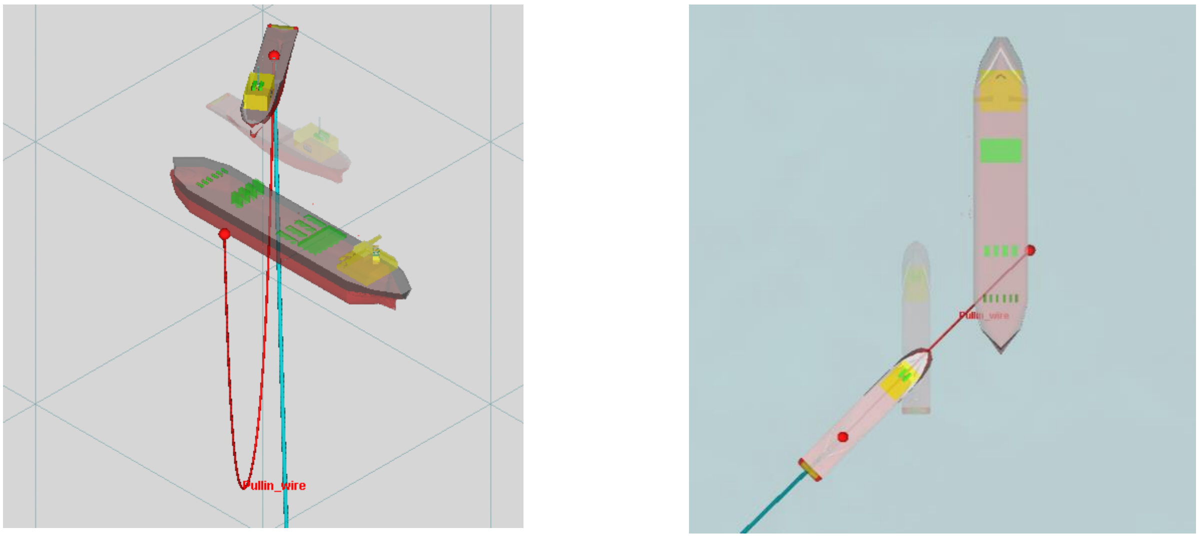


Figure 21 - PLV approaching FPSO Starboard for Keelhauling operation.

16.2 Riser Transfer via Keelhauling

The PLV lowers the riser while the FPSO retrieves the main pull-in wire until a predetermined length for load transfer. This length will be defined by SURFCONTR, considering the acceptable utilization factors over riser structure on expected maximum sea states during installation, and boundary conditions related to maximum angle and horizontal loads of both PLV A&R wire and FPSO main pull-in wire. At this operation, it is estimated a minimum length of 300 m of the main wire rope below the LRB.

In the load transfer only the PLV A&R wire will run until the riser load is transferred to the FPSO. This phase is illustrated in figure 22.

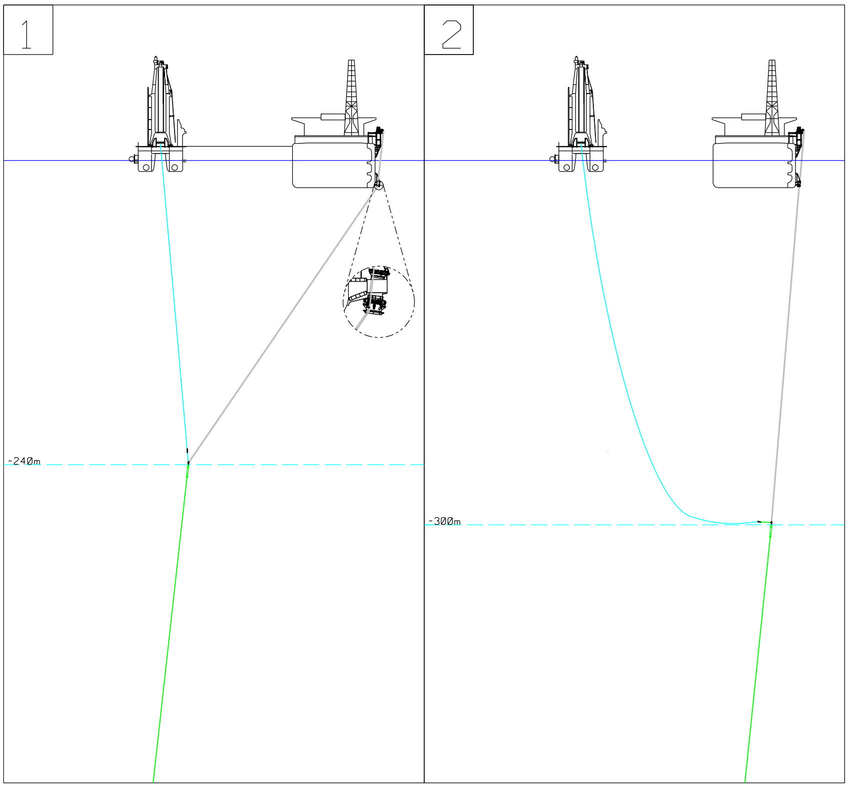


Figure 22 – Riser Transfer via Keelhauling.

