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	PROGRAM: MARLIM LESTE E SUL		-
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SRGE	TITLE: FPSO Structures and Facilities for Riser System		INTERNAL
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INDEX OF REVISIONS

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1 INTRODUCTION

1.1 Project Description

PETROBRAS, as operator, intends to implement the revitalization of the **Marlim Sul** and **Marlim Leste** Oil Fields — located in Campos Basin, offshore Brazil, at water depths ranging from 780 m to 2600 m, considering 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, moored at circa of 1150 m WD and connected to the subsea facilities via a coupled riser system, with the following general composition of Riser-slots.

- 43 *slots* for *bundles* of flexible sealines for connection of production wells (functions of production – PO, Gas-Lift – GL, service – SV, and Gas-Lift test – TGL)
- 7 *slots* for water injection sealines
- 30 *slots* for umbilical risers for various functions
- Two *slots* for gas export risers
- One *slot* for oil import

FPU engineering and construction project will comply with the FPSO-SMS Basic Design developed by PETROBRAS.

1.2 Scope of Document

The purpose of this specification and documents referenced hereafter is to provide the SELLER 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 this area.

Topics include, but are not limited to:

- Riser Balcony Support Structures
- Riser Hang-off Systems
- Riser interface connections
- Riser Top Interface Loads
- Riser Pull-in/Pull-out (Overview)
- Underwater activities
- Riser integrity monitoring systems
- Control and monitoring of BSDL-SI

This specification has to be read in conjunction with referred project documentation (see sec. 3.1) and general technical specifications (see sec. 3.2), as well as any other contract documents describing the related FPSO facilities and interfacing equipment, or presenting design features or operating 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 etc.

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 structures and pull-in facilities shall comply, and to provide considerations for the design and arrangement of the associated systems.

2 DEFINITIONS

For 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
- SELLER — The Organization in charge of detailed engineering, supply, and construction phase of the FPSO, under contract to PETROBRAS
- VENDOR — The party that manufactures and/or supplies equipment, materials, goods, and/or services for the project through SELLER Purchase Order
- WORK — All work to be performed by the SELLER and/or VENDORS 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 moulded 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 PULL-IN	Guided pull-in through structural tubes on the Balcony. (see Lower I-Tube and Upper I-Tube)
• DUMMY SPOOL	Or Dummy End Fitting. Device that replicates riser flange elevation of riser top assembly (end fitting), with the function to hang and seal closing spool on its position in the upper riser balcony.
• 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 parts will be locked or seated.
• HANG-OFF COLLAR	Riser hang-off device, two part structural plate that promotes anchoring the top connector of the flexible riser / umbilical to the riser support on the FPSO.
• INSTALLATION (ACTIVITY)	All activities carried out by the FPSO for the riser installation: riser pull-in, including pull-in preparation activities; post-pull-in handlings; Riser-to-SDV connections; assistance to sealine pre-commissioning (if any); connection of riser integrity monitoring system to Topsides, riser demobilization (pull-out); Bellmouth (or its latch system) replacement 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 flange position of riser top assembly.
• PULL-IN COLLAR	Installation accessory that ties the bend stiffener to the riser end fitting via fusible wires, until its connection with Bellmouth.
• OVERPULL	In this specification means additional lifting at the end of riser pull-in operation.
• RISER BALCONY	Denomination referring to the whole set of balcony features, comprising the LRB, the URB and the RPS.
• TOP (INTERFACE) SPOOL	Or Closing Spool. Piping at URB connecting Flexible Riser w/ Topside SDV.
• 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: Flexible; Umbilical.
• "SEALINE"	Is used in this document as a general term to refer to the risers and related flowlines attached to FPU.

2.4 Abbreviations

FPSO	Floating Production, Storage and Offloading
FPU	Floating Production Unit
SMS	Spread Mooring System
WD	Water Depth

LRB	Lower Riser Balcony
URB	Upper Riser Balcony
RPS	Riser Pull-in Structure

AFT, FWD	Afterwards, Forward (referring to locations along riser balcony)
PS, SB	Portside, Starboard

Hs	Wave Spectrum Significant Wave
Tp	Wave Spectrum Peak Period
DAF	Dynamic Amplification Factor
SWL	Safe Working Load (w/o DAF, for the purposes of this spec.)
WLL	Work Loading Limit

ID	Internal Diameter
OD	Outside Diameter

Prod	or PO, Production Riser
GE	Gas Export Riser
GL, TGL	Gas-Lift Riser, Gas-Lift Test Riser
SV	Service Riser
WI	Water Injection Riser

MSI	*Injection Subsea Manifold*
MSP	*Production Subsea Manifold*

FO	Fiber Optic Umbilical Riser
STU	Steel Tube Umbilical
TPU	Thermoplastic Umbilical
UEH	*Electro-hydraulic Umbilical*
ec	Electrical Cable of subsea umbilical riser)
epc	Electrical Power Cable (of subsea umbilical riser)
oc	Optical Cable (of subsea umbilical)
F	Function (control or chemical inj.) (of subsea umbilical riser)

API	American Petroleum Institute
BSDL-SI	*Diverless Bellmouth* - standard interface
CMM	Coordinate Measure Machine
CP	Cathodic Protection
EJB	Electrical Junction Box
HPU	Hydraulic Power Unit
MBR	Minimum Bend Radius
MODA	*Optical Monitoring Directly on the Wire*
A&R	Abandonment and Recovery (acronym related to pipelay)
PLSV	Pipelay and Support Vessel
RSMS	Riser Supports Monitoring System
RAO	Response Amplitude Operator
ROV	Remotely Operated Vehicle for Underwater Activities
SDV	Topside Emergency Shut-down Valve
TUTU	Topside Umbilical Termination Unit

3 REFERENCE DOCUMENTS

3.1 FPSO Project Documentation

Ref.#	Doc. No.	Doc. Title
\1\	I-MD-3010.2Q-1500-940-P56-001	Descriptive Memorandum – Riser and Hull Interface
\2\	I-ET-3010.2Q-1351-140-P4X-001	Hull Structural Requirements
\3\	I-ET-3010.2Q-5268-968-P4X-001	Specification of Riser Pull-in and Pull-out System
\4\	I-DE-3A26.00-1500-941-P56-002	Riser Supports Arrangement - FPSO Balcony Sequence
\5\	I-MD-3010.2Q-1500-940-P56-001	Descriptive Memorandum – Subsea Monitoring System
\6\	I-MD-3010.2Q-1200-940-P4X-009	Descriptive Memorandum - Piping

3.2 PETROBRAS General Technical Specifications

Ref.#	Doc. No.	Doc. Title
\7\	I-ET-3010.00-1300-279-PPC-350	Diverless Bellmouth Standard Interface Supply Specification
\8\	I-LI-3010.00-1300-279-PPC-350	BSDL-SI Part List
\9\	I-ET-3010.00-1300-279-PEK-001	Specification of Hydraulic Actuator System for BSDL-SI
\10\	I-DE-3010.00-1300-279-PEK-003	5K Hydraulic Actuator Assembly for BSDL-SI
\11\	I-ET-3010.00-1500-274-PLR-001	Riser Top Interface Loads Analysis
\12\	I-ET-3010.00-5529-854-PEK-001	MODA (Flexible) Riser Monitoring System – FPU Scope (Spread Mooring)
\13\	I-ET-3010.00-5529-812-PAZ-001	Flexible Riser – Annulus Pressure Monitoring and Relief System
\14\	I-ET-3000.00-1519-29B-PZ9-012	Topside Arrangement and Interfaces with Subsea Umbilical Systems
\15\	I-ET-3000.00-1300-941-PEH-002	Diving System for Risers, Mooring, Hull, and Jacket of Offshore Production Units
\16\	I-ET-3010.00-1300-172-PEK-001	Portable Umbilical Pressurization System (PUPS) – FPU Scope

4 GENERAL OVERVIEW

4.1 Riser System Summary

The riser system of the Unit will encompass a number up to 83 risers, according to Table 4-1.

- Regarded information will be ratified in the Notice to Proceed.

Table 4-1: Sealine Riser-Slots Summary

Application	Riser	Line Function	Quant.	Comments
Production Satellite Wells	6-in ID	**Production**	7	Flexible Riser
	4-in ID	**Gas-Lift**	7	Flexible Riser
	STU	Control, power, signals	2	Umbilical Riser: 15x*F* + *ec* + *oc*
	STU or **TPU**	Control, signals, chemical inj.	5	Umbilical Riser: 15x*F*
Production Wells, via MSP	8-in ID	**Production**	13	Flexible Riser
	6-in ID	**Gas-Lift**	9	Flexible Riser
	4-in ID	**Gas-Lift Test (TGL)**	7	Flexible Riser
	STU	Control, signals, chemical inj.	5	Umbilical Riser: 12x*F* + *ec*
	STU	Control, power, signals	9	Umbilical Riser: 15x*F* + *epc* + *oc*
Injection Satellite Wells	6-in ID	**Water Injection**	2	Flexible Riser
	STU or **TPU**	Control, signals	2	Umbilical Riser: 5x*F* + *ec*
Injection Wells, via MSI	8-in ID	**Water Injection**	5	Flexible Riser
	STU	Control, signals	5	Umbilical Riser: 9x*F* + *ec*
Gas Export	11.13-in ID	**Gas Export**	1	Flexible Riser
	STU or **TPU**	Control, signals	1	Umbilical Riser: 5x*F* + *ec*
Fiber Optic	**FO**	Control	1	Umbilical Riser
Oil Import	9.13-in ID	**Oil Import**	1	Flexible Riser
Gas Export (spare)	8-in ID	**Gas Export**	1	Flexible Riser
		TOTAL	**83 RISERS**	

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

- Preliminary Riser Balcony sequence (riser functions and sizes) is presented in Ref. \4\, which will be updated (see sec. 10.4) at the Notice to Proceed.

