| PETROBRAS | TECHNICAL SPECIFICATION | Nº I-ET-3010.00-1300-279-PX9-001 |
|---|---|---|
| | CLIENT PETROBRAS | SHEET 1 of 105 |
| | JOB | |
| | AREA – | |
| SUB | TITLE **UNIFIED DIVERLESS SUPPORT TUBE (TSUDL) - GENERAL REQUIREMENTS** | ***PUBLIC*** SUB/ES/EDA/EAI |

## REVISION INDEX

| REV. | DESCRIPTION AND/OR REVISED SHEETS |
|---|---|
| 0 | Original This document is based on the previous technical specifications for TSUDL: *I-ET-3010.00-1519-140-P56-002_A, I-ET-3010.00-1519-140-P56-001_C, I-ET-3010.00-1300-279-PEK-002_0, I-ET-3010.00-1300-850-PEK-001_H and I-ET-3010.00-1300-850-PEK-002_F* |
| A | Minor changes in the references |
| B | Revised where marked |

**Note (*):** the following team has supported in the development of this Technical Specification:

- (BYE8) SUB/ES/EDA/EAI
- (DVHV) SUB/ES/EDA/EAI
- (B8WL) SUB/ES/EDA/EAI
- (FWN1) SUB/ES/EDA/EAI
- (FGWO) SUB/ES/EDA/EAI
- (CX4H) SUB/ES/EDA/EAI
- (CJLZ)) SUB/ES/EDA/EAI
- (EVJN) SUB/ES/EDA/EAI
- (QM63) SUB/ES/EDA/EAI
- (EVLB) SUB/ES/EDA/EAI
- (BERK) CENPES/PDIDP/ESUB/TDUT
- (CMC1) CENPES/PDIDP/ESUB/TDUT
- (C5E3) CENPES/PDIDP/ESUB/TECES
- (KZ04) CENPES/PDIDP/TIA/TMI
- (BW12) CENPES/PDIDP/TIA/TMI
- (ELYS) SRGE/ESUP/APS/ESC

| | REV. 0 | REV. A | REV. B | REV. C | REV. D | REV. E | REV. F | REV. G | REV. H |
|---|---|---|---|---|---|---|---|---|---|
| DATE | 28/03/2025 | 17/04/2025 | 15/09/2025 | | | | | | |
| DESIGN | EAI - **Note(*)** | EAI | EAI | | | | | | |
| EXECUTION | BYE8/DVHV | BYE8/DVHV | BYE8 | | | | | | |
| CHECK | U4B8/CX4H/ EVJN | U4B8/CX4H/ EVJN | DVHV | | | | | | |
| APPROVAL | NTHF | NTHF | NTHF | | | | | | |

# TABLE OF CONTENTS

## 1 SUBJECT

This document presents the Technical Specification and main parameters for the UNIFIED DIVERLESS SUPPORT TUBE (TSUDL). The document describes the requirements for design, manufacture, inspections and automation.

## 2 ABBREVIATION

| | |
|---|---|
| BSDL-SI | Diverless Bell Mouth - Standard Interface (Portuguese acronym) |
| CRA | Corrosion-Resistant Alloy |
| DL | Diverless |
| FAT | Factory Acceptance Test |
| FEA | Finite Elements Analysis |
| FPSO | Floating Production Storage and Offloading |
| FPU | Floating Production Unit |
| GA | General Assembly (Drawing) |
| HMI | Human Machine Interface |
| HOA | Hang Off Adaptor |
| HPU | Hydraulic Power Unit |
| ITP | Inspection and Test Plan |
| MTL | Lateral Locking Module (Portuguese acronym) |
| NDT | Non-Destructive Testing |
| PSL | Product Specification Level |
| PTFE | Polytetrafluoroethylene |
| PUPS | Portable Umbilical Pressurization System |
| QA | Quality Assurance |
| QAP | Quality Assurance Plan |
| QC | Quality Control |
| QHSE | Quality Health, Safety and Environment |
| ROV | Remotely Operated Vehicle |
| RTU | Remote Terminal Unit |
| SAK | A series of screw-type terminal blocks |
| SFC | Specific classification level |
| TiPT | Titanium Pullin Tube |
| TSUDL | Unified Diverless Support Tube (Portuguese acronym) |
| TRS | Test Report Sheet |
| XT | Xmas Trees |

## 3 REFERENCE DOCUMMENTS, CODES AND STANDARDS

This section lists standards and documents applicable to the design of the monitoring system:

### 3.1 International Standards and Patents

[1] API-RP 2A-WSD – Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design

[2] API 6A - Specification for Wellhead and Christmas Tree Equipment

[3] API 6X - Design Calculations for Pressure-containing Equipment

[4] API 17E – Specification for Subsea Umbilicals

[5] API 17F - Standard for Subsea Production Control Systems

[6] API RP 17G - Design and Operation of Subsea Production Systems

[7] API 17Q - Recommended Practice on Subsea Equipment Qualification

[8] API 2RD – Dynamic Risers for Floating Production Systems

[9] API RP 2X – Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Ultrasonic Technicians

[10] API 20F level BSL 2 – Corrosion Resistant Bolting for Use in the Petroleum and Natural Gas Industries

[11] ASTM A370 - Standard Tests Methods and Definitions for Mechanical Testing of Steel Products

[12] ASTM A517 - Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

[13] ASTM A578 - Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

[14] ASTM B841 - Standard Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits

[15] ASTM A703M - Standard Specification for Steel Castings, General Requirements, for Pressure Containing Parts

[16] ASTM A707M - Standard Specification for Forged Carbon and Alloy Steel Flanges for Low Temperature Service

[17] ASME B16.5:2013 - Standard Specification for Alloy-Steel and Stainless-Steel Bolting for Low-Temperature Service

[18] ASME B16.5:2013 - Pipe Flanges and Flanged Fittings

[19] ASME Section VIII, Division 1 - ASME Boiler & Pressure Vessel Code

[20] ASME Section VIII, Division 2 - ASME Boiler & Pressure Vessel Code

[21] ASME PCC 1-2010 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly

[22] DNVGL-RP-B401:2017 - Cathodic Protection Design

[23] DNV-RP-0034 - Steel forgings for subsea applications - technical requirements

[24] DNV-RP-B401 – Cathodic Protection Design

[25] DNV-RP-C203 – Fatigue Design of Offshore Steel Structures

[26] DNVGL-RP-C205 – Environmental Conditions and Environmental Loads

[27] IEC 60529 (latest revision) - Degrees of Protection Provided by Enclosures (IP Code)

[28] IEC 60079 (latest revision) - Explosive atmospheres

[29] ISO 13628-6:2006 - ISO 13628-6:2006

[30] EN ISO 13628-7 - Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems

[31] ISO 2859 - Sampling Procedures for Inspection by Attributes

[32] ISO 8501 - Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness

[33] ISO 8504 - Preparation of steel substrates before application of paints and related products – surface preparation methods

[34] ISO 9001 - Quality management systems – Requirements

[35] ISO 9712 - Non-destructive testing - Qualification and certification of NDT personnel

[36] ISO/IEC 17024 - Conformity assessment – General requirements for bodies operating certification of persons

[37] ISO/IEC 17020 - Conformity assessment – Requirements for the operation of various types of bodies performing inspection

[38] ISO GUIDE 65 - General Requirements for Bodies Operating Product Certification Systems

[39] ISO/IEC 17024 - Conformity assessment – General requirements for bodies operating certification of persons

[40] SSP-SP1 – Solvent Cleaning

[41] SSPC-SP10 - Near-White Metal Blast Cleaning

[42] AWS D1.1 – Structural Welding Code

[43] EN 473 - Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment

[44] BR 10 2021 017362-9 – Patent: “SISTEMA DE ATUAÇÃO HIDRÁULICA PARA BOCA DE SINO”

## 3.2 Petrobras Technical Specifications

[45] I-ET-3010.00-1300-279-PX9-002 – Diverless Bell Mouth Standard Interface Supply Specification

[46] I-ET-3000.00-1500-251-PEK-001 – High Strength Low-Allow Steel Fasteners for Subsea Applications

[47] I-ET-3010.00-1200-251-P4X-001 – Requirements for Bolting Materials

[48] I-ET-3010.00-1200-800-P4X-015 - Requirements for tubing and fitting (aligned to iogp-jip33 s-716)

[49] I-ET-3010.00-1519-140-PPC-001 - Wear Bushing for Unified Diverless Support Tubes

[50] I-ET-3010.00-1200-956-P4X-003 - Thermal Spray Coating Application of Aluminum

[51] I-ET-3010.00-1500-274-PLR-001 - Riser Top Interface Loads Analysis

[52] I-ET-3010.00-1200-970-P4X-003- Requirements for personnel qualification and certification

[53] I-ET-3010.00-1200-956-P4X-002 - General Painting

[54] I-ET-3000.00-1500-29B-PAZ-003 - 3/8" & 1/2” id hydraulic hoses

[55] I-ET-3000.00-1519-29B-PZ9-002 - Low voltage/signal electric cables and terminations for subsea umbilical systems

[56] I-ET-3000.00-1519-29B-PZ9-012 - Topside arrangement and interfaces with subsea umbilical systems

[57] I-ET-3010.00-5139-172-PX9-001 - Portable umbilical pressurization system (PUPS) – FPU scope

[58] I-ET-3010.00-5537-850-PEA-001 - Positioning and navigation system

[59] I-ET-3010.00-5267-750-P4X-001 – Technical Specification for Cathodic Protection

[60] I-ET-3010.00-1200-955-P4X-001 – Welding

## 3.3 Petrobras Additional Documents

[61] I-LI-3010.00-1300-270-P56-001 - Unified Diverless Support Tube Part List

## 3.4 Brazilian Documents

# 4 DEFINITIONS

| | |
|---|---|
| FPU CONTRACTOR/SELLER | The entity that is responsible for the Engineering Procurement, and Construction of the Floating Production Unit (FPU) as established in the contract of the FPU. |
| SUBCONTRACTOR | Company contracted by FPU CONTRACTOR/ SELLER, to supply the entire TSUDL subsystems or part of them. |
| INTEGRATOR | Company contracted by FPU CONTRACTOR/SELLER responsible for all SUBCONTRACTORS interfaces during design, supply, tests and commissioning (Subsea and Topside scopes). |
| MAY | It is used when alternatives are equally acceptable. |

| | |
|---|---|
| SHOULD | It is used when a provision is not mandatory, but is recommended as a good practice. |
| SHALL | It is used when a provision is mandatory. |
| DUMMY HOA | Mechanical part used to simulate the rigid riser top termination on FAT. |
| DUMMY CAP | Mechanical part used to simulate the flexible riser top termination on FAT. |
| PULL IN | Riser transfer operation from installation ship to the FPSO. |
| PULL OUT | Riser Removal Operation. |
| RISER | A length of flexible or rigid pipe used to connect the subsea collecting/exporting system to the FPSO. |
| RISER SUPPORT | General reference for lower balcony riser's support. Comprising BSDL-SI, TSUDL and Receptacle. |

# 5 TECHNICAL CARACTERISTICS

## 5.1 Overview

**5.1.1** TSUDL final design is FPU CONTRACTOR/SELLER responsibility. FPU CONTRACTOR/SELLER shall detail the concept, including and not restricted to: structural analysis, general geometric dimensioning and tolerance analysis, complete mechanical design including standards mechanical fixation elements (e.g. screws, bolts, nuts) and its quantities, surface coating thickness, cathodic protection design for moving parts, pre-selected materials, manufacturing process, or any other detailing issue for final manufacturing drawings.

**5.1.2** FPU CONTRACTOR/SELLER shall generate its own drawings, according to its design and manufacturing methodology, and shall submit them to PETROBRAS for review and approval.

**5.1.3** FPU CONTRACTOR/SELLER shall be attentive to the revision of the manufacturing drawings. Any questions, PETROBRAS shall be consulted.

**5.1.4** FPU CONTRACTOR/SELLER shall only start manufacturing the TSUDL after approval of manufacturing drawings by PETROBRAS.

**5.1.5** FPU CONTRACTOR/SELLER is responsible for defining an internationally accepted design code to guide the whole design. If any potential failure mode is not predicted on the selected code, complementary codes shall be established to fulfill this gap. Mixing of many design codes or requirements for different versions of the same code, shall be avoided. The design premises document shall clearly present the selected code for each failure mode.

**5.1.6** All data shall be reported in primarily SI units. Customary US units may also be indicated for reference only.

## 5.2 Design and Fabrication

**5.2.1** All subsea control components shall be designed in accordance with [4] and [5].

**5.2.2** All subsea equipment shall be qualified in accordance with [7] or [29].

**5.2.3** Selection of materials for all subsea structures shall be in accordance with [22] item 5.5 and be designed for the same design life as the riser.

**5.2.4** All enclosures and equipment to be placed in hazardous areas shall comply and be certificated according to [28].

**5.2.5** All enclosures with a required degree of ingress protection shall comply with [27].

**5.2.6** Electrical subsea connectors shall be wet-mate connectors designed, as a minimum, with the following requirements:

- Diver-mate solution
- Be housing made with stainless steel (AISI 316L)
- Be suitable for operation in the foreseen environment
- Have a double barrier solution to protect the electrical connections/pins
- Be able to withstand at least 100 connections/disconnection cycles
- Be qualified according to [5]
- Have a design life at least 25 years

FPU CONTRACTOR/SELLER shall present evidence for each of the aforementioned requirements.

**5.2.7** Optical subsea connectors shall be wet-mate connectors designed, as a minimum, with the following requirements:

- Diver-mate solution
- Be 8 (eight) or more-ways optical fiber cores, with fibers end face angled physical contact (APC)
- Be housing made with stainless steel (AISI 316L)
- Be suitable for operation in the foreseen environment
- Have a double barrier solution to protect the electrical connections/pins
- Be able to withstand at least 100 connections/disconnection cycles
- Be qualified according to [5]
- Have a design life at least 25 years

FPU CONTRACTOR/SELLER shall present evidence for each of the aforementioned requirements.

**5.2.8** The Hydraulic fluid shall be water-glycol based hydraulic control fluid, with cleanliness class according to Norm ISO 4406 CLASS 17/15/12. (Equivalent to class 6 from the old Norm NAS1638 Cleanliness Requirements used in Hydraulic Systems). The following water-glycol based hydraulic fluids are allowed:

- Castrol Transaqua HT (Compatible with Castrol Transaqua DW)
- MacDermid Oceanic ECF (Compatible with MacDermid HW443 & HW525P)

**5.2.9** The design of the hydraulic components and any other component that is in touch with the hydraulic control fluid shall be fully compatible with 5.2.8.

**5.2.10** The design shall consider the following requirements, otherwise noted on their specific sections:

- Hydraulic Maximum operating pressure (Design Pressure): 5000 psi
- Hydraulic Test Pressure: 5500 psi
- External Environment: Sea Water

- Maximum sea water temperature: 30 °C
- Minimum sea water temperature: 20 °C
- Operational life: 30 years
- Design locking cycles: 100
- Maximum external pressure: 40 m water column

## 6 TSUDL DESIGN REQUIREMENTSSystem Overview

**6.1.1** The Unified Diverless Support Tube (TSUDL), illustrated on Figure 1 is a riser support system that can be used for either a rigid or a flexible riser. The design shall allow pull-in operations with minimal diver assistance. Figure 2 illustrates TSUDL for a rigid riser system and flexible riser, respectively.

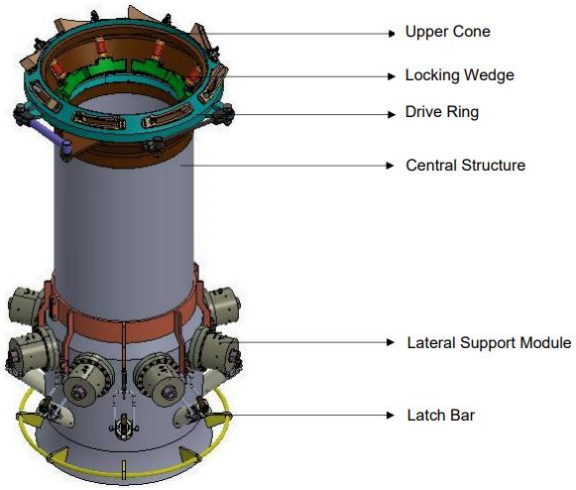



Figure 1: Unified Diverless Support Tube Assembly

(a) (b)

Figure 2: TSUDL main parts for (a) rigid risers and (b) flexible risers

**6.1.2** The scope of this document covers not only the TSUDL manufacture, but also all

the monitoring system and its infrastructure.

**6.1.3** FPU CONTRACTOR/SELLER shall provide a 3D analysis to demonstrate that there is no clashing or interference caused by the supports, bilge plates and shellside plates in the lower riser balcony. If any clashing is identified along FPU CONTRACTOR/SELLER analysis, a detailed report, including recommended corrections shall be submitted to PETROBRAS for review and approval.

**6.1.4** The verification of 6.1.3 is critical for the system and its verification shall be carried out in the engineering phase, integrated into the 30% Design Review of the FPSO.

**6.1.5** Updated Basic revision of [61] will be issued by PETROBRAS in notice to proceed.

## 6.2 Upper Cone

**6.2.1** The Upper Cone is a component with mechanisms for locking the rigid riser top termination and supporting the riser top tension, connected to the Central Structure.

**6.2.2** The Locking Wedge is a forged sliding component responsible for supporting the rigid riser's weight. During both pull-in and pull-out operations, its retraction is primarily driven by the rotation of the Drive Ring, which engages the wedge mechanism. In pull-in, this allows the Hang-Off Adaptor to pass through, while in pull-out, it enables riser release. Once the actuation pressure is released, the wedge returns to its load-bearing position due to gravity and spring force.

**6.2.3** The Drive Ring is a rotating component, connected to the top of the upper cone, providing an automatic and simultaneous retraction of all Locking Wedges.

**6.2.4** The design requirements applicable for the Upper Cone shall include, but not be limited to the following:

- The Upper Cone design shall be configured to allow a welded connection with the Central Structure.
- The Upper Cone shall be designed to support the full range of loads imposed by the risers throughout the design life without replacement.
- The Upper Cone shall transfer all loads and moments at their maximum design limits without gross yielding, buckling or failing during the specified product life.
- Offshore installation aids (guides) shall be designed to facilitate the installation of the hang-off system during offshore installation.
- If the fatigue assessment on Structural Calculation considers a post weld heat treatment, this procedure shall be documented as outlined on 15.5.2.

**6.2.5** The Upper Cone internal profile and overall length shall be in accordance with the reference design selected standard HOA type as per [61].

**6.2.6** As a minimum, the Upper Cone shall be designed to meet the functional characteristics outlined below:

- Upper Cone shall be inherently fail-safe. If there is a complete failure of the Upper Cone parts, the HOA shall not detach from the TSUDL, preventing the loss of the riser.

- The Upper Cone shall have a temporary protection system to safeguard all components of locking system during shipyard construction, and to keep installed during operational phase of FPSO and pull-in operation as illustrated in Figure 3.

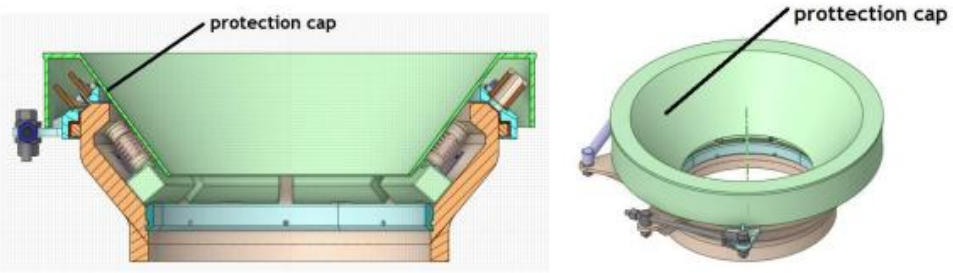



Figure 3: Protection Cap General Concept

- Protection cap shall have rigging passage and be diverless retrievable during pull-in operation. Its format shall be designed considering pull in cable accessories access.
- Protection Cap shall be designed in a bipartite structure to allow its removal after hook passage.
- Protection Cap shall be designed to have free access for cleaning procedures for the cam, top cone sliding wedges, shafts, wedge springs.
- Protection Cap shall be designed to resist slamming loads (as defined by Section 7.6.4), impact loads from pull in hooks and environmental loads including waves and currents during shipyard construction phase, transit and FPU final installation site. Protection Cap design report shall be submitted to PETROBRAS for review and approval.
- Protection Cap shall be designed to have eye bolts for handling hoist.
- Protection Cap shall be manufactured with anti-fouling coating to prevent marine growth.
- The design shall consider an unlock mechanism to allow a diverless pull-out primary by a hydraulic cylinder operated by the FPSO topside, with secondary operation by ROV (see “Upper Cone Mechanism” on [61]).
- Upper Cone hydraulic cylinder is a double action hydraulic actuator installed on TSUDL as shown on Figure 4 that provide means for remote control to unlock the TSUDL during diverless pull-out operation.
- Upper Cone hydraulic actuator is responsible primarily for retracting locking wedges, usually on pull-out or preparation for pull-in. Pull-out operation does require hydraulic actuation since locking wedges device operates mechanically and automatically by hang off adaptor direct contact and movement.
- Upper Cone hydraulic actuator shall have triple redundancy devices against unintentional activation due to hydrostatic pressure of remaining fluid on umbilical. Triple redundancy may be achieved by spring, dual pilot operated valve, check valve, a special locking device inside actuator.

- On pull-in operations, prior to Hang off adaptor connection, it is expected to have contact between the FPSO pull-in wire rope with the Upper Cone, which the main contact surface shall be the Wear Bushings. At this moment, the locking wedges must be designed to properly retract due to cable contact, while the guide rails provide an addition support to withstand any lateral forces that may occur on this process. The Locking Wedge's design may be optimized to reduce the lateral forces (e.g. chamfer, fillets), which area reduction shall be validated on Structural Calculation (See 7.6) for a proper rigid riser weight bearing.
- ROV mode of operation is also available by screw rod device as shown in Figure 4

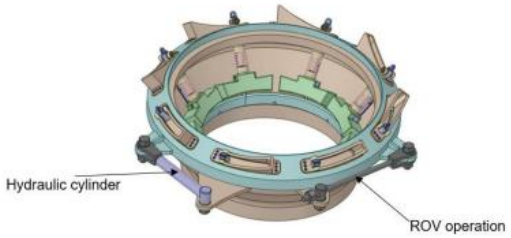



Figure 4: Upper Cone Assembly

**6.2.7** Upper Cone should be designed based on the requirements described on 5.2.10.

**6.2.8** Hydraulic Control fluid shall comply with 5.2.8.

**6.2.9** Detailed design shall define whether Upper Cone Hydraulic cylinder components will be subjected to cathodic protection. Any component not cathodic protected shall be selected from the following corrosion resistance alloys: UNS S31266 and/or UNS C17200.

**6.2.10** Minimum spring force: 2x rod hydraulic force due to pressure produced by hydrostatic column in umbilical considering 30 m and fluid density (see 5.2.8).

**6.2.11** Spring material shall be made of CuBe2 according to EN 12166 and shall be electrical insulated from the cathodic protection.

**6.2.1** Sealing shall be fully compatible with all water glycol based hydraulic (see 5.2.8).

**6.2.2** Minimum hydraulic cylinder force shall be limited to 20 kN. Note: this limit is defined to prevent unintentional unlocking wedges and consequent riser release, and it is a preliminary value based on the feed design. This value shall be reassessed according to the structural calculation required on 7.6

**6.2.3** Stress analysis shall be performed, and allowable stress shall be considered according to [3].

**6.2.4** Hydraulic actuator manufacturing, quality control, storing and shipping shall comply with [2] considering PSL 3.

**6.2.5** Performance requirements level PR2 shall be fulfilled.

**6.2.6** Manufacturing and quality control databook shall be issued including full traceability of materials used. Each hydraulic actuator shall be low stress stamped with serial number linked with tests and material certificates.

**6.2.7** Upper Cone shall include visual wedge position indicators to enable subsea inspection to assure that wedges are in operation position. Wedge position indicators may be done by wedge shaft.

## 6.3 Central Structure

**6.3.1** The Central Structure is a main cylindrical structural part that integrates all other TSUDL subcomponents for riser connection: Upper Cone is welded on the upper part while latch bars and lateral support modules on the lower part.

**6.3.2** The design requirements applicable to the Central Structure shall include, but not be limited to:

- The Central Structure design shall be configured to be welded onto SPU hull porches during hull fabrication.
- The Central Structure shall be designed to support the full range of loads imposed by the risers throughout the design life without replacement.
- The Central Structure shall transfer all loads and moments at their maximum design limits without gross yielding, buckling or failing during the specified product life.
- The Central Structure shall incorporate any features needed for handling during assembly into SPU hull.

## 6.4 Lateral Support Module (MTL)

**6.4.1** The MTL is a sub-assembly responsible for providing lateral stabilization of the top riser's termination, in which the riser searing effort will be transmitted, which together with the reaction loads at the Upper Cone, will provide equilibrium forces to support the bending moments from the riser.

**6.4.2** MTL is completely illustrated in [61]. MTL should be actuated after riser hang off adaptor is already seated on top cone.

**6.4.3** The MTL comprises 8 radially arranged assemblies as show in [61], including components that move towards hang off adaptor surface at pull-in's final stage driven by hydraulic cylinders and keep its position to prevent Hang Off adaptor movement inside TSUDL. The MTL moving parts shall be stopped as soon as contact with HOA is initiated, in any position inside TSUDL, since MTL shall not force Hang Off adaptor to be centralized. Once in contact, however, MTL shall support riser loads and keep its position even without hydraulic pressure. Besides hydraulic actuation mode, MTL shall be capable to be actuated by ROV as well.

**6.4.4** MTL components shall be retractable by both hydraulic pressure and ROV actuation to release HOA and clear TSUDL inner space for pull-out operation.

**6.4.5** Alternative MTL designs may be proposed during project design endorsement process subject to PETROBRAS approval based on fulfilling the functional and design requirements, track record and qualification reports.

**6.4.6** The MTL assembly shall have the following functional requirements:

- Primary operation mode shall be based on hydraulic actuation for locking and unlocking.

- Secondary operation mode shall be compatible with ROV for locking and unlocking.
- Stroke visual indication shall be provided.
- MTL materials shall be selected considering biofouling prevention, crevice corrosion, cathodic protection detrimental effects as calcareous layer and hydrogen induced stress cracking.
- MTL shall be capable of performing at least five locking and unlocking operations.
- MTL design shall comply with international recognized standards.
- MTL locking components shall be able to support operation loads without transferring to hydraulic components such as piston and cylinder tube.
- Hydraulic actuator shall have springs to avoid unintentional movement of MTL components during pulling considering 30 m hydrostatic column from lower balcony to main deck.
- MTL design shall have enough clear space and reaction plates for torque tools as [61].
- Fitting sealings type shall comply with ISO 8434-2 (JIC 37) standard.

**6.4.7** As minimum, the MTL shall be designed to meet the functional characteristics outlined below:

- Maximum Gap: 15 mm (defined as difference between minimum hang off adaptor diameter and maximum TSUDL diameter).
- Design Loads: Individual MTL load in mechanical mode is the highest value between accidental and extreme conditions. MTL's head and MTL assembly in hydraulic mode of operation load requirement is extreme load condition.
- MTL shall be designed based on 5.2.10, except the maximum sea water temperature shall be 29,25 °C; minimum sea water temperature shall be 20,76°C; and design locking and unlocking cycles shall be 5.
- Hydraulic Control fluid shall be based on 5.2.8.
- MTL surfaces with sealing or locking components continuously exposed to seawater like 22-piston, 20-mandrel, 30-load ring liner, 21-mandrel nut as show in Figure 5 shall be electrically insulated from TSUDL cathodic protection as a mean to activate cooper-based alloys biofouling inhibition as well as preventing calcareous layer formation. Electrical isolation is performed by wear rings, isolating rings and liners coatings.

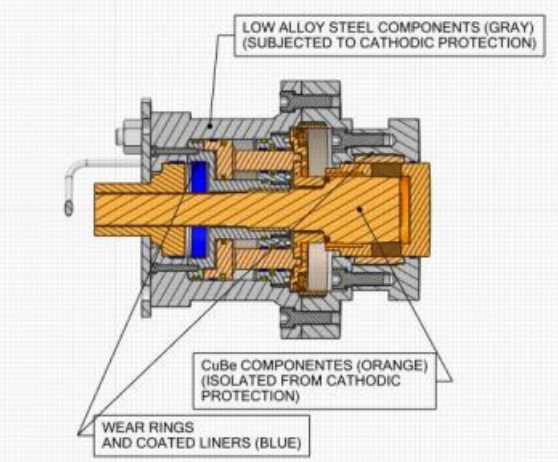



Figure 5: MTL Cathodic Protected Components (gray) and isolated Components (orange)

- MTL design shall be compatible with cathodic protection connection after pulling operation due to contact between MTL components and HOA.
- Corrosion resistance alloys shall be selected to MTL components due to cathodic protection insulation.
- Fasteners material shall comply with [61].
- Wedge locking washers shall be used to prevent loosening of bolts.
- Minimal Spring force: 2.5x rod hydraulic force due to pressure produced as a result of hydrostatic column in umbilical considering 20 m and fluid density.
- Support components displacement.
- Minimum preload shall be analyzed.
- Nominal material dimensions may normally be assumed, but the effect of tolerances and corrosion/erosion shall be included when their effect is significant.
- The effect of varying friction coefficients should be analyzed when applicable.
- Buckling should be analyzed if applicable.