17 ADDITIONAL PROVISIONS FOR PULL-IN OF RIGID RISERS

In this section, PETROBRAS outlines the facilities and operations required for pull-in/pull-out of rigid risers. Rigid risers pull-in operations include the preparation and pre-comissioning activities listed below.

- Handling of main pull-in wires, assembly of riggings, etc.
- PLR valves operations; recovery of riggings; PLR and pull-in head recovery and transfer to installation vessel; hardpiping and top spool assembly; seal test, etc.

Figure 23 illustrates the pull-in of starboard-facing rigid risers (HOA case).

SUPPLIER shall consider a maximum length of 20 m for the main rigging: this length does not include the HOA. Detailed information will be provided by PETROBRAS during contract execution.

Clashing between the pull-in wires and the FPSO structures during pull-in/pull-out operations is not acceptable.

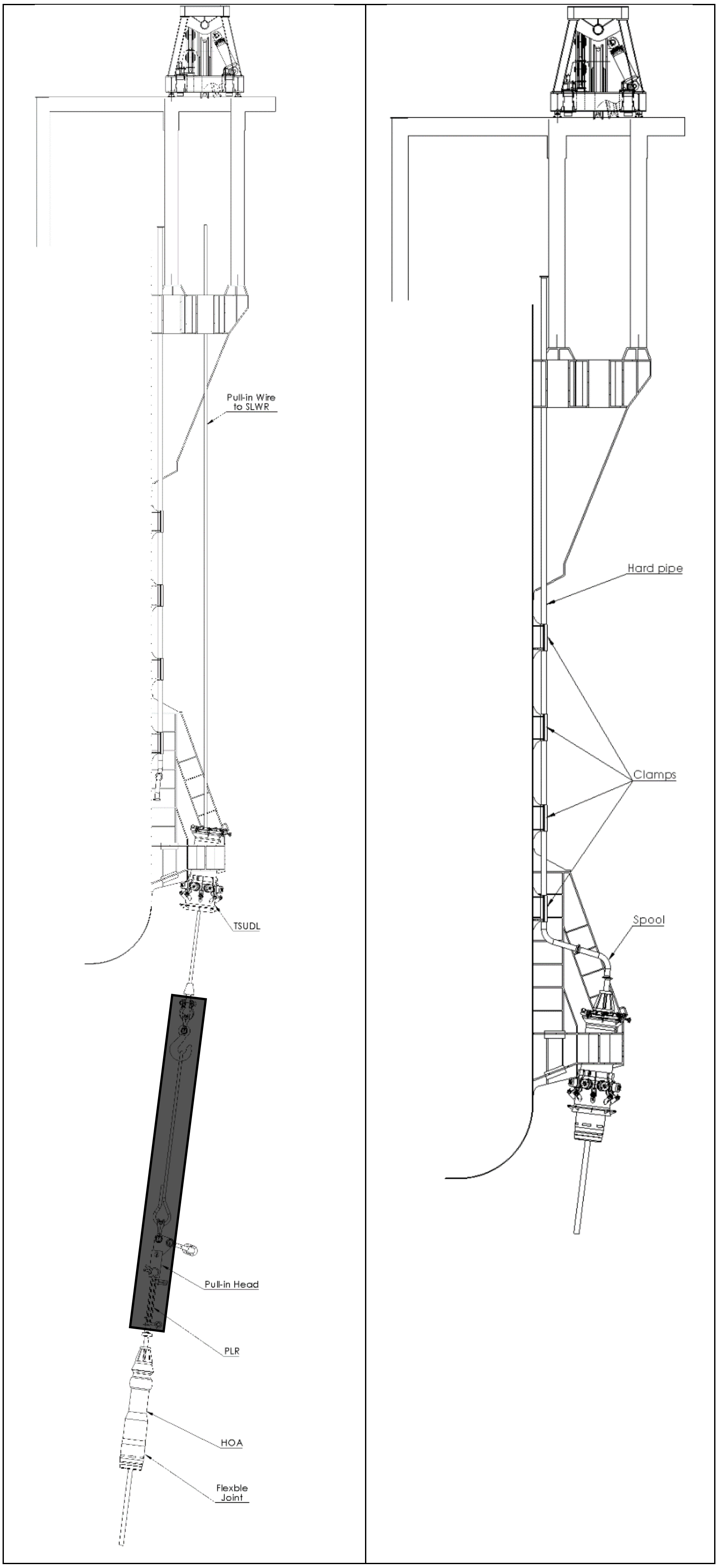


Figure 23 - Rigid riser Pull-in Operation (Starboard-facing Risers).