4.2 Riser System and Mooring Layout

Riser are attached along Portside of the FPSO, but Platform approach will include risers at both eastern (PS) and western (SB) sectors.

FPSO heading is in the sector South – Southwest.

The SPM includes 28 mooring lines, equally divided in 4 clusters, with distribution that will depend on subsea layout. The number of mooring lines may still be updated.

4.3 General Description of the Riser Balcony

Riser Balcony of the Unit is located at the Portside of the hull and comprises 83 Riser-slot positions, distributed in “two layers” of I-Tubes.

- Figure 1 indicates the typical allocation for each layer: risers approaching from portside are connected to outermost layer, while innermost layer is dedicated to the risers located in the starboard sector of the Unit.

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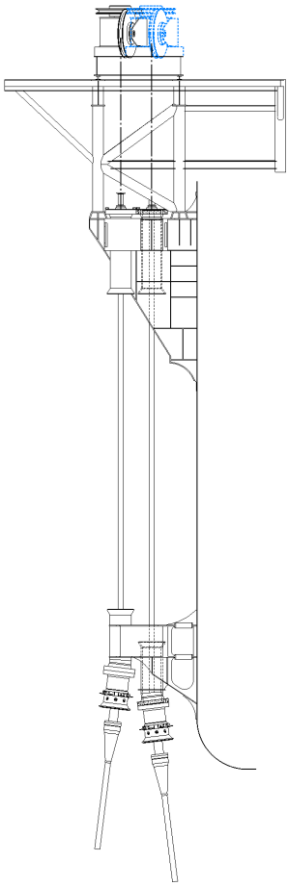


Figure 1: Lateral View of Riser Balcony presenting two layers of I-Tubes

The three Riser Balcony levels (see Figure 2) are called:

- Lower Riser Balcony (LRB)
- Upper Riser Balcony (URB)
- Riser Pull-in Structure (RPS)

I. The Lower Riser Balcony is a structure in the lower part of the hull and includes the lower I-Tubes, provided with bolted Bellmouths (BSDL-SI).

II. The deck of Upper Riser Balcony includes the upper I-Tubes, where the risers will be supported. Walkway (not shown) is provided.

III. Riser Pull-in Structure includes the main structures and equipment for risers pull-in / pull-out. (see Ref. \3\)

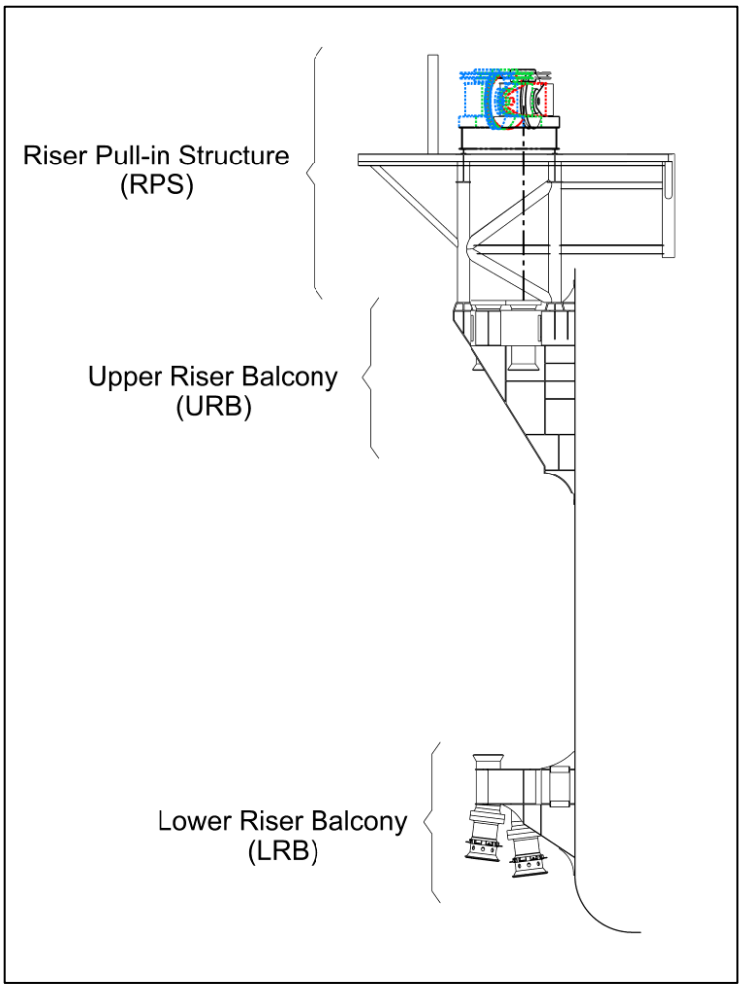


Figure 2: Riser Balcony Levels

4.4 Riser-Slots Distribution

The document I-DE-3A26.00-1500-941-P56-002 (Ref. \4\) shall be considered as a base case for the balcony design, that BIDDER shall consider for the analyses to be carried out during bidding phase. However, the final distribution of Riser-slots per function and diameter, as well as the required angles of inclination (top angle) and azimuth (local angle) for each respective location of lower I-Tube (see sec. 5.2 and sec. 6.1) will be provided by PETROBRAS at the Notice to *Proceed,* through updating of mentioned document.

5 RISER BALCONY OVERALL CONFIGURATION

This section introduces the Riser Balcony configuration in terms of main structures. Emphasis is placed on the support systems that attach the risers to the hull structure.

The total risers hang-off capacity of the FPSO is of 83 riser-slots, being 42 positions at innermost layer and the others at outermost layer. (see Ref. \4\)

Flexible and Umbilical Risers will be fitted to the hull through the upper and lower sections of the Balcony, the LRB and the URB.

5.1 Support Structures

Flexible and Umbilical Risers will be connected to the hull through vertical I-Tube assembly in two sections, attached to Upper and Lower Riser Balcony levels.

(i) The upper I-Tube will anchor the riser axial loads on the URB.

(ii) the lower I-Tube arranged within the LRB will incorporate a bolted Bellmouth (BSDL-SI) to sustain the Bend Stiffener of the flexible riser or umbilical riser.

5.2 Lower Riser Balcony Configuration

The LRB structure will be arranged with two layers of I-tubes, in two different levels (see Figure 3) to promote vertical staggering between Bellmouths, required to avoid physical interferences, as well as to enhance the accessibility to the internal layer.

- Bottom sections of the lower I-Tubes must fulfill requirement of specific angles of inclination and azimuth, for each Riser-slot, to accommodate the individual nominal top angle and heading of the risers.

The risers will be pulled through these lower I-Tubes for hang-off at the upper balcony deck.

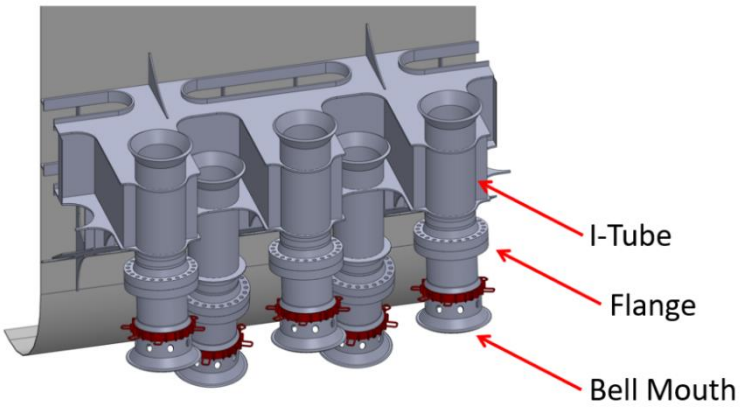


Figure 3: The two layers of I-Tubes w/ Bellmouths on LRB

5.3 Upper Riser Balcony Configuration

The URB structure will be configured with upper I-Tubes (see sec. 6.2) in two layers, centered with the lower I-tubes on LRB. Risers will be connected to upper I-Tubes by means of Hang-off Collars, provided by PETROBRAS (see Figure 4).

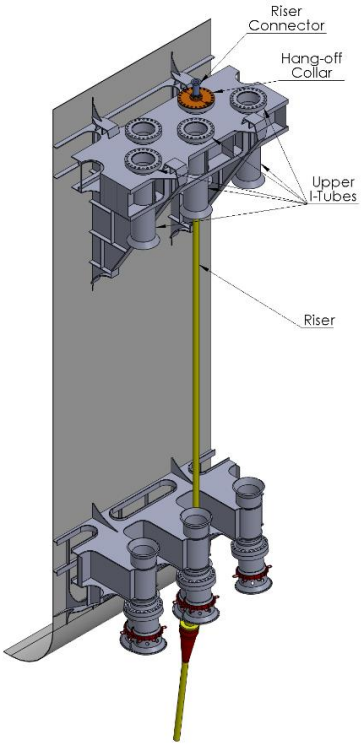


Figure 4: Riser connected to I-Tube Assembly

6 HANG-OFF SYSTEMS

6.1 General Requirements

SELLER 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.