**6.4.8** MTL shall have at least five modes of operation:

**6.4.9** Hydraulic Actuation mode for HOA locking at pull-in operation.

6.4.9.1 Hydraulic fluid flows through LOCK LINE (ref [61]) into cylinder advance chamber while unlocks check valve at RELEASING LINE by pressurizing PILOT LINE. Cylinder advance chamber consists of the inner space inside parts 32 (cylinder external tube), 16 (cylinder internal tube) and 22 (piston). Cylinder chamber is pressurized in order to move the following part towards hang of adaptor: 21(nut); 20(mandrel); 22 (piston); 17 (drive ring); 24 (spring holder); 11 (cage); 3 (shoes).

6.4.9.2 The moving parts mentioned (21, 20, 22, 17, 24, 11 and 3) will be stopped when reaching hang off adaptor at any position in stroke (max 15 mm). After component 11 (cage) stops by reaching HOA, 20 (mandrel) is forced to keep moving towards 11 (cage) and resulting in 3 (shoes) moving outwards by tapered surface sliding inside inner 3 (shoes) surface. Lower taper angle, 2.86° (1/20 in radius), provides self-holding feature to mechanism.

**6.4.10** Hydraulic Actuation Mode for MTL retract and HOA unlocking at pull in operation

6.4.10.1 Hydraulic fluid is pressurized into cylinder retract inlet to do opposite movements as described in 6.4.9.

**6.4.11** ROV Actuation Mode for HOA locking at pull-in operation

6.4.11.1 Check valve at release line shall be opened by pressurizing LOCK LINE shall be opened by pressurizing LOCK LINE prior to ROV locking operation. ROV hydraulic torque wrench (see for reference RSL14h308) is positioned over 21 (nut). Torque reaction pins (5) are placed on 32 (cylinder) external tube to provide anti-rotation support for torque wrench.

6.4.11.2 Rotating 21 (nut) clockwise will drive the following components towards HOA: 20 (mandrel); 22 (piston); 17 (drive ring); 24 (spring holder); 11 (cage); 3 (shoes).

6.4.11.3 When reaching HOA the same way as described in 6.4.9.2 the 11 (cage) will stop moving, but 20 (mandrel) will keep moving and 3 (shoes) will be forced over 29 (load ring).

6.4.11.4 ROV mode of operation may be used as back up mode of operation in the case of hydraulic actuation failure.

**6.4.12** ROV Actuation mode for HOA releasing at pull-out operation

6.4.12.1 Check valve at LOCK LINE shall be opened by pressurizing release line prior to ROV locking operation. Rotating 21 (nut) counterclockwise will retract the same components as described in 6.4.11.2.

**6.4.13** For MTL material selections:

6.4.13.1 Bio fouling preventing shall be considered in MTL materials selection mainly in space surrounded by 29 (load ring), 8 (cage), 3 (shoes) and 9 (mandrel) since marine growth at locking surfaces will affect MTL load capacity and its functionality. To account for marine growth prevention PETROBRAS establishes the following material to be used in 29 (load ring), 11 (cage) and 20 (mandrel): ASTM B570 – UNS No C17200 (CuBe).

6.4.13.2 Copper based alloys anti-fouling features can only be achieved without cathodic protection. For that reason, as electrical isolating component is placed as shown in Figure 6.

6.4.13.3 Slotted disk spring (25) shall be designed to prevent unintentional MTL actuation due to hydrostatic head considering umbilical 30 m from lower balcony to FPSO deck level. Anti-fouling material shall be selected for spring so that CuBe is required also for spring.

6.4.13.4 Slotted disk spring (9) shall be designed to assure that mandrel moves along with cage and shoes in approaching stage instead of mandrel moving inside cage and locking shoes before cage reaches hang off adaptor.

**6.4.14** FPU CONTRACTOR/SELLER shall provide detailed design for MTL FEED studies.

**6.4.15** Hydraulic Actuator manufacturing, quality control, storing and shipping shall comply with [2] considering PSL 3.

**6.4.16** Performance requirements level PR2 shall be fulfilled.

**6.4.17** The scope of supply includes procurement, construction, assembly, FAT of MTLs and two units of hydraulic torque wrench as specified in the detailed design (See [61] for type example).

**6.4.18** Manufacturing and quality control databook shall be issued including full traceability of materials used. Each hydraulic actuator shall be low stress stamped with Serial Number linked with tests and material certificates.

**6.4.19** MTL design and test conditions shall follow 5.2.8 and 5.2.10 (except locking cycles). Additionally, MTL testing shall consider the maximum external pressure of 20 m water column.

**6.4.20** Each MTL shall be tested according to detailed design criteria.

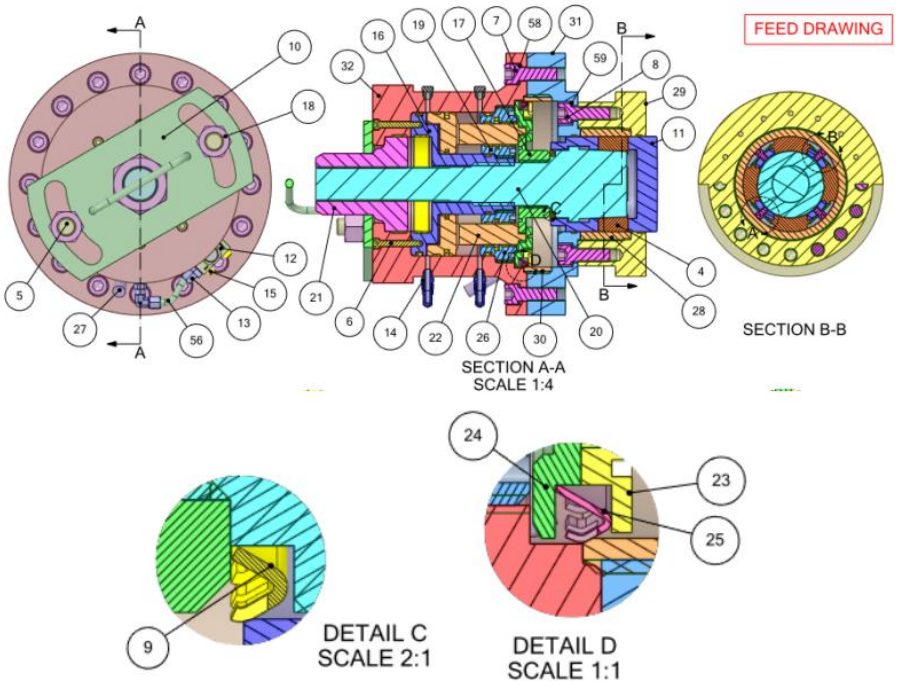



Figure 6: MTL Assembly Drawing

## 6.5 Latch Bar Mechanism

**6.5.1** The latch bar is a sliding component used to lock and secure Cap DL-SI on TSUDL for flexible riser connection.

**6.5.2** The Latch Bar Mechanism shall be designed to support the full range of loads imposed by the flexible risers throughout the design life without replacement.

**6.5.3** The latch bar mechanism shall be in accordance with the reference Cap DL design

as [61].

**6.5.4** As a minimum, the latch bar mechanism shall be designed to meet the functional characteristics outlined below:

- Cap DL bearing shall be inherently fail-safe. If there is a complete failure of the latch bars parts, the Cap DL shall not detach from the TSUDL, preventing the loss of the flexible riser's Bend Stiffener.
- The FEED design considers an automatic mechanism for pull-in operation, without assistance of any diving or ROV operations.
- During the pull-out operations, the feed design considered an unlock mechanism with a handler, which has been optimized for diving operations. To perform a diverless pull-out operation, the final design shall consider an optimized ROV interface, as the preliminary conceptual drawing shown on Figure 7.

Figure 7: Latch Bar Mechanism

**6.5.5** FPU CONTRACTOR/SELLER shall not machine the latch bars to force the contact with the dummy cap. The shape and angles of the latch bars shall not be changed from the dimensions and tolerances shown in the manufacturing drawings approved by FPU CONTRACTOR/SELLER.

**6.5.6** Hydraulic Actuator Assembly for the Latch Bar

**6.5.6.1** The hydraulic actuator is responsible primarily for diverless unlocking mechanism of the flexible line bend stiffener during pull-out operation.

6.5.6.2 The scope of hydraulic actuator assembly is shown in Figure 8. The left figure presents the external view while the right one shows internal parts. Red parts represent the hydraulic actuator components, and the blue parts are part of the latch bar design.

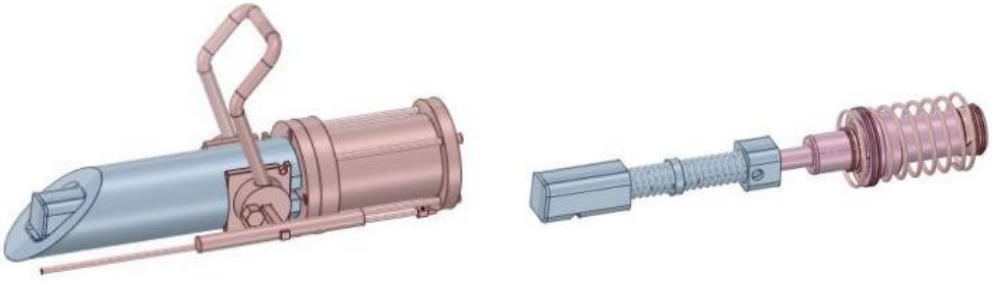


Figure 8: Scope of latch bar (blue) x scope of hydraulic actuation system (red)

6.5.6.3 Drawing ref [61] presents conceptual hydraulic actuator assembly and establishes detailed scope separation between the latch bar and hydraulic actuator.

6.5.6.4 Detailed design for actuators and tubing lines shall be submitted to PETROBRAS approval prior to start of hydraulic system component production. Technical requirements described in the following paragraphs shall be fulfilled as a minimum.

6.5.6.5 As a minimum design documentation shall comprise assembly and component drawings with dimensional and tolerances, stress analysis and material description.

6.5.6.6 Stress analysis shall be performed, and allowable stress shall be considered based on [3].

6.5.6.7 Refer to Hydraulic Pressure tests in HYDRAULIC PRESSURE TESTS.

6.5.6.8 Hydraulic Actuator design shall be compatible with 3 (three) modes of operation, where 1 (one) is for pull-in and 2 (two) are for pull-out operations:

- Mechanical Automatic Latching (Pull-in)

This is the primary mode of operation during pull-in activities and its latching/unlatching function is independent of hydraulic actuation. The latch bar internal components provide all the necessary functionality for pull-in operation. Handler remains at same position while latching bar moves towards inside by compressing the springs as shown in Figure 9. Driving force for the latch bar retraction is done by Cap DL ([61]) upwards movements during pull-in operation.

Return of latching bar is performed by spring force after Cap DL reaches a level with reduced section releasing space for latching.

Actuator design shall have drilled rod to allow free movement of latch mechanism axis as shown in Figure 9 in yellow.

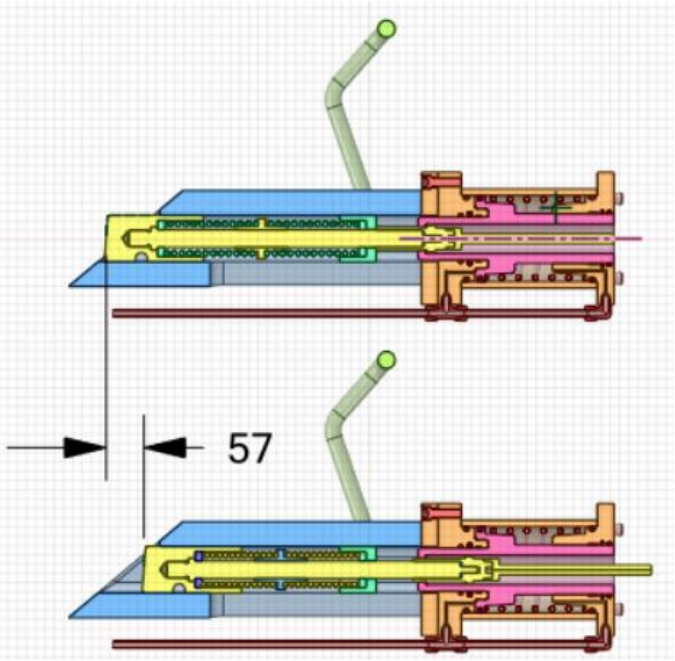



Figure 9: Mechanical Automatic Latching During Pull-in

- Manual Override Mode Diver Operation (Pull-out)

Latch bar retraction may be performed by handler movement operated by diver for pull-out activities. During override the internal components highlighted in yellow in Figure 10, Figure 11 and Figure 12 moves on right direction driven by eccentric/sliding plate mechanism.

Two types of handlers shall be designed to perform override operation:

- In plane detachable handler is used initiate rotation until 45°.
- Lateral detachable handler is used to complete 180°.

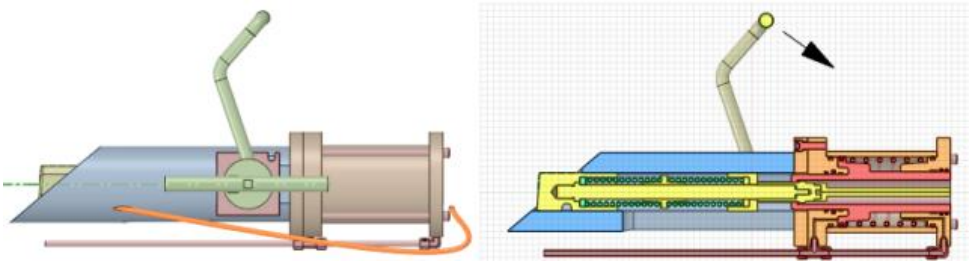


Figure 10: Manual Override Diver Operated for pull out activities

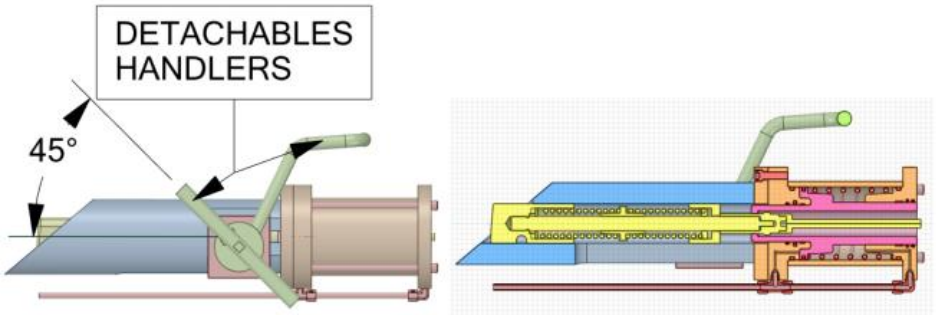



Figure 11: Detachable in plane handler restricted rotation movement

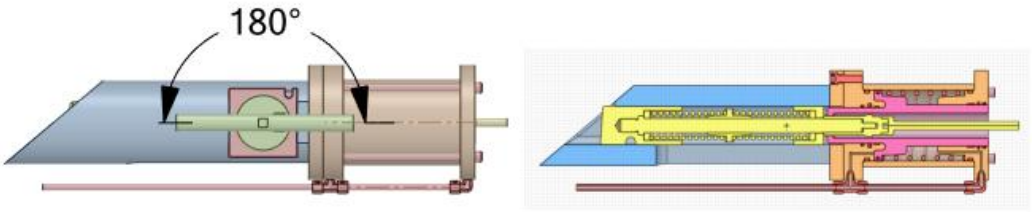



Figure 12: 180° rotation performed by lateral detachable handler

Note that in override mode of operation none of the springs are compressed, since the whole assembly is moved as shown in the previous figure. Internal moving parts are highlighted in yellow.

Hydraulic actuator piston rod and internal cap shall leave enough space for latch bar reaction block stroke, 57 mm, during override operation. [61] shall be consulted for latch bar assembly dimensions to be considered in hydraulic actuator design.

- Hydraulic Remote Control Diverless Operation (Pull-out)

Latch bar single action hydraulic cylinders with spring return shall be designed for regenerative hydraulic circuit. Only one tubing line is used for all cylinders at each latch bar.

During pull-in operation the hydraulic actuator is aligned to HPU atmospheric pressure tanks the only remaining pressure acting over hydraulic actuator is due to 20 m hydrostatic column and its FPSO dynamic effects from lower riser balcony to FPSO deck as shown in Figure 13.

Hydraulic actuator is pressurized by FPSO valves to retract latch bars during pull-out operation an allowing bend stiffener downwards movement (see Figure 13).

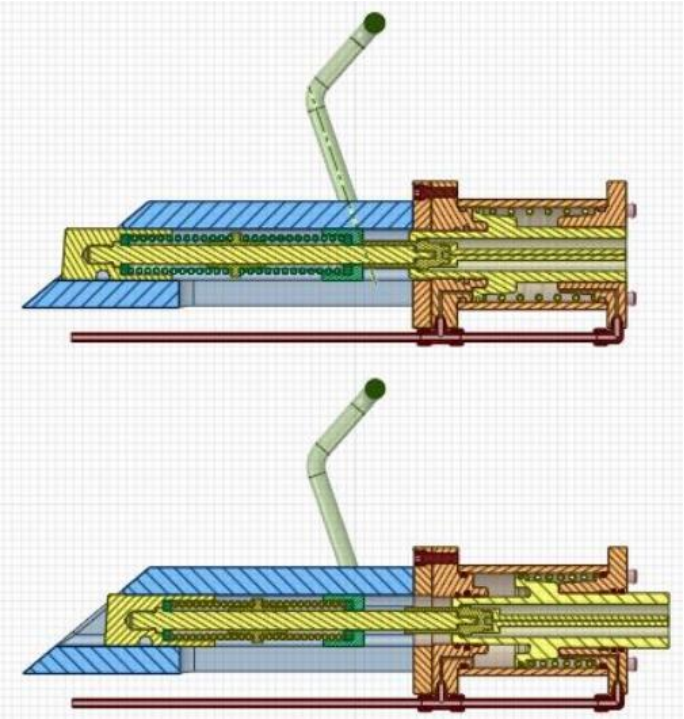


Figure 13: Hydraulic Actuation

6.5.6.9 Actuator Interface and Material Requirements:

6.5.6.9.1 Bolting

Hydraulic actuator shall be hold to round blocks by four ½ inch socket heads bolts. Wedge locking washers shall be used to prevent loosen bolts.

A mounting plate may be used to fix hydraulic actuator in the round block.

Bolt materials, including tie rods, shall comply with [46] if selected low alloy steel if selected corrosion resistant alloy ASTM A453 Gr.660D and electrical connected to the cathodic protection.

6.5.6.9.2 Selection of materials (other than bolting) and cathodic protection and Subsea hydraulic actuator and tubings shall be compatible with sea water environment and a combination of cathodic protection and use of corrosion resistance alloys are required as described in the following paragraphs.

6.5.6.9.3 3 (three) regions of round block and hydraulic actuator shall be considered for cathodic protection:

- Moving parts highlighted in yellow in Figure 14 shall be protected by cathodic protection connected to round block by copper cable shown in Figure 15. Handlers also shall be connected by another copper cable to round block.

- Hydraulic actuator piston rod shall be made as a single part of corrosion resistant alloy due to long time sea water exposure and need to keep sealing dimensions. Also, calcareous deposit under cathodic protection in sea water environment needs to be prevented and its possible harmful effects in rod surface and possible sealing failure. So, hydraulic actuator piston rod shall be insulated from cathodic protection by internal wear rings, insulating internal bush and gaps shown in [61]. Additionally, resistance to biofouling needs to be considered and copper alloys are required to combine sea water and biofouling resistance. Beryllium-copper, UNS 17200 shall be considered for hydraulic actuator rod.
- Stationary parts like actuator tube and caps are connected to round blocks thus are subjected to cathodic protection. Hydraulic actuator tube and caps may use either CRA alloys or low alloy steels with external painting and internal hard coated in sliding surfaces provided that a numerical cathodic protection model (FEA type) using recognized software has been performed to show that regions like gaps between internal cap and rod will not be affected by calcareous deposit.

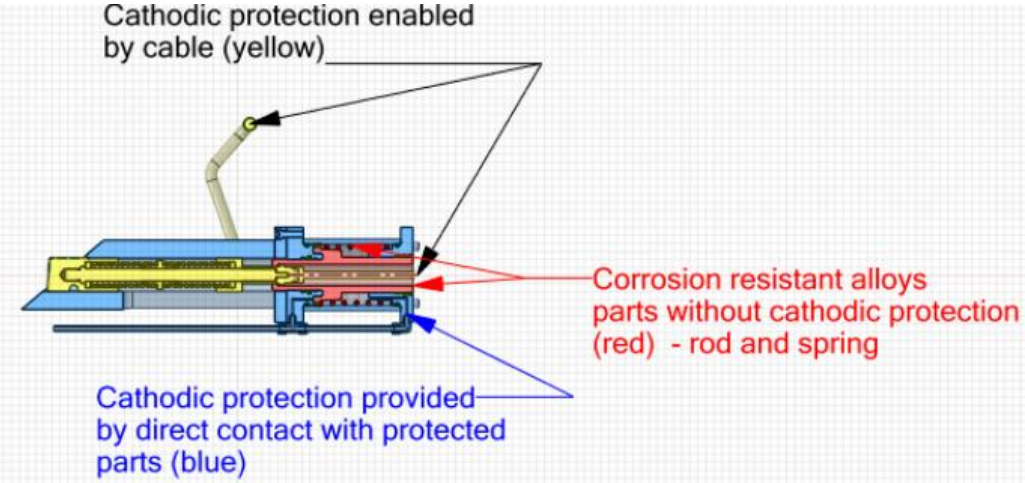



Figure 14: Corrosion Resistance and Cathodic Protection

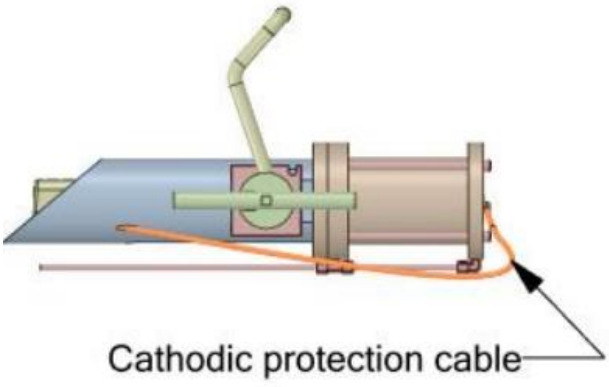



Figure 15: Cathodic Protection Cable

6.5.6.9.4 Hydraulic actuator spring shall be made of copper-beryllium alloy designation CuBe2 according to EN 12166 and shall be electrical insulated from

cathodic protection. Any changes in the hydraulic actuator spring materials shall be submitted to PETROBRAS for review and approval.

6.5.6.9.5 Hydraulic actuator length shall be limited to 300 mm or 357 mm considering piston rod end of stroke.

6.5.6.9.6 Fitting sealings type shall comply with ISO 8434-2 (JIC 37) standard when applied at forged blocks or at main equipment components. Fitting sealings type shall comply with Medium Pressure standard as defined in [56] between tubing connections.

6.5.6.9.7 Allowable working pressures shall be calculated according to ASME B31.3.

6.5.6.9.8 Sealings shall be selected considering, at least:

- Hydraulic Fluid requirements on Sections 5.2.8 and 5.2.9.
- External Environment described on 5.2.10
- Minimum and Maximum Temperatures described on 5.2.10
- Sealing components are expected to remain stationary for periods of up to 30 years. It is recommended to consider PTFE-faced seals.
- As a minimum, the sealing and wear rings configuration shall be considered as shown in [61].

6.5.6.9.9 Scope of supply includes procurement, construction, assembly, FAT.

6.5.6.9.10 Hydraulic actuator manufacturing, quality control, storing and shipping shall comply with [2] considering PSL 3.

6.5.6.9.11 Performance requirements level PR2 shall be fulfilled.

6.5.6.10 Manufacturing and quality control databook shall be issued including traceability of materials used. Each hydraulic actuator shall be low stress stamped with serial number linked with tests and materials certificates.

6.5.6.11 Hydraulic line cleanness shall be compatible with the control fluid cleanness requirements described in 5.2.8.

6.5.6.12 Design Data shall be considered as follows, please see Figure 16 and Figure 17:

- Minimal spring force: 2,5 x rod hydraulic force due to pressure produced as a result of hydrostatic column in umbilical considering 30 m and fluid density
- Stroke equal to 57 mm
- Minimum net rod force at 5000 psi internal pressure at initial stroke: 15 kN net force is calculated considering hydraulic force minus the three-spring force as follows:

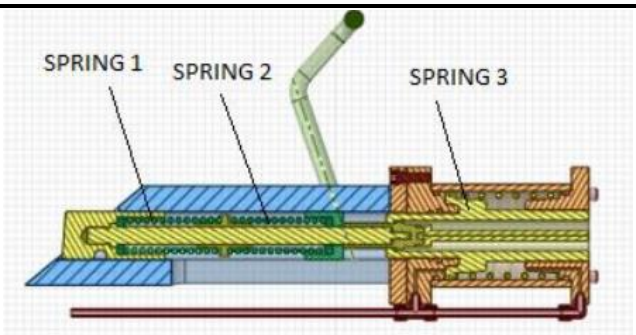



Figure 16: Spring net force calculation

**COMPRESSION SPRING**

| MATERIAL: ICONEL 718 (HARDNESS LESS THAN 35 HRC) | | | | |
|---|---|---|---|---|
| LEFT HAND | | | | |
| SQUARED AND GROUND END (*) | | | | |
| **I-TUBE** | | **DN 48"/46"** | **DN 32"** | |
| ACTIVE COILS | N | 12 | 12 | |
| TOTAL COILS | Nt | 14 | 14 | |
| WIRE DIAMETER | d | 7,5 | 7,5 | mm |
| OUTSIDE DIAMETER | De | 57,5 | 52,5 | mm |
| FREE LENGHT | L | 167,6 | 156,2 | mm |
| SOLID LENGHT | Ls | 105,0 | 105,0 | mm |
| **TEST** | | | | |
| FORCE | F1 | 55,00 | 42,00 | kgf |
| | | 539,6 | 412,0 | N |
| LENGHT | L1 | 142,0 | 142,0 | mm |
| | | | | |
| FORCE | F2 | 119,5 | 130,5 | kgf |
| | | 1172,6 | 1280,4 | N |
| LENGHT | L2 | 112,0 | 112,0 | mm |

Figure 17:Compress Spring Data

6.5.6.13 The requirements from hydraulic fluid cleanness of 5.2.8 and 5.2.9 shall be fulfilled.

6.5.6.14 Requirements described on section 5.2.10 shall be fullfeed, with exception of the test pressure (described on 6.5.6.12) and operational cycles. Design operational life shall be 30 years and 50 cycles.

# 7 TSUDL MANUFACTURING REQUIREMENTS

## 7.1 General Requirements

**7.1.1** The TSUDL fabrication shall be subject to the scrutiny, inspection, verification, qualification, and documentation in accordance with FPU CONTRACTOR/SELLER and industry standards as set in this specification and project documentation.

**7.1.2** Pad eyes and other lifting devices used for general handling of the equipment shall be designed in accordance with internationally accepted code (e.g. [30]).

**7.1.3** Only one Dummy HOA and Dummy Cap must be manufactured for testing all the TSUDL. The design is going to be defined by PETROBRAS at the kickoff meeting as per [61].

**7.1.4** FPU CONTRACTOR/SELLER shall not machine the Locking Wedges to force the

contact with the Dummy HOA. The shape and angles of the locking wedge shall not be changed from the dimensions and tolerances shown in the manufacturing drawings approved by FPU CONTRACTOR/SELLER.

**7.1.5** FPU CONTRACTOR/SELLER may manufacture a prototype of the TSUDL previous starting the production. This prototype shall include all sensors and actuators (MTL, Top Cone and latch bars). This prototype shall be tested in accordance with this technical specification and, in addition to the current documentation, the acceptance of these tests blocks start of fabrication.

## 7.2 Materials and Components

**7.2.1** FPU CONTRACTOR/SELLER shall provide materials certificates of raw materials used in TSUDL manufacturing to be included in the databook.

**7.2.2** FPU CONTRACTOR/SELLER shall provide water absorption material report for all polymeric components. Those reports shall be included in the databook.

**7.2.3** Material Selection

7.2.3.1 All equipment and material manufactured and/or supplied under this technical specification shall be new and following the best engineering fabrication and manufacturing practices. It is preferred to use existing designs or modifications that have already been qualified and accepted. As a minimum, the selected materials shall comply with 0.

7.2.3.2 FPU CONTRACTOR/SELLER shall verify all critical components material described in drawings list [61]. FPU CONTRACTOR/SELLER may suggest a different material for these components; however, it shall be submitted to PETROBRAS review and approval.

7.2.3.3 All materials shall be suitable for the intended service, described within Project Documentation. The selected materials shall be under the relevant applicable codes, standards, and specifications and be able to meet the requirements defined for the Project.

7.2.3.4 The origin of all materials used in the manufacture shall be clearly identified. FPU CONTRACTOR/SELLER shall submit any required material manufacturing process details, tests, examinations, inspections, and acceptance criteria for PETROBRAS review.