18 RISER INTEGRITY MONITORING

The main purpose of these systems is to provide operational information on the risers integrity during service life. All Rigid and flexible risers will require real time integrity monitoring (see ref. \18\, \19\ and \20\).

Further general information is presented in the Monitoring System Block Diagram (see ref. \4\).

18.1 Rigid Risers Monitoring Interconnections

As required in ref. \18\, the rigid riser monitoring system will be linked to the FPSO through:

- Electrical cables, for the monitoring circuit of riser top angles.
- Optical cables for the monitoring circuit of riser top loads.

For the interconnection between LRB and URB, this set of electrical and optical cables shall be provided by SUPPLIER integrated to multipurpose hullside umbilicals (see sec.19).

SUPPLIER shall take special attention to the mechanical protection of cable connections underneath the LRB against the severity of offshore environment (particularly wave and current loads and effects) in the battery limit with SURFCONTR scope.

19 HULLSIDE UMBILICALS FOR LRB INTERFACES

SUPPLIER shall provide multipurpose hullside umbilicals, according to PETROBRAS specification doc. \15\, for the circuits of hydraulic, electrical and optical functions required for actuation of mechanisms and monitoring (end course, CP monitoring) of diverless riser supports on LRB (TSUDL and BSDL), as well as for RRMS interconnections (see sec. 18).

SUPPLIER shall perform the mechanical and structural detailed design, fabrication, installation and onshore site testing, integration and commissioning of the hydraulic, optical and electrical functions throughout the circuits from LRB structures to platform operational area.

SUPPLIER shall take special attention to the mechanical protection of connections underneath the LRB for all these circuits (see ref. \12\, \13\, \15\ and \18\, against the severity of offshore environment (particularly wave and current loads and effects).

20 PRE-COMMISSIONING ACTIVITIES OF RIGID SEALINES

20.1 Pre-Commissioning Activities Overview

Once the rigid risers and flowlines are installed, each of them will be filled with inhibited or filtered seawater, cleaned and gauged. Pigs will be run from the PLET to the top of the riser fitted with a Pig Launcher/ Receiver (PLR). This will be done by SURFCONTR using subsea pumping equipment. Two locations for this PLR are envisaged:

(1) For the rigid riser attached to the TSUDL (HOA case), the PLR may be integrated to the riser pull-in head;

(2) For the rigid riser attached to the URB (TiPT case), a vertical PLR will be installed onboard FPSO after pull-in, directly connected to the riser termination flange.

Upon completion of the cleaning and gauge pigging, the PLR with the gauge pig is removed and the riser connected onto FPSO hardpiping, by divers. The rigid sealine will then be hydrostatically tested by SURFCONTR from the FPSO to the PLET. For Production and WAG wells, this test may alternatively include the complete loop of the subsea lines, hardpiping and topside piping associated. These operations may include attaching pressure test caps on topside piping, realigning valves etc.

Activities on FPSO include but are not limited to:

- Receive treated or filtered seawater used for flooding & hydrotesting.
- Hydrotesting from FPSO.

The Unit shall provide facilities (access, scaffolding, hoisting/material handling and utilities) and sufficient laydown areas to allow the installation / operation of the pressurization equipment to be provided by SURFCONTR.

SUPPLIER shall be responsible for the following provisions on FPSO facilities:

- Air supply: Air flowrate 350scfm (approx. 590m^3/h) @ 7bar.
- Seawater flowrate 2m^3/h.
- Power/ electricity: 220V 3phases 50Hz 60A or 440V 3phases 50Hz 60A.
- Deck Space: from 100m^2 to 120m^2.

Fitting and/or manufacture of temporary pig traps for the pre-commissioning activities, if applicable (see ref. \3\), will be provided by SURFCONTR.

The final procedure for pre-commissioning activities shall be agreed by both Parties and approved by PETROBRAS during execution phase of FPSO construction.

20.2 Gas Export Pre-Commissioning

Following Hydrotesting, the pre-commissioning for Gas Export sealine will include de-watering drying and inerting of pipeline and riser with nitrogen. For this operation another temporary surface PLR will be connected directly to the top of the riser (TipT case), or to the upper flange of hard pipe (HOA case) using an associated pipework.

The Unit shall provide facilities (access, scaffolding, hoisting/material handling and utilities) to allow the installation / operation of this temporary PLR with its pipework connection provided by SURFCONTR. However, the temporary PLR pipework connection (**Figure 24**) shall be provided by SUPPLIER. The temporary PLR length is estimated around 5 m.

The unit shall provide facilities and space (approximately 10m x 10m) on the deck to allow the handling / acommodation of the pre-commissioning equipment (tools container and such, provided by PETROBRAS), a service tank of 21 m^3 vol. to collect the MEG, and means to receive and storage the sea water with chemicals: for instance, directing the water to FPSO drainage system, for further transference to a support vessel.