The lower I-Tubes on LRB, for each Riser-slot 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.

SELLER shall inform the as-built coordinates, top angle and azimuth angle for all riser supports at URB level (Hang-off) and LRB level (Bellmouths).

All these structures shall be identified regarding their numbering of Riser-slot position on Balcony arrangement: markings shall be performed in three points (top and sides of support), in bas-relief 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.

SELLER 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 I-Tube Assemblies for Flexible and Umbilical Risers

The Flexible and Umbilical Risers will be attached to both URB and LRB through I-Tube assemblies having a Bellmouth (BSDL-SI) 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 Collar (under PETROBRAS scope) to be installed onto the I-Tube upper flange 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.

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

The upper I-Tubes shall end in MSS SP-44-2019 FFWN #300 seat flanges matching the respective riser Hang-off 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.

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

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 6-1.

Table 6-1 – I-Tubes Sizes

Function, Riser ID	BSDL-SI	LOWER I-TUBE	UPPER I-TUBE
	Nominal Diameter [in]		
Production, 6-in	46	46	40
Production, 8-in			
Water Injection, 6-in			
Water Injection, 8-in			
Gas-Lift & TGL, 4-in			
Gas-Lift, 6-in			
Gas Export, 8-in			
Oil Import, 8-in			
Gas Export, 11.13-in	48		
Oil Import, 9.13-in			
Oil Import, 11.13-in			
Umbilical Risers	32		

6.2.1 Bellmouths

Bellmouths will be connected to the lower I-Tubes, close to FPSO keel level, and will sustain the Bend Stiffeners of flexible and umbilical risers.

Reference is made to BSDL-SI Supply Standard Specification, Ref. \7\, and Part List for BSDL-SI, Ref. \8\.

BSDL-SI will require automation capabilities for diverless pull-in and pull-out operations, as well as for RSMS (CP monitoring, and end stroke monitoring of complete unlatching of actuators sets), fully integrated to the Topside (see sec. 18). Reference is made to PETROBRAS Project I-MD Ref. \5\, as well as Standard Specifications I-ET Ref. \9\ and I-DE Ref.\10\.

Figure 5 presents a sketch of the Bend Stiffener coupled on BSDL by means of its metallic extension.

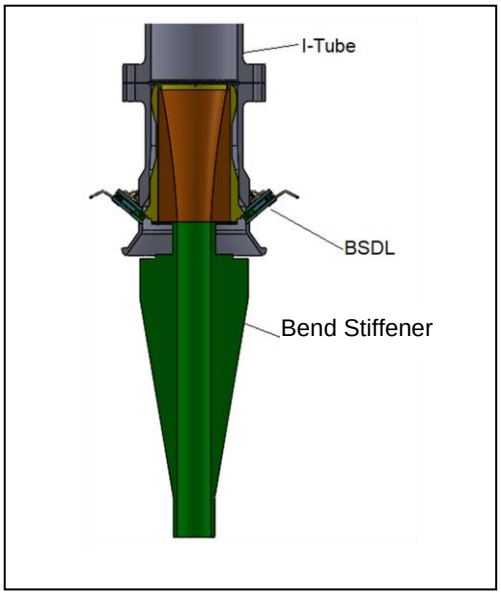


Figure 5: Bend Stiffener coupling with BSDL (illustrative)

Preliminary information regarding geometries of Bend Stiffeners are presented in APPENDIX A – RISER CONFIGURATION DATA. (see sec. 10.1)

SELLER 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 SELLER'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.

SELLER shall fabricate jigs to perform interference checking during dry dock, after Bellmouths are bolted to the lower I-Tubes, according to BSDL documentation. (see §19 of Ref. 10).

SELLER shall supply spare parts of the BSDLs for use in case replacement is needed. (see sec. 19.2)

SELLER shall verify the design including structural analysis (strength and fatigue), select (where needed) and procure materials and coatings, manufacture, test, supply and install all BSDLs already bolted in their positions, and fully commissioned and integrated with their automation system.

Structural durability of BSDL-SI and moving parts shall be sufficient for intended design life of the Hull, according to Ref. \2\.

Note: *For the structural design of Bellmouths and LRB structures, SELLER shall consider the work point location at the Bend Stiffener, where Riser shear and bending loads will take place, which means that length of its metallic extension, for each riser application, shall be accurately taken into account when determining reaction forces into the Bellmouth and proper load distribution to LRB support structures.*

7 FLEXIBLE RISER TO PLATFORM PIPING CONNECTIONS

7.1 General Requirements

Flexible risers will be supported in the URB hang-off structure, and will require Top Interface Spools (closing spools) for connection with SDV.

Figure 6 shows a sketch of this closing spool.

SELLER shall supply Top Interface Spools for all Riser-slots of Flexible Risers.

- The Top 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.

Scope of supply for these 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 project specifications according to Ref. \6\.

- SELLER shall develop and provide the procedure for offshore installation of Top Interface Spools.

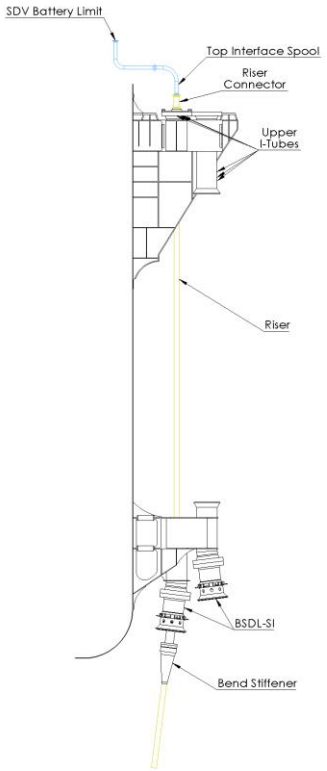


Figure 6: Top Interface Spools for Flexible Risers (illustrative)

Note: *Initial and Future Risers will be defined until FPSO integration phase. Depending on this definition, top interface spools with risers on upper balcony may have to be dismounted after piping system hydrotesting and preserved onboard, or kept in position with appropriate support hangers (dummy spools, according to contract requirements) with sealings and flange surfaces compatible with interface piping material.*

7.2 Design Considerations

The design of top interface spools shall provide sufficient flexibility to allow for global and local displacements at the riser connection points, associated to the same interface loads employed in the URB structural analysis, with the URB subjected to Design Operating (DOC) and Design Environmental (DEC) loading conditions, as well as any relevant conditions expected during riser installation phase (for instance, displacements at riser connection point at the moment that riser load is fully supported in the hang-off system must be taken into account as an additional tolerance for offshore assembly of the closing spool). In addition, the corresponding levels of hull flexing, if relevant, shall be considered.

Top interface spools shall fulfill piggability requirements included in related project specifications.

- It is worth noting the need to perform, within these interface spools, the ID smooth transition with Riser ID. (see. sec. 9.1)

7.3 Construction Adjustments

SELLER is responsible for the dimensional compatibility of the Top interface spools with the end fittings of the Flexible Risers assembled onto their respective slots, by means of performing all the necessary piping adjustments (under very stringent connection tolerances) and corresponding fit-up and tests (from the Unit) at the URB, during construction phase, on each position of Riser-slot, using riser termination Mockups.

- Fit-up Procedures shall be submitted to PETROBRAS approval.

SELLER shall design and fabricate the Mockups adequate to the specifications of interface flanges, and prescribed heights of tie-in points elevations associated to riser sizes. (see sec. 9.1),

- Each Mockup shall present seal test port for N_2/He leak testing, required during onshore site fit-up tests of top interface (closing) spools.

- Mockup drawings shall be submitted for PETROBRAS comments.

7.4 Flange Connections

SELLER shall provide the top interface spools for the risers with swivel flanges – according to API 6A and API 17D – at the lower end (battery limit with riser end fitting), compatible with risers flanges and bores (see Table 9-1). 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.

SELLER shall provide the ring gaskets, stud bolts and nuts for all the interface flanges with risers, according to API 6A and API 17D. The datasheets, including dimensional drawings, shall be submitted for PETROBRAS.

- 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 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.

8 CONTROL UMBILICAL CONNECTION ARRANGEMENT

SELLER shall supply and install Hydraulic Plates (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 Electrical Junction Boxes (EJBs) for the electrical cables.

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

Reference is made to Standard Specification, Ref.\14\.

Figure 7 presents a typical sketch for these connections and battery limits between SELLER and PETROBRAS, regarding both STU and TPU Umbilical Risers.

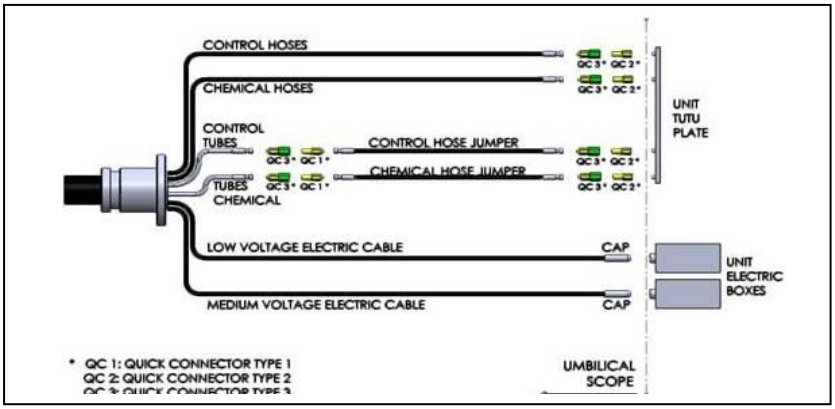


Figure 7: Typical arrangement for connections of Umbilical Risers on URB

- SELLER shall provide removable seat supports for TUTU plates and EJBs, in order to clear the area for Pull-in and Pull-out operations of Umbilical Risers. Furthermore, tubings and trays from FPU, at these tie-in points, shall also need to be removed for pull-in operation, at a radial distance of 1.5 m from the center of the slot.