7.2.3.5 The selection of materials is a responsibility of FPU CONTRACTOR/SELLER and shall be made under:

- Relevant codes listed in this document and related project specifications.
- Results of both the structural and the fatigue analysis.
- Maintenance-free requirement during the product life, as per project specifications.
- Corrosion protection.

7.2.3.6 Wear losses, including deleterious effects on the surface topography and its consequences on tribo-corrosion, fatigue or corrosion-fatigue life, due to relative movement and contact (e.g. fretting) of the parts according to 7.2.4.

7.2.3.7 The compatibility between all materials shall be checked. Materials shall not be affected corrosion reactions (galvanic, crevice, pitting) and may be required to be welded to other specified metallic pieces where necessary.

7.2.3.8 Inspection criteria shall consider as a minimum the requirements as specified for the FPSO.

**7.2.4** Material Selection for Parts and Components under Wear

7.2.4.1 Materials for parts with relative movement must be selected based on tribological considerations referenced on appropriated literature and proven through laboratory wear tests and with conduction of near full-scale (e.g. contact pressure, sliding speed, environment, temperature) to demonstrate the adherence to the specified product life. A technical specification for the mentioned wear tests shall be submitted to PETROBRAS as well as the laboratories where such tests are planned.

7.2.4.2 The fatigue and corrosion-fatigue performance of these parts must also be proven through mechanical-corrosion tests. A technical specification for the mentioned fatigue and corrosion-fatigue tests shall be submitted to PETROBRAS as well as the laboratories where such tests are planned.

7.2.4.3 The hardness of the material and the surface roughness of these parts must be in accordance with the tribological requirements of each pair in contact. For example, the hardness of the locking wedge must be adequately superior to the adjacent parts.

7.2.4.4 Wear bushing shall be design according to [49].

**7.2.5** Ferrous Materials

7.2.5.1 Ferrous Materials for manufacture the TSUDL and its parts shall be certified by a classification society.

**7.2.6** Thermally Pretreated Steels

7.2.6.1 Parts manufactured with thermally pretreated steels may need heat treatment after welding and/or machining to ensure that its mechanical properties will remain unaltered. FPU CONTRACTOR/SELLER shall contact SUBCONTRACTOR that is providing the steel to specify the appropriate heat treatment.

## 7.3 Forging

**7.3.1** The material shall be selected to have good weldability, strength, and toughness when welded to steel plate (e.g. ASTM A131 EH36). The forgings shall be forged to a near net shape, rough machined, heat treated and final machined. FPU CONTRACTOR/SELLER shall document a written specification complete with chemistry, material properties, toughness, testing, test coupon locations, inspection requirements, and NDE requirements. The forging SUBCONTRACTOR shall provide an MPS detailing the material, forging processing with reduction rations, heat treatment with times and temperature ranges, location of material sampling locations, and inspections. Test material for mechanical tests shall be representative of the production part and be from a portion of the actual forging such as the “cut-out” area or a prolongation. The forging reduction ratio shall not be less than 3.5:1. An alloy such as ASTM A707 L5 having good weldability and high toughness should be selected. Forgings shall be UT inspected after heat treatment and MT inspected

after final machining. Consideration shall be given to the effects of weld distortion, to ensure the final profile after completion of all welding is acceptable.

**7.3.2** As a minimum, the forging requirement shall meet Classification Society Rules for hull construction and [23] – SFC 3 with the following modifications and additional information:

- Min. Yield Strength (0.2% Offset): 355 MPa
- Min. Tensile Strength: 455 MPa
- Elongation in 2 in. or 50 mm, min 20%
- Charpy V-Notch Impact test temperature: -40°C
- Charpy V-Notch Minimum Average Absorbed Energy: 50 J (set of 3 samples)
- Charpy V-Notch Minimum Individual Absorbed Energy: 34 J

*Note:* Charpy V-Notch Impact test temperature exemptions may be proposed by FPU CONTRACTOR/SELLER by submitting to PETROBRAS approval a fracture mechanics assessment based on BS 7910 at the temperature of -20°C and considering the stress levels and the minimum detectable flaw size.

**7.3.3** Locking wedges forging shall meet, at least ASTM A694 F65 mechanical properties and [23] – SFC 3.

## 7.4 Welding

**7.4.1** All welds shall be in accordance with [42].

**7.4.2** Personnel qualification of welders shall comply with 12.2.1. Qualification of NDE inspectors shall comply with 12.2.2.

**7.4.3** Preparation of the welding technical documentation shall comply with item 5.3 (welding documents) of [52]. Each WPS shall be supported by suitable(s) PQR(s). Each PQR shall have attached on it the following documents, as minimum: base material certificates, consumable certificates, non-destructive testing reports, PWHT reports, laboratory testing reports. Pre-qualified welding procedures provided in [42] and standard procedures specified in AWS D1.1 are not acceptable.

**7.4.4** Welding Qualification Procedures shall comply with 12.3.5.

**7.4.5** All complete joint penetration welds shall be inspected by means of ultrasonic examination. Ultrasonic testing shall comply with 12.3.1.

**7.4.6** All welds and surrounding area of base metal shall pass through magnetic participle inspection. Partial NDE is not allowed. Magnetic particle shall comply with 12.3.3.

**7.4.7** The extent of the Weld NONDESTRUCTIVE TESTS shall 100% ultrasonic test, 100% magnetic particle test and 100% visual inspected.

**7.4.8** Welding to lower riser balcony shall be carried out through an intermediate plate supplied together with TSUDL from factory to prevent distortion inside the TSUDL. The intermediate plates shall comply with lower riser balcony design and with their specific top and azimuth angle. The plate tolerance design is FPU CONTRACTOR/SELLER responsibility.

**7.4.9** For full penetration joints welded from one side only, without a backing the nondestructive inspection percentage shall be complemented as follows: Butt joint

with full penetration - Longitudinal = 5 % Radiography (full penetration butt joint); Butt joint with full penetration - circular = 5 % Radiography.

**7.4.10** The selection of welding consumables shall be in accordance with [60]. For processes not covered, the corresponding specification of ASME BPVC Section II Part C or AWS specification and classification shall be followed. Welding consumables shall be provided with its respective batch certificates (ISO 1O204 Type 3.1 or AWS A5.01 Sch J).

**7.4.11** Heat Treatment for stress relief shall be performed in the TSUDL structural body after all welds have been performed and before the inner diameters machining to avoid the structure ovalization.

## 7.5 Corrosion Protection

### 7.5.1 General

7.5.1.1 Corrosion Protection of the TSUDL shall be accomplished with a combination of protective coating and cathodic protection.

7.5.1.2 External Areas of TSUDL shall be painted with marine epoxy coating as per [53]. Top Coat color shall be specified by PETROBRAS.

7.5.1.3 FPU CONTRACTOR/SELLER will touch up the coating at the interface to the hull structure.

7.5.1.4 Internal surfaces and contacting surfaces of the TSUDL shall be coated with anti-fouling painting.

7.5.1.5 All coatings and coating procedures used by FPU CONTRACTOR/SELLER and SUBCONTRACTOR are subject to PETROBRAS review and approval.

7.5.1.6 The TSUDL main parts shall include 0,25 mm/year of corrosion allowance per side exposed to seawater.

### 7.5.2 Cathodic Protection

7.5.2.1 The TSUDL cathodic protection is provided by the electrical contact with the main hull structure, which is provided by the impressed current (definitive system) from the FPU. A numerical simulation of the potential distribution shall be performed for TSUDL cathodic protection designs to confirm the absence of harmful electrochemical potential in the TSUDL components.

7.5.2.2 TSUDL temporary cathodic protection system can be impressed-current or galvanic type and shall operate whenever the hull is in contact with sea water and the definitive system is not in operation [59]. Temporary cathodic protection shall not interfere with tubing and cable routing of the TSDUL body.

7.5.2.3 TSUDL Cathodic protection design report shall be issued considering both definite and temporary phases.

7.5.2.4 All moving parts, except the MTL, that are subjected to corrosion and is connected to the TSUDL by other means than welding and without a reliable electrical connection shall consider an electric cable for cathodic protection transmission.

7.5.2.5 Electrical continuity between all components shall be tested after assembly.

7.5.2.6 A specific electrical continuity procedure shall be prepared by the FPU/CONTRACTOR and submitted for Petrobras' approval.

7.5.2.7 Cathodic Protection for specific equipment is described within its respective sections, such as 6.5.6.9.3.

**7.5.3** Painting

7.5.3.1 FPU CONTRACTOR/SELLER shall observe that parts whose drawings present the indication “DO NOT PAINT” are not to be either painted or electrically isolated.

7.5.3.2 Painting procedure shall comply with 7.5.4.1 or paint manufacturer specification. In case of divergence, paint manufacture specification shall be used, observing the thickness specification for each layer and final thickness.

**7.5.4** Final Thickness

7.5.4.1 The maximum thickness of the painting after the application of finishing and antifouling layers shall not exceed 0.6 mm.

**7.5.5** Final Painting

7.5.5.1 The TSUDL shall be delivered with the paint free of defects.

7.5.5.2 For the FAT, TSUDL shall be painted with last layer of paint applied (antifouling). If any TSUDL component is not in its final painting, such fact shall be reported, the tests shall be postponed, and the painting of the parts shall be finished.

7.5.5.3 After FAT, painting shall be touched up to remove any risks and defects caused by the test. Final thickness shall not exceed that required in 7.5.4.

7.5.5.4 If necessary, the paint shall be touched up only in parts that do not require disassembly of the locking mechanisms. If FPU CONTRACTOR/SELLER needs to disassemble the locking mechanisms, the TSUDL shall be retested.

**7.5.6** Anti-friction Coat

7.5.6.1 Apply on coat of PTFE finishing with a minimum dry film thickness of 25 microns in parts whose drawings specify this type of coating.

## 7.6 Structural Calculation

**7.6.1** FPU CONTRACTOR/SELLER shall perform a structural assessment (Static Loads and Corrosion-Fatigue, including the deleterious effects on thickness and surface topography due to the wear caused by the relative movement of the parts) considering the loads defined in [51], [30] and the specific riser configuration defined by the project.

**7.6.2** If calculous indicate small structural changes, the design modification requirement shall only be implemented after PETROBRAS approval.

**7.6.3** Design methodology and acceptance criteria shall be in accordance with an international recognized code such as [6]. Other design codes or methodologies previously validated by FPU CONTRACTOR/SELLER may be accepted after PETROBRAS approval.

**7.6.4** Slamming Loads

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

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

7.6.4.3 Slamming loads can be calculated considering CFD software, model tests or by approximations as described on [26].

7.6.4.4 If wave slamming probability of occurrence and associated loads provide a relevant contribution to fatigue damage, fatigue calculations shall include wave slamming loads.

**7.6.5** Finite Element Analysis

7.6.5.1 Finite Element Analysis shall be used to establish structural, buckling, and fatigue performance of the TSUDL.

7.6.5.2 Care shall be exercised in the finite element analysis to ensure that appropriate element types, mesh refinement, element aspect ratio/distortion and boundary conditions are used.

7.6.5.3 Applied boundary conditions shall be clearly indicated in model sketches and/or in finite element plots.

7.6.5.4 Mesh sensitivity analysis shall be performed to ensure that accurate results are predicted. Mesh density convergence checks shall be presented in the reports.

7.6.5.5 The sensitivity calculation model and the parameters utilized in the model shall be examined.

**7.6.6** FEA methods to evaluate plastic collapse capacity

7.6.6.1 There are different ways of estimating the plastic collapse capacity of a component using FEA: elastic analysis; limit analysis; elastic-plastic analysis.

7.6.6.2 The criteria used to determine limit or plastic loads assume defect-free, though and ductile material behavior. Fracture mechanics should be considered if the above conditions are not fulfilled.

7.6.6.3 Explicit dynamic simulations shall be considered to analyze plastic collapse due to impact loads on specific components.

**7.6.7** Elastic Analysis

7.6.7.1 Finite Element Analysis shall be used to establish structural, buckling, and fatigue performance of the TSUDL. Service criteria whenever applicable shall also be evaluated to avoid excessive deformation that may compromise the proper functionality of all components, and the moving parts of the TSUDL (See [20]).

7.6.7.2 The principle used in some design codes when verifying a component by linear elastic FEA is that critical sections shall be identified and verified by linearizing the stress across the sections. Stresses are in general decomposed into membrane, bending and peak stresses as well as categorized as primary or secondary stresses. Several FEA programs include modules that perform stress linearization which may be used by FPU CONTRACTOR/SELLER.

7.6.7.3 For the FE models where the analysis in nonlinear because contact behavior is essential to simulate the interaction between different components, the method of code compliance check for linear elastic FEA may be used provided that the material model is linear elastic. In such cases, the code compliance check must be carried out at critical load steps in the non-linear analysis.

7.6.7.4 Primary average shear and average bearing stresses shall be calculated and compared to allowable limits. In case where the selected code does not address the shear primary average shear and average bearing stress checks, PETROBRAS shall be consulted on which methodology to be used.

7.6.7.5 In using elastic finite element analysis to calculate the TSUDL plastic collapse capacities, FPU CONTRACTOR/SELLER shall be aware of the following limitations of this approach:

- For components with a complex geometry and/or complex loading, the categorization of stresses as primary or secondary in the elastic analysis requires significant knowledge and judgment on the part of the analyst. Application of elastic-plastic analysis methods is recommended for cases where the categorization process can produce ambiguous results.
- The use of elastic stress analysis and stress categorization to demonstrate structural integrity for heavy thickness components, especially around structural discontinuities, can produce non-conservative results and is not recommended.
- In cases where calculated peak stresses are above yield over a through-thickness dimension, which is more than 5% of the wall thickness, linear elastic analysis can give a non-conservative result.

7.6.7.6 The structural evaluation procedures based on elastic stress analysis provide only an approximation of the protection against plastic collapse.

7.6.7.7 For the reasons listed above, the decision to perform elastic finite element analysis to calculate the TSUDL plastic collapse capacities shall be reported and justified at the beginning of the project, on the first revision of the Design Premises document. SUBCONTRACTOR shall also consider that, due to the aforementioned limitations of the elastic analysis technique, PETROBRAS may require additional limit analyses or elastic-plastic analyses of the TSUDL as per sections 7.6.8 and 7.6.9.

**7.6.8** Limit Analysis

7.6.8.1 Limit analysis is based on elastic-perfectly plastic material model and small deformation theory. The objective of a limit analysis is to guarantee that the relevant loading is below the load that produces overall structural instability.

7.6.8.2 The limit analysis shall be carried out following the guidelines of the respective codes selected for the verification of the TSUDL.

7.6.8.3 PETROBRAS may require the performance of limit analysis in addition to the elastic one when the presented result of elastic analysis is not conclusive.

**7.6.9** Elastic-plastic Analysis

**7.6.9.1** Elastic-plastic analysis is generally based on material model which considers true strain hardening and large deformation theory. Some codes recommended the use of idealized stress-strain curves based on the material properties.

**7.6.9.2** Elastic-plastic finite element analysis gives more realistic and accurate simulation of the stresses, strains and displacements than elastic finite element analysis and limit analysis, including local load redistribution due to yielding up to maximum load carrying capacity or resistance.

**7.6.9.3** The objective of an elastic-plastic analysis is to guarantee that the relevant loading is below the load that produces overall structural instability.

**7.6.9.4** The elastic-plastic analysis shall be carried out following the guidelines of the respective selected codes for the verification of the TSUDL.

**7.6.9.5** PETROBRAS may require the performance of elastic-plastic analysis in addition to the elastic one when the presented result of elastic analysis in not conclusive.

**7.6.10** FEA Methods to Evaluate Protection Against Local Failure

7.6.10.1 Strength verification of the TSUDL carried out by FPU CONTRACTOR/SELLER shall include the evaluation of protection against local failure. This check shall be aligned with the rules and procedures of selected internationally accepted codes.

7.6.10.2 Design Codes usually recommended a simplified local stress check procedure to be carried out as part of a linear elastic FEA. For some codes, the protection against local failure is guaranteed by limiting the sum of the principal components at any point in the structure. For other codes the limit is imposed on the maximum principal stress component at any point in the structure.

7.6.10.3 For FEA involving plasticity, plastic collapse load analysis via the elastic-plastic method is preferable for checking local failure because it closely represents the actual structural response in comparison with a limit analysis. The local geometry of the structure shall be correctly represented in the FE-model to allow an accurate estimate of local strains that will be used in the code compliance verification.

**7.6.11** FEA Methods to Evaluate Protection Against Progressive Collapse

7.6.11.1 Methods for protection against progressive collapse from repeated loading are found on internationally recognized design codes. FPU CONTRACTOR/SELLER shall follow the recommended procedure of the respective selected codes for the verification of the TSUDL.

7.6.11.2 For a FE elastic analysis, the sum of primary plus secondary stresses shall be less than the respective allowable value defined on the selected code. Note that if all requirements for protection against plastic collapse are met in an elastic FE analysis with all stresses categorized as primary then the load is safe regarding progressive collapse. In the context of verification of protection against progressive collapse by means of elastic analysis, it is considered acceptable the use of stress linearization as per [20].

7.6.11.3 However, if elastic-plastic results are used, then an assessment method compatible with such type of analysis shall be employed instead (see [20]).

**7.6.12** FEA for Fatigue

7.6.12.1 Fatigue life evaluation of the TSUDL carried out by FPU CONTRACTOR/SELLER shall include the assessment of both welds and plain material following the rules and procedures of a selected internationally accepted code.

7.6.12.2 When creating FE models for calculation stresses for subsequent fatigue analysis, care must be taken to ensure that the mesh density and level of detail modeled are in accordance with the assumptions in the chosen S-N curve.

7.6.12.3 FE meshes for the calculation of stress ranges in plain material (e.g. forged components far from any weld) should be extra fine in areas where stresses are determined (notch stress method). The geometry of the elements should be carefully evaluated to avoid errors due to deformed elements. The size of the model shall be sufficiently large so that the calculated results are not significantly affected by assumptions made for boundary conditions and application of loads.

7.6.12.4 A minimum a DFF (Design Fatigue Factor) equal to 10, as defined by [25], is required.

**7.6.13** FEA Documentation

7.6.13.1 The analysis report shall be sufficiently detailed to allow independent verification by a third party, approved by the PARTIES, either based on review of the documentation, or using independent analyses (sensible data may be provided under a non-disclosure agreement and provision). The documentation should include at least description of:

- Purpose of the analysis
- Failure Criteria
- Geometry model and reference to drawings used to create the model
- Boundary conditions
- Element types
- Element mesh
- Material models and properties
- Analysis approach
- Application of safety factors
- Mesh convergence study results
- Analysis results
- Sensitivity analysis
- Discussion of results
- Conclusions

- Loads and load sequence
- Any performed verification

# 8 HULLSIDE UMBILICAL

## 8.1 System Overview

**8.1.1** The hydraulic/electrical components of the TSUDL system shall be connected to the topside by a hullside umbilical. It is FPU CONTRACTOR/SELLER responsibility to provide the umbilicals and make all the connections on the system.

**8.1.2** Umbilical Outer Sheat material shall be either Polyurethane or HDPE (High Density Polyethylene).

**8.1.3** The construction materials to be used in the umbilical and its functional components, hoses, electrical cables and optical fibers and terminations, shall withstand all types of degradation arising from the exposure of these components to marine environment or atmosphere. This includes, but not limited to the following components:

- Seawater, microorganisms and marine life, considering the functional components and their terminations, when sea water penetrates through the interstices between umbilical components. It should also be considered that the materials that make up the functional components shall not suffer degradation due to the phenomenon of hydrolysis.
- Ultra-violet radiation, as the ends of the functional components will be exposed to sunlight during transport, storage and operation of the umbilical.
- High temperatures resulting from sun exposure during the transport, storage and operation of the umbilical.
- Specified hydraulic fluid.

**8.1.4** The number of umbilical's armor wire layers shall guarantee the robustness of the design and lifetime operation. It is FPU CONTRACTOR/SELLER responsibility to provide an analysis to demonstrate that the proposed number of layers fulfil the requirements. As a minimum, the number of armor wire layers shall be equal to 2 (two).

**8.1.5** Some umbilical characteristics will depend upon the project. Information such as umbilical cross section, number of hydraulic lines, number of electrical conductors, number of fiber optics cores will be fully available in the specific MD.

**8.1.6** A general diagram of the Hull Side umbilical infrastructure is illustrated on Figure 18.

**8.1.7** FPU CONTRACTOR/SELLER shall foresee all handling/installation at dry dock accessories like slings, shackles, etc.

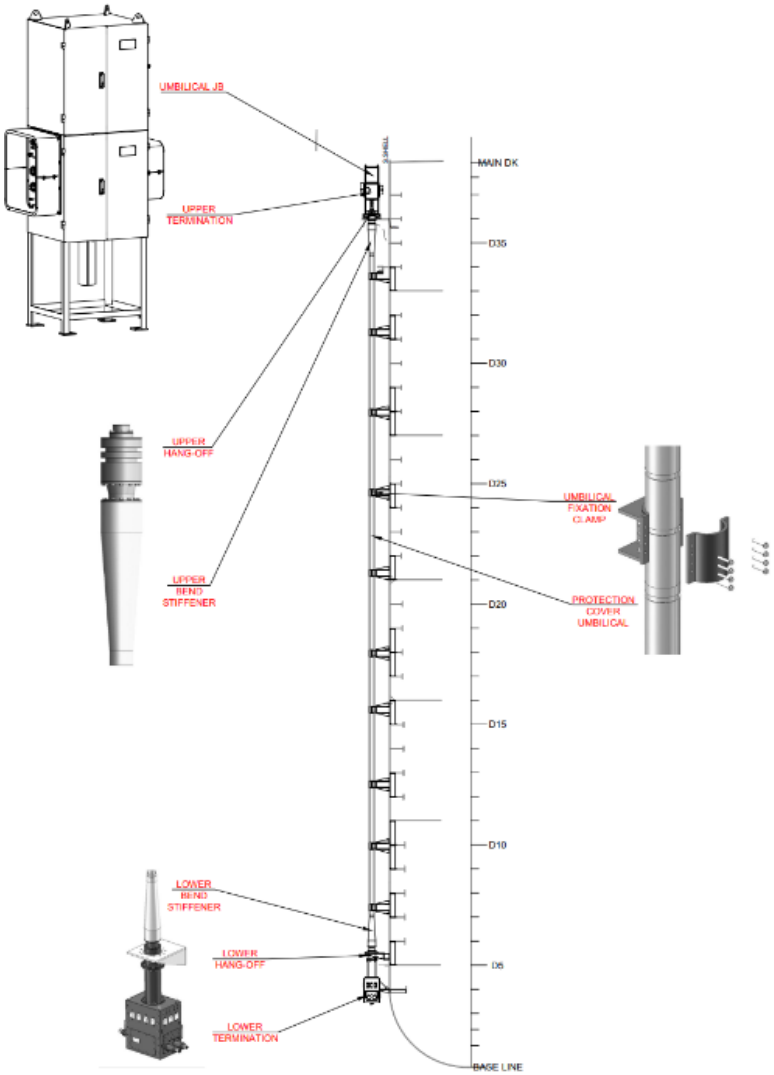



Figure 18: Hullside Umbilical basic infrastructure

**8.1.8** The umbilical lines shall be supplied with all accessories to protect both ends (for example, armor pots, bend stiffener) and for handling and fixation at riser balconies.

## 8.2 Mechanical Infrastructure

**8.2.1** All top umbilical ends shall be supplied with pull-in heads designed to handle umbilical lines installation at dry dock.

**8.2.2** Both ends of the lines at upper and lower riser balconies supports shall be fixed by a bipartite hang off structures as demonstrated on Figure 19.

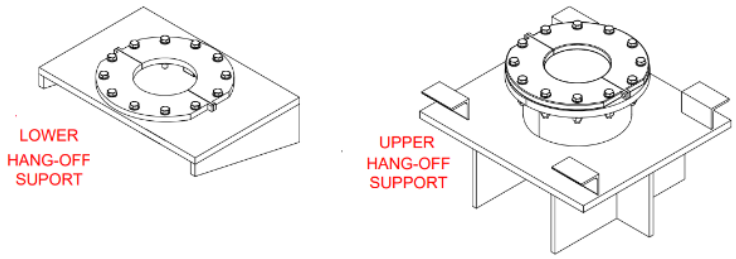



Figure 19: Upper and Lower Hang off structures

**8.2.3** Upper hang off shall be designed to allow different levels of umbilical fixation. As demonstrated on Figure 20, these levels permit proper fixation of the umbilical at the FPU with minimum length adjustments.

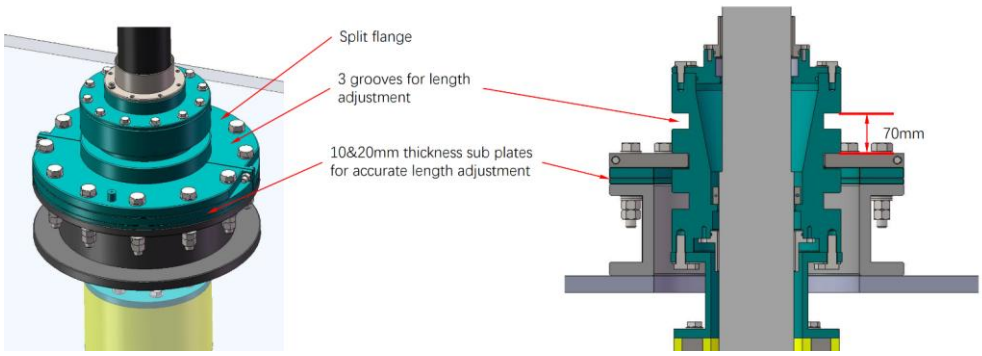



Figure 20: Hang off design with length adjustment

**8.2.4** The umbilical lines shall be terminated in plates at both sides. Each plate shall have connectors (Medium pressure standard tube fitting as [56]) to connect each pigtails thermoplastic hoses in a steel tubing.

**8.2.5** In terminations, FPU CONTRACTOR/SELLER shall observe:

- Thermoplastic hoses need a minimum 400 mm of straight section after terminal connector.
- Thermoplastic hoses need a minimum bend radius of 150 mm.
- Cathodic protection to hydraulic, electrical and optical connectors (if applicable).
- Steel tubing routing at lower and upper balcony.
- All pigtails (hydraulic, optical and electrical) shall be housed internally of umbilical termination to protect from UV radiation and mechanical impacts.

**8.2.6** The umbilical body shall be fixed along the hull side of FPU by welded fixing/clamps supports at double plates. The fixing/clamps supports quantities, mechanical details and welded locations shall be submitted to PETROBRAS for review and approval. A general fixation scheme is shown on Figure 21.

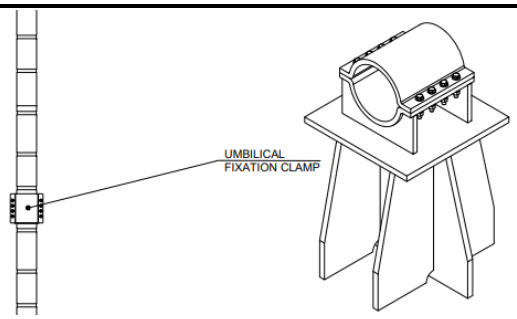



Figure 21: Clamps design for hull side umbilical fixation

**8.2.7** Regarding fasteners for umbilical fixation, FPU CONTRACTOR/SELLER shall follow requirements on ref [46].

**8.2.8** Umbilical and its supports design shall consider, at least, hydrodynamic loads (waves and current) acting on umbilical length over hull side.

**8.2.9** The number of clamps shall be consistent with the stress analysis described in 8.2.6. A minimum number of 10 umbilical clamps supports over hull side shall be considered, unless clearly demonstrated by previous analyses.

**8.2.10** Umbilical supports shall be calculated to withstand the most stringent loads combination due to pipe, wave, currents, and hull movement. Hydrodynamic loads (wave and current) acting over the support shall be included in the stress analysis.

**8.2.11** The installation positions for umbilical lines hydraulic actuation system shall not use any riser slot in balcony reserved to subsea riser arrangement, as illustrated on Figure 22 and Figure 23.

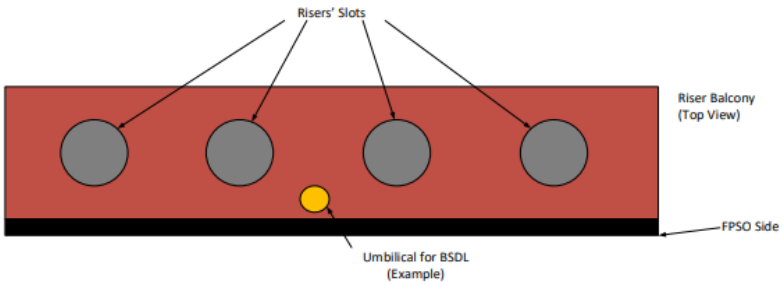



Figure 22: Umbilical Position

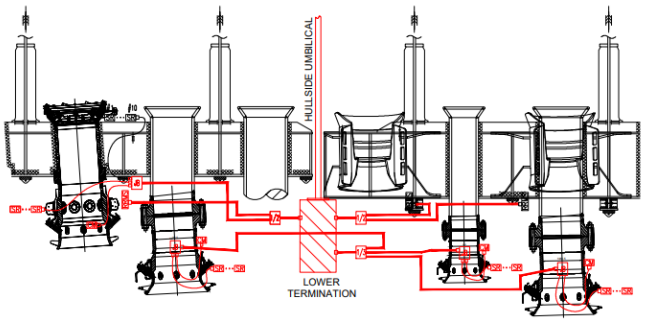



Figure 23: Hull Side umbilical position and routing

**8.2.12** The upper termination shall observe the following requirements:

- FPU CONTRACTOR/SELLER shall provide medium pressure standard tube fitting connector to connect each pigtails thermoplastic hoses in a steel tubing (for local panel interface).
- FPU CONTRACTOR/SELLER shall guarantee that any thermoplastic hose will not be exposed to solar UV light to avoid upper balcony pigtails degradation.
- Electrical and optical cables shall interface to Riser Junction Box. FPU CONTRACTOR/SELLER shall provide this connection (by spare length or jumpers).
- The upper umbilical termination shall be fixed in upper riser balcony area with free access to terminal plate to allow future maintenance.