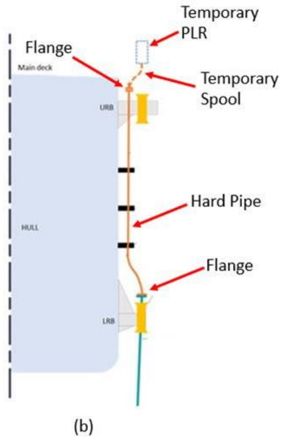


Figure 24 - Temporary PLR pipework connection (temporary spool).

SUPPLIER shall be responsible for the piping from the PLR to the drainage system. The Unit shall handle properly the residual inert gas from the gas pipeline during pre-commissioning. The final procedure for the gas pipeline pre-commissioning shall be agreed with PETROBRAS during execution phase.

Provision shall be made for the necessary support and access for the personnel who will operate the PLR and perform other assembly operations (equipment/piping) during the pipeline pre-commissioning (will be executed by SURFCONTR / PETROBRAS).

SUPPLIER shall be responsible for the provisions related only to the part of the pre-commissioning procedure that requires operations and support personnel onboard the FPSO.

21 SUPPLEMENTARY SCOPE OF SUPPLY

In addition to the Riser Balcony permanent structures and facilities whose composition is explained within this Specification, SUPPLIER shall provide the following complementary and ancillary materials.

21.1 Messenger Wire Ropes

SUPPLIER shall provide messenger wire ropes of 19 mm (3/4 in) and/or 22 mm (7/8 in) diameter (definition of size(s) during contract execution), 6x37 construction, EIPS, in steel core, galvanized, preformed, heavy duty lubrication, right regular lay, Flemish eyes with steel clamps pressed on both ends.

Messenger wire rope for portside operation shall have 100 m length.

Messenger wire rope for starboard side operation shall have 200 m length.

Additionally, SUPPLIER shall provide 4 polypropylene ropes with 220 m length and 1-in diameter.

21.2 Complementary Hardware

SUPPLIER shall provide complete package of the following items as spare parts:

- 1 spare BSDL-SI 48-in, with set of stud bolts.
- 1 spare BSDL-SI 32-in, with set of stud bolts.
- 2 Set of MTLs.
- 2 sets of internal parts for TSUDL Top Cone (mechanisms and wear bushing).

22 VERIFICATION TESTING

This section highlights particular tests required to be performed in advance regarded to BSDL-SI and TSUDL interface components. SUPPLIER shall finish these tests within 12 months from the Notice to Proceed.

22.1 Hydraulic Actuator System Test (BSDL)

SUPPLIER shall perform underwater validation testing of the Hydraulic Actuator System for BSDL (see Figure 25) to verify its functionality, according to PETROBRAS specification ref. \12\.

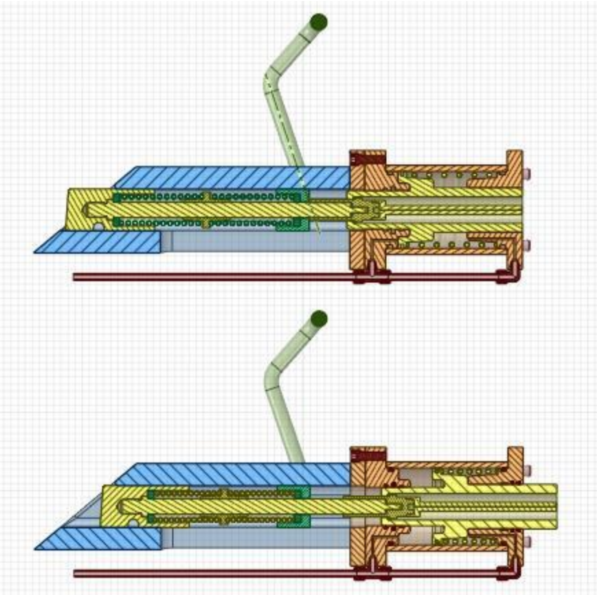


Figure 25 – Hydraulic Actuator System and Locking Mechanism assembly (see ref. \14\).

The validation test shall include two sets of actuators and locking mechanisms, where one presents a sacrificial anode for cathodic protection and the other is exposed to free corrosion. The second test is only for comparison.

As these tests are only to verify the functionality in terms of actuation of moving parts, the materials used in the locking mechanism may be different from those defined in the design, except for the spring material, the coating material and Beryllium-copper parts, which shall comply with design definition. The material used in the hydraulic actuator shall follow the design definition.

22.2 Lateral Support Module – MTL (TSUDL)

SUPPLIER shall perform a Design Validation Test of the Lateral Support Module for TSUDL (see Figure 26) according to PETROBRAS specification ref. \5\, by submitting a complete MTL assembly to immersion in seawater to verify its functionality and load capacity prior to start production of the MTLs.