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

9 RISER TOP TERMINATIONS BASIC DATA

This section provides primary information about top terminations of Flexible and Umbilical Risers.

9.1 End Fittings of Flexible Risers and Umbilicals

The specifications of risers top termination flanges, as well as their elevations at the tie-in points with closing spools are depicted in Table 9-1 and Figure 8.

- As shown in this table, the FPSO top interface (closing) Spool termination connection (flange that interfaces with riser) shall always follow API17D type API17SV (swivel type flanges) with bore compatible with the riser ID.

Table 9-1 – Risers Interface Flanges

Riser Top Flange		FPSO interface Flange		
Riser ID [in]	**Spec**	**ID(*) [mm]**	**Spec**	**Dimension A (Figure 8) [mm]**
4	7 1/16" API 6BX 10000 psi BX-156	101.60	7 1/16" API 17SV 10000 psi BX-156	810 ± 2.5
6	7 1/16" API 6BX 10000 psi BX-156	152.40	7 1/16" API 17SV 10000 psi BX-156	810 ± 2.5
8	9" API 6BX 10000 psi BX-157	203.20	9" API 17SV 10000 psi BX-157	960 ± 2.5
9.13	11" API 17SS 5000 psi BX-158	231.78	11" API 17SV 5000 psi BX-158	960 ± 2.5
11.13	13 5/8" API 17SS 5000 psi BX-160	282.58	13 5/8" API 17SV 5000 psi BX-160	1000 ± 2.5
UEH	9" API 6B 2000 psi flat face	n/a	n/a	350 ± 2.5

(*) For each Riser-slot, the internal diameters of FPSO interface flanges shall be compatible with respective risers.

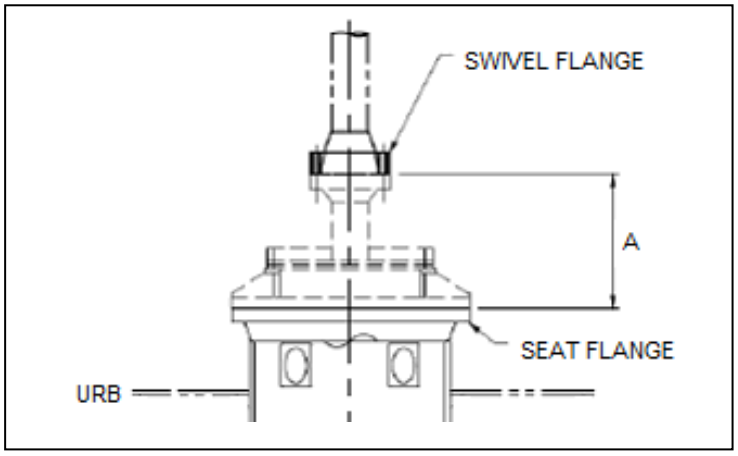


Figure 8: Riser interface flange Tie-in point Elevation (according to Table 9-1: "Dimension A")

The Flexible Riser Hang-off Collar will be supplied by PETROBRAS for all Flexible & Umbilical Risers, including bolts and nuts.

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 of annulus gas: SELLER shall design the venting system in accordance with I-ET-ANNULUS PRESSURE MONITORING AND RELIEF SYSTEM, Ref. \13\. (see also sec. 17)

9.2 Subsea Umbilical Top Termination

Figure 9 presents a typical arrangement of the *pigtails* provided on top terminations of STU Umbilical Risers. Please note the minimum bend radii for the hoses jumpers and electrical cables, which shall be respected in final positioning of TUTU plates and EJBs.

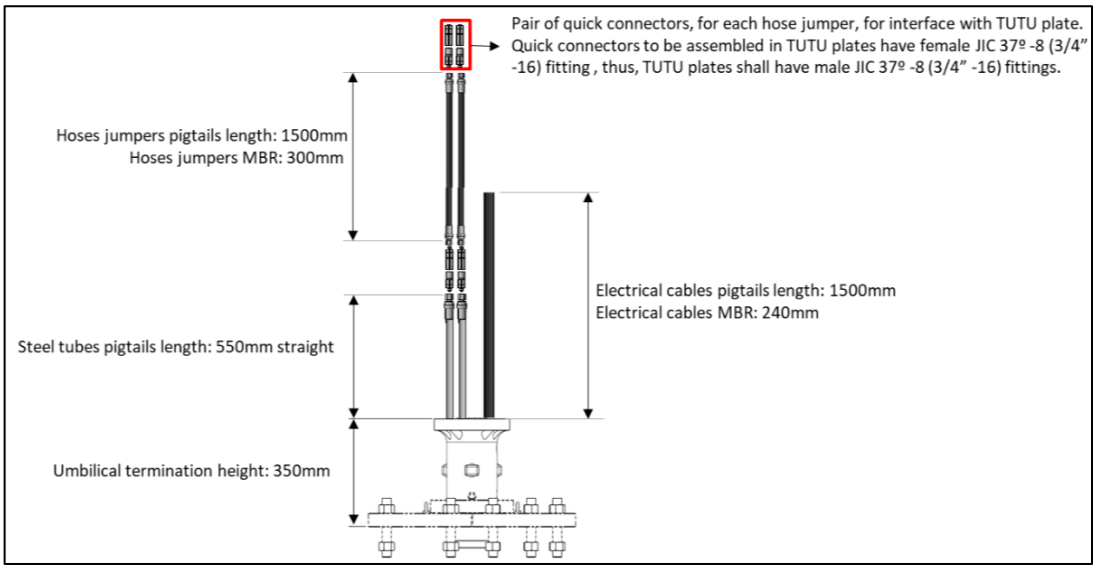


Figure 9: Typical arrangement for *pigtails* of STU Umbilical Risers

10 TECHNICAL DATA FOR SELLER

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

10.1 Riser Configuration Data

PETROBRAS will provide Risers´ input data[1] (configurations, physical properties, and boundary conditions) for Top Interface Load Analyses (see sec. 11), at the Notice to Proceed.

10.2 Environmental Conditions

PETROBRAS will provide or confirm sea states data[1] (waves and currents) for Top Interface Load Analyses, at the Notice to Proceed.

10.3 Offsets for Extreme Conditions

PETROBRAS will provide the Offsets[1] for Extreme Conditions related to Top Interface Load Analyses, at the Notice to Proceed.

10.4 Riser Balcony Sequence

PETROBRAS will provide the Riser Supports Arrangement[2], including the riser sequence distribution for all support positions, risers´ functions, diameters, local azimuths and nominal top angles, at the Notice to Proceed.

10.5 Pull-in Rigging Drawings

PETROBRAS will provide reference drawings of Pull-in riggings during detail design, for the development of Pull-in and Pull-out Procedures and Topsides Mechanical Handling Procedure(s).

10.6 Hang-off Collar Drawings

PETROBRAS will provide reference drawings of Hang-off collars during detail design, for the development of Pull-in and Pull-out Procedures, and Topsides Mechanical Handling Procedure(s).

Notes:

[1] *To be provided in the issue for construction of Ref. \1\.*

[2] *To be provided in the issue for construction of Ref. \4\.*

11 RISER TOP LOAD ANALYSIS

SELLER shall carry out global analysis of the risers, in order to ensure proper structural dimensioning of the Riser Balcony and Pull-in System structures.

- Preliminary riser configurations and properties are informed in APPENDIX A – RISER CONFIGURATION DATA. (see sec. 10.1)

The acceptable methodology is described in I-ET- RISER TOP INTERFACE LOADS ANALYSIS, Ref. \11\. SELLER shall consider that:

- Mark-up factors to be applied on extreme and survival loads shall be in accordance with Ref. \11\, except for the bending moments of Umbilical Risers, that shall employ a mark-up factor of 1.8.
- Bending moments, shear forces and 10% of tension are applied on the Lower Riser Balcony (due to friction) while 100% of tension is applied on the Upper Riser Balcony.
- Analysis of pull-in/pull-out to check operational capacity of pull-in system shall consider the following environmental conditions: Waves with Hs = 4.0 m and Tp limited to 16 s.

For assessment of fatigue top loads, SELLER 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.

SELLER shall report the interface loads for riser design, within 9 months after the project kickoff meeting.

12 PULL-IN / PULL-OUT FACILITIES

Main facilities of Pull-in and Pull-out System are located at the upper platform of the Riser Balcony (RPS), to enable access each Riser-slot without interference from other risers or components of the Riser Balcony.

Reference is made to Riser Pull-in and Pull-out System Specification (Ref. \3\), for a description of the RPS and details of the scope and requirements for Main facilities of Pull-in and Pull-out System.

The Pull-in and Pull-out System shall be designed to support all necessary activities for risers installation and de-installation, including mobilization of subsea service equipment, preparations on upper and lower riser balconies, reeving, connection and traveling of winch wires, pull-in and pull-out initiation, and post-pull-in and pull-out handling activities.