**8.2.13** Upper Umbilical Termination body material shall be AISI 316L.

**8.2.14** Upper Umbilical Termination shall be supplied with 4 adjustable legs to guarantee that any of the umbilical pigtails (i.e. optic, electric and hydraulic pigtails) not be exposed to solar UV light to avoid upper balcony pigtail degradation.

**8.2.15** Upper Umbilical Termination shall be installed after hullside umbilical erection during dry dock phase.

**8.2.16** Umbilical JB shall be installed bolted over the Umbilical Upper Termination.

**8.2.17** The set of (Umbilical JB & Upper Umbilical Termination) shall be installed bolted over the umbilical hang off with the maximum height of 2 meters where is dismiss the use of safety harness for high work for any operator during offshore activities. Figure 24 illustrates this requirement.

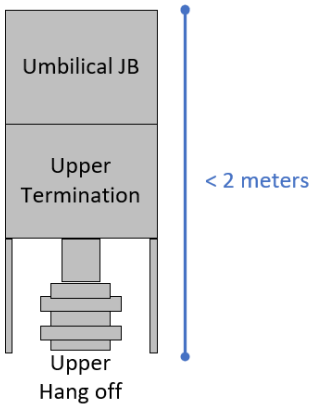



Figure 24: Umbilical JB and Upper termination installation requirements

**8.2.18** The lower umbilical termination shall be fixed in lower riser balcony area, with terminal plate sided to below area as shown on Figure 23.

**8.2.19** Lower Termination body shall be designed with the same metallic material from the hull structure.

**8.2.20** Lower Umbilical Termination body shall be supplied with anodes for protection.

**8.2.21** Lower Umbilical Termination shall be provided by FPU CONTRACTOR/SELLER with medium pressure standard tube fitting connector to connect each hydraulic thermoplastic hoses with a steel subsea tubing.

**8.2.22** Lower Umbilical Termination shall be provided by FPU CONTRACTOR/SELLER with electrical and optical cables to interface with Riser Monitoring JB. FPU CONTRACTOR/SELLER shall provide this connection (by spare length or jumpers). Please see Figure 25.

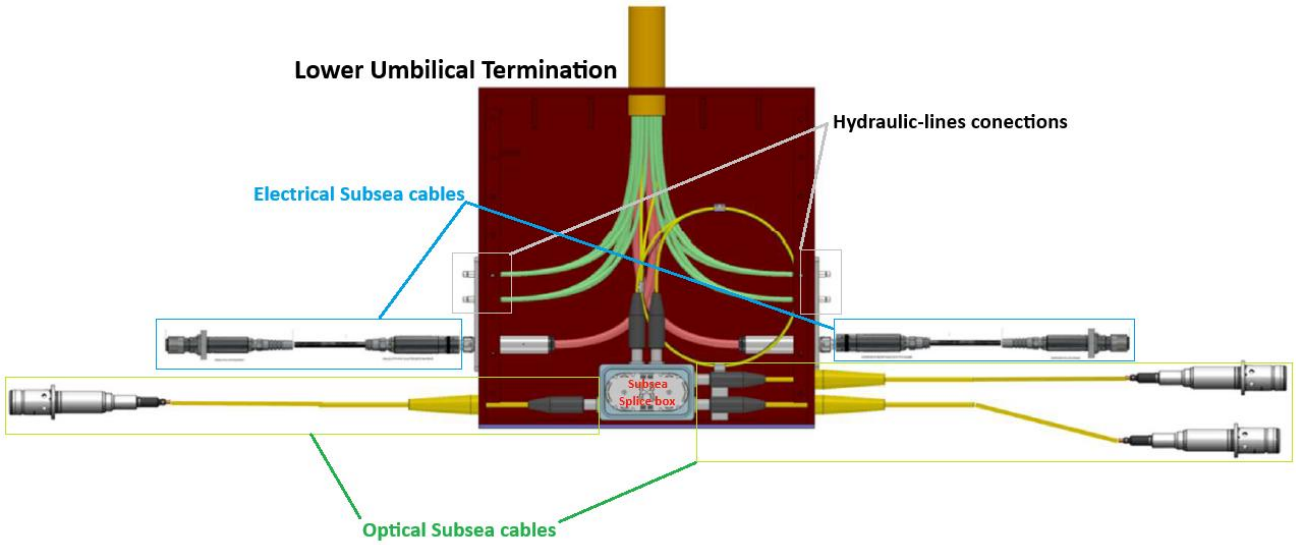



Figure 25: Schematical drawing for the Lower Umbilical Termination

**8.2.23** FPU CONTRACTOR/SELLER shall provide a routing analysis and a 3D model demonstrating all the connections between each umbilical lower termination and electrical/hydraulic components. There shall be no clashing and no interference with any other structure in the lower balcony. This analysis shall be submitted to PETROBRAS review and approval before operations in the dry dock.

## 8.3 Hydraulic Infrastructure

**8.3.1** The hydraulic infrastructure of the umbilical will be responsible for providing hydraulic force to actuate the pistons along pull-in and pull-out activities for the system lifetime.

**8.3.2** Hydraulic Control: Thermoplastic hoses (DWP = 7500 psi).

**8.3.3** Thermoplastic hose shall be designed and qualified following the requirements on [54].

**8.3.4** All thermoplastic hoses shall be supplied from umbilical factory filled with the same hydraulic fluid planned to be used on PUPS (in accordance with 5.2.7) and plugged with hydraulic hose caps at both ends.

**8.3.5** All thermoplastic hoses shall be flushed to guarantee supply of water glycol based hydraulic fluid in accordance with 5.2.7 and ensure no air bubbles are inside.

**8.3.6** All hydraulic pigtails not used shall be filled with the hydraulic fluid and closed with caps at both ends.

**8.3.7** FPU CONTRACTOR/SELLER shall guarantee that any thermoplastic hose shall not be exposed to solar UV light to avoid upper balcony pigtails degradation.

**8.3.8** At Lower Umbilical Termination, it shall be terminated the hydraulic pigtails with a medium pressure standard ([56]) for interface with lower balcony tubings.

**8.3.9** All hydraulic pigtails shall have individual identification. Identification may be done by numbers, letters and/or insulation color. Identification shall withstand handling and installation of hydraulic lines and umbilical system.

**8.3.10** FPU CONTRACTOR/SELLER shall evaluate in their detailed design to have at least one hydraulic spare at lower umbilical termination structure for each hull side umbilical line.

**8.4** Electrical Infrastructure

**8.4.1** The electrical infrastructure of the umbilical shall be responsible for providing the communication between the sensors installed for the RSMS and RRMS with the topside supervisory system.

**8.4.2** Low Voltage Electrical Conductors: 2.5 $mm^2$ 0.6/1.0(1.2) kV.

**8.4.3** Low voltage electrical cable shall be designed and qualified following the requirements on [55].

**8.4.4** All electric cables construction materials shall be selected considering environmental resistance for the specified umbilical system service life. Environmental conditions include, at least, sea water, marine growth, UV radiation, and hydrogen generated in electric cables and/or umbilical armoring and/or umbilical cathodic protection.

**8.4.5** The electric cables design shall minimize gap and voids between layers to reduce air and gas accumulation in electrical cable.

**8.4.6** Fillers, if used, shall be polymeric material.

**8.4.7** Electrical cables shall have at least two barriers to protect conductors against seawater. The electric cable outer sheath shall not be considered as a barrier.

**8.4.8** The conductors shall have a longitudinal water blocking material (within strands) to minimize water migration in case of conductors flooding.

**8.4.9** At lower umbilical termination, it shall be terminated with electrical wet-mate connectors in accordance with 5.2.6.

**8.4.10** FPU CONTRACTOR/SELLER shall evaluate in their detailed design to have at least one electrical spare connector at lower umbilical termination structure for each hull side umbilical line.

**8.4.11** Conductors shall have individual identification. Identification may be done by numbers, letters and/or insulation color. Identification shall withstand handling and installation of electrical cables and umbilical system.

**8.4.12** Subsea electrical cables at lower riser balcony shall be installed at trays attached with mechanical clamps. The distance between each clamp shall be measured between 200 to 300 mm. Mechanical clamps shall be designed considering the cathodic protection from the hull.

**8.4.13** At lower riser balcony a solution shall be designed to accommodate cable overlength. An example of the solution is shown on Figure 26.

Figure 26: Cable overlength solution example at lower riser balcony

**8.4.14** At the transition from cable tray to the support, extra protection shall be included for all cabling. As an example (Figure 27), a heavy-duty spiral wrap shall be used.

Figure 27: Extra Protection for electrical cables

## 8.5 Optical Infrastructure

**8.5.1** The optical infrastructure of the umbilical shall be responsible for providing the communication between the sensors installed for the RRMS with the topside supervisory system.

**8.5.2** Optical Fibers: Single Mode (ITU-T G.652 standard).

**8.5.3** The optical fibers shall be suitably arranged “loose” with a defined over-length within a watertight metal tube (stainless steel). The metal tube shall be welded filled with a water blocking and hydrogen-absorbing compound and sheathed. The umbilical supplier shall mention in its technical proposal how those features are going to be addressed in the cable design and manufacture.

**8.5.4** Metal tube splices design shall be mechanically suitable and watertight. The metal tube sheath shall provide corrosion protection for the metal tube, mechanical protection during manufacturing and installation (offshore splicing).

**8.5.5** All optical cables construction materials shall be selected considering environmental resistance for the specified umbilical system service life. Environmental conditions include, at least, sweater, marine growth, UV radiation and hydrogen generated in optical cables and/or umbilical armoring and/or umbilical cathodic protection.

**8.5.6** At lower umbilical termination, all the umbilical fibers optical pigtails shall be mounted in splice boxes. At the splice boxes it shall also be connected with optical subsea cables. Both connections to the splice boxes shall be made with optical penetrators. Please see Figure 28.

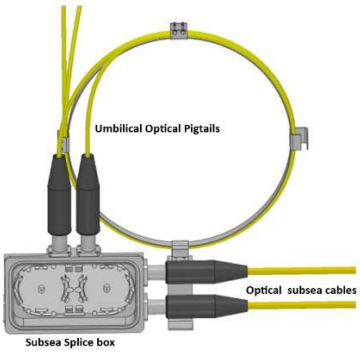



Figure 28: Schematic drawing of the subsea splice box

**8.5.7** Inside the subsea splice box al fiber shall be spliced, and all internals shall be covered with an epoxy resin in order to avoid water ingress when the hull is going out from the dry dock.

**8.5.8** The optical subsea cables shall have in the other termination subsea wet mate connectors in accordance with 5.2.7.

**8.5.9** FPU CONTRACTOR/SELLER shall evaluate in their detailed design to have at least one optical spare connector at lower umbilical termination structure for each hull side umbilical line.

**8.5.10** Subsea optical cables at lower riser balcony shall be installed at trays attached with mechanical clamps. The distance between each clamp shall be measured between 200 to 300 mm. Mechanical clamps shall be designed considering the cathodic protection from the hull.

**8.5.11** At lower riser balcony a solution shall be designed to accommodate cable overlength. An example of the solution is shown on Figure 26.

## 9 HYDRAULIC SYSTEM

### 9.1 System Overview

**9.1.1** The hydraulic system shall be responsible for providing hydraulic force to move the actuators when commanded, allowing pull-in and pull-out diverless activities.

**9.1.2** The system is composed by the topside, lower balcony and umbilical infrastructure.

**9.1.3** Hydraulic System shall be filled with water glycol-based fluid in accordance with 5.2.8. FPSO CONTRACTOR/SELLER shall inquire PETROBRAS about what will be the fluid predicted for this project before any filling operations.

**9.1.4** System design and material selection shall fulfil the requirements described 5.2.9.

**9.1.5** PETROBRAS highlights the necessity to meet the assembly and spacing requirements for tubing and its supports, especially those set out in 9.3, as being critical for the operation of the system.

**9.2** Topside Infrastructure

**9.2.1** Topside infrastructure is composed by the equipment that provides hydraulic force and controlling mechanisms for the correct operation of the actuators.

**9.2.2** The design for each component is fully described on Sections 11, 11.4 and 11.5.

**9.3** Lower Balcony Hydraulic Infrastructure

**9.3.1** The hydraulic circuits between the support and umbilical lower termination (plate) shall be made by steel tubing.

**9.3.2** Subsea tubing supports at lower riser balcony shall be installed at trays with distance L between each support measuring between 200 to 300 mm.

**9.3.3** Subsea tubings, fittings and supports be made of one of this options:

- Super austenitic stainless steel (SS alloy with 6% molybdenum) and shall comply with [24].
- S32750 with hardness limited to 35 HRC and tubing design shall comply with DNVGL-RP-F112 (ed.2018).

**9.3.4** Steel tubing shall have a minimum external diameter of 1/2 inch.

**9.3.5** Subsea tubings shall be electrically connected to the Hull cathodic protection system.

**9.3.6** The steel tubing shall be properly fixed and routed below lower riser balcony. The routing shall prioritize protected areas to avoid mechanical damage of the tubing.

**9.3.7** FPU CONTRACTOR/SELLER shall provide a routing analysis and a 3D model demonstrating all the connections as described on Section 8.2.13.

**9.3.8** Design of the Lower riser balcony shall consider ROV access and Diver operations in case of maintenance.

**9.3.9** FPU CONTRACTOR/SELLER shall provide proper hydraulic connection between the steel tubing and umbilical lower termination (plate), considering the environment and lifecycle.

**9.3.10** Tubing design shall consider proper flexibility for components that presents displacement (for example, top cone hydraulic actuator). Flexible hoses will not be acceptable as part of the solution.

**9.4** Umbilical Infrastructure

**9.4.1** Umbilical infrastructure will connect the topside and lower riser balcony equipment.

**9.4.2** Umbilical mechanical, electrical/optical and hydraulic characteristics are fully described on Section 8.

## 10 MONITORING SYSTEM

### 10.1 System Overview

**10.1.1** FPU CONTRACTOR/SELLER shall provide a Monitoring System comprising all the sensors for monitoring the TSUDL main parameters, such as: hydraulic actuators, the electrochemical process and the correct attachment of the bend stiffener adaptor cap.

**10.1.2** Each Quad cable of Hull side Umbilical shall be dedicated to one TSUDL. Four conductor's way shall be designed in a CANBUS topology to gather all the TSUDL information.

**10.1.3** All conductors related to each umbilical/local panel shall be terminated in an appropriated junction box with SAK connectors.

**10.1.4** Figure 29 presents a block diagram of control and monitoring system related to a single TSUDL.

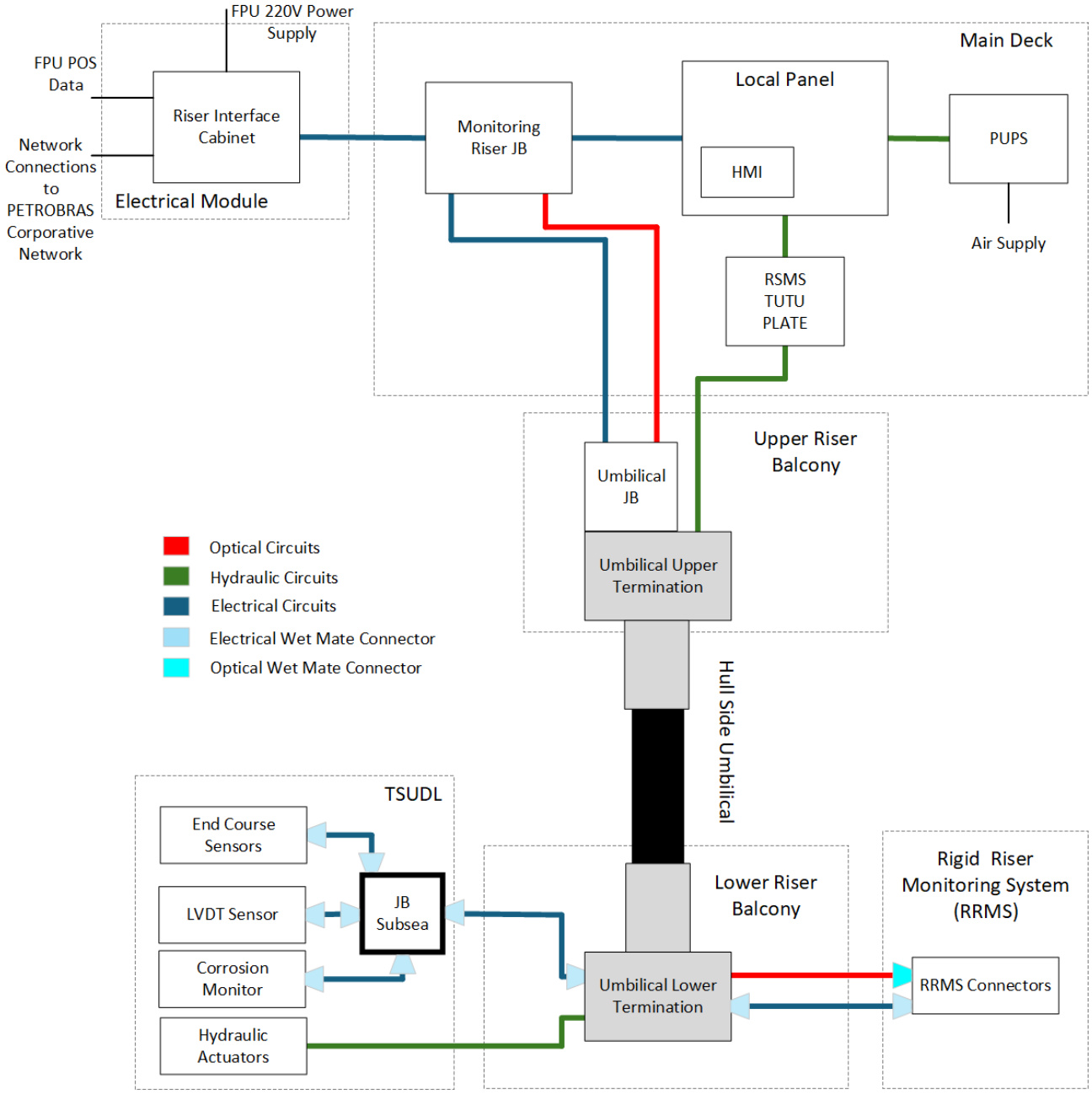



Figure 29: TSUDL Control and Monitoring System

**10.1.5** The interface between the monitoring components and the subsea interface cabling connected to the Hull side umbilical shall be done by electrical wet-mate connectors with the minimum requirements described on 5.2.6.

**10.1.6** Each sensor shall be a self-contained unit, composed by all the necessary electronics embedded for signal conditioning and topside communication.

**10.1.7** Sensor location shall not interfere with ROV maneuverability. FPU CONTRACTOR/SELLER shall design and submit to PETROBRAS for approval each sensor location followed by an analysis to demonstrate that each sensor does not interfere with ROV activities and the structural integrity of the TSUDL.

**10.1.8** A 3D analysis containing all sensor location shall be provided to PETROBRAS. This analysis shall guarantee that no interference neither structural clashing between the sensors and TSUDL structure.

**10.1.9** FPU CONTRACTOR/SELLER shall provide all electronics inside the Monitoring JBs and Local Panels for each sensor, and it displayed on the HMI screen inside the corresponding Local Panel and Riser Interface Cabinet.

## 10.2 Top Cone Position Detector

**10.2.1** FPU CONTRACTOR/SELLER shall provide a position detector sensor to monitor the rod excursion along the top cone after a hydraulic actuation.

**10.2.2** The position detector sensor shall be based on 2 end-course detectors, which provides the shaft limit position (full retracted and full extended) from the Drive Ring Hydraulic Actuator. Other additional sensors for the actuator rod displacement may be proposed for PETROBRAS evaluation and approval.

**10.2.3** Sensor solution shall follow the design principles of 10.1.6.

**10.2.4** Sensor installation location shall not compromise TSUDL structure and its main functionalities. It shall also comply with 10.1.7.

## 10.3 End Course Detector

**10.3.1** FPU CONTRACTOR/SELLER shall provide end course detectors to monitor the final position of the components from TSUDL (Top cone wedges, MTL and latch bars) after a pull in/pull out operation.

**10.3.2** These sensors shall be installed on each point of interest as demonstrated on the Figure 30, Figure 31 and Figure 32.

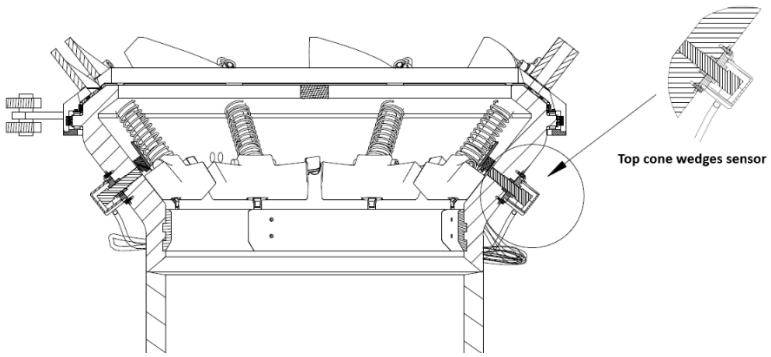



Figure 30: Schematic drawing of the top cone wedges sensor

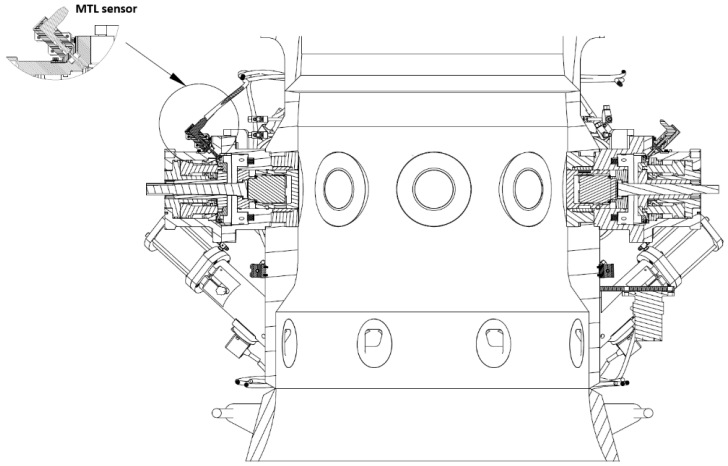



Figure 31: Schematic drawing of the MTL sensor

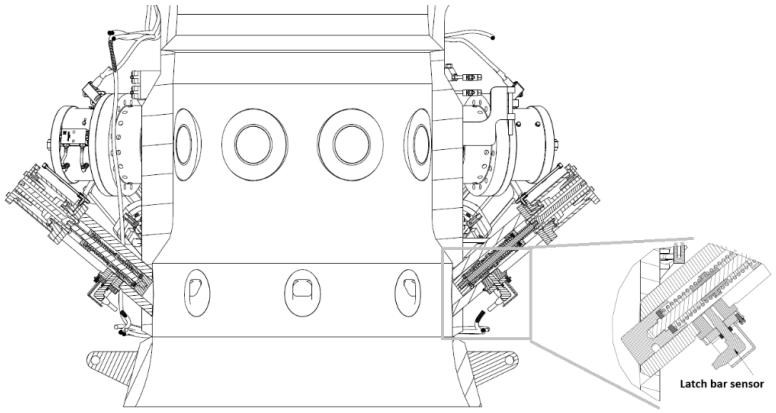



Figure 32: Schematic drawing of the Latch bar sensor

**10.3.3** The end course detector work principle shall be based on a subsea inductive ultrasonic proximity sensor.

**10.3.4** End Course Detectors for Top cone wedges and Latch bars shall be designed to inform three different stages, including a transition stage.

**10.3.5** End Course Detectors for MTL shall be designed to inform two different stages.

**10.3.6** Sensor solution shall follow the design principles of 10.1.6.

**10.3.7** Sensor installation location shall not compromise TSUDL structure and its main functionalities. It shall also comply with 10.1.7.

## 10.4 Corrosion Monitoring

**10.4.1** FPU CONTRACTOR/SELLER shall provide an electrochemical potential monitoring solution of the support structure to verify an indication of corrosion process, as illustrated at Figure 33.

**10.4.2** The electrochemical potential monitoring shall comprise one conductor connected to the support structure and other conductor connected to a Zinc reference electrode. Both connection points shall be close but not electrically connected. Both connection points shall be designed for easy access, maintenance and visualization

by divers. The Zinc reference electrode shall be dimensioned for 25 years design life.

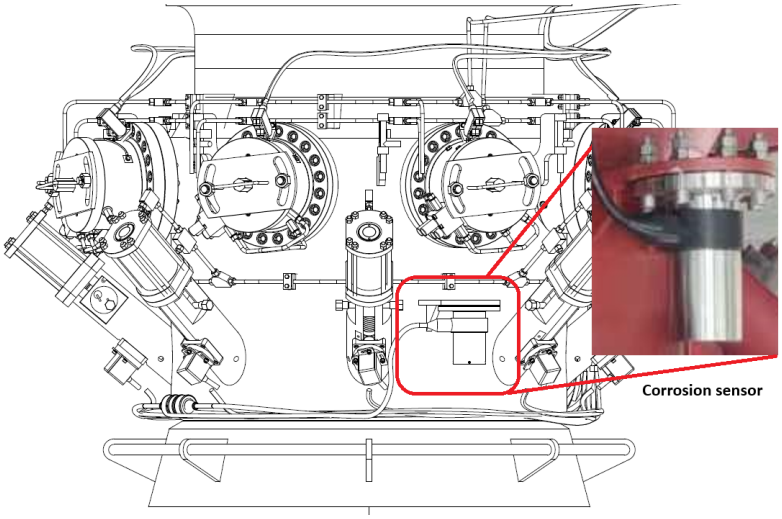



Figure 33: Schematic drawing of the Corrosion sensor

**10.4.3** The electrochemical potential solution shall follow 10.1.6.Figure 34 illustrates a general concept design of the sensor and its embedded electronic circuits.

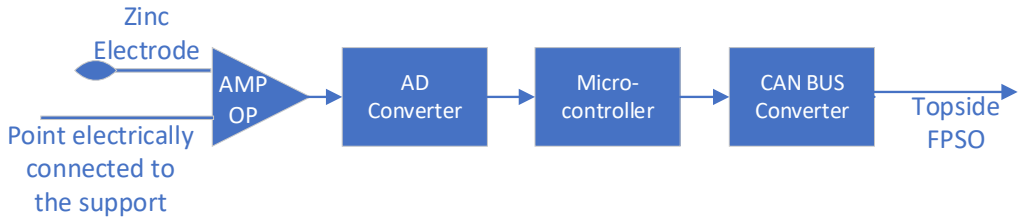



Figure 34: General Schematic of the Embedded Sensor Solution

**10.4.4** The solution shall be calibrated to address both overprotection and general corrosion of the system. Calibration shall be within the range -50mV to 250 mV, which are the limits for overprotection and general corrosion, respectively.

**10.4.5** Sensor installation location shall not compromise TSUDL structure and its main functionalities. It shall also comply with 10.1.7.

## 10.5 Subsea Junction Box (aka CAN Hub)

**10.5.1** A Subsea Junction box shall be provided for each instrumented support as shown on Figure 29.

**10.5.2** Subsea JB shall be responsible for gathering all the information from the sensors and transmit them via CANBUS to the lower riser balcony termination infrastructure.

**10.5.3** Subsea JB shall fulfill the requirements for subsea units described on 5.2.1, 5.2.2 and 5.2.3.

**10.5.4** Subsea JB is part of the Lower Balcony Infrastructure, and its design shall comply with 8.2.23.

## 10.6 Lower Riser Balcony Infrastructure

**10.6.1** Lower Riser Balcony Infrastructure shall be in accordance with Section 8 and in

specific project MD.

**10.7** Umbilical Infrastructure

**10.7.1** Umbilical Infrastructure shall be in accordance with Section 8 and in specific project MD.

## 11 TOPSIDE REQUIREMENTS

**11.1** RSMS TUTU Plates

**11.1.1** FPU CONTRACTOR/SELLER shall provide 1 (one) RSMS TUTU plate and 1 (one) umbilical JB for each hull side umbilical located in the upper balcony.

**11.1.2** RSMS TUTU plate shall have 1 (one) manual operated valve and 1 (one) pressure indicator for each hydraulic control line. The RSMS TUTU plate shall be connected in the topside with the corresponding Local Panel.

**11.1.3** FPU CONTRACTOR/SELLER shall provide a seal tag for each hydraulic circuit at RSMS TUTU plate to certificate the correct assembly (avoid switching hydraulic lines during Construction and Assembly or operational phase). Each change during FPU construction and Assembly shall be registered.