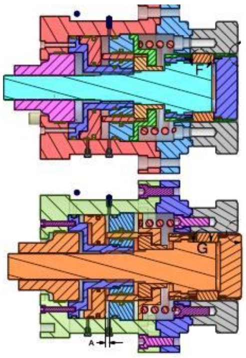


Figure 26 – Lateral Support Module – MTL (illustrative; see ref. \5\).

22.3 Top Cone Functional Testing (TSUDL)

SUPPLIER shall perform a validation test for the Top Cone. This test shall be done in the first piece being manufactured to verify at least the following functionalities:

i. Check the Locking Mechanisms functionality as designed.

ii. Check the interaction between Locking Mechanisms and pull-in wire rope during pull-in simulation.

iii. Check the interaction between Locking Mechanisms and the Dummy HOA during pull-in simulation.

iv. Check the interaction between Locking Mechanisms and the Dummy HOA during seating simulation.

v. Check the interaction between Unlocking Mechanism and the Locking Mechanisms during pull-out simulation.

22.4 Wear Bushing Full Scale Test (TSUDL)

SUPPLIER shall perform a full-scale wear test of the sacrificial bushing that protects TSUDL Top Cone from damage due to the contact and relative movements of the main wire rope during Pull-in/Pull-out operations, according to PETROBRAS specification ref.\9\.

APPENDIX A – RISER CONFIGURATION DATA

The riser configurations herein informed consider the field WD and connection points at 2.80 m (flexible risers), 1.80 m (rigid risers) above keel in a typical FPSO at ballast draft (11.2 m) and 2300m. The operational fluids informed in Table A. 1 were also considered to establish the riser configurations.

Table A. 1 – Operational fluids.

Riser	Operational Fluid	γ [kgf/m³]
Production	Oil	1080
Water/Gas Injection	Water	1048
Service	Diesel	850

For the mooring analysis, the specific masses above shall be considered.

For the top loads estimation, all risers shall be analyzed for the full of water and empty conditions. All risers shall be considered full of water for the pull-in system assessment. See I-ET-RISER TOP INTERFACE LOADS ANALYSIS.

FLEXIBLE RISERS

Some flexible risers shall be considered in free-hanging configuration and other in lazy-wave, as shown in Table A. 3.

Table A. 2 – Configuration

Function	Configuration	Top Angle	Support Angle
PO 8”	Lazy wave	7º	5,5º
PO 6”	Lazy wave	7º	7,5º
GAS 9,13”	Lazy wave	7º	5,5º
IG 6”	Lazy wave	5º	4,5º
IA 6”	Catenária Livre	5º	4,5º
GL 4”	Catenária Livre	5º	5º
UEH	Catenária Livre	5º	5º

Table A. 3 presents the riser mechanical properties to be considered for the analyses.

Table A. 3 – Riser structures.

Função	Est. Topo	ID [mm]	OD [mm]	Internal Volume [l/m]	Dry Weight Empty [kgf/m]	Axial Stiffness [kN]	Bending Stiffness [kN.m^2]
PO 8" Top	TCP 203.51308	211.80	404.92	35.23	330.88	2.65E+06	334.51
PO 8" Inter	TCP 203.51291 MOD	213.10	369.74	35.67	249.68	1.44E+06	309.81
PO 8" Bot	TCP 203.51305 MOD	213.10	407.26	35.67	347.69	1.84E+06	384.21
PO 6" Top	TCP 152.53421	152,40	333,94	19,68	211,58	1,70E+06	127,34
PO 6" Inter	TCP 152.53717	152,40	367,44	19,68	182,84	9,51E+05	165,04
PO 6" Bot	TCP 152.53677	152,40	391,06	19,99	205,19	7,90E+05	192,43
IA 6" Top	TCP 152.52496	152,40	326,68	19,68	213,54	1,82E+06	113,91
IA 6" Inter	TCP 152.52521	152,40	241,74	19,68	107,40	7,50E+05	18,03
IA 6" Bot	TCP 152.52553	152,40	253,06	19,99	125,37	4,92E+05	21,54
GL 4" Top	TCP 101.51150	101,60	232,12	8,88	114,63	1,00E+06	24,42
GL 4" Inter	TCP 101.51348	101,60	191,34	8,88	69,56	5,19E+05	10,79
GL 4" Bot	TCP 101.51335	101,60	191,34	8,88	69,56	5,19E+05	10,79
IG 6" Top	TCP 152.52836	152,40	347,32	19,38	282,59	2,14E+06	120,54
IG 6" Inter	TCP 152.52307	152,40	287,54	19,68	177,95	8,01E+05	53,22
IG 6" Bot	TCP 152.52294	152,40	284,34	19,68	169,14	5,60E+05	51,36
EG 9” Top	TCP 231.50529	231,78	405,36	45,10	310,40	2,64E+06	202,55
EG 9” Inter	TCP 231.50528	231,78	356,58	45,10	179,80	5,66E+05	132,25
EG 9” Bot	TCP 231.50538	231,78	385,48	46,17	240,91	5,71E+05	183,63
UEH	FDT-0606	-	163,80	-	50,80	4,80E+05	12,00

Table A. 4 presents the free-hanging riser compositions to be considered for the analyses.