In addition, service facilities of Pull-in and Pull-out System will be used on handling of Riser Balcony components in general, as appropriate.

12.1 Main Facilities

The main equipment in the pull-in system shall be in accordance with Ref. \3\, and is summarized below:

I. Main winch (fixed), with a nominal capacity of 500 tonnes, for pull-in / pull-out of flexible risers and umbilicals.

II. Auxiliary service winch (fixed), with a nominal capacity of 40 tonnes, for Pull-in and Pull-out support activities.

III. Sheave Trolley installed on rails on the Pull-in Platform, with the function of guiding the main and service winches to each I-Tube position (slot). The trolley assembly can slide longitudinally and lock at specific locations for riser pull in installation. The assembly must have movement mechanisms to allow the turndown sheave to reach the two layers of I-Tubes, with the main wire exit point centered with I-Tube for each Riser-slot.

IV. Rigging winch installed on the Sheave Trolley, with a nominal capacity of 20 tonnes, for moving the main and service wires on the Pull-in Platform and passing through their exit turndown sheaves.

V. Overhead crane installed on the pull-in platform, with *SWL* of 10 tonnes (at subsea lifting), for general use as a service facility for lifting, handling, assembly and disassembly operations in the pull-in area and side shell. (see sec. 12.3)

12.2 Requirements for Traveling of Winch Wires

The facilities and structures of the Pull-in System shall be capable to carry on the correct set-up of winch wires for the Pull-in / Pull-out of the Flexible and Umbilical risers, and their deployment to the sea, including:

- Routing[1], hoisting and reeving of main wire and auxiliary service wire through respective turndown sheaves, and their connection to the Sheave Trolley, in the preparation stages for Pull-in or Pull-out.
- Set-up of the main and auxiliary service winch wires accessing each I-Tube, through the movement and unobstructed setup of the Sheaves Trolley (see sec. 16.216.1.2) for each pull-in / pull-out.
- Vertical alignment of the descent of the main pull-in wire, precisely centered with the upper I-Tube, in all locking positions of the Sheave Trolley for Pull-in / Pull-out.
- Traveling[2] of the main and auxiliary service wires to the sea, through auxiliary equipment that ensures a minimum tension to overcome the resistant forces through their routings.

Notes:

[1] *20 t "rigging winch" on Sheave Trolley will perform the routing of main and auxiliary service wire ropes from the respective FWD and AFT winches, but SELLER shall detail and provide the necessary pulling equipment (e.g movable pneumatic utility winch and snatch blocks on pull-in deck) to bring rigging winch wire to each fixed winch on RPS.*

[2] *For traveling of main winch wire, both the 20 t and 40 t winches of pull-in system need to be used. For the latter, SELLER shall detail and provide the necessary structural equipment (e.g. fixed and/or portable padeyes) on Upper Riser Balcony to lower the main wire until the point the wire is already able to start moving due to gravity.*

12.3 Requirements for Handling on Riser Balcony

12.3.1 Service Facilities

Service Facilities of Riser Pull-in System shall be capable to handle all subsea service equipment and tools for installation / de-installation and maintenance activities on Riser Balcony, and are used to move, manipulate and in making riser hang-off assemblies and riser-to-platform tie-ins. Among the required cargo handling services(*) on Riser Balcony Area, are:

- Moving and positioning of Diving equipment (see Ref. \15\) and ROV equipment (see sec. 14) on Diving Stations of riser balcony area, during mobilizations for Pull-in or Pull-out services, as well as for inspection and maintenance operations on side shell.
- Lower all material (Hang off collar, fixing screws, gaskets, tools and other accessories) to the Upper Riser Balcony close to the slot where the riser pull-in will be carried out.
- Recovery, handling along pull-in area, and transfer of transfer riggings and pull-in heads to deck trolleys on topside area, aiming their handling in order to return these installation items to the PLSV.
- Lower and raise of piping components (closing spools, dummy connectors etc.) for the connection of risers after Pull-in.
- Move, raise, and lower Bellmouths (BSDLs), or their components, outwards the FPSO, in case of intervention for their replacement are needed.

Note:

(*)*The related handling procedures on riser balcony area and topside area shall minimize interference with Pull-in and Pull-out operations.*

12.3.2 Outfittings

SELLER shall design, fabricate, and install all the required outfittings (see sec. 16.1) on URB and LRB structures, for assembly of handling devices (e.g. chain hoists, snatch blocks, manual winches), needed to complement the capability of Pull-in and Service Facilities to perform the pull-in/pull-out operations and all other related installation activities.

13 RISER INSTALLATION PROCEDURES

SELLER 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 PLSV starts the laying from the Unit to a subsea equipment.

ii) ***Second end pull-in:*** The PLSV starts the laying from a subsea equipment to the FPSO;

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

For umbilical risers, SELLER 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 and auxiliary service pull-in winches, the passage of wires through sheaves, steel wire paths required for all risers positions etc.

SELLER 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.

SELLER 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.

SELLER 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

SELLER shall specify and provide all necessary steel wire rope length for messenger wires (see sec. 19.1), which shall be installed on onshore site in accordance with the installation sequence of the risers. This information shall be checked by SELLER 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). The messenger wires shall be easily identified according to the balcony positions and structures.

14 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. \15\.

Project documentation presents **three** 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 I- tubes, handling and routing of main and auxiliary service pull-in wires through lower I-tubes.
- Bellmouth visual inspection.
- Cleaning of Bellmouth and mechanisms, using manual tools, water jet or semi-automatic cleaning tool.
- Bend-stiffener connection/disconnection at Bellmouths, where needed.
- Connection/disconnection to the pull-in/pull-out rigging, were needed. (PLSV A&R wire connection to transfer rigging for pull-out operations, etc.)
- Bellmouth replacement, or its locking pins.

In addition to the requirements for the diving operations (see Ref. \15\), SELLER shall provide additional dedicated supply of the following utilities(*) in the diving stations of riser area, to allow the use of both electric mini-ROV(*) – for the wide visual monitoring during pull-in and pull-out operations (see example on Figure 10), and Light work-class ROV(*) for diverless inspection and intervention: ´

- electric power 100-240 VAC alternate current (for the mini-ROV)
- electric power 440 V / 60 Hz (for the work-class ROV)
- Compressed air
- Fresh water

Figure 10: mini-ROV model Seaeye Falcon 12249 specs (for Pull-in and Pull-out operations)

Note:

(*) *All features required for the mobilization and operation of mentioned ROVs in the diving platforms of riser area will be detailed in the early stage of FPSO detailed design.*

15 RISER TRANSFER AND PULL-IN STAGES

15.1 Overview of Second End Pull-in

To prepare for pull-in, the Sheaves Trolley is translated and secured at the appropriate position, aligned with the I-tube of Flexible or Umbilical Riser to be installed for an efficient operation.

The riser may be empty, partially, or fully flooded during installation.

The main stages involved in transfer and pull-in of a flexible riser from the PLSV to the FPSO are as follows (figures are illustrative only).

- For the transfer of flexible risers, the pull-in wire is usually collected on board the PLSV to connect it to the pull-head via the Pull-in rigging, and it is therefore necessary to pay out a significant length of pull-in wire in these situations. This condition, particularly in keelhauling operations, should be considered when defining the total length of wire rope for the main pull-in winch.
- In the load transfer the PLSV A&R wire will run until the riser load is transferred to the FPSO.
- When pulling flexible riser up the I-Tube, the Bend Stiffener is automatically locked to the BSDL-SI, and the flexible riser pulled to URB.

For the pull-out, riser is fully flooded of sea water following these stages in reverse order.

- *Stage 1* (*Figure 11)*

The main pull-in winch deploys the pull-in wire to a predetermined length. The installation vessel (PLSV) takes the pull-in wire. Slack wire rope paid out from FPU is attached to the riser pull-head by means of Pull-in (transfer) rigging.

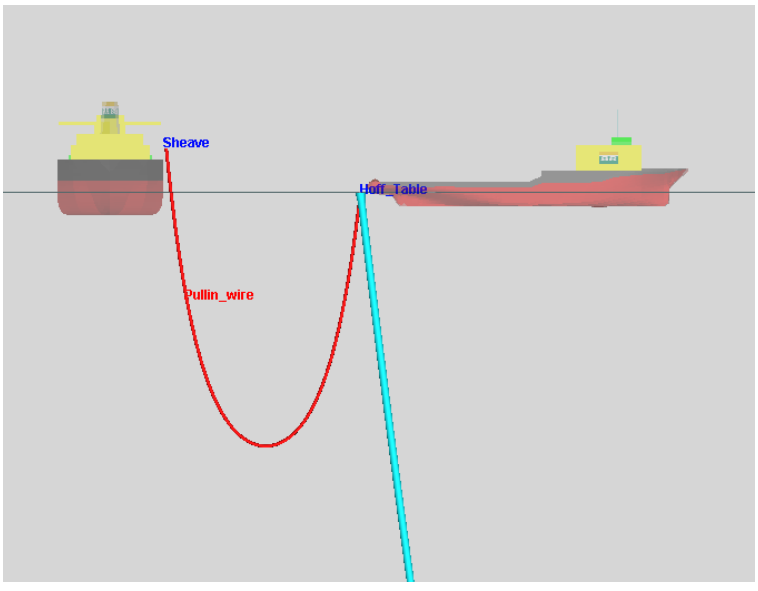


Figure 11: 2nd end Pull-in - Start Position

❖ *Stage 2* (Figure 12)