**11.2** Umbilical Junction Boxes

**11.2.1** Umbilical JBs shall comply with the requirements on 8.2.16 and 8.2.17. Please see Figure 35 below:

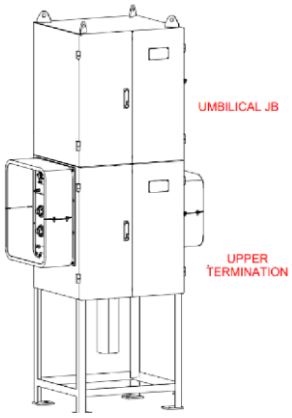



Figure 35: Umbilical JB and Upper Termination Design

**11.2.2** Umbilical JBs shall aggregate all optical fiber at splice trays and all electrical conductors at SAK terminals from umbilical pigtails. The umbilical JB shall be connected in the topside with the corresponding monitoring riser JB.

**11.2.3** Umbilical JB shall be sealed against dust and powerful water jets (protection degree IP-66).

**11.2.4** Umbilical JB shall be in accordance with its corresponding area classification.

**11.2.5** Umbilical JB and cable glands specification/installation shall be in accordance with its corresponding area classification.

**11.3** Monitoring Riser Junction Boxes

**11.3.1** FPU CONTRACTOR/SELLER shall provide 1 (one) junction box (aka monitoring

riser JB) for each hull side umbilical, and it shall be installed in the main deck at a level without green water issue.

**11.3.2** Monitoring Riser JB comprises the main functions.

- Collect/process TSUDL monitoring system electrical signals.
- Collect Local Panel monitoring system electrical signals.
- Transmit data to SCADA Master Station (at Riser Interface Cabinet).

**11.3.3** Monitoring Riser JB shall be designed with a RTU automation solution. This RTU shall collect/process all analog signals and transmit using TCP-IP standard protocol to the SCADA Master Station at Riser Interface Cabinet).

**11.3.4** RTU shall process/digitalize the following main variables:

- TSUDL locking module end stroke signals.
- TSUDL structure corrosion monitoring indication.
- TSUDL Drive Ring Hydraulic Actuator position readings.
- Local Panels pressure transmitters.

**11.3.5** Monitoring Riser JB shall be installed in places with easy access, in maximum height of 2 meters and where is dismiss the use of safety harness for high work.

**11.3.6** Monitoring Riser JB shall be sealed against dust and powerful water jets (protection degree IP-66).

**11.3.7** Monitoring Riser JB and cable glands specification/installation shall be in accordance with its corresponding area classification.

**11.3.8** Monitoring Riser JBs may be shared between RRMS system and RSMS system. See specific MD for general block diagram of the system.

**11.4** Local Panel.

**11.4.1** FPU CONTRACTOR/SELLER shall provide 1 (one) Local Panel for each Hull Side Umbilical.

**11.4.2** Local Panels main functions comprise:

- Terminate the hydraulic connections of each Hull side Umbilical.
- Provide Hydraulic Interface (hydraulic connector and control valve) to PUPS.
- House HMI of monitoring system interface.

**11.4.3** For each hydraulic circuit, FPU CONTRACTOR/SELLER shall provide inside Local Panel 5 (five) manual valves to interface with PUPS hydraulic headers.

**11.4.4** The hydraulic circuit between Umbilical Upper Termination and Local Panel shall be made by steel tubing and follow the requirements on [48].

**11.4.5** The hydraulic supply for Riser Support control system shall be provided by PUPS system, that will be placed close and connected to all local panels for the pull-in and pull-out operations.

**11.4.6** The Local Panel shall be installed in the main deck. The place shall consider the access and supply for PUPS hydraulic headers and for any maintenance of the

internal components during FPU life.

**11.4.7** FPU CONTRACTOR/SELLER shall provide hydraulic jumpers to connect PUPS to the hydraulic headers.

**11.4.8** Hydraulic circuits routed in the same umbilical can share the same local panel, with individual circuits for each TSUDL. FPU CONTRACTOR/SELLER shall guarantee the unmistakable correspondence solution between umbilical termination and Local Panel Outlets.

**11.4.9** Local Panel arrangement shall organize control valves the hydraulic outlets with clear identification, avoiding connection misunderstanding.

**11.4.10** The design of Local Panel shall include pressure transmitters for hydraulic supply. Each hydraulic actuation lines shall be monitored and have its data logged/showed in the supervisory system (see Figure 29).

**11.4.11** Local Panels shall be supplied inside a closed cabinet to protect its internal items. It shall have front and rear access for any internal component maintenance during operational life.

**11.4.12** Local Panel shall have an HMI as described in 11.7.22.

**11.4.13** Each Local Panel shall have an internal solenoid valve aligned to each hydraulic supply header from PUPS Unit. This activation shall use electrical switches (ON/OFF) able to be locked to avoid activation by mistake. The control logic of the solenoid actuation shall be controlled by the SCADA system inside the Riser Interface Cabinet, allowing only one local panel to be energized at a time.

**11.4.14** The design of Local Panel shall include a signal indicator of each solenoid activation.

**11.4.15** The design of Local Panel shall include pressure indicators to verify pressure in the hydraulic headers and at all hydraulic outlets of the TSUDL.

**11.4.16** Manual isolation valves shall be installed before each directional valve for TSUDL actuation.

**11.4.17** FPU CONTRACTOR/SELLER shall supply a physical hydraulic jumper that guarantees uncoupling from TSUDL hydraulic circuit, avoiding actuation of unwanted support by mistake.

**11.4.18** Local Panels' final design shall be defined according to specific MD from the project, depending on its scope.

**11.5** Portable Umbilical Pressurization System (PUPS)

**11.5.1** PUPS is a topside portable device to allow the FPU CONTRACTOR/SELLER to safety pressurize control line of hull side umbilical.

**11.5.2** FPU CONTRACTOR/SELLER shall provide two PUPS units (main and redundant) according to [57]. They shall be located in the same deck level from the Local Panel.

**11.5.3** PUPS operation location shall be with easy access for operator and with all air supply facilities required to operate.

**11.5.4** PUPS shall be designed in accordance with its corresponding are classification where it will operate.

**11.5.5** FPU CONTRACTOR/SELLER shall provide the hydraulic supply headers for all local panels according to [57].

**11.5.6** PUPS shall be filled with water glycol-based fluid in accordance with 5.2.8. FPU CONTRACTOR/SELLER shall inquire PETROBRAS about what will be the fluid predicted for this project before any filling operations.

**11.5.7** PUPS design shall be fully compatible to 5.2.9.

## 11.6 Riser Interface Cabinet

**11.6.1** The Riser Interface Cabinet is a multipurpose cabinet that can be shared among different types of monitoring systems, for example, RSMS (Riser Supports Monitoring System), RRMS (Rigid Riser Monitoring System) and MODA (Brazilian acronym for Flexible Riser Monitoring System). For detailed information of which systems are applicable to the project, FPU CONTRACTOR/SELLER shall consult the specific MD.

**11.6.2** Riser Interface Cabinet, including all components/equipment to be installed and respective connections are FPU CONTRACTOR/SELLER responsibility.

**11.6.3** Detailed Riser Interface Cabinet design information can be found in the specific MD.

## 11.7 Supervisory and Data Server.

**11.7.1** Supervisory system shall observe a topology of Figure 36.

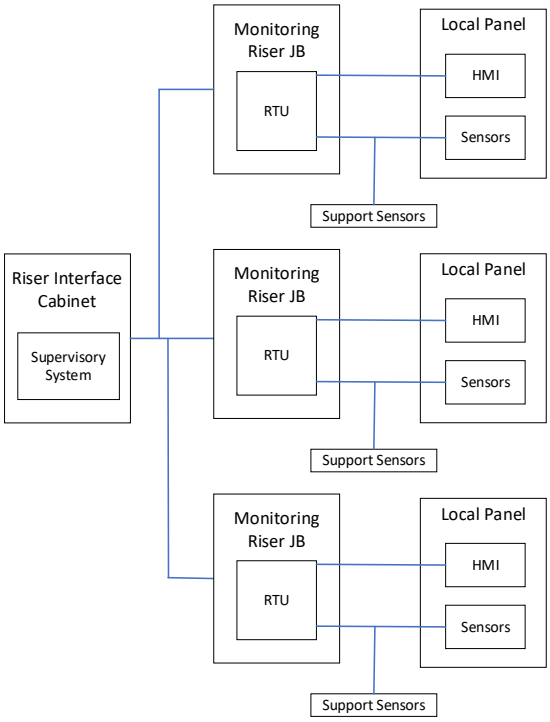



Figure 36: Supervisory System Topology

**11.7.2** A supervisory system shall communicate with the RTU and act as an interface to human operators and external systems of the monitoring system.

**11.7.3** The use of a well-established integrated supervisory solution able to provide all required functionalities is strongly advised.

**11.7.4** Dedicated supervisory screens shall report the value of every monitored variable as they are acquired along with the status of communication channels and each monitoring unit, including Local Panels, RTU and Cabinet housekeeping data.

**11.7.5** FPU CONTRACTOR/ SELLER shall design supervisory to receive data from all risers supports position in FPU.

**11.7.6** Riser Support Supervisory System shall be connected to FPU automation network and shall have a server installed in Riser Interface Cabinet to allow manage all system and register data log of all sensors.

**11.7.7** RSMS Processing Equipment shall be installed in the Riser Interface Cabinet.

**11.7.8** Riser Supervisory System shall not be part of the FPU cause and effect matrix, i.e. shall not be used to trigger emergency shutdown.

**11.7.9** In the case of power loss, the main processing equipment shall be able to restart automatically without the need for operator intervention.

**11.7.10** Riser Supervisory System shall be capable to configure alarms (Low low/ low/ high/high high) for each parameter. FPU CONTRACTOR/SELLER shall present to PETROBRAS recommendations of the alarm limits and discuss with PETROBRAS before implementing them to the software. Alarms limits shall be possible to be changed during operation.

**11.7.11** The FPU position provided by on-board GPS and AHRS (Attitude and Heading Reference system) shall be retrieved by the supervisory system from the POS system (Positioning and Navigation System for Floating Production Unit (FPU)).

**11.7.12** Supervisory system shall be able to receive a customized input of FPU Positioning System.

**11.7.13** The GPS UTC time provided by the FPU Positioning System shall be used as reference for the timestamps of all acquired data.

**11.7.14** Data shall be continuously retrieved from the instrumentation installed on risers. The sampling period shall be 1 second and a timeout event shall be understood as the unsuccessful retrieval of 3 consecutive samples.

**11.7.15** A database system for storage of generated data points shall be included in a OPC server.

**11.7.16** The database shall operate on a circular buffer pattern, whereby older records shall gradually be overwritten by newer samples once the database reaches its capacity. Storage space shall be provided as a dedicated RAID 1 array, sized for at least 24 months of logging at the highest possible data sampling rate.

**11.7.17** Data shall be provided to external systems and users via standardized OPC UA (Unified Architecture) interfaces as follows:

- OPC UA Data Access (DA) for real-time data.
- OPC UA Historical Access (HA) for historical data

**11.7.18** Real time data shall be made available for external access through a standardized OPC UA Data Access Interface.

**11.7.19** Historical data stored on the local database shall be accessible through an OPC UA Historical Access Interface.

**11.7.20** Alarms shall be made available for external clients through an OPC UA Alarms & Conditions Interface.

**11.7.21** The provided interfaces shall be ready for use by external systems from PETROBRAS corporate network which are allowed through FPU network firewalls.

**11.7.22** Local Panel HMI

11.7.22.1 FPU CONTRACTOR/SELLER shall provide a supervisory system to allow operator in local panel to check the status of each sensor installed in the TSUDL and manage the entire system and to data log at Riser Interface Cabinet.

11.7.22.2 FPU CONTRACTOR/SELLER shall provide an HMI Integrated to Local Panel to check all supports related to respective panel. The supervisory screen shall show graphically all supports and the data sensors related to each one.

## 12 INSPECTION, TEST, INSTALLATION AND COMMISSIONING REQUIREMENTS

### 12.1 Quality Control

**12.1.1** FPU CONTRACTOR/SELLER shall have quality control system, ensuring compliance with PETROBRAS requirements.

**12.1.2** Each element of the Work shall be executed in accordance with quality management systems that comply with the requirements of FPU CONTRACTOR/SELLER and PETROBRAS project requirements.

**12.1.3** SUBCONTRACTOR shall refer to the document “Project Quality Management Plan”.

**12.1.4** FPU CONTRACTOR/SELLER shall produce for PETROBRAS review and approval a project quality plan and a project quality control plan:

- *Project Quality Plan: Detail the organization, responsibilities, activities, and an index of referenced and applicable procedures to complete the work, including that of FPU CONTRACTOR/ SELLER.*
- *Project Quality Control Plan (ITP): Detail quality control plan and control monitoring to be employed during mobilization, acquisition and reporting phases.*

### 12.2 Personnel Qualification

**12.2.1** Personnel qualification of welders, NDT and dimensional inspectors shall comply with [52].

**12.2.2** Qualification of NDE Inspectors shall be according to [42], [9] and [52].

### 12.3 Procedure Qualification

**12.3.1** Ultrasonic testing of Welds shall conform to [42] and [52].

**12.3.2** The acceptance criteria for ultrasonic inspection and testing of complete joint penetration welds shall be [9] Level A.

**12.3.3** Magnetic Particle Testing shall conform to [9].

**12.3.4** The acceptance criteria for magnetic particle inspection shall be [9]. Local grinding of the weld to enhance interpretation of examination results shall be carried out as determined necessary by FPU CONTRACTOR/SELLER.

**12.3.5** Welding Procedure Qualification (WPS) shall meet, at least, Classification Society Rules for hull construction and [42] with the following modifications and additional information:

- Min. Yield Strength (0.2 % Offset): 355 Mpa
- Min. Tensile Strength: 455 Mpa
- Elongation in 2 in. or 50 mm, min 20%
- Charpy V-Notch Impact test temperature: -20 °C
- Charpy V-Notch Minimum Average Absorbed Energy: 50 J (set of 3 samples)
- Charpy V-Notch Minimum Individual Absorbed Energy: 34 J
- The maximum hardness in the HAZ and weld metal is 325 HV10 for C-Mn and low alloy steels

**12.4** Manufacture Inspection

**12.4.1** General

12.4.1.1 FPU CONTRACTOR/SELLER shall maintain a fabrication inspector during manufacturing process of the TSUDL.

12.4.1.2 All inspection records and results shall be included in the databook.

12.4.1.3 Inspections shall be performed in accordance with specific procedures and shall be included at least the activities listed herein.

12.4.1.4 FPU CONTRACTOR/SELLER shall always keep available for the inspectors the ITP, procedures, technical specifications standards, and other documents necessary to perform the inspection and interpretation of results.

12.4.1.5 All nonconformities records shall be part of the databook.

12.4.1.6 All TSUDL mechanical components shall be visual and dimensional inspected and as a result from the inspection shall be reported and included on the databook.

**12.4.2** Inspection and Test Plan - ITP

12.4.2.1 FPU CONTRACTOR/SELLER shall define the extent of his participation in the monitoring of inspections and factory tests through an Inspection and Test Plan – ITP – to be prepared and submitted by FPU CONTRACTOR/SELLER.

12.4.2.2 FPU CONTRACTOR/SELLER shall send the ITP for PETROBRAS approval respecting the contractual terms.

12.4.2.3 The ITP is a document within FPU CONTRACTOR/SELLER Quality Plan that follows the standards set by quality management standards, which shall contain at least:

- A description of activities of the manufacturing process, including those carried out in SUBCONTRACTORs, indicating the types and extent of exams, tests or checks to be performed during the manufacturing process.

- Identification of intervention type that will be performed by FPU CONTRACTOR/SELLER´s personnel and by FPU CONTRACTOR/SELLER's inspection representative throughout the manufacturing cycle (document verification, monitoring point, an observation point, and holding point).
- Indication of procedures, technical specifications, and standards for each activity.
- Acceptance criteria for all features and quality requirements of each activity, including activities carried out at SUBCONTRACTOR facilities.
- Identification and preparation of quality records, citing the record type applicable to each activity.

**12.4.3** Preparation and Cutting

12.4.3.1 Verify if parts to be cut are identified in accordance with item 13.3.

12.4.3.2 Verify if materials certificates correspond to the specified ones in the drawings.

12.4.3.3 Verify if parts dimensions are in accordance with drawings.

**12.4.4** Pre-assembly

12.4.4.1 Verify if the traceability of the parts is in accordance with item 13.3 and belong to the same assembly.

**12.4.5** Non-destructive tests

12.4.5.1 All procedures and personnel used in NDT shall be qualified and certified in accordance with 12.2 and 12.3.

12.4.5.2 Visual Inspection – All welds shall be inspected in 100% (both sides) of their extension to check aspect and continuity.

12.4.5.3 Liquid penetrant inspection – All welds shall be inspected in 100% of their extension.

**12.4.6** Tensile and Impact Tests

12.4.6.1 An additional latch bar shall be supplied to prepare 2 (two) samples for tensile tests and 2 (two) samples for the impact test. For samples dimensions see ASTM A370 and Figure 37.

12.4.6.2 Similar to item 12.4.6.1, and additional locking wedge shall be supplied to prepare 2 (two) samples for tensile tests and 2 (two) samples for impact tests, which sample position shall be obtained near from part surface, similar as outlined on Figure 37.

12.4.6.3 The samples shall be extracted after latch bars heat-treatment.

12.4.6.4 A Test Inspection and Certification Society (TIC -Society) shall certify the tests results.

12.4.6.5 The results shall be part of databook.

12.4.6.6 Tensile Tests

12.4.6.6.1 The yield strength, tensile strength, stretching and are reduction shall be obtained by tensile test.

12.4.6.6.2 The yield strength shall be 500 (five hundred) MPa minimum for the latch bar samples, and 450 (four hundred fifty) MPa minimum for locking wedge samples. These minimum values correspond to the selected Material on FEED Design. If another material is selected for these components, the minimum yield strenght shall comply with the detailed design.

12.4.6.7 Impact Test

12.4.6.7.1 Charpy tests shall be performed at -10 °C (minus ten degrees Celsius).

12.4.6.7.2 The result shall be 27 (twenty-seven) Joules minimum.

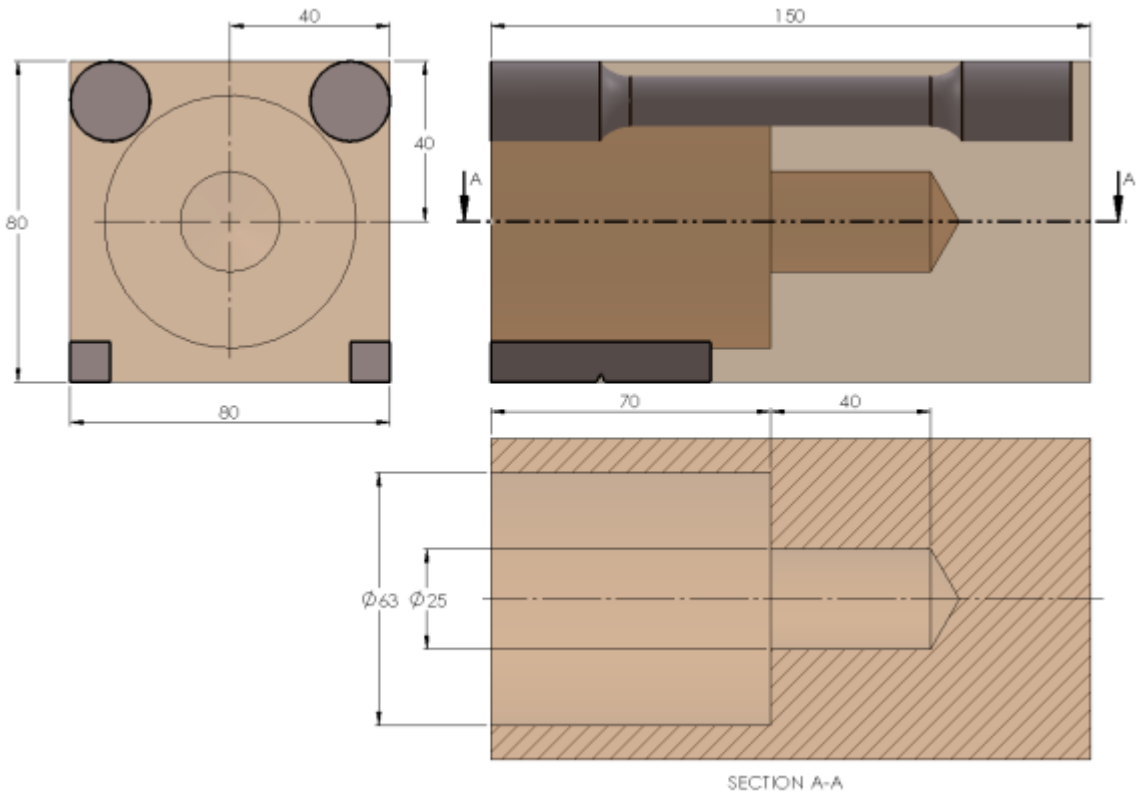



Figure 37: Position for extraction of tensile and impact tests samples on the additional latch bar

**12.4.7** Dimensional

12.4.7.1 Verify if dimensions are in accordance with the drawings.

12.4.7.2 Dimensional control inspectors shall be qualified in accordance with 12.2.

**12.5** Factory Acceptance Test (FAT)

**12.5.1** All TSUDL shall be tested individually to verify their mechanical and control

functioning.

**12.5.2** For the Monitoring Systems, all circuits (i.e. hydraulic, optical and electrical) shall be tested individually. After confirmation of their individual functionality, tests shall be performed with its corresponding system (RSMS and RRMS) completely integrated.

**12.5.3** All TSUDL shall be completely assembled, i.e. all instrumentation (sensors), cathodic protection cables, hydraulic cylinder and auxiliary equipment shall be assembled before FAT starts. TSUDL's FAT shall include all sensor components to be accepted.

**12.5.4** All components of TSUDL/MTL made of copper-based alloys shall be inspected to check electrical insulation. This electrical insulation procedure shall be subjected for Petrobras approval before execution of the tests.

12.5.4.1 For copper-based actuator parts, insulation testing shall be performed by measuring the electrical potential of the parts submerged in saline water, following the requirements described in Annex A:.

**12.5.5** All components of TSUDL/MTL made of steel shall be inspected to check for electrical continuity to central structure to assure cathodic protection. This electrical continuity procedure shall be subjected for Petrobras approval before execution of the tests.

**12.5.6** All tests for the TSUDL are FPU CONTRACTOR/SELLER responsibility.

**12.5.7** A member of Quality Control Department of FPU CONTRACTOR/SELLER shall witness all tests and is responsible for registering the tests results and filling out the TRS. This member is also responsible for report any deviation that occurred during the tests.

**12.5.8** FAT procedure shall be submitted to PETROBRAS for review and approval.

**12.5.9** Rigid Riser's pull-in and pull-out simulation tests shall be performed with a dummy HOA manufactured in accordance with the drawings supplied by PETROBRAS.

**12.5.10** Flexible Riser's pull-in and pull-out simulation tests shall be performed with a Dummy Cap manufactured in accordance with drawings supplied by PETROBRAS.

**12.5.11** The inner parts of the TSUDL as well as the locking wedge sets shall be fully coated, including the anti-fouling layer, for rigid and flexible risers pull-in and pull-out assessment tests.

**12.5.12** A contractor representative shall witness all tests. This representative will be responsible for approving or rejecting the FAT.

**12.5.13** PETROBRAS reserves the right to send a representative to monitor the tests. This representative will not have the responsibility of approving or rejecting the tests. The representative shall be allowed to take pictures and record videos at any time.

**12.5.14** An independent third-party representative shall witness and approve all tests.

**12.5.15** A third-party service is contractor and/or supplier responsibility.

**12.5.16** For TSUDL components manufactured in Brazil, the contractor shall notify PETROBRAS, at least 10 calendar days in advance or as defined in the terms of the contract, the date when the TSUDL will be available for FAT.

**12.5.17** For TSUDL components manufactured abroad, the contractor shall inform

PETROBRAS at least 30 calendar days in advance or as defined in the terms of the contract the date when the equipment will be available to be tested.

**12.5.18** During all testing, the TSUDL components and its parts shall be transported on pallets and is not acceptable to transport them in direct contact with the fork of the forklift.

**12.5.19** Tests performed with the TSUDL components inverted (upside down) are not acceptable.

**12.5.20** Tests shall be performed by lifting the Dummy HOA/Dummy Cap into a fasten and secured TSUDL on a test stand. It is not allowed to perform the tests with Dummy HOA/Dummy Cap fixed and moving the TSUDL.

**12.5.21** A load cell shall be installed between the lifting cable and the Dummy HOA/Dummy Cap to measure the load required to overcome the force exerted by the springs. This measurement shall be reported in the TRS and sent to PETROBRAS for information.

**12.5.22** All images in this document are for information only and their purpose is to help one understand tests steps and acceptance criteria.

**12.5.23** Photographic records of all tests shall be included in FAT reports.

**12.5.24** Supplier shall evaluate and correct any unsafety conditions on all testing procedures.

**12.5.25** Intermediate plates shall be welded to TSUDL prior to FAT.

**12.5.26** The FAT procedure shall observe at least the requirements in [49] and FAT PROCEDURE.

**12.5.27** FAT shall be performed using the same hydraulic control fluid planned to be used on PUPS and in accordance with 5.2.8.

**12.5.28** FPU CONTRACTOR/SELLER shall comply with PUPS system requirements [57] predicted for TAP-1.

**12.5.29** FPU CONTRACTOR/SELLER shall comply with Section 11.7 within HMI system requirements during TAP-1. Verification of the sensors functionality shall be clearly demonstrated by means of exercising each single reading, including transition stages where applicable.

**12.6** Commissioning Requirements

**12.6.1** The requirements presented in this section shall be met regarding commissioning activities. Planning of installation and commissioning activities shall be developed and submitted to PETROBRAS for approval.

**12.6.2** Commissioning is understood, in this context, as the process of placing the system (or parts thereof related to a particular monitored structure) in a fully functional state, without any pending issues.

**12.6.3** All equipment shall be tested onshore and pass the FAT (Section 12.5) and any other FPU CONTRACTOR/SELLER approved procedures.

**12.6.4** After installation at FPSO, during the commissioning of the hydraulic actuator system, FPU CONTRACTOR/SELLER shall perform integrated tests to verify that:

- All system is correctly installed and operational

- Each local panel is activating the correct TSUDL
- All hydraulic actuators are operational
- All sensors from sections 10.2 to 10.4 are operational
- There is no leak and no bubbles in the hydraulic circuit

**12.6.5** All tests from 12.6.4 shall be done in the dry dock, to perform any possible corrections and shall use the same hydraulic fluid planned to be used on PUPS and in accordance with 5.2.8.

**12.6.6** FPU CONTRACTOR/SELLER shall inform, during the commissioning activities, all administrator passwords needed to operate and manage all equipment.

**12.6.7** All components of TSUDL/MTL made of copper-based alloys shall be inspected to confirm electrical insulation, performing at dry dock with the components emerged and installed at lower balcony. This electrical insulation procedure shall be subjected for Petrobras approval before execution of the commissioning activities.

## 12.7 Recommendations for TSUDL and FPSO Integration

### 12.7.1 General

12.7.1.1 FPU CONTRACTOR/SELLER shall define the TSUDL preservation recommendations (e.g. UV exposure restriction, packing condition, or any other issue) in order to assure any quality loss due to inappropriate storage on shipyard.

12.7.1.2 For an appropriate preservation recommendation, FPU CONTRACTOR/SELLER shall inform the main FPSO schedule milestones related to the TSUDL integration.

12.7.1.3 The milestones shall include, but not limited to, the expected time between the FAT and TSUDL integration with the Riser Balcony and the end of dry dock condition.

12.7.1.4 In principle, no coating touch-up is allowed during the dry dock phase.

12.7.1.5 This disallowance is due to the importance of the DFT tolerances for the TSUDL compatibility with the Cap DL-SI, particularly on the TSUDL inner diameters.

12.7.1.6 If by any eventuality it is considered that TSUDL coating must be repaired, FPU CONTRACTOR/SELLER shall submit the repair procedure for PETROBRAS review and approval.

12.7.1.7 The cable connections integrity (cathodic protection transmission for moving parts) shall be verified after the bellmouth assembly on the riser balcony and before the end of dry dock. If necessary, these connections shall be repaired by FPU CONTRACTOR/SELLER.

12.7.1.8 FPU CONTRACTOR shall issue a Handling Procedure to PETROBRAS, including the requirements for moving and installing the TSUDL, indicating information such as existing eyebolts, static loads, accelerations and movements involved, lifting balancer, use of steel cables and/or straps and/or transport skid, safety measures, etc. This item is critical for the TSUDL operation.

12.7.1.9 FPU CONTRACTOR shall issue an Assembly and Installation Procedure to PETROBRAS, including the requirements for construction, assembly and installation of the TSUDL, indicating information such as step-by-step assembly with instructions and sequence, checks to be made (alignment/leveling), details of the hydraulic connections and their integration with other systems of the unit, tests, list of tools (including special ones) and materials required for assembly and commissioning, etc., in order to facilitate understanding. This item is critical for the TSUDL operation.

12.7.1.10 FPU CONTRACTOR/SELLER shall provide the TSUDL Top Load Analysis for PETROBRAS review and approval until the end of 30% FPU design review.