Table A. 4 – Free-hanging Riser compositions

Riser	L [m]			
	Top Angle	Top Section	Intermediate Section	Bottom Section
IA6	5º	500,0	1800,0	1000,0
GL4	5º	1500,0	800	1000,0
UEH	5º	500,0	1800,0	1000,0

Table A. 5 presents lazy wave configuration parameters.

Table A. 5 – Lazy Wave Configuration Global Parameters for full of water

Parameter			Static configurations - Flooded of water
Oil Production 8”	S1 [m]	Bottom	750.0
	S2 [m]	Intermediate	95.0
	S3 [m]	Buoys	600.0
	S4 [m]	Intermediate	1755.0
	S5 [m]	Top	650.0
	S6 [m]	Bend Stiffener	3.71
	Total length [m]		3853.71
	Horizontal projection [m]		2269.8
	Top angle [°]		7.0
	Tension [kN]		4427.18
	Sag height [m]		325.0
	Hog height [m]		391.0
Oil Production 6”	S1 [m]	Bottom	850.0
	S2 [m]	Intermediate	95.0
	S3 [m]	Buoys	350.0
	S4 [m]	Intermediate	1755
	S5 [m]	Top	650.45
	S6 [m]	Bend Stiffener	3.26
	Total length [m]		3703.71
	Horizontal projection [m]		2075.7
	Top angle [°]		7.0
	Tension [kN]		2371.13
	Sag height [m]		441.0
	Hog height [m]		566.0

Table A.5 – (cont.)

Gas Injection 6”	S1 [m]	Bottom	950.0
	S2 [m]	Buoys	400.0
	S3 [m]	Bottom	550.0
	S4 [m]	Intermediate	1370.0
	S5 [m]	Top	500.0
	S6 [m]	Bend Stiffener	3.51
	Total length [m]		3773.5
	Horizontal projection [m]		1987.3
	Top angle [°]		5.0
	Tension [kN]		3229.7
	Sag height [m]		330.0
	Hog height [m]		482.0
Gas Exportation 9,13”	S1 [m]	Bottom	950.0
	S2 [m]	Buoys	350.0
	S3 [m]	Intermediate	1300.0
	S4 [m]	Top	1000.0
	S5 [m]	Bend Stiffener	2.38
	Total length [m]		3602.3
	Horizontal projection [m]		2115.4
	Top angle [°]		7.0
	Tension [kN]		3760.5
	Sag height [m]		398
	Hog height [m]		403

Obs.: the riser horizontal projection informed above shall be fixed when considering different fluid densities.

Table A. 6 presents the buoyance module properties to lazy wave risers.

Table A. 6 – Buoyance Module Properties

Buoyancy Module Properties		
Production 8”	Length [m]	1.17
	Diameter [m]	1.95
	Uptrust per Buoyancy Module [kN]	12.3
	Associated weight [kN]	21.5
	Modules	163
	Distance between center to center of the Modules [m]	3.67
Production 6”	Length [m]	1.17
	Diameter [m]	1.95
	Uptrust per Buoyancy Module [kN]	12.3
	Associated weight [kN]	21.5
	Modules	95
	Distance between center to center of the Modules [m]	3.67
Gas Injection 6”	Length [m]	1.17
	Diameter [m]	1.95
	Uptrust per Buoyancy Module [kN]	12.5
	Associated weight [kN]	21.9
	Modules	108
	Distance between center to center of the Modules [m]	3.67
Gas Exp 9.13”	Length [m]	1.17
	Diameter [m]	1.95
	Uptrust per Buoyancy Module [kN]	12.3
	Associated weight [kN]	21.6
	Modules	95
	Distance between center to center of the Modules [m]	3.67

Markup factors for the estimated flexible riser loads shall be as per I-ET-RISER TOP INTERFACE LOADS ANALYSIS, except for the Umbilicals Bending Moments, whose markup factor shall be 1.8.

Table A. 7 presents the data related to the bend stiffeners for each riser function. To design the bellmouths, CONTRACTOR shall consider the use of extenders, as shown in Figure A. 1.

Table A. 7 – Bend-stiffener data.