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

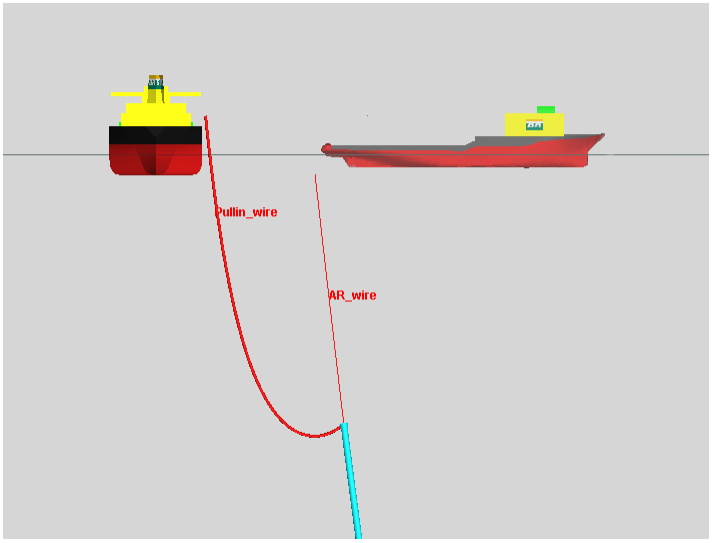


Figure 12: 2nd end Pull-in - Lowering Riser on A&R Wire

❖ *Stage 3* (Figure 13)

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

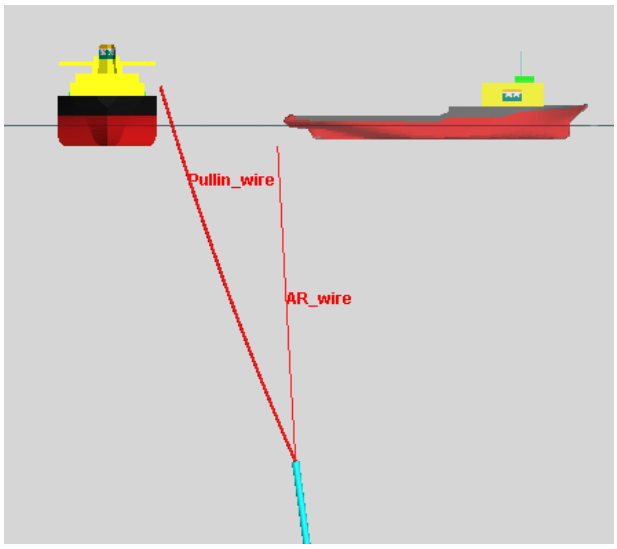


Figure 13A: Start of Load Transfer (maximum Pull-in wire angle)

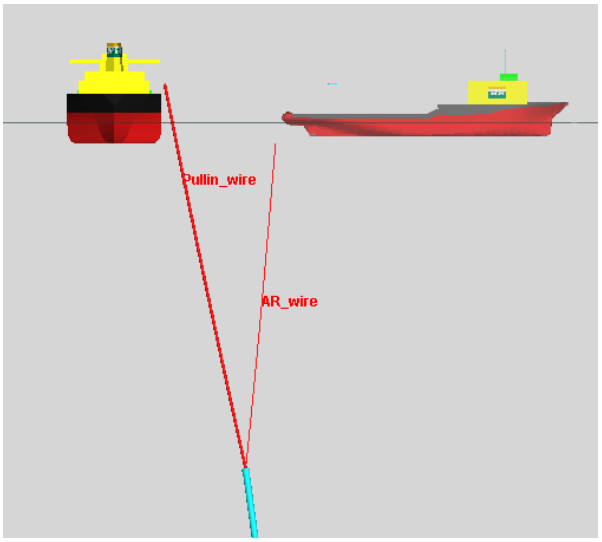


Figure 13B: During Load Transfer

Figure 13: 2nd end Pull-in - Load Transfer

- *Stage 4* (Figure 14)

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

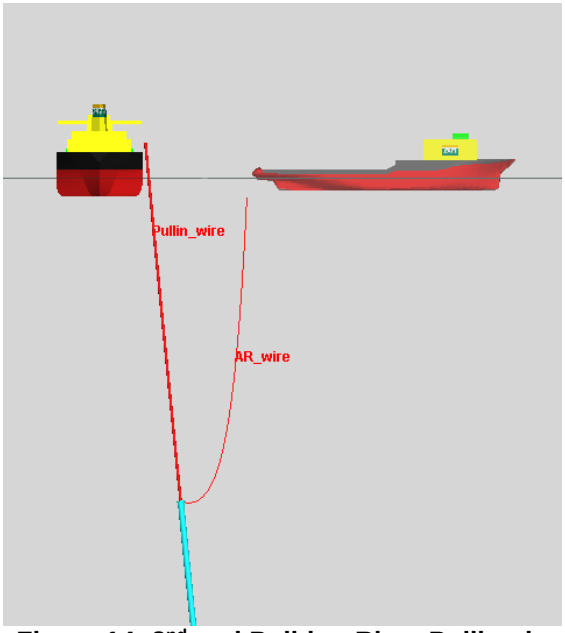


Figure 14: 2nd end Pull-in - Riser Pulling in

- *Stage 5* (Figure 15)

The main pull-in winch travels hauling the wire, and guides the riser through the lower I-Tube:

(1) As soon as the flexible riser reaches approximately 5 meters from the BSDL, the winch speed will be reduced. This maneuver will be monitored by the mini-ROV;

(2) ENTRY INTO THE LOWER I-TUBE (BSDL-SI): The passage of the rigging and coupling of the Bend Stiffener will be monitored by the Pull-in ROV. The pulling will be continuous. As soon as the male connector of the Bend Stiffener enters the BSDL, the locking pins will be mechanically activated and will lock the Bend Stiffener;

(3) FUSIBLE CABLE BREAKAGE: After the Bend Stiffener is coupled, the tension should increase with the fusible cables (break wires) being activated by the winch tension. The pulling will continue, and the pull-in load will visibly increase. The minimum breaking load of the fusible cables will be approximately 25 t. The rupture of these cables will be clearly heard in the URB, and there should be a reduction in the load by the same amount, with the pull-in continuing until the pull-head reaches the URB level.

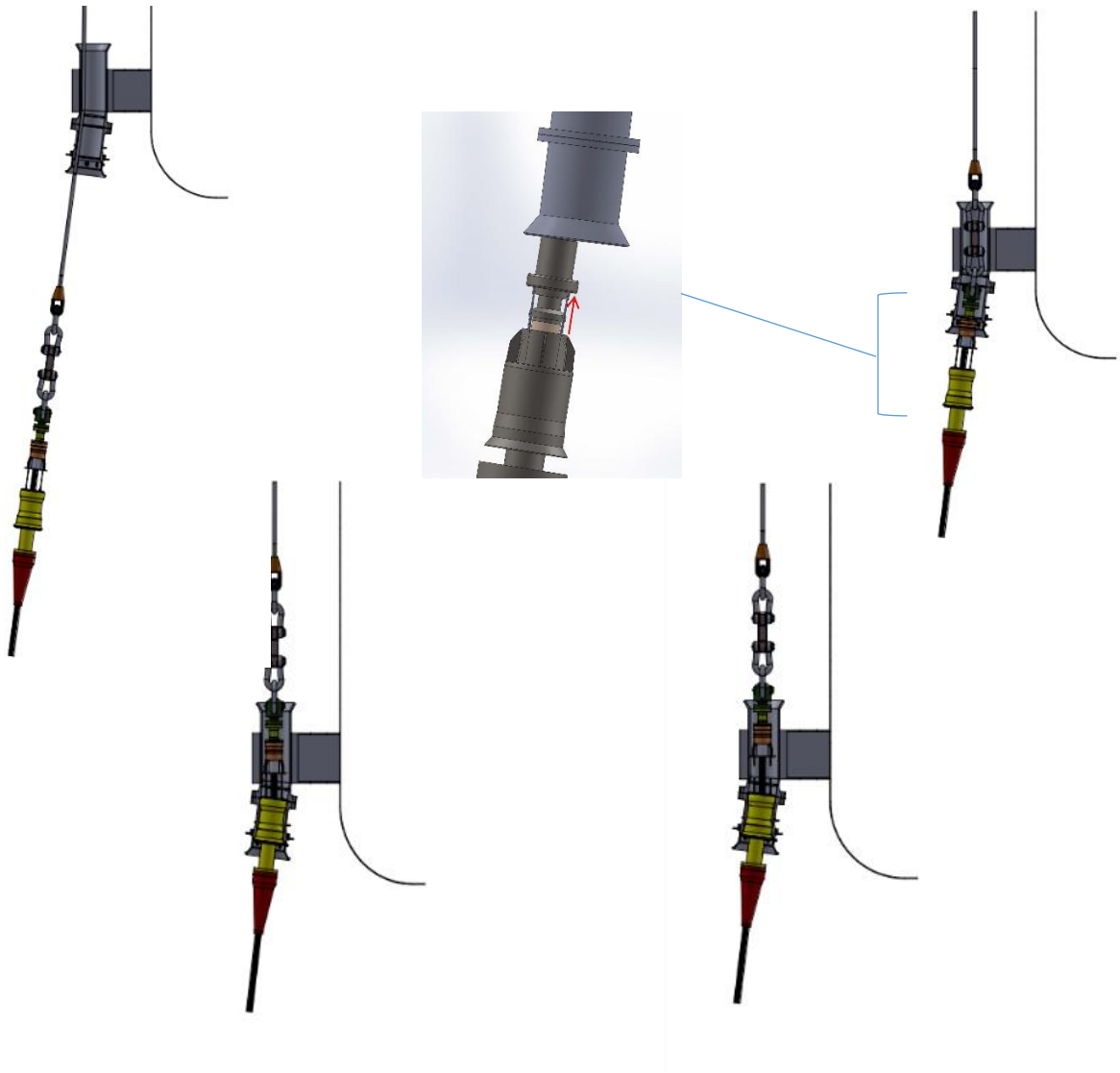


Figure 15: Pull-in of Flex. / Umb. Risers – Entry on Lower I-Tube

Stage 6 **(Figure 16 and**

- Figure 17)

- PULL-IN CLOSEOUT

(4) The main winch will continue to travel hauling the wire until the riser end fitting is raised above the upper I-Tube.