**12.7.2** FPSO Dimensional Gauge Test

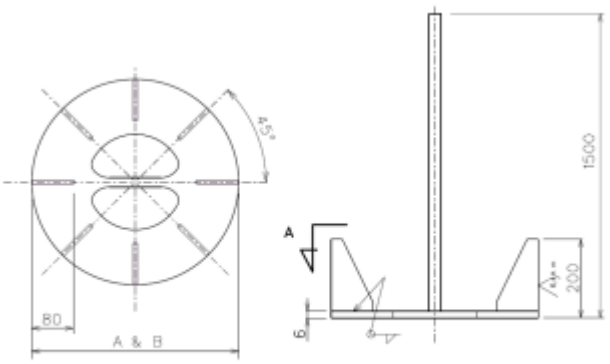
12.7.2.1 The dimensional gauge should be used in shipyard to verify the main TSUDL's dimensions after its integration to the FPSO riser balcony and the subsequent compatibility with the CAP DL-SI that will be provided by the Riser SUBCONTRACTOR.

12.7.2.2 The dimensional gauge should be used to assure that no unexpected event occurred to the TSUDL between the FAT and the FPSO integration (e.g. disallowed coating touch up or damage during TSUDL's shipment).

12.7.2.3 The dimensional gauge may be produced with a lightweight material (e.g. aluminum) for a better handling.

12.7.2.4 PETROBRAS reserves the right to require the use of the dimensional gauge on shipyard whenever it considers to be necessary.

12.7.2.5 Figure 38 shows a preliminary design for the dimensional gauge, which can be used to inspect the respective inner diameters shown in Figure 39.




| BSDL-SI model | ØA | ØB |
|---|---|---|
| 48" | 1075,5/1075,0 mm | 1111,5/1111,0 mm |

Figure 38: Dimensional Gauge Preliminary Design

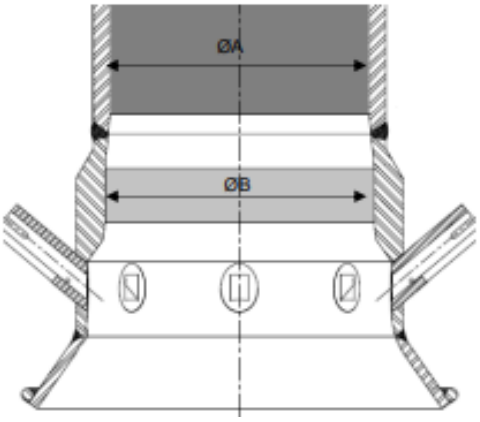



Figure 39: TSUDL's inner diameter to be inspected with the Dimensional Gauge

## 13 IDENTIFICATION, PROTECTION, TRACEABILITY AND PACKING

### 13.1 Protection and Packing

**13.1.1** TSUDL shall be delivered packed to ensure the integrity of the parts, in particular the mobile locking devices.

**13.1.2** The packing shall avoid the ingress of any debris in the round block and upper cone mechanism.

### 13.2 Identification

**13.2.1** All TSUDLs shall be identified according to their numbering of riser slot position on balcony arrangement. Marking shall be performed in 3 (three) points (top and sides of support), in an indelible form (linear and weld bead) and painted in contrasting color. Characters shall be visible and identifiable by divers and by ROV. The choice of the positions of these marking shall be submitted to PETROBRAS approval.

**13.2.2** Each sector shall be marked in two different locations: external cylindrical surface and bell mouth cone.

**13.2.3** The minimum paint height shall be equal to 200 mm (two hundred millimeters).

### 13.3 Traceability

**13.3.1** Codification and traceability procedures shall be in accordance with item 7.5.3 of [34] plus the following requirements.

- Alphanumeric codes for traceability shall be punctured in materials using low stress punches.
- Each equipment shall receive a unique codification to allow tracing back its respective inspection and tests reports.

## 14 MODIFICATIONS AND ADJUSTMENTS

**14.1.1** FPU CONTRACTOR/SELLER may implement small changes in the design to make it appropriate to its manufacturing process or to correct small non-conformities. In this case, FPU CONTRACTOR/SELLER shall submit a written document to PETROBRAS describing the problem and proposed solutions.

**14.1.2** Changes mentioned in 14 will only be implemented after FPU CONTRACTOR/SELLER and PETROBRAS approval.

**14.1.3** A Design Review event, with representatives from FPU CONTRACTOR/SELLER and PETROBRAS shall be held before the start of the TSUDL manufacturing.

**14.1.4** To avoid major changes on the detailed design performed by FPU CONTRACTOR/SELLER at a later stage, it is highly recommended for the FPU CONTRACTOR/SELLER to schedule preliminary meetings with PETROBRAS before design review.

## 15 DOCUMENTATION REQUIREMENTS

### 15.1 General

**15.1.1** FPU CONTRACTOR/SELLER shall furnish all data generated during the design cycle of the TSUDL, including the results of the numerical analyses that will be carried out to fulfill the design requirements, the hull structural requirements defined on FPSO documentation and [30]. In case of any conflict identified, PETROBRAS shall be consulted. This documentation shall be comprised of written reports in accordance with FPU CONTRACTOR/SELLER standards, and the electronic input and output files of the finite element analysis.

**15.1.2** Design Methodology reports and analysis results reports shall be submitted by FPU CONTRACTOR/SELLER and approved by PETROBRAS before start of fabrication. Design revision cycles, including proprietary documents, when necessary, can be requested by PETROBRAS under FPU CONTRACTOR/SELLER premises.

**15.1.3** FPU CONTRACTOR/SELLER shall demonstrate the adequacy and the reliability of the TSUDL by proven methods of design. The conservatism of calculation methodology employed shall also be clearly demonstrated, and no question of the adequacy of the project-specific service conditions shall remain.

**15.1.4** Commercial local analysis package accepted are Abaqus and Ansys.

**15.1.5** All materials intended for the fabrication of TSUDL components shall undergo Positive Material Identification (PMI) prior to manufacturing.

### 15.2 Bidding Documentation

**15.2.1** FPU CONTRACTOR/SELLER shall inform conflicting data present in PETROBRAS drawings during Basic Design Endorsement period. If any problem is identified during manufacturing phase, the solution taken by FPU CONTRACTOR/SELLER shall follow Article 12 of the agreement.

**15.2.2** FPU CONTRACTOR/SELLER shall present the chosen SUBCONTRACTOR portfolio, which must include details about engineering and design staff experience and resources, construction and quality test capabilities as well as company experience in similar projects.

**15.2.3** FPU CONTRACTOR/SELLER shall present the outline design and manufacturing plan, from raw material supply up to the hull integration.

**15.2.4** FPU CONTRACTOR/SELLER will be responsible to comply with all PETROBRAS requirements.

**15.3** Manufacturing and Test Documentation

**15.3.1** The points described in this section comprises the requirements for manufacturing and tests phases. For a list of expected minimum documentation, please see LIST OF MINIMUM DOCUMENTATION.

**15.3.2** Any other document may be requested by PETROBRAS at any time, depending on the project evolution.

**15.3.3** QA/QC procedures (e.g. ITP, NDT, FAT, traceability, nonconformance, document control) shall be submitted to PETROBRAS for review prior to the start of design and production work.

**15.3.4** Design Basis and Methodology (DBM) shall be submitted to PETROBRAS for review before starting of design and production work, as a minimum, including the following:

- Design Parameters
- Design methodology including FEA tools to be used as agreed by PETROBRAS
- Proposed material specifications
- Chemical composition and mechanical properties of steel components (yield strength, tensile strength, percent elongation, area reduction, and other required properties)
- Component material lists and descriptions, including any “in-house” material specifications, which shall be made available at FPU CONTRACTOR/ SELLER facilities
- List of Design Drawing
- Design calculations and reports for each element

**15.3.5** The QA/QC, DBM and MPS shall be written specifically for the PURCHASE ORDER and shall be approved by PETROBRAS prior to commencement of manufacturing operations.

**15.3.6** FPU CONTRACTOR/SELLER shall notify PETROBRAS of any changes in these practices for PETROBRAS review/approval prior to implementation.

**15.3.7** Design calculations and reports shall be issued to PETROBRAS for review prior to the manufacturing.

**15.3.8** Nonconformity reports shall be issued to PETROBRAS within the contractual deadline. All nonconformity reports, including concession requests, shall be submitted to PETROBRAS for review.

**15.3.9** Prior to start of manufacture, FPU CONTRACTOR/SELLER shall generate General Assembly drawings of the subassemblies upper cone, central structure, and a general assembly drawing of the TSUDL. These drawing and any other auxiliary drawing of individual parts or subassemblies shall be submitted to PETROBRAS for review. Subsequent revisions to drawings shall also be issued to PETROBRAS for review, as they are prepared. These GA drawings shall include the following, as a minimum:

- Interface, overall dimensions, and tolerances (including total length, body diameter and body external profile)

- Presented dimensions and tolerances shall be sufficient to FPSO constructor to design the topside hard pipe spool
- Position of the CoG (in air and water) of the TSUDL and each subassembly
- Total weights of the assembled TSUDL and of each main subassembly
- Material Identification and source part number
- Details of handling attachments
- Dimensional details of the assembly flanges
- Assembly between Upper Cone, Central Structure, showing any auxiliary device.

**15.4** Installation, Operation and Maintenance Manual

**15.4.1** This section comprises the general requirements to elaborate the Installation, Operation and Maintenance Manual.

**15.4.2** Manuals shall be submitted in English and Portugues languages.

**15.4.3** The document shall be self-contained, i.e. shall provide all the necessary steps to correctly install, operate and maintain the support.

**15.4.4** The manual shall include a specific section with step-by-step information on how to identify the actuator position on the HMI and how to actuate each of them following the process for riser installation/deinstallation.

**15.4.5** Manuals are part of FPU CONTRACTOR/SELLER deliverables. For a list of expected minimum documentation, please see LIST OF MINIMUM DOCUMENTATION.

**15.5** Databook

**15.5.1** For TSUDL manufactured in Brazil, the databook shall be emitted in Portuguese language, unless otherwise requested. For TSUDL manufactured abroad, the databook must be issued in the language defined by the contract.

**15.5.2** FPU CONTRACTOR/SELLER shall issue a databook of the products, to allow traceability of all parts, containing at least the following items:

- Records of heat treatment and tests according to this specification and project standards
- Records of Non-Destructive Examinations according to this specification and project standards
- Records of FAT according to this specification and project standards
- Qualifications of the welding process and welders according to this specification and project standards
- Records of dimensional Inspection according to this specification and project standards
- Inspection and Tests Plan (ITP) approved by PETROBRAS
- Identification and inclusion of all reports issued by FPU CONTRACTOR/SELLER inspection, concerning the released products

- Identification and incorporation of critical non-conformities of FPU CONTRACTOR/SELLER and the corrective actions taken concerning the released products
- Drawings of set containing traceability of all essential components of the project, reported in the ITP
- Reports from water absorption for polymeric components.

## 16 SCOPE OF WORK

### 16.1 FPU CONTRACTOR/SELLER Responsibilities

**16.1.1** FPU CONTRACTOR/SELLER shall furnish all labor, consumables, tools, equipment, and materials other than those explicitly identified as supplied by FPU CONTRACTOR/SELLER required to manufacture, test and deliver. FPU CONTRACTOR/SELLER shall perform all required operations for design, manufacture, inspection, testing and handling.

**16.1.2** Nothing contained in this Specification or omitted from it shall be construed as relieving FPU CONTRACTOR/SELLER of the obligation to supply the TSUDL in accordance with the functional requirements outlined herein, said to be capable of functioning properly in a riser system for the entire design period specified by PETROBRAS for the project, without need for replacement of any of its parts.

**16.1.3** FPU CONTRACTOR/SELLER shall develop a written Manufacturing Plan/Procedure, including a Quality Control/ Quality Assurance Plan (QAP), which shall be submitted to PETROBRAS for review prior to commencement of material procurement and manufacturing.

**16.1.4** A pre-production meeting shall be held between PARTIES representatives, plus any third-party inspection personnel involved. The purpose of the meeting is to ensure that all parties involved fully understand job requirements and resolve any outstanding issues before the beginning of the manufacturing start.

**16.1.5** PETROBRAS furnished Drawings and Specifications shall be checked by FPU CONTRACTOR/SELLER immediately upon receipt, and FPU CONTRACTOR/SELLER shall promptly notify PETROBRAS of any discrepancies therein.

**16.1.6** For any requirement in question by FPU CONTRACTOR/SELLER, it shall be FPU CONTRACTOR/SELLER’s responsibility to:

- Obtain clarification from PETROBRAS, which shall be final and binding
- Review and resolve conflicts with PETROBRAS prior to initiation or continuation of Work

**16.1.7** FPU CONTRACTOR/SELLER shall allow PETROBRAS and third-party representatives, under FPU CONTRACTOR/SELLER premises, reasonable access to all areas concerned with Design, manufacture, inspection, and testing during all times while Work is being performed for the Project.

**16.1.8** FPU CONTRACTOR/SELLER shall provide all reasonable facilities to PETROBRAS’S inspectors, without extra charge, to satisfy the inspector that product is being manufactured in accordance with PETROBRAS’Ss specifications.

Such facilities shall include, but not limited to, office equipment and telecommunication equipment. All inspection shall be made at the place of manufacture prior to shipment. If any inspection or testing reveals details not in accordance with PETROBRAS'S Specification, then FPU CONTRACTOR/SELLER may demonstrate to PETROBRAS that the product still satisfies the design requirement. If FPU CONTRACTOR/SELLER is unable to prove this to PETROBRAS'S satisfaction, then the manufacturing and/or testing procedure shall be repeated until compliance is demonstrated. All such remedial Work shall be performed at FPU CONTRACTOR/SELLER's cost.

**16.1.9** Equipment used for the manufacture shall be of proven Design and in good operating condition.

**16.1.10** Methods employed shall be in accordance with prudent engineering, fabrication and construction practice.

**16.1.11** All costs, including taxes are to FPU CONTRACTOR/SELLER account in undertaking the responsibilities.

**16.1.12** Deviations from this Specification are not permitted. All proposed changes or modifications to this Specification shall be submitted in writing for PETROBRAS approval. Procurement, Fabrication and Procedures Approved changes shall be incorporated into a revised, approved Project (purchase) specification. Disclaimers are not permitted.

## 17 SUBCONTRACTOR REQUIREMENTS

**17.1.1** FPU CONTRACTOR/SELLER shall choose SUBCONTRACTOR(S) with experience (track record) with PETROBRAS' previous projects or with proved experience (track record) in:

- Subsea systems
- Umbilical systems
- Hydraulic systems
- Instrumentation/automation systems.

**17.1.2** FPU CONTRACTOR/SELLER shall provide an INTEGRATOR that shall be responsible for all SUBCONTRACTORS interfaces and technical support during design, supply, tests, commissioning (dry dock TAP-1 & topside integration TAP-2 phases) and offshore operations.

**17.1.3** During the executive design FPU CONTRACTOR/SELLER shall submit to PETROBRAS approval a Technical Proposal including the evidence of attending items requested.

## ANNEX A: FAT PROCEDURE

### 1. FAT Infrastructure

1.1. FPU CONTRACTOR/SELLER shall provide the entire infrastructure necessary to perform the tests.

1.2. FPU CONTRACTOR/SELLER shall supply Inspection devices as go no-go gauges for testing and shall be presented for Petrobras approval to be used as acceptance criteria.

1.3. The infrastructure necessary to perform the test shall contain, at least, the following items:

- One Dummy HOA and one Dummy Cap.
- One HMI device and power supply with cabling to energize and acquire all TSUDL sensors readings.
- One wire rope with suitable mechanical resistance to lift up Dummy HOA, Dummy Cap and TSUDL components.
- Shackles with suitable mechanical resistance to lift up Dummy HOA, Dummy Cap and TSUDL components.
- Synthetic cables (ropes) for guiding Dummy HOA/Dummy Cap during pull-in tests.
- A lifting device, that can be a crane, an overhead crane, capable of suspending the Dummy HOA/ Dummy Cap with a speed of 4m/min.
- A test stand containing a device specifically designed to secure the TSUDL components, so the cylindrical body is plumb. The lower conical part of TSUDL shall be at an appropriate distance from the floor so the Dummy HOA/ Dummy Cap can be positioned below it and the handling mechanisms of the latch bars can be operated manually.
- Load Cell to measure the force needed to overcome the springs.
- A walkway and a guardrail shall be available for secure access to the components moving parts.
- An example of test stand with appropriate walkway is presented on Figure 40.

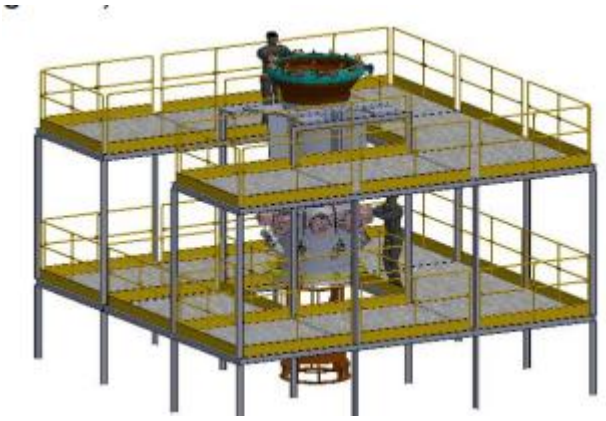


Figure 40: Test Stand Example

- One hydraulic Power Unit (HPU) capable to provide hydraulic power that meets the specifications for hydraulic actuation tests including pressure safety relief valves and pressure regulation valves to be adjusted for the actuation pressures during FATs.
- The present document is referred for a flexible riser full mechanical locking/unlocking mechanism (latch bars mechanism). If hydraulic actuation system for this mechanism is applied to the present project, the HPU shall also meets its technical specification.
- Hoses and connectors to bring hydraulic power from HPU to Lateral Support Modules hydraulic circuit.
- A device to measure the force necessary to actuate the ROV override mechanism.
- A four-wire sensing micro-ohmmeter, with suitable resolution for measuring values around 0.1Ω.
- A feeler gauge set suitable for measuring clearances of 0.5 mm and 2 mm.
- Synthetic cables (ropes) for simulating marine growth resistance during Drive Ring ROV override Test.
- A structure with pad eyes for attaching and securing the synthetic cables described on the previous item.

## 2. FAT Results

2.1. FAT results shall be reported in the Test Report Sheet (TRS). A TRS model is provided and instructions on how to fill it out is provided on A7.

2.2. Supplier quality control member and the contractor representative shall issue one report by TSUDL components tested stating one of two results: accepted or rejected.

2.3. The TSUDL components with status “send to repair” shall be repaired and retested. It will only be considered “accepted” after correction of all non-conformities and after passing through all tests.

2.4. Any repair made in the TSUDL components invalidates all tests performed until that moment.

2.5. The TSUDL rejected components shall be discarded and a new TSUDL component with the same characteristics shall be manufactured.

2.6. In this case, the new TSUDL component shall receive a new serial number.

2.7. The TRSs rejected and discarded TSUDL components shall be included in the databook set of approved ones.

2.8. In case of any TSUDL components performance problems, Contractor shall contact PETROBRAS and it reserves the right to send a representative in order to assist in the evaluation of non-conformities.

## 3. Flexible Riser Pull-In and Pull-out simulation FAT procedure minimum requirements, sequence and acceptance criteria

3.1. Preparation

3.1.1. Supplier shall verify prior to the test if the infrastructure listed in A1 needed to perform the tests is available and ready to be used.

3.1.2. Preparation for TSUDL sensors required for the Flexible riser FAT:

a) Assemble all sensors to the TSUDL corresponding components for this FAT (End-course latch bars sensors, as per section 10.3).

b) Assemble all cabling to the sensors.

c) Install the HMI device and power supply to the sensors' cabling.

d) Check if all sensors are operational.

3.1.3. Preparation for latch bars sets test (A3.2):

e) Place and secure TSUDL with its Central Structure plumb to the lifting device.

f) Check if all handlers are in "upper" position, locked by TSUDL's Bracer, and latch bars are in "extended" position (Figure 42b and Figure 43b).

3.1.4. Preparation sequence for TSUDL Drifting Test (A3.3) and Pull-in and Pull-out Simulation Tests (A3.4)

a) Place and secure TSUDL with its Central Structure plumb to the lifting device.

b) Place Dummy Cap below TSUDL and axially aligned with it and with the lifting device cable, with the wire rope sling passing inside the Central Structure.

c) Attach the wire rope to Dummy Cap upper eyebolts symmetrically spaced using specified shackles (Figure 41).

d) Check if MTL mechanisms are assembled in the TSUDL and are in "retracted" position (Figure 52a).

e) Check if all handlers are in "upper" position, locked by TSUDL's Bracer and latch bars are in "extended" position (Figure 42b and Figure 43b).

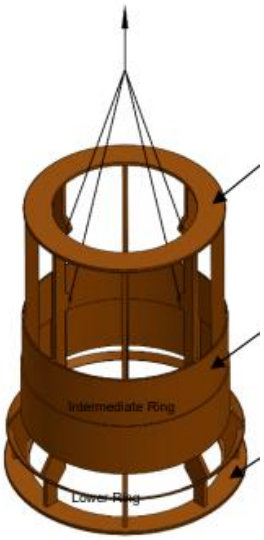



Figure 41: Dummy Cap - Template for the TSUDL Flexible Riser Pull-In Simulation Tests

3.2. Latch Bars Set Test

3.2.1. The objective of this test is to verify if latch bars set are fully functional an if each latch bar is properly aligned to TSUDL's inner surface.

3.2.2. Handler Performance Test Sequence:

a) Actuate each latch bar set handler to "lower" position (Figure 42a), so latch bars move to "retracted" position (Figure 43a).Figure

b) Insert latch bar locking tools in round blocks (Figure 44) to lock latch bars in "retracted" position.

c) Actuate 3 (three) times each handler, from "lower" to "upper" position and back (Figure 42). **Acceptance Criteria Ra1**, item A3.7.1.

d) Return Handler to "lower" position and remove LBLTs from round blocks in order to release latch bars.

e) Actuate 3 (three) times each latch bar from "retracted" to "extended" position (Figure 43) using respective handler. **Acceptance Criteria Ra2**, item A3.7.2. Verify if the end-course latch bar sensors indication flag from "retracted" to "extended" position is working properly. **Acceptance Criteria Sa1**, item 3.7.18.

3.2.3. Latch Bars Alignment Test Sequence

f) Actuate each latch bar set handler to "lower" position (Figure 42a), so the latch bars move to "retracted" position (Figure 43a). **Acceptance Criteria Ra3**, item A3.7.3.

g) Actuate each latch bar set handler to "upper" position (Figure 42b), so latch bars move to "extended" position (Figure 43b) **Acceptance Criteria Ra4**, item A3.7.4.

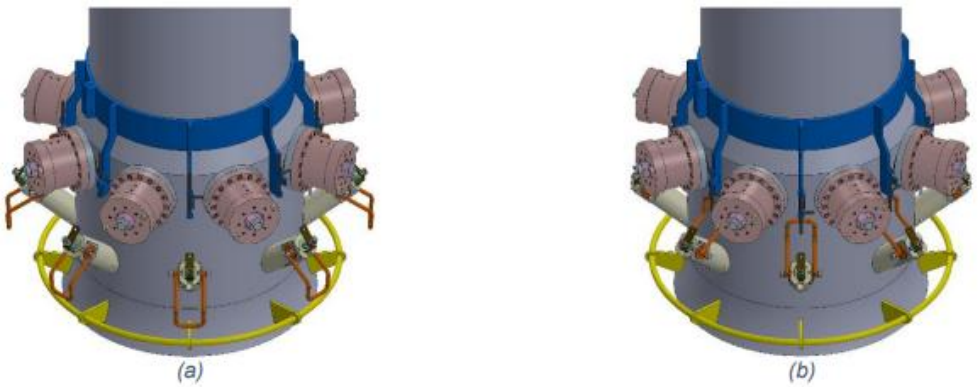



Figure 42: Handlers (a) "Lower" position and (b) "Upper" position

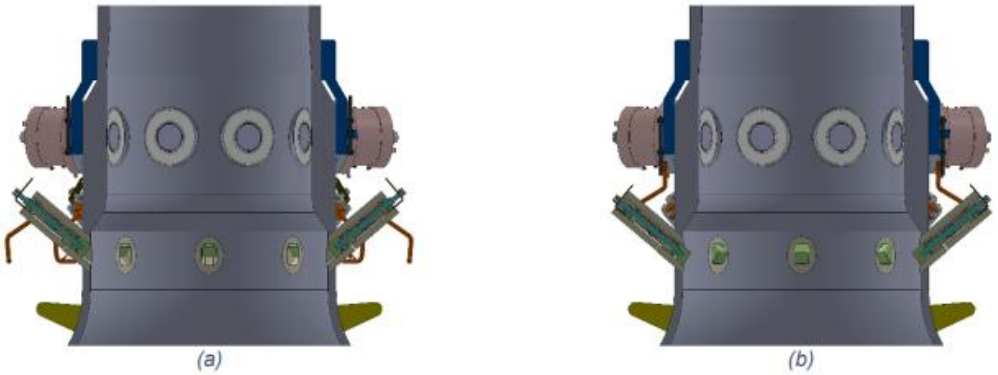



Figure 43: Latch bars: (a) "retracted" and (b) "extended"

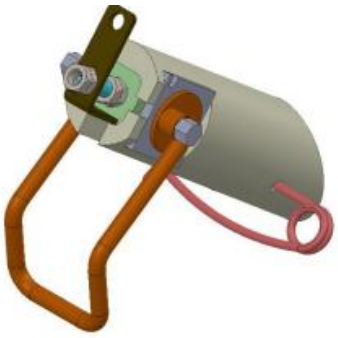


Figure 44: Latch Bar locking tool inserted in the round block to lock the latch bar

3.3. TSUDL Drifting Test

3.3.1. The objective of this test is evaluating TSUDL internal diameter through a pipe drifting test.

3.3.2. The Dummy Cap Upper and Lower Rings diameters are slightly bigger than bend stiffener's cap ones (Figure 41) and are used as templates to verify TSUDL internal diameter.

3.3.3. The Upper Ring verifies the TSUDL internal main interface surface compatibility with Bend Stiffener's Cap that will be furnished by the riser supplier. The lower Ring verifies the concentricity of the TSUDL larger internal diameter with its main internal surface. This verification guarantees the correct position of round blocks and latch bars on TSUDL Central Structure.

3.3.4. The Drifting Test may be performed during Pull-in and Pull-out Simulation Tests (A3.4) at supplier's choice.

3.3.5. Test Sequence:

a) Pull up Dummy Cap through TSUDL.

b) Observe the entrance of Dummy Cap into TSUDL and its passage through Central Structure (**Acceptance Criteria Ra5**, item A3.7.5).

c) Lower Dummy Cap until it rests on the floor (**Acceptance Criteria Ra6**, item A3.7.6).

3.4. Pull-in and Pull-out Simulation Tests

3.4.1. The objective of this test is to verify latch bars sets performance and alignment and how Dummy Cap rests on latch bars. This is done by observing the automatic and simultaneous expansion of the latch bars, after the passage of Dummy Cap through TSUDL, and by measuring the clearance between them and Dummy Cap and checking the readings from end-course sensors indication.

3.4.2. Pull-in Test Sequence:

a) Pull up Dummy Cap into TSUDL at a speed of 4 m/min (four meters per minute).

b) Observe the coupling of Dummy Cap into TSUDL and Latch Bars simultaneous and automatic locking (**Acceptance Criteria Ra7**, item A3.7.7) Check end-course latch bars sensors (**Acceptance Criteria Sa2**, item A3.7.19) readings.

c) Record Load Cell measured value in TRS if applicable.

d) Spool out lifting device cable so Dummy Cap is freely seated on latch bars. Check how Dummy Cap is seated on Latch Bars, the expansion of Latch Bars and measure the clearance between each of them and Dummy Cap with a feeler gauge (**Acceptance Criteria Ra8**, item A3.7.8).

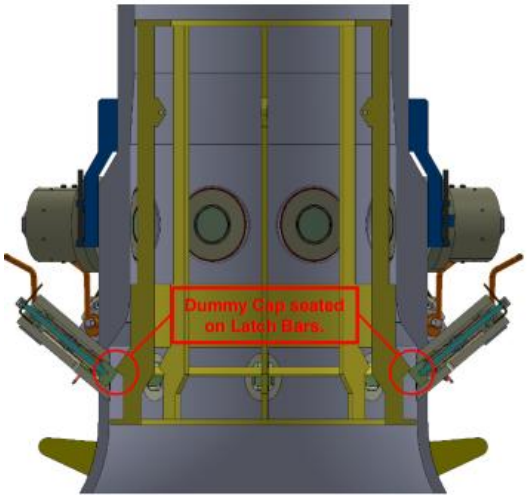



Figure 45: Dummy Cap seated on the Latch Bars

3.4.3. Pull-out test sequence:

e) Spool in the lifting device cable until Dummy Cap is no longer seated on Latch Bars.

f) Individually actuate each handler to move Latch bars to “retracted” position (Figure 43a), allowing Dummy Cap to be lowered to the floor (**Acceptance Criteria Ra9**, item A3.7.9). Check end-course latch bars sensors (**Acceptance Criteria Sa3**, item A3.7.20) readings.

g) Lower the Dummy Cap until it rests on the floor (**Acceptance Criteria Ra10**, item A3.7.10)

h) Individually actuate each handler to move the latch bars to the “extended” position (Figure 43b) **Acceptance Criteria Ra11**, item A3.7.11). Check end-course latch bars sensors (**Acceptance Criteria Sa4**, item A3.7.21) readings.