Riser	Bend-stiffener data				
	Db [mm]	Din [mm]	L [m]	d [m]	E [MPa]
PO8	1370.0	506.0	3.7	1.5	77.0
PO6	1370.0	401.0	3.3	1.5	77.0
IA6	1220.0	350.0	3.3	1.5	77.0
GL4	1000.0	282.0	3.4	1.5	77.0
IG6	1200.0	409.0	3.5	1.5	77.0
EG9	1000.0	435.8	2.4	1.5	77.0
UEH	500.0	160.0	3.2	1.2	77.0

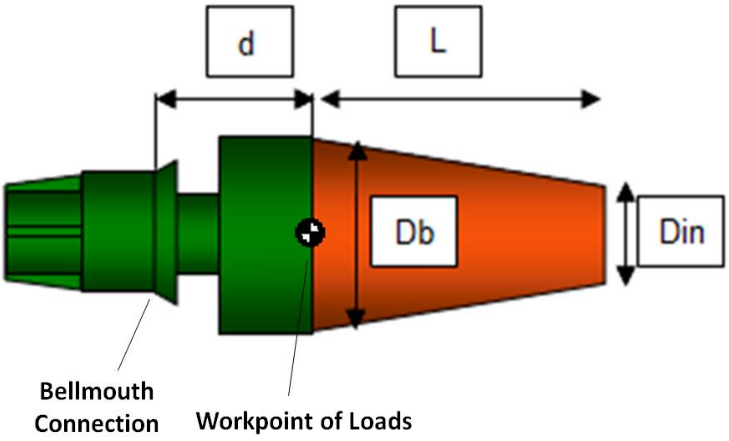


Figure A. 1 – Bend-stiffener dimensions and workpoint.

RIGID RISERS

The rigid pipe properties, hydrodynamic coefficients, stress joint parameters and global parameters for rigid risers are presented in the tables Table A. 8, Table A. 9, **Erro! Fonte de referência não encontrada.** and Table A. 11, respectively. Both water-flooded and empty conditions shall be considered in the analyses.

Figure A. 2 and Figure A. 3 illustrate a straked cross-section schematic, the stress joint located in the support and reference point for the riser top interface load results (r.p.) and riser configuration parameters, respectively.

Table A. 8 – Rigid pipe properties.

Wall thickness and diameters details		**Carbon steel**
Production 8”	External diameter [mm]	259.2
	Internal diameter [mm]	203.2
	Wall thickness [mm]	28
Production 6.5”	External diameter [mm]	221.1
	Internal diameter [mm]	165.1
	Wall thickness [mm]	28
WAG Injection 6.5”	External diameter [mm]	221.1
	Internal diameter [mm]	165.1
	Wall thickness [mm]	28
Gas Export 7”	External diameter [mm]	227.8
	Internal diameter [mm]	177.8
	Wall thickness [mm]	25
Material properties		
Carbon steel	Density [kg/m3]	7908.3
	Young’s Modulus [GPa]	207

Table A.8 – (cont.)

External coating properties		
Production 8”	Thickness [mm]	33
	Specific weight [kN/m3]	6.77
Production 6.5”	Thickness [mm]	72
	Specific weight [kN/m3]	6.77
WAG Injection 6.5”	Thickness [mm]	20
	Specific weight [kN/m3]	6.77
Gas Export 7”	Thickness [mm]	3
	Specific weight [kN/m3]	8.829
Buoyancy Module Properties		
Production 8”	Length [m]	2.30
	Diameter [m]	2.30
	Uptrust per Buoyancy Module [kN]	38.0
	Associated weight [kN]	56.2
	Modules	36
	Distance between center to center of the Modules [m]	12
Production 6,5”	Length [m]	2.30
	Diameter [m]	2.33
	Uptrust per Buoyancy Module [kN]	38.9
	Associated weight [kN]	57.5
	Modules	40
	Distance between center to center of the Modules [m]	12
WAG Injection 6.5”	Length [m]	2.20
	Diameter [m]	2.5
	Uptrust per Buoyancy Module [kN]	43.5
	Associated weight [kN]	64.4
	Modules	18
	Distance between center to center of the Modules [m]	24
Gas Export 7”	Length [m]	2.30
	Diameter [m]	2.19
	Uptrust per Buoyancy Module [kN]	34.7
	Associated weight [kN]	51.5
	Modules	34
	Distance between center to center of the Modules [m]	12
Strake properties		
Production / WAG Injection / Gas Export	Shell Wall Thickness [mm]	15
	Strake Vane Height [mm]	60
	Density [kg/m3]	1149

Table A. 9 – Hydrodynamic Coefficients.

Hydrodynamic coefficient for		Extreme Analysis	Fatigue Analysis
Coated pipe	Normal drag	1.2	0.7
	Tangential drag	0.001	
	Inertia Coefficient	2.0	
Coated pipe with strake	Normal drag	1.4	
	Tangential drag	0.001	
	Inertia Coefficient	2.5	
Coated pipe with buoys	Normal drag	1.2	0.7
	Tangential drag	0.9	
	Inertia Coefficient	2.0	
Structural damping			
Structural damping [%]		0.3	

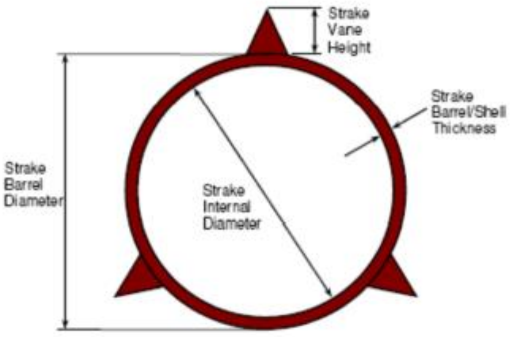


Figure A. 2 – Straked cross-section schematic.