(5) The pull-in collar with broken fusible cables are then removed.

(6) The winch lowers the riser to align the end fitting at connection level and Pull-in team assembles the Hang-off Collar around the end fitting.

(7) The rigging team carries out the bolting of Hang-off Collar onto the I-Tube flange, until the riser is supported and completely anchored to the URB structure.

(8) Removal of Pull-in rigging.

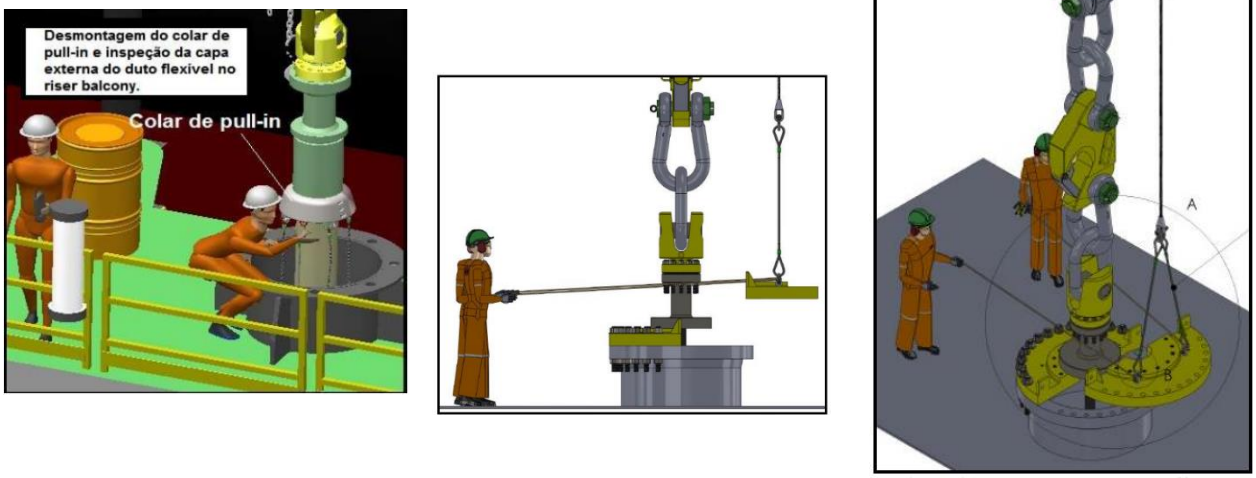
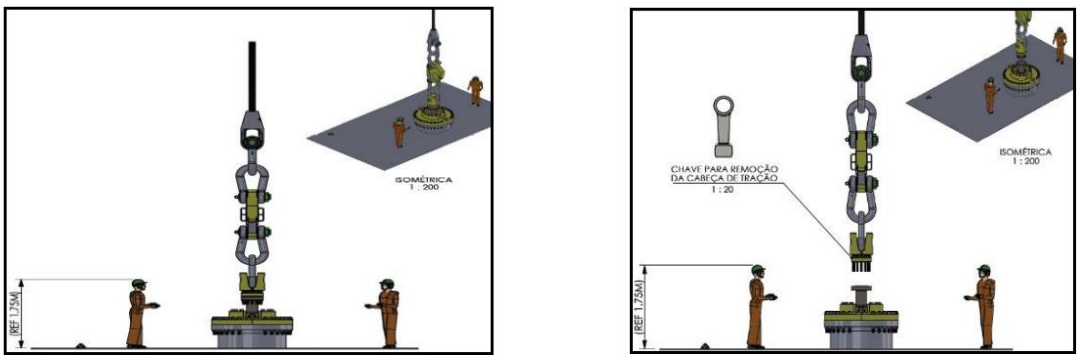


Figure 16: Flexible Riser Final Pulling and Hang-off



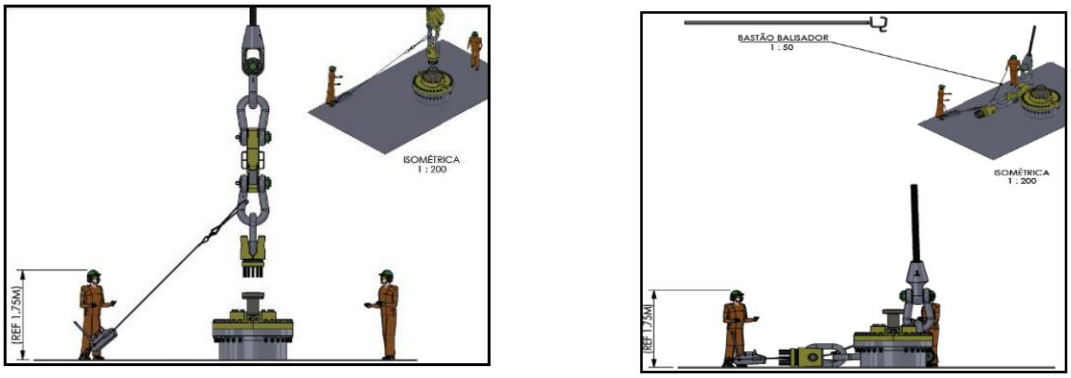


Figure 17: Removal of Riser Pull-in Rigging

16 ADDITIONAL PROVISIONS FOR OFFSHORE OPERATIONS IN RISER AREA

In this section, PETROBRAS outlines the relevant features required in riser balcony area for the riser installation activities to be carried out, as well as for inspection and maintenance of essential parts of riser / hull interfaces.

16.1 Other Structural Outfittings on Riser Balcony

SELLER shall design, fabricate, install and integrate the required outfittings on Riser Balcony and Hullside, not only for permanent structures related to hang-off and connection systems aforementioned, but also others that may be necessary to support all installation, inspection and maintenance activities, as follows.

16.1.1 Handling Outfittings on Lower Riser Balcony

The LRB shall be provided with the following ancillary features, required for inspection and maintenance activities with divers or work-class ROV:

- The underneath of the LRB shall be provided with four padeyes (WLL: 12 t) for each I-Tube/BSDL.
- The underneath of the LRB shall be provided with a handrail system in a closed pattern.
- Grab handles shall be provided on the LRB features, for each Lower I-Tube, positioned and sized in such a way that the inspection ROV arm can reach and keep taking hold of during the intervention.
    - **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.*

In addition, handrails, grab handles and small padeyes may be needed on the lower and upper gussets of LRB.

16.1.2 Handling Outfittings on Upper Riser Balcony

The URB structures shall be provided with padeyes or portable handling outfittings as applicable, for attachment of installation devices (wire pullers, snatch blocks, chain hoists etc.) to be used on the required handlings during installation phase, such as those related to Riser Pull-in/Pull-out activities and Riser-to-FPSO tie-ins.

- These features shall be established on the basis of mechanical handling studies on riser area, during detailed design.

In addition, handrails and small padeyes may be needed underneath of the URB LRB, to enhance access for IRATA inspectors.

16.2 Vertical Clearance for Pull-in

The Pull-in system and RPS shall be designed to make the maneuvers for riser lifting in the URB straightforward. On that sense, consideration must be given to the vertical clearance for the hauling of main wire socket at the last stage of Pull-in:

- to accommodate the Pull-in rigging at the maximum pulling elevation during riser installation, taking also into account an additional lifting (overpull) of flexible riser end-fitting, to remove the pulling collar (see Figure 16) before mounting the Hang-off Collar, the clear height for hauling main wire socket, measured from the flange of the upper I-Tube shall **not** be less than **8.5** meters. To meet this requirement, the following conditions shall apply:
- Headroom (see Figure 18) between the bottom elevation of main turndown sheave within sheave trolley, and the top (flange face) of the upper I-Tube shall be at least **8.5** meters.
- The hatches on both RPS and Sheave Trolley skid shall have clear openings exceeding the passage volume of the larger upper I-Tube section, to allow hauling the Pull-in / Transfer rigging through them.

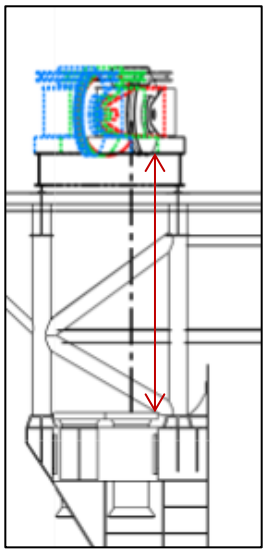


Figure 18: Vertical Clearance for final Pull-in Stages

Information about Pull-in riggings 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.