3.5. Hydraulic Actuator Integration Tests

3.5.1. The objective of this test is to verify if hydraulic actuators are fully functional when actuated by its hydraulic circuit and if each latch bar is properly aligned to TSUDL’s inner surface.

3.5.2. Preparation sequence for hydraulic actuator integration tests is the same as in A3.1.3.

3.5.3. Test Sequence:

a) Pressurize hydraulic fluid into cylinder chamber so latch bars move to “retracted position” (Figure 43a).

b) Check the minimum pressure needed to start moving latch bars. **Acceptance Criteria Ra12**, item A3.7.12). Check the end-course latch bars sensors (**Acceptance Criteria Sa5**, item A3.7.22) readings.

c) Measure the gaps between each latch bar and TSUDL inner surface. (**Acceptance Criteria Ra13**, item A3.7.13).

d) Align the hydraulic actuator circuit to HPU atmospheric pressure tanks so Latch Bars move to “extended position” (Figure 43b) due to spring return force. Check the end-course latch bars sensors (**Acceptance Criteria Sa6**, item A3.7.23) readings.

e) Measure the gaps between each latch bar and TSUDL inner surface. (**Acceptance Criteria Ra14**, item A3.7.14).

f) Repeat steps a through e 3 (three) times.

3.6. Pull-in and Pull-out Simulation Tests with hydraulic Actuation

3.6.1. The objective of this test is to verify if hydraulic actuators are fully functional when actuated by its hydraulic circuit and if each latch bar is properly aligned to TSUDL’s inner surface.

3.6.2. The Pull-in and Pull-out simulation tests with hydraulic actuation may be performed during pull-in and pull-out simulation tests (Section A3.4) at supplier’s choice.

3.6.3. Preparation sequence for hydraulic actuator integration tests is the same as in Section A3.1.4.

3.6.4. Pull-in test sequence is the same as in A3.4.2.

3.6.5. Pull-out test sequence:

a) Spool in the lifting device cable until Dummy Cap is no longer seated on Latch Bars.

b) Pressurize hydraulic fluid into cylinders chamber so Latch Bars move to “retracted” position (Figure 43a), allowing Dummy Cap to be lowered to the floor. (**Acceptance Criteria Ra15**, item A3.7.15) Check end-course latch bars sensors (**Acceptance Criteria Sa3**, item A3.7.20) readings.

c) Lower the Dummy Cap until it rests on the floor (**Acceptance Criteria Ra16**, item A3.7.16).

d) Align the hydraulic actuator circuit to HPU atmospheric pressure tanks so Latch Bars move to “extended” position (Figure 43b) due to spring return force. **Acceptance Criteria Ra17**, item A3.7.17. Check end-course latch bars sensors (**Acceptance Criteria Sa4**, item A3.7.21) readings.

3.7. Acceptance Criteria

3.7.1. Ra1

I. Handler performance: the only expected effort to be done by operator in order to perform this test is the one necessary to overcome the spring elastic strength. The reference strength necessary to actuate each handler is 3 kgf. If the operator is able to move each handler smoothly and softly, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.2. Ra2

I. Visual inspection: Observe if Latch Bars freely move from “retracted” position to “extended” one and back. If they do, then this step is approved, and one shall proceed to II criteria. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS then restart the test.

II. Handler and Latch Bar set performance: the only expected effort to be done by operator in order to perform this test is t he one necessary to overcome the handler and Latch Bar Set Inertia. If operator is able to move each Latch Bar smoothly and softly from “retracted” position to “extended” one and back, using only respective handler, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair Register in the TRS. Then restart the tests.

3.7.3. Ra3

I. All Latch Bars shall be in “retracted” position (Figure 43a) and upper aligned to the TSUDL inner surface (Figure 46). If the gaps between each Latch Bar and the TSUDL inner surface are less than or equal to 3 mm, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair Register in the TRS. Then restart the tests.

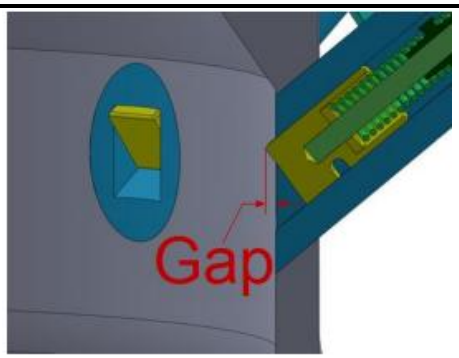



Figure 46: Upper Alignment between Latch Bar and TSUDL inner surface

3.7.4. Ra4

I. All Latch Bars shall be in “extended” position (Figure 43b) and lower aligned with the TSUDL inner surface (Figure 47). If gaps, presented between each latch bar and the TSUDL inner surface, are less than or equal to 5 mm, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required.

II. In case of any latch bar is on a cantilever position (Figure 48), the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

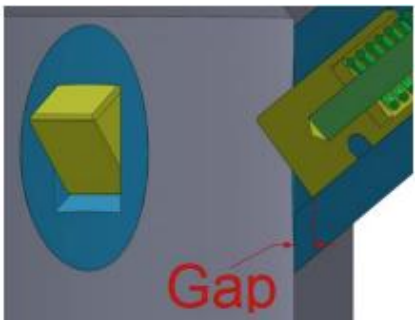



Figure 47: Lower Alignment between latch bar and TSUDL inner surface

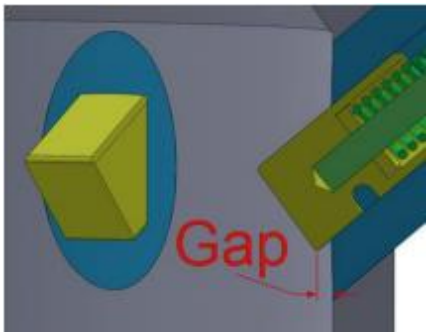



Figure 48: Latch Bar on cantilever position

3.7.5. Ra5

I. Dummy Cap shall pass through Central Structure smoothly, without bumps on the lifting device cable. If it does so, the step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.6. Ra6

I. Dummy Cap shall descend freely through the Central Structure and then rest on the floor. If it does so, the step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.7. Ra7

I. Latch Bars shall automatically and simultaneously expand after the passage of the Dummy Cap. The verification shall be made through the thud of the latch bars expanding. The thud of the latch bars locking shall be a single and “dry” sound, in unison. If this condition is met, then this step is approved, and one shall proceed to the next step. Register in the TRS.

II. Delays/advances sonorously perceived indicate that some latch bar is locking later/earlier than expected. If the sound is neither single and “dry” nor in unison, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the test.

III. If any latch bar does not expand at all, then the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.8. Ra8

I. Dummy Cap is seated on all latch bars and all of them are evenly expanded (Figure 45) or gaps between Dummy Cap and Latch Bars (Figure 49) are less than or equal to 2 mm. This step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required.

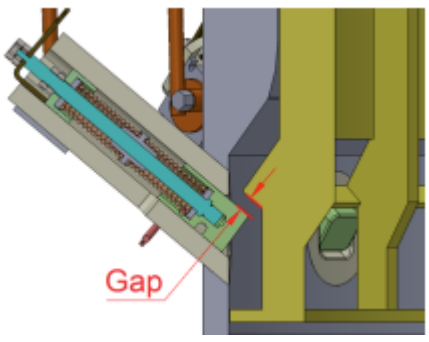



Figure 49: Gap Between locking wedge and Dummy Cap

II. Dummy Cap is seated on Latch Bars in the following sequence: “One yes one no”. Check if the gap between Dummy Cap and 2 or more Latch Bars (not properly seated) is greater than 2 mm. If so, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. If not, this step is approved. Register in the TRS.

III. Dummy Cap is not seated on two adjacent Latch Bars. Check if the gap between Dummy Cap and 1 of the Latch Bars is greater than 2 mm. If so, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. If not, this step is approved. Register in the TRS.

IV. In the event of a combination of II and III deviations above mentioned, the test shall be decommissioned and TSUDL shall be sent to repair, regardless the gap between Dummy Cap and Latch Bars. Register in the TRS. Then the tests must be restarted.

3.7.9. Ra9

I. Visual Inspection: Observe if Latch Bars freely move from “extended” position to “retracted” one. If they do, then this step is approved, and one shall proceed to II criteria. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

II. Handler and Latch Bar set performance: the only expected effort to be done by operator to perform this test is the one necessary to overcome the handler and Latch Bar set inertia. If operator is able to move each Latch Bar smoothly and softly from “extended” position to “retracted” one, using only the respective handler, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.10. Ra10

I. See Ra6

3.7.11. Ra11

I. See Ra4

3.7.12. Ra12

I. The minimum pressure necessary to start moving latch bars shall be greater than or equal to 10 bars. If so, this step is approved, and one shall proceed to the next step. Register in the TRS. Record minimum pressure value necessary to move latch bars. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. Photographic record required.

3.7.13. Ra13

I. See Ra3

3.7.14. Ra14

I. See Ra4

3.7.15. Ra15

I. Visual Inspection: Observe if latch bars freely move from “extended” position to “retracted” one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.16. Ra16

I. See Ra6

3.7.17. Ra17

I. See Ra4

3.7.18. Sa1

I. Sensor’s indication: Observe if end-course signal latch bar indication flag changes value from “extended” position and “retracted” position are according to the flag indications. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.19. Sa2

I. Sensor’s indication: Observe the register in a graph plot of all end-course signal latch bar indication flag changes value from “extended” to “retracted” to “extended” position one, i.e., it shall be observed a gate signal in the graphs for all sensors from the Dummy Adapter Cap locking operation. If they do, then this step is approved. Register the gate data graphs signals in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.20. Sa3

I. Sensor’s indication: Observe if end-course signal latch bar indication flag changes value from the transition of “extended” position to “retracted” one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.21. Sa4

I. Sensor’s indication: Observe if end-course signal latch bar indication flag changes value from the transition of “retracted” position to “extended” one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.22. Sa5

I. Sensor's indication: Observe if all the end-course signal latch bar indications flag changes value from the transition of "extended" to "retracted" position one after hydraulic pressurization. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

3.7.23. Sa6

I. Sensor's indication: Observe if all end-course signal latch bar indications flag changes value from the transition of "retracted" to "extended" position one due to all springs return forces. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

## 4. Rigid Riser Pull-In and Pull-out simulation FAT procedure minimum requirements, sequence and acceptance criteria

4.1. Preparation

4.1.1. Supplier shall verify prior to the tests if the infrastructure listed in A1 needed to perform the tests is available and ready to be used.

4.1.2. Preparation for TSUDL sensors required for the Rigid Riser FAT:

a) Assemble all sensors to the TSUDL corresponding components for this FAT (Top cone position detector Drive Ring Hydraulic Actuator Position sensor, as per section 10.2; End-course MTL and Top cone Wedge sensors, as per section 10.3).

b) Assemble all cabling to the sensors.

c) Install the HMI device and power supply to the sensors' cabling.

d) Check if all sensors are operational.

4.1.3. Preparation sequence for MTL Hydraulic Actuation Test (A4.2), MTL ROV Override Test (A4.3), Drive Ring Hydraulic Actuation (A4.4), and Drive Ring ROV Override (A4.5):

a) Place and secure TSUDL with its Central Structure plumb to the lifting device.

b) Verify if all MTLs are in "retracted" position (Figure 42a).

c) Verify if the end-course MTL sensors indication flags from "retracted" position are all working properly.

d) Verify if locking wedges sets are aligned in "extended" position (Figure 43b).

e) Verify if the end-course Top cone wedges sensors indication flags from "extended" position are all working properly.

f) Verify if the Top cone position detector sensor Drive Ring Hydraulic Actuator Position reading is working properly.

4.1.4. Preparation sequence for Pull-in and Pull-out Simulation Tests for MTL (A4.7):

a) Place and secure TSUDL with its Central Structure plumb to the lifting device.

b) Place Dummy Cap below TSUDL and axially aligned with it and with the lifting device cable, with the wire rope passing inside the Central Structure.

c) Verify if all MTLs are in “retracted” position (Figure 42a).

d) Verify if the end-course MTL sensors indication flags from “retracted” position are all working properly.

e) Check if all handlers are in “upper” position, locked by TSUDL’s Bracer, and Latch Bars are in “extended” position (Figure 42b and Figure 43b).

4.1.5. Preparation sequence for TSUDL Drifting Test (A4.6) and Pull-in and Pull-out Simulation Tests for Upper Cone (A4.8):

a) Place and secure TSUDL with its central Structure plumb to the lifting device.

b) Place Dummy HOA below TSUDL and axially aligned with it and with the lifting device cable, with the wire rope passing inside the Central Structure.

c) Attach the wire rope to Dummy HOA upper eyebolts symmetrically spaced using specified shackles (Figure 51).

d) Check if Lateral Support Modules and Latch Bars Sets are assembled in the TSUDL.

e) Check if locking wedges sets are assembled in the Upper Cone and are in the “extended” position (Figure 50b).

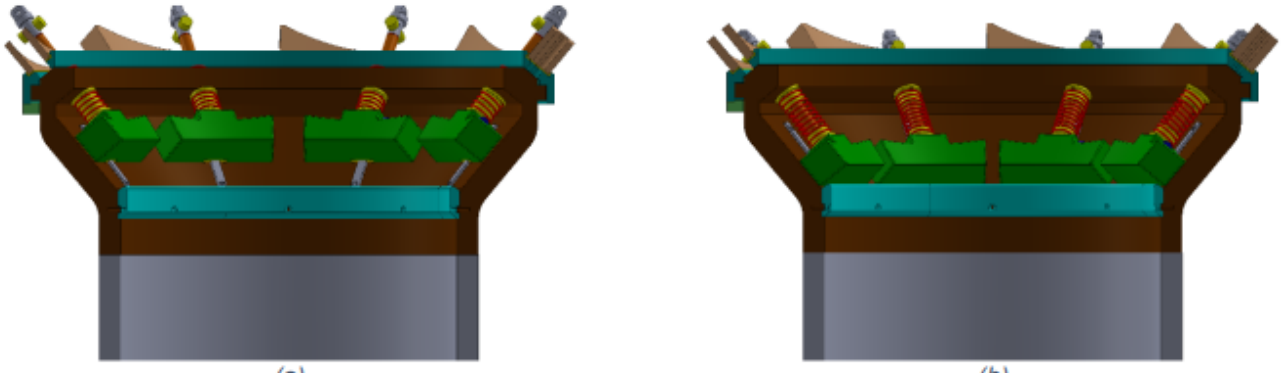



Figure 50: Locking Wedge in the (a) "retracted" and (b) "extended" positions

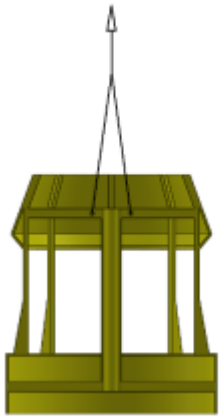


Figure 51: Pull-in Cable attached to a two-leg sling, keeping the dummy HOA plumb

## 4.2. MTL Hydraulic Actuation Test (just mechanism without dummy)

4.2.1. The objective of this test is verifying if Lateral Support Modules are fully functional when actuated by its hydraulic circuit and to verify if minimum pressure needed to move the piston meets the safety requirements to prevent unintentional MTL locking and/or unlocking.

4.2.2. Test Sequence:

a) Verify if MTL's "retract" inlet chamber hydraulic circuit has no pressure.

b) Pressurize hydraulic fluid into cylinders extend inlet chamber so MTL Cages move to "extended" position (Figure 52b), **Acceptance Criteria Rb1**, item A4.9.1. Check end-course MTL sensors (**Acceptance Criteria Sb1**, item A4.9.24) readings.

c) After MTL reaches its final extended position, keep pressurizing the system until it reaches maximum operation pressure. Then shut off pump and close valve between pump and MTLs and monitor pressure gauge during 5 min. **Acceptance Criteria Rb2**, item A4.9.2.

d) Pressurize hydraulic fluid into cylinders retract inlet chamber so MTL Cages move to "retracted" position (Figure 52a) **Acceptance Criteria Rb3**, item A4.9.3. Check end-course MTL sensors (**Acceptance Criteria Sb2**, item A4.9.25) readings.

e) After MTL reaches its final retracted position, keep pressurizing the system until it reaches maximum operation pressure. Then shut off pump and close valve between pump and MTLs and monitor pressure gauge during 5 min. **Acceptance Criteria Rb4**, item A4.9.4.

f) Repeat steps a, b and d 3 times.

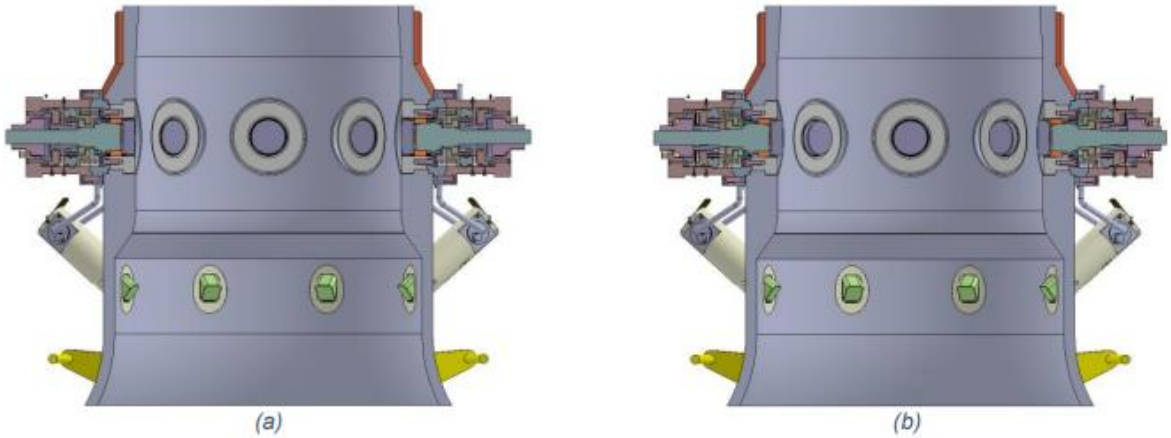



Figure 52: MTL Cages: (a) "Retracted" and (b) “Extended”

4.3. **MTL ROV Override Test (just mechanism without dummy)**

4.3.1. The objective of this test is verifying if Lateral Support Modules are fully functional when actuated by its ROV Override Interface without Dummy HOA.

4.3.2. Test Sequence:

a) Actuate the ROV override interface, so MTL Cages moves to “extended” position (Figure 52b). **Acceptance Criteria Rb5**, item A4.9.5.

b) Record the force value measured in TRS.

c) Actuate the ROV override interface, so MTL Cages move so MTL Cages move to “retracted” position (Figure 52a). **Acceptance Criteria Rb6**, item A4.9.6.

d) Record the force value measure in TRS.

e) Repeat steps a through d 3 times.

4.4. **Drive Ring Hydraulic Actuation Test (just mechanism without dummy)**

4.4.1. The objective of this test is verifying if the Drive Ring mechanism is fully functional when actuated by its hydraulic cylinder and to verify if minimum pressure needed to move the piston meets the safety requirements to prevent unintentional wedges unlocking. Please see Figure 53 below:

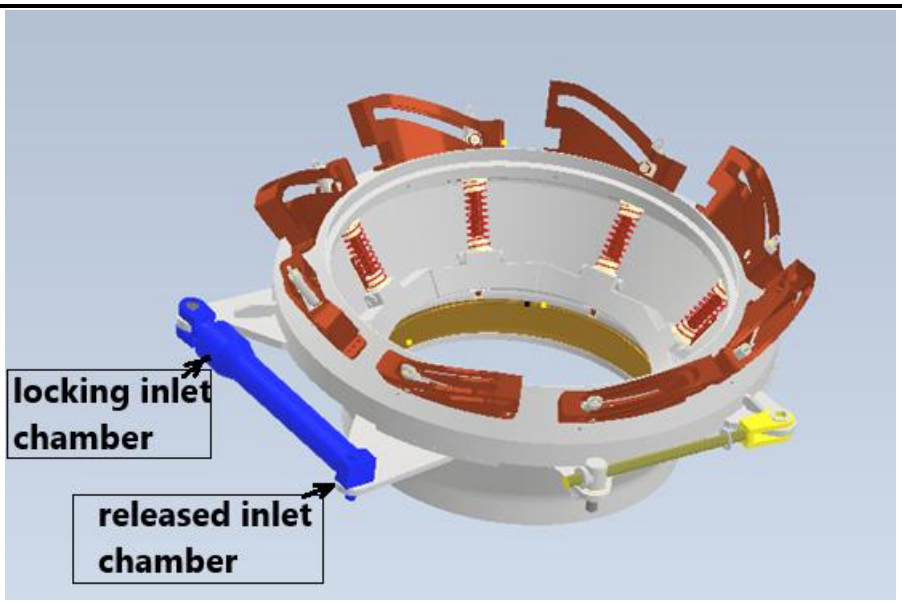



Figure 53: Drive ring actuator inlet chambers

4.4.2. Test Sequence:

a) Verify if locking wedges sets are aligned in “extended” position (Figure 54b) **Acceptance Criteria Rb7**, item A4.9.7. Set the pressure safety relief valves for the lock and release function lines for the safety maximum admissible pressure limits.

b) Verify if actuator’s “wedges locking” inlet chamber hydraulic circuit has no pressure.

c) Start pressurization at actuator’s “wedge released” inlet chamber increasing slowly the pressure regulated valve set until start the Drive ring movement until all locking wedges reach the fully “retracted” position. Register this minimum retract pressure at TRS.

d) Set the pressure actuator’s “wedges released” inlet chamber hydraulic circuit to zero.

e) Start pressurization at actuator’s “wedges locking” inlet chamber increasing slowly the pressure regulated valve set until start the Drive ring movement until all locking wedges reach the fully “extended” position. Register this minimum extend pressure at TRS.

f) Set the pressure actuator’s “wedges locking” inlet chamber hydraulic circuit to zero.

g) Pressurize hydraulic fluid into cylinder “wedges released” inlet chamber (limited to the maximum operation pressure for the pressure regulated valve) so the Drive Ring rotates clockwise until all locking wedges reach the fully “retracted” position (Figure 54a) **Acceptance Criteria Rb8**, item A4.9.8. Check end-course wedges sensors and Top cone position detector Drive Ring Hydraulic Actuator Position sensor (**Acceptance Criteria Sb3**, item A4.9.26) readings. Set the pressure actuator’s “wedges released” inlet chamber hydraulic circuit to zero.

h) Check actuator’s “wedges released” inlet chamber hydraulic circuit has no pressure.

i) Pressurize hydraulic fluid into cylinder wedges locking inlet chamber (limited to the maximum operation pressure for the pressure regulated valve) so the Drive Ring rotates counterclockwise until all locking wedges reach the fully “extended” position (Figure 54b) **Acceptance Criteria Rb9**, item A4.9.9. Check end-course wedges sensors and Top cone position detector Drive Ring Hydraulic Actuator Position sensor (**Acceptance Criteria Sb4**, item A4.9.27) readings.

j) Repeat steps f through i (3 times).

## 4.5. Drive Ring ROV Override Test (just mechanism without dummy)

4.5.1. The objective of this test is verifying if the Drive Ring mechanism is fully functional when actuated by its ROV override interface and the force necessary to break the cables used to simulate marine growth resistance on upper cone.

4.5.2. Test Sequence:

a) Verify if the locking wedges are in “extended” position (Figure 54b). Check design torque wrench limits prior to start drive ring override test.

b) Verify if the cables used to simulate marine growth are installed and secured (Figure 55) and are pretensioned as defined in detailed design.

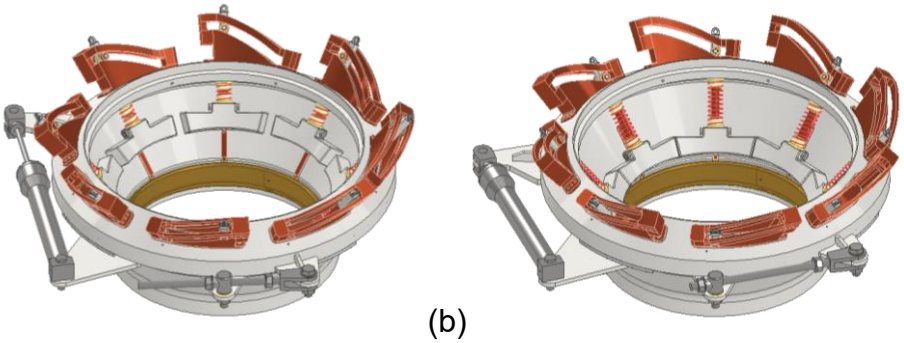
c) Actuate the ROV override interface, so the Drive Ring rotates clockwise until all locking wedges reach the fully “retracted” position (Figure 54a). **Acceptance Criteria Rb10**, item 4.9.10. Check end-course wedges sensors (**Acceptance Criteria Sb3**, item A4.9.26) readings.

d) Record the force value necessary to break the cables in TRS.

e) Record the force value measured during Drive Ring rotation in TRS.

f) Actuate the ROV override interface, so the Drive Ring rotates counterclockwise until all locking wedge reaches the fully “extended” position (Figure 54b). **Acceptance Criteria Rb11**, item 4.9.11. Check end-course wedges sensors (**Acceptance Criteria Sb4**, item A4.9.27) readings.

g) Record the force value measured during Drive Ring rotation in TRS.



(a) (b)

Figure 54: Drive Ring and Locking Wedges in the(a) “retracted” and (b) “extended” positions

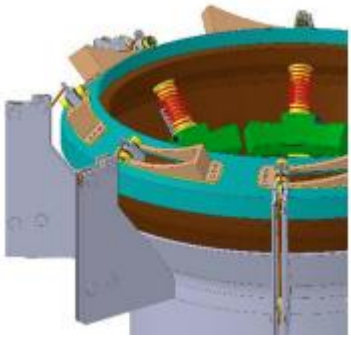


Figure 55: Cables to simulate marine growth (illustrative)

## 4.6. TSUDL Drifting Test

4.6.1. Locking wedges shall be in released position prior to TSUDL drifting test.

4.6.2. The objective of this test is to evaluate TSUDL internal diameter through a drifting test. The Dummy HOA is used as a template (Figure 56) to verify TSUDL internal diameter.

4.6.3. This test shall be performed with MTLs, Latch Bars Sets and Pull-in Wear Bushing (Figure 57) assembled in the TSUDL.

4.6.4. This test may be performed prior to locking wedges sets assembly in upper cone at supplier’s choice.

4.6.5. The Drifting test may be performed during Pull-in and Pull-out Simulation Tests for Upper Cone (A4.8) at supplier’s choice.

4.6.6. Test Sequence:

a) Pull up Dummy HOA through TSUDL until the Upper Ring reaches the Upper Cone.

b) Observe the entrance of Dummy HOA into TSUDL and its passage through the Central Structure **Acceptance Criteria Rb12**, item A4.9.12.

c) Lower Dummy HOA until it rests on the floor. **Acceptance Criteria Rb13**, item A4.9.13.

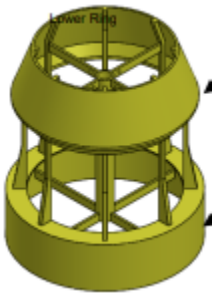



Figure 56: Dummy HOA - Template for Upper Cone FAT

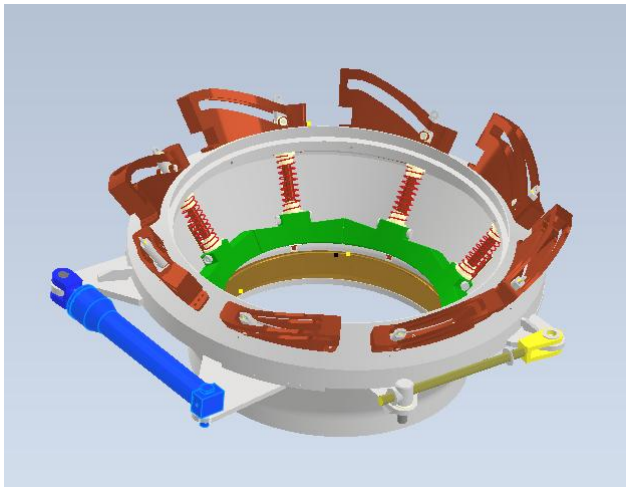


Figure 57: Upper Cone with Pull-in Wear Bushing Installed

## 4.7. Pull-in and Pull-out Simulation Test for MTL

4.7.1. The objective of this test is to check the interaction between MTLs and Dummy Cap during pull-in operation.

4.7.2. The Pull-in and Pull-out Simulation Tests for MTL may be performed during Pull-in and Pull-out Simulation Tests (A3.4) at supplier's choice.