Table A. 10 – Titânium Stress joint parameters

Titanium Stress Joint data			
Production 8”	Length [m]	Taper Section (LA)	13.5
		Straight Section (LB)	1.0
		Total Active Section (L)	9.0
		Distance from stress joint r.p (d) [m] Note: only for TSUDL	0.872
	Top Wall Thickness (TWT)[mm]		138.4
	Bottom Wall Thickness (BWT)[mm]		68.4
	E [GPa]		105
	Density [kg/m3]		4500
Production 6.5”/ WAG Injection 6.5”	Length [m]	Taper Section (LA)	15.5
		Straight Section (LB)	1.0
		Total Active Section (L)	10.0
		Distance from stress joint r.p (d) [m] Note: only for TSUDL	0.872
	Top Wall Thickness (TWT)[mm]		177.5
	Bottom Wall Thickness (BWT)[mm]		47.5
	E [GPa]		105
	Density [kg/m3]		4500
Gas Export 7”	Length [m]	Taper Section (LA)	13.5
		Straight Section (LB)	1.0
		Total Active Section (L)	8.0
		Distance from stress joint r.p (d) [m] Note: only for TSUDL	0.872
	Top Wall Thickness (TWT)[mm]		121.1
	Bottom Wall Thickness (BWT)[mm]		59.9
	E [GPa]		105
	Density [kg/m3]		4500

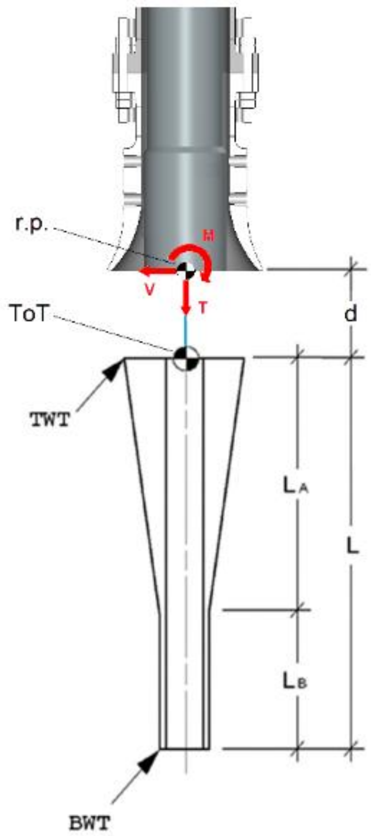


Figure A. 3 – Stress joint located in TSUDL

Markup factors for the estimated flexible riser loads shall be as per I-ET-RISER TOP INTERFACE LOADS ANALYSIS.

Table A. 11 – Global parameter for rigid risers

Parameter			Static configurations for fluid contents – Empty	Static configurations for fluid contents – Flooded of water (or Operational fluid)
WAG Injection 6.5”	S1[m]	Coated pipe	504	
	S2 [m]	Coated pipe with strake	144	
	S3 [m]	Coated pipe with buoys	444	
	S4 [m]	Coated pipe with strake	2430	
	S5 [m]	TiPT	15.7	
	Total length [m]		3737.7	
	Horizontal projection [m]		1816.8	
	Top angle [°]		5.76	5.53
	Top tension [kN]		2105	2675
Production 8”	S1 [m]	Coated pipe	840	
	S2 [m]	Coated pipe with strake	204	
	S3 [m]	Coated pipe with buoys	456	
	S4 [m]	Coated pipe with strake	2379	
	S5 [m]	Stress Joint	13.8	
	Total length [m]		3893	
	Horizontal projection [m]		2181	
	Top angle [°]		7.8	6.3
	Top tension [kN]		1989	2819
Production 6.5”	S1 [m]	Coated pipe	1194	
	S2 [m]	Coated pipe with strake	312	
	S3 [m]	Coated pipe with buoys	504	
	S4 [m]	Coated pipe with strake	2269	
	S5 [m]	Stress Joint	15.7	
	Total length [m]		4295	
	Horizontal projection [m]		2198	
	Top angle [°]		10.8	8.07
	Top tension [kN]		1364	1888

Table A.11 – (cont.)

Gas Export 7”	S1 [m]	Coated pipe	792	
	S2 [m]	Coated pipe with strake	204	
	S3 [m]	Coated pipe with buoys	432	
	S4 [m]	Coated pipe with strake	2379	
	S5 [m]	Stress Joint	13.8	
	Total length [m]		3821	
	Horizontal projection [m]		2063	
	Top angle [°]		7.01	5.8
	Top tension [kN]		1794	2428

Note: Water depth of 2,300 meters