,

17 RISER INTEGRITY MONITORING

The main purpose of these systems is to provide operational information on the risers integrity during service life.

All Flexible Risers will require real time integrity monitoring:

(1) Optical Monitoring System (MODA) for tensile armor wires (see Ref. \12\ for the scope of supply / work).

- Further general information related to MODA are presented in Ref. \5\.

(2) Annulus pressure monitoring (see Ref. \13\ for the scope of supply / work).

18 HULLSIDE UMBILICALS FOR LRB INTERFACES

SELLER shall provide multipurpose hullside umbilicals, according to Standard Specifications I-ET Ref. \9\, for the circuits of hydraulic and electrical functions required for actuation of mechanisms (hydraulic actuators) and monitoring (RSMS) of diverless Bellmouths (BSDL-SI). (see sec. 6.2.1)

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

SELLER shall take special attention to the mechanical protection of tubing and electrical cable connections underneath the LRB for all these circuits (see Ref. \9\), against the severity of offshore environment (particularly wave and current loads and effects).

19 SUPPLEMENTARY SCOPE OF SUPPLY

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

19.1 Messenger Wire Ropes

SELLER shall provide messenger wire ropes of 19 mm (3/4 in) and/or 22 mm (7/8 in), L= 100 m, for each Riser-slot, 6x37 construction, EIPS, in steel core, galvanized, preformed, heavy duty lubrication, right regular lay, Flemish eyes with steel clamps pressed on both ends.

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

19.2 Complementary Hardware

SELLER shall provide, as loose items, kits of latch assembly (complete packages of moving parts: hydraulic actuators, latch bars, axis pins and springs etc.), as follows, as contingency for commissioning of BSDLs during construction:

For BSDL-SI 32-in	One spare kit of of latch assembly
For BSDL-SI 46-in	One spare kit of of latch assembly
For BSDL-SI 48-in	One spare kit of of latch assembly

(latch assembly – complete sets of moving parts)

20 VERIFICATION TESTING

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

20.1 Hydraulic Actuator System Test (BSDL)

SELLER shall perform underwater validation testing of the Hydraulic Actuator System for BSDL (see Figure 19) to verify its functionality, according to PETROBRAS specification Ref. \9\.

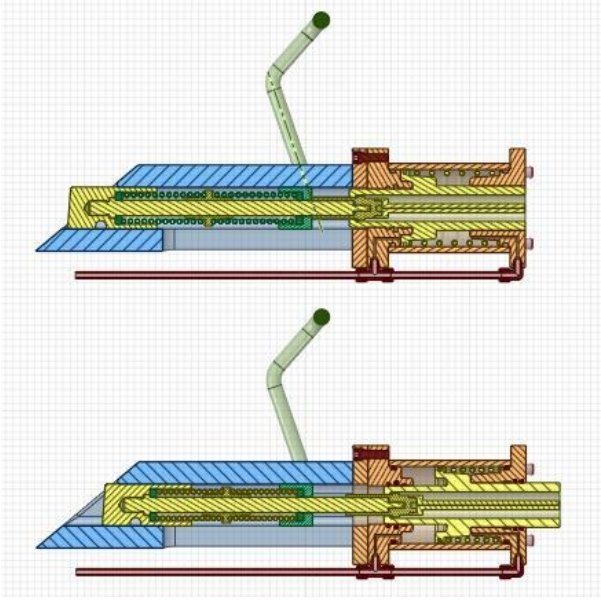


Figure 19: Hydraulic Actuator System and Locking Mechanism assembly (see Ref. \9\)

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.

APPENDIX A – RISER CONFIGURATION DATA

All information provided hereafter is preliminary and will be updated at the Notice to Proceed. Final input data for Riser Analysis will be provided in the issue for construction of doc. no. I-MD-3010.2Q-1500-940-P56-001, Ref. \1\.

The riser configurations herein informed consider the field WD, connection points beneath Lower Riser Balcony, and FPSO at full load draft. 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/m^3]
Production	Oil	990
Water/Gas Injection	Water	1080
Service	Diesel	850
Oil Importation	Oil	990
Gas Exportation	Gas	250
Oil Exportation	Oil	990

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

All flexible risers shall be considered in free-hanging configuration with top angle of 9 degrees. Tables A.2, A.3 present the riser compositions and mechanical properties to be considered for the analyses.

Table A.2 – Riser structures

Function	Structure	ID [mm]	OD [mm]	Internal Volume [l/m]	Dry Weight Empty [kgf/m]	Axial Stiffness [kN]	Bending Stiffness [kN.m^2]
PO 6" Top	NOV 152-9077	161.00	281.00	20.38	132.20	1.11E+06	188.00
PO 6" Bot	NOV 152-9078	161.00	401.00	20.38	177.00	1.10E+06	410.00
PO 8" Top	WSI 203.1555-RD-4253-6	200.00	345.00	35.59	194.42	1.44E+06	65.49
PO 8" Int	WSI 203.1556-DR-4042-6	200.00	347.00	35.59	186.74	1.16E+06	76.16

Function	Structure	ID [mm]	OD [mm]	Internal Volume [l/m]	Dry Weight Empty [kgf/m]	Axial Stiffness [kN]	Bending Stiffness [kN.m^2]
GL 4" Top	NOV 101-9061	101.60	209.16	9.10	85.30	8.28E+05	62.90
GL 4" Bot	NOV 101-9062	101.60	206.54	9.10	78.20	6.77E+05	60.40
GL 6" Top	TCH 15252974	157.00	314.12	19.38	211.80	1.83E+06	81.33
GL 6" Int	TCH 15253632	158.20	265.90	19.68	132.89	9.22E+05	38.68
GL 6" Bot	TCH 15253633	159.50	271.26	19.90	140.08	5.36E+05	41.15
IA 6" Top	NOV 152-9063	152.40	267.37	20.38	117.90	9.40E+05	162.90
IA 6" Bot	NOV 152-9064	152.40	248.97	20.69	106.50	6.94E+05	86.00
IA 8" Top	NOV 203-9066	214.00	336.00	35.99	183.30	1.44E+06	379.00
IA 8" Bot	NOV 203-9067	215.00	316.00	36.24	170.10	1.16E+06	203.00
ImpO 9,13" Top	WSI 232.1517-RD-4253-6	232.00	379.00	45.83	246.92	1.01E+06	158.88
ImpoO 9,13" Bot	WSI 232.1518-RD-4252-6	232.00	387.00	45.83	251.75	1.02E+06	180.9
EG / EO 11" Top	NOV 283-9082	282.70	447.66	70.21	308.10	1.92E+06	643
EG / EO 11" Bot	NOV 283-9083	282.70	461.63	70.21	293.70	1.95E+06	953.9
UEH	FDT-0606	-	163,80	-	50,80	4,80E+05	12,00

Table A.3 – Riser compositions

Riser	L [m]		
	Top Section	Intermediate Section	Bottom Section
PO6	500		1250
PO8	500		1250
GL4	400		1350
GL6	400	500	450
IA6	400		1350
IA8	400		1350
ImpO 9,13	500		1250
EG / EO 11	600		1150
UEH	500	500	500

Markup factors for the estimated flexible riser loads shall be as per I-ET-RISER TOP INTERFACE LOADS ANALYSIS except for the bending moments of umbilicals, for which the markup factor of 1.8 shall be applied.

Table A.4 present 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.4 – Bend-stiffener data

Riser	Bend-stiffener data				
	Db [mm]	Din [mm]	L [m]	d [m]	E [MPa]
PO6	1011.5	306.4	2.3	1.5	77.0
PO8	1311.0	370.4	3.1	1.5	77.0
GL4	661.5	234.6	1.4	1.5	77.0
GL6	1000.0	339.5	2.2	1.5	77.0
IA6	1011.5	292.8	2.4	1.5	77.0
IA8	1150.0	361.4	2.6	1.5	77.0
ImpO 9.13	1311.0	404.4	3.0	1.5	77.0
EG / EO 11	1311.0	473.1	2.8	1.5	77.0
UEH	600.0	189.2	2.2	1.2	210.0

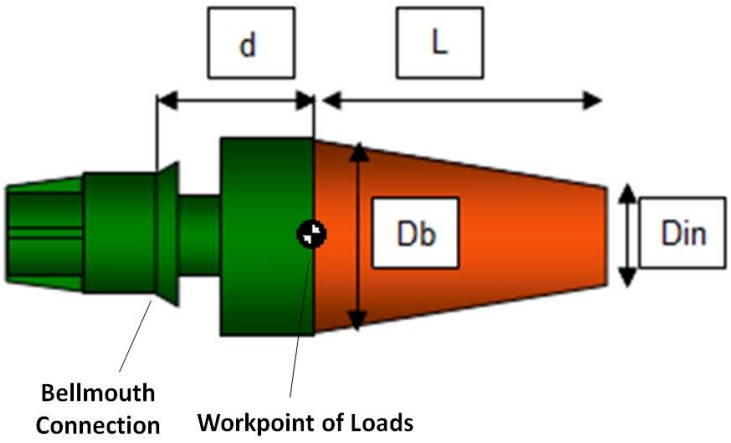


Figure A.1 – Bend-stiffener dimensions and workpoint