4.7.3. Test Sequence:

a) Fill the MTL retract inlet chamber with hydraulic fluid.

b) Pull up the Dummy Cap through the TSUDL.

c) Stop when Dummy Cap intermediate Ring reaches the position showed in Figure 58.

d) Pressurize hydraulic fluid into cylinder extend inlet chamber (maximum operation pressure) so MTL Cages move to "extended" position until they reach Dummy Cap Intermediate Ring. (Figure 62) **Acceptance Criteria Rb14**, item A4.9.14. Check end-course MTL sensors (**Acceptance Criteria Sb1**, item A4.9.24) readings.

e) Pressurize hydraulic fluid into cylinder retract inlet chamber (retract test pressure, defined during detailed design) to check if all MTL are locked. **Acceptance Criteria Rb15**, item A4.9.15.

f) Pressurize hydraulic fluid into cylinder retract inlet chamber (maximum operated pressure) so all MTLs unlock, and their respective Cages move to “retracted” position releasing the Dummy Cap. **Acceptance Criteria Rb16**, item A4.9.16. Check end-course MTL sensors (**Acceptance Criteria Sb2**, item A4.9.25) readings.

g) Actuate the ROV override interface, meeting maximum torque limit and maximum number of driving bolt turns, so MTL Cages move to “extended” position until they reach Dummy Cap Intermediate Ring (Figure 62). **Acceptance Criteria Rb17**, item A4.9.17. Check end-course MTL sensors (**Acceptance Criteria Sb1**, item A4.9.24) readings.

h) Actuate the ROV override interface to lock MTL using a torque resulting in a locking force less than 1200 kN. Record force value measured on TRS. **Acceptance Criteria Rb18**, item A4.9.18

i) Actuate the ROV override interface so all MTLs unlock, and their respective Cages move to “retracted” position releasing the Dummy Cap. **Acceptance Criteria Rb19**, item A4.9.19. Check end-course MTL sensors (**Acceptance Criteria Sb2**, item A4.9.25) readings.

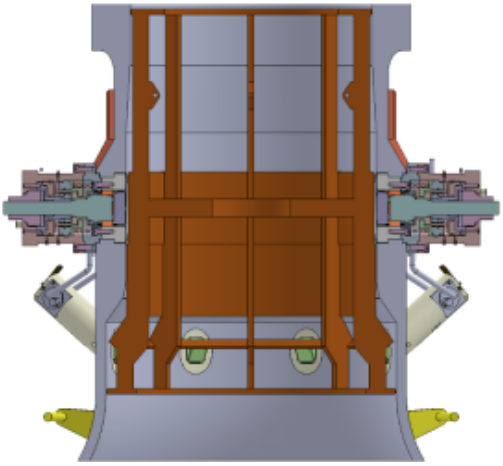


Figure 58: Dummy Cap Intermediate Ring Position

## 4.8. Pull-in and Pull-out Simulation Test for Upper Cone

4.8.1. The objective of this test is to check the integration between locking wedges and Dummy HOA during pull-in and pull-out operations.

4.8.2. Test Sequence:

a) Pressurize hydraulic fluid into cylinder “wedges released” inlet chamber (limited to the maximum operation pressure for the pressure regulated valve) so the Drive Ring rotates clockwise until all locking wedges reach the fully “retracted” position (Figure 54a) **Acceptance Criteria Rb8**, item A4.9.8. Check end-course wedges sensors and Top cone position detector Drive Ring Hydraulic Actuator Position sensor (**Acceptance Criteria Sb3**, item A4.9.26) readings.

b) Pull up the Dummy HOA through the TSUDL at a speed of 4 m/min and stop at overpull position point.

c) Observe the Dummy HOA passing through the Upper Cone. Set the pressure actuator's "wedges released" inlet chamber hydraulic circuit to zero.

d) Check actuator's "wedges released" inlet chamber hydraulic circuit has no pressure.

e) Pressurize hydraulic fluid into cylinder wedges locking inlet chamber (limited to the maximum operation pressure for the pressure regulated valve) so the Drive Ring rotates counterclockwise until all locking wedges reach the fully "extended" position (Figure 54b) **Acceptance Criteria Rb9**, item A4.9.9. Check end-course wedges sensors and Top cone position detector Drive Ring Hydraulic Actuator Position sensor (**Acceptance Criteria Sb4**, item A4.9.27) readings.

f) Pull down the Dummy HOA through the TSUDL wedges. **Acceptance Criteria Rb20**, item A4.9.20

g) Spool out the lifting device cable so the Dummy HOA is freely seated on the locking wedges (Figure 59). **Acceptance Criteria Rb21**, item A4.9.21.

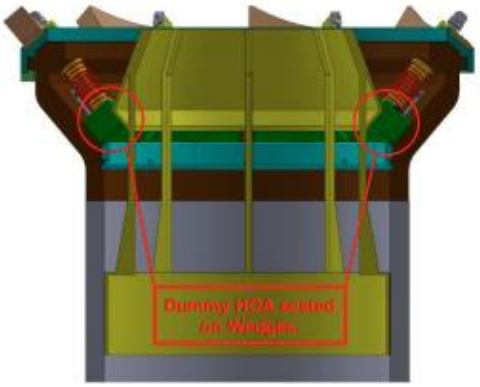



Figure 59: Dummy HOA seated on the locking wedges

4.8.3. Pull-out test sequence for hydraulic actuation:

h) Spool in the lifting device cable until Dummy HOA is no longer seated on the locking wedges.

i) Actuate the Drive Ring Hydraulic Actuator so the locking wedges move to the "retracted" position (Figure 54a) allowing the removal of Dummy HOA. **Acceptance Criteria Rb22**, item A4.9.22.

j) Lower the Dummy HOA until it rests on the floor. **Acceptance Criteria Rb23**, item A4.9.23.

## 4.9. Acceptance Criteria

### 4.9.1. Rb1

I. The minimum pressure necessary to start moving MTL Cages from “retracted” to “extended” position shall be greater than or equal to 10 bars. If so, one shall proceed to the criteria II. Register in the TRS. Record minimum pressure value necessary to move MTL Cages. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Photographic record required.

II. Observe if the MTL Cages freely move to “extended” position. If they do, one shall proceed to criteria III. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Observe if maximum pressure during free stroke movement is less than unloaded extending pressure defined in detailed design. If so, one shall proceed to criteria IV. Record value of maximum pressure registered during free stroke movement. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

IV. Check if MTL Cages reach their maximum unloaded stroke as defined in detail in Figure 60 and if end-of-stroke sensor indicates the correct position of the piston. If they do, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

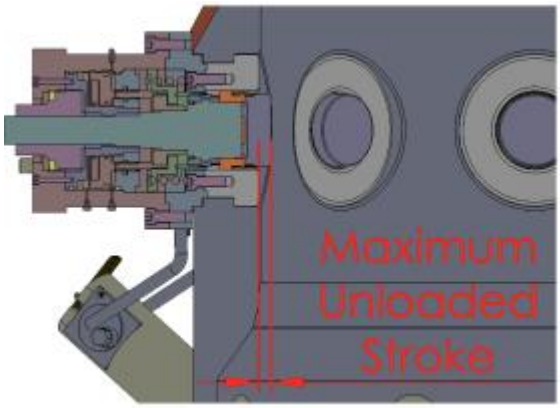



Figure 60: MTL Cage Maximum Unloaded Stroke

4.9.2. **Rb2**

**I.** After MTL mobile parts reaches final extended position and maximum operational pressure is achieved, no pressure drop shall be observed or, in case of a pressure drop, it shall not be greater than 50 psi and no visible leakage shall be detected. If so, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.3. **Rb3**

**I.** Observe if the MTL Cages freely move to “retracted” position. If they do, then one shall proceed to II criteria. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

**II.** Observe if maximum pressure during free stroke movement is less than unloaded extending pressure defined in detailed design. If so, one shall proceed to criteria III. Record value of maximum pressure registered during free stroke movement. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

**III.** Check if MTL Cages are aligned to MTL Load Ring external surface (Figure 61) MTL Cages shall not be bulged towards the center of TSUDL Central Structure. If they do not, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

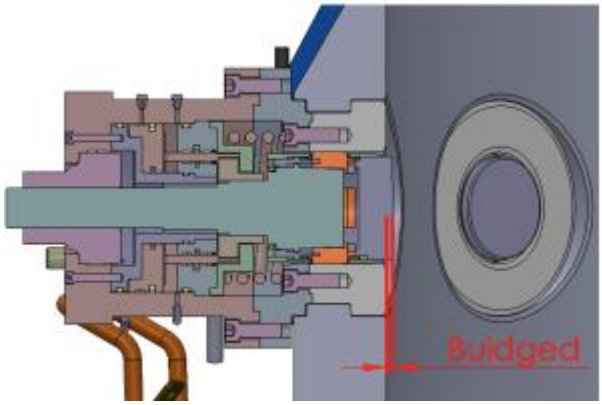



Figure 61: MTL Cage bulged

4.9.4. **Rb4**

I. After MTL mobile parts reaches final retracted position and maximum operational pressure is achieved, no pressure drop shall be observed or, in case of a pressure drop, it shall not be greater than 50 psi and no visible leakage shall be detected. If so, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.5. **Rb5**

**I.** Observe if the MTL Cages freely move to “extended” position. If they do, then one shall proceed to criteria II. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

**II.** Observe if maximum torque during free stroke movement is less than or equal to the defined value in detailed design. If so, one shall proceed to criteria III. Record value of maximum pressure registered during free stroke movement. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

**III.** Check if MTL Cages reach their maximum unloaded stroke as defined in detailed design (Figure 60). If they do, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.6. **Rb6**

I. The minimum torque necessary to start moving MTL Cages from “retracted” to “extended” position shall be less than or equal to the defined value in detailed design. If so, one shall proceed to the criteria ii. Register in the TRS. Record minimum pressure value necessary to move MTL Cages. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. Photographic record required.

II. Observe if the MTL Cages freely move to “retracted” position. If they do, then this step is approved, and one shall proceed to III criteria. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Observe if maximum torque during free stroke movement is less than or equal to the defined value in detailed design. If so, one shall proceed to criteria IV. Record value of maximum pressure registered during free stroke movement. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

IV. Check if MTL Cages are aligned to MTL Load Ring external surface (Figure 61). MTL Cages shall not be bulged towards the center of TSUDL Central Structure. If they do not, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.7. **Rb7**

I. Check if all Locking Wedge Sets are aligned in “wedges extended” position, if so, one shall proceed to the next step. Register in the TRS. If not, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.8. **Rb8**

I. The minimum pressure necessary to start moving the Drive Ring clockwise shall be greater than or equal to 10 (ten) bars. If so, one shall proceed to the criteria II. Register in the TRS. Record minimum pressure value necessary. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. Photographic record required.

II. Observe if the Drive Ring rotates clockwise smoothly and the Locking Wedges move from “extended” position to “retracted” one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Observe if maximum pressure during Drive Ring rotation is less than unloaded extending pressure defined in detailed design. If so, one shall record value of maximum pressure registered during free stroke movement. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.9. **Rb9**

I. Visual inspection: Observe if the Drive Ring rotates counterclockwise smoothly and the Locking Wedges move from “retracted” to “extended” position. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

II. Observe if maximum pressure during Drive Ring rotation is less than the specified value in detailed design. If so, and one shall proceed to criteria iii. Record value of maximum pressure necessary to rotate Drive Ring. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Check if all Locking Wedge Sets are aligned. If so, this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. If not, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.10. **Rb10**

I. The minimum torque necessary to start rotating Drive Ring clockwise shall be less than or equal to the defined value in detailed design. If so, one shall proceed to the criteria II. Register in the TRS. Record minimum torque value necessary to rotate Drive Ring. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. Photographic record required.

II. Observe if the Drive Ring rotates clockwise smoothly and the Locking Wedges move from “extended” to “retracted” position. If so, one shall proceed to the criteria III. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Observe if maximum torque during Drive Ring rotation is less than the specified value in detailed design. If so, then this step is approved, and one shall proceed to the next step. Record value of maximum torque necessary to rotate Drive Ring. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.11. **Rb11**

I. The minimum torque necessary to start rotating Drive Ring counterclockwise smoothly from “retracted” to “extended” position shall be less than or equal to the defined value in detailed design. If so, one shall proceed to the criteria II. Register in the TRS. Record minimum torque value necessary to rotate Drive Ring. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests. Photographic record required.

II. Observe if maximum torque during Drive Ring rotation is less than the specified value in detailed design. If so, and one shall proceed to criteria iii. Record value of maximum torque necessary to rotate Drive Ring. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

III. Check if all Locking Wedge Sets are aligned. If so, this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. If not, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.12. **Rb12**

I. The Dummy HOA shall pass through Central Structure smoothly, without bumps on the lifting device cable. If it does so, the step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.13. **Rb13**

I. The Dummy HOA shall descend freely through Central Structure and then rest on the floor. If it does so, the step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned, and the Upper Cone shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.14. **Rb14**

I. Check if MTL Cages reach their working stroke as defined in detailed design (Figure 62). It can be checked measuring the displacement of MTL Mandrel and Nut. If they do, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record required. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

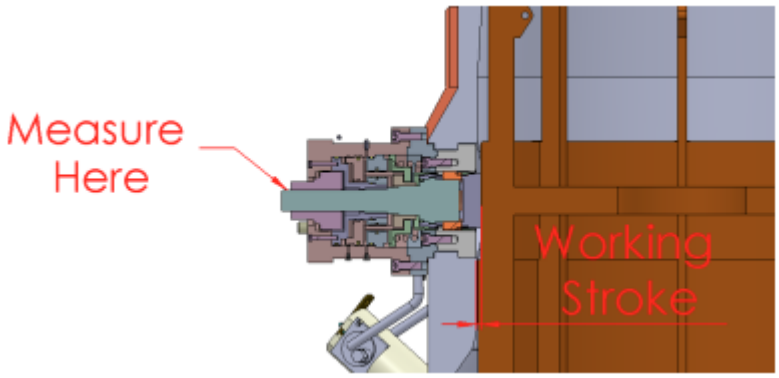



Figure 62: MTL Cage Working stroke

4.9.15. **Rb15**

I. Check if all MTL remain locked. If they do, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.16. **Rb16**

I. All MTL shall unlock, and their respective Cages shall smoothly move to “retracted” position. If they do, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.17. **Rb17**

I. See Rb14.

4.9.18. **Rb18**

I. See Rb15.

4.9.19. **Rb19**

I. See Rb16.

4.9.20. **Rb20**

I. After Locking Wedges slides downwards for the wedges fully extended position, the Dummy HOA Upper Ring shall be layed over all wedges. The verification shall be made by visualization if all Locking Wedges are aligned with the Dummy HOA Upper Ring. If this condition is met, then this step is approved, and one shall proceed to the next step. Register in the TRS.

4.9.21. **Rb21**

I. If Dummy HOA is fully seated on all Locking Wedges or the gaps between Dummy HOA and Locking Wedges are less than or equal to 0.5mm (zero point five millimeters) as shown in Figure 63, then this step is approved, and one shall proceed to the next step. Register in the TRS. Photographic record. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

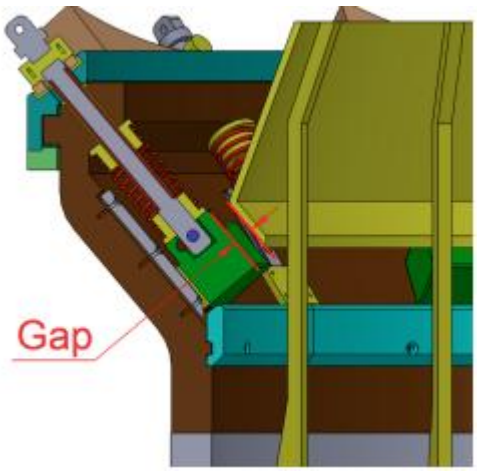



Figure 63: Gap Between locking wedge and Dummy HOA (illustrative)

4.9.22. **Rb22**

I. Visual Inspection: Observe if all Locking Wedges have moved smoothly and are in the “retracted” position. If this condition is met, then this step is approved, and one shall proceed to the next step. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.23. **Rb23**

I. Dummy HOA shall descend smoothly through the TSUDL and then rest on the floor. If Dummy HOA descends smoothly, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.24. **Sb1**

I. Sensor’s indication: Observe if all end-course signals MTL indication flag values from initial position are according to the flag indications (“extended” status). If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.25. **Sb2**

I. Sensor's indication: Observe if all end-course signals MTL indication flag values from final position are according to the flag indications ("retracted" status). If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.26. **Sb3**

I. Sensor's indication: Observe if end-course signal wedges indication flag changes value from the transition of "extended" position to "retracted" one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

II. Sensor's indication: Observe the register in a graph plot of Top cone position detector's Drive Ring Hydraulic Actuator Position sensor indication flag changes value from "fully extended wedges" to "fully retracted wedges" position one, i.e., it shall be observed a saw tooth signal in the graphs for Drive Ring Hydraulic Actuator Position sensor from the hydraulic actuator operation. If they do, then this step is approved. Register the gate data graphs signals in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

4.9.27. **Sb4**

I. Sensor's indication: Observe if end-course signal wedges indication flag changes value from the transition of "retracted" position to "extended" one. If they do, then this step is approved. Register in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the test.

II. Sensor's indication: Observe the register in a graph plot of Top cone position detector Drive Ring Hydraulic Actuator Position sensor indication flag changes value from "fully retracted wedges" to "fully extended wedges" position one, i.e., it shall be observed a saw tooth signal in the graphs for Drive Ring Hydraulic Actuator Position sensor from the hydraulic actuator operation. If they do, then this step is approved. Register the gate data graphs signals in the TRS. Otherwise, the deviation shall be evaluated, the test shall be stopped and decommissioned and TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

## 5. Electrical Continuity Test

5.1. The objective of electrical continuity test is to ensure that all TSUDL/MTL moving parts are electrically connected to the TSUDL main structure, with exception of all components of TSUDL/MTL made of copper-based alloys that shall be isolated from TSUDL cathodic protection.

5.2. Supplier shall submit an Electrical continuity test procedure with clear indication of the parts to be measured.

5.3. Measurements shall be made using a calibrated DC multimeter. Calibration due date shall be part of final report.

5.4. Acceptance criteria for the electrical continuity tests shall be below 1Ω and in accordance with [22] and TSUDL detail design. In case the criteria is not satisfied, FPU CONTRACTOR/SELLER shall present technical justification for PETROBRAS approval. The deviation shall be evaluated, the test shall be decommissioned and the TSUDL shall be sent to repair. Register in the TRS. Then restart the tests.

5.5. In the event that PETROBRAS is not the Contractor, Contractor shall submit the Electrical Continuity Test Procedure and Acceptance Criteria to PETROBRAS for information purpose only.

5.6. Results of Electrical Continuity Test shall be recorded in TRS.

## 6. Electrical Insulation Tests

6.1. All components of TSUDL/MTL made of copper-based alloys shall be inspected to check electrical insulation. This electrical insulation procedure shall be subjected for Petrobras approval before execution of the tests.

6.1.1. For copper-based actuator parts, insulation testing shall be performed by measuring the electrical potential of the parts submerged in saline water, following the requirements:

- It shall be submerged in saline water;
- Carbon steel parts shall be connected to the anode;
- Insulation shall be assessed using electrical potential, compared to the electrical potential of a submerged copper part not connected to any anode.

## 7. Test Record Sheet – TRS

7.1. General

7.1.1. The FAT procedure shall include a document to record the results of each step of the tests, named Test Record Sheet – TRS.

7.1.2. All sheets of all tests shall be filled out using pen.

7.1.3. TRS of TSUDL rejected and sent for scrapping shall be stored along with the data book sets of approved ones.

7.2. Minimum Content

7.2.1. The Supplier can add any information considered necessary in the TRS, by inserting a new page at the end of the table.

7.2.2. The following fields shall be part of TRS:

- Date – Date of the test.
- Supplier – Manufacturer of the TSUDL.
- Sheet – Indication of page number and total number of pages.

- Rep. Num. – Report number defined according to supplier's methodology.
- ND – TSUDL nominal diameter.
- SN – TSUDL serial number.
- FPU – Production unit where the TSUDL will be installed.
- Report – Field to be filled in with any information regarding the current test step.
- AP/SR/RE – Indication of Approved, Send to Repair and Reproved.
- Ra1 through Ra17– Flexible Riser Tests.
- Rb1 through Rb23 – Rigid Riser Tests.
- Responsible – Name and signature of the responsible for releasing the TSUDL.
- Result – Result of the tests, Approved or Rejected.

7.3. Fields AP, SR and RE

7.3.1. The AP, SR and RE fields shall be marked with an "X" or checked "√", in accordance with one of the three situations shown below.

7.3.2. AP – Approved

7.3.2.1. The TSUDL is released to the next test. This option will be marked alone if the test passes with no indication of repairs.

7.3.3. SR – Send to Repair

7.3.3.1. There was a deviation during the test and the TSUDL must be repaired and retested.

7.3.3.2. The deviation occurred shall be reported, as well as the description of what shall be done to repair the TSUDL. After repairing, the TSUDL shall be submitted to test again from the beginning (Ra1 test).

7.3.3.3. In case of repairing the TSUDL, besides the SR field, the AP or RE field may be marked after the second test, depending on the result of this test. That is, if both AP and SR fields are marked, it means that the TSUDL was tested and failed; it was sent to repair, tested again and later approved. Similarly, if SR and RE are marked, it means that the TSUDL was tested and failed, it was sent to repair, tested again, and failed once more, indicating that it shall be discarded.

7.3.4. RE – Reproved

7.3.4.1. The TSUDL shall be discarded. This option will be marked alone if the rejection indicates discard without repairs.

7.3.4.2. The new TSUDL manufactured to replace the rejected one shall receive a new serial number.

## ANNEX B: LIST OF MINIMUM DOCUMENTATION

1. This Annex contains a list of minimum documentation to be provided as part of the TSUDL design.
2. These lists summarize the main content of each expected document.
3. First column of the tables contains PETROBRAS recommended document type according to standard N1710.
4. Last column of the tables contains the expected documents to be provided per phase of the project.
5. All drawings of TSUDL components shall include internal parts design and the details of isolation mechanism for CuBe alloys.
6. All 3D models of the TSUDL, in CAD (Computer-Aided Design) or CAE (Computer-Aided Engineering) format, shall be included in the documentation list for Petrobras' approval.

CMS = Control and Monitoring System SMD = Support Manufacture Design

Table 1: CMS Minimum Documentation List

| Type | Document Title | Phase |
|---|---|---|
| LD | Vendor Document List (VDL) | Pre-Project |
| LD | Final Documentation Folder | Pre-Project |
| CR | Project Main Schedule | Pre-Project |
| DB | Data Book | Pre-Project |
| FD | Data Sheet | Detailing |
| LI | Spare Part List | Detailing |
| LI | Equipment & Special Tool & Hazardous Equipment List | Detailing |
| LI | Supplier / Sub-Supplier Equipment List | Detailing |
| MD | Design Basis | Detailing |
| DE | General Arrangement Drawing | Detailing |
| RL | Hullside Umbilical Calculation Report | Detailing |
| DE | Umbilical Erection and Installation Drawing Hullside Umbilical for Riser Supports | Detailing |
| DE | Piping And Instrument Diagram (P&ID) | Detailing |
| DE | Single Line Electrical Diagrams | Detailing |
| DE | Electrical Termination Wiring Drawing | Detailing |
| DE | System Topology | Detailing |
| RL | Network Topology and HMI | Detailing |
| DE | Instrument / Electrical Logic Diagram | Detailing |
| DE | Loop Diagrams | Detailing |
| RL | VDU Screen Display Graphics | Detailing |
| ET | WPS and PQR Hullside Umbilical for Riser Supports | Detailing |
| DE | Welding Map Hullside Umbilical for Riser Supports | Detailing |
| LI | I/O List | Detailing |
| RL | Lower Riser Balcony Clashing and Interference Analysis | Detailing |

| | | |
|---|---|---|
| ET | Inspection & Test Plan | Implementation |
| PR | Factory Acceptance Test Procedure | Implementation |
| RL | Factory Acceptance Test Report | Implementation |
| PR | Chemical Cleaning and Flushing Procedure | Implementation |
| PR | Hydrostatic Test Procedure | Implementation |
| PR | NDT Procedure Hullside Umbilical for Riser Supports | Implementation |
| PR | Painting Procedure Hullside Umbilical for Riser Supports | Implementation |
| CE | NDT Operator Qualification Hullside Umbilical for Riser Supports | Implementation |
| RL | NDT Report Hullside Umbilical for Riser Supports | Implementation |
| PR | Site Integration Test Procedure | Implementation |
| RL | Site Integration Test Report | Implementation |
| CE | Instrument Test/Calibration Certificate | Implementation |
| MA | Installation and Operation Manual (English) | Implementation |
| MA | Installation and Operation Manual (Portuguese) | Implementation |
| MA | Preservation and Maintenance Manual | Implementation |
| RL | Life Cycle Support Statement | Implementation |
| RL | RSMS Login/Password Document | Implementation |
| ET | Training Program | Implementation |

Table 2: SMD Minimum Documentation List

| Type | Document Title | Phase |
|---|---|---|
| LD | Vendor Document List (VDL) | Pre-Project |
| LD | Final Documentation Folder | Pre-Project |
| CR | Project Production Schedule | Pre-Project |
| DB | Data Book | Pre-Project |
| LI | Spare Parts List | Pre-Project |
| MD | Design Basis and Methodology | Pre-Project |
| RL | Riser Balcony Interference Report | Pre-Project |
| DE | General and Structure Drawing | Detailing |
| DE | ISO Drawing | Detailing |
| DE | Piping And Instrument Diagram (P&ID) | Detailing |
| DE | Typical Electrical Wiring Diagram | Detailing |
| RL | Dimensional Report | Detailing |
| MC | Calculation Report | Detailing |
| MC | Upper Cone Hydraulic Cylinder Calculation Report | Detailing |
| MC | Hydraulic Actuator Calculation Report | Detailing |
| MC | MTL Calculation Report | Detailing |
| DE | Dummy Cap Drawing | Detailing |
| DE | Dummy HOA Drawing | Detailing |
| DE | Cap Drawing | Detailing |
| DE | Upper Cone Hydraulic Actuator Assembly & Structure Drawing | Detailing |
| DE | Hydraulic Actuator Assembly & Structure Drawing | Detailing |
| DE | MTL Assembly & Structure Drawing | Detailing |
| ET | Project Quality Plan | Detailing |

| | | |
|---|---|---|
| ET | HSE Plan | Detailing |
| DE | Welding and NDT Map | Detailing |
| ET | Weld Procedure Specifications(WPS) | Detailing |
| RL | Welder Performance Qualification | Detailing |
| RL | NDT Operator List and Certificate | Detailing |
| CE | Calibration Certificate | Implementation |
| ET | Inspection & Test Plan | Implementation |
| PR | Chemical Cleaning and Flushing Procedure | Implementation |
| PR | FAT Procedure | Implementation |
| RL | FAT Report | Implementation |
| MA | Installation Operation and Maintenance Manual (English) | Implementation |
| MA | Installation Operation and Maintenance Manual (Portuguese) | Implementation |
| MA | Preservation and Maintenance Manual (Procedure) | Implementation |
| PR | Upper Cone Hydraulic Cylinder FAT Procedure | Implementation |
| PR | Hydraulic Actuator FAT Procedure | Implementation |
| PR | MTL FAT Procedure | Implementation |
| RL | Upper Cone Hydraulic Cylinder FAT Report | Implementation |
| RL | Hydraulic Actuator FAT Report | Implementation |
| RL | MTL FAT Report | Implementation |
| PR | Wearing Test Procedure | Implementation |
| RL | Wearing Test Report | Implementation |
| RL | Requests for Deviations | Implementation |
| CE | Material Test Certificate | Implementation |
| RL | Asbestos-Free Declaration | Implementation |
| PR | Hydrostatic Test Procedures | Implementation |
| PR | Surface Painting Procedure | Implementation |
| PR | Packing and Shipping Procedure | Implementation |
| PR | NDT Procedure | Implementation |
| PR | UT Procedure | Implementation |
| PR | MT Procedure | Implementation |
| PR | Heat Treatment Procedure | Implementation |
| RL | NDT Report | Implementation |
| RL | Material Traceablity Record | Implementation |
| RL | Surface Treatment Inspection Record | Implementation |
| RL | Welding Traceability Records | Implementation |
| RL | UT Report | Implementation |
| RL | MT Report | Implementation |
| RL | Heat Treatment Record | Implementation |
| PR | TSUDL Handling Procedure | Implementation |
| LI | Shipping and Packaging List | Implementation |

## ANNEX C: HYDRAULIC PRESSURE TESTS

1. **Integrity Test**

The purpose of this test is to verify the assembly of the actuator cylinder-piston. According to API 6A (21st edition), item 14.16.4.1, this test must be performed with the entire actuator assembly mounted on the valve.

FPU CONTRACTOR/SELLER shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) Integrity pressure (1.5x operating pressure, i.e. 1.5 * 5000 psi = 7500 psi) must be applied to the system. After reaching and stabilizing the pressure, FPU CONTRACTOR/SELLER must wait for at least 3 minutes.
4) The applied pressure must be reduced to 0 (zero).
5) Integrity pressure (1.5x operating pressure, i.e. 1.5 * 5000 psi = 7500 psi) must be applied to the system again. After the pressure is reached and stabilized, FPU CONTRACTOR/SELLER must wait for at least 3 minutes.

**Note:** If any part of the system cannot be submitted to this test, it shall be submitted to PETROBRAS approval.

2. **Actuator Sealing Test**

According to item 14.16.4.2 (a) of API 6A, this test basically consists of a sealing test at low (20%) and high pressure (100%). This test can be performed with the entire actuator system coupled.

FPU CONTRACTOR/SELLER shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) A pressure of up to 20% operating pressure, i.e., up to 20% * 5000 psi = 1000 psi, must be applied for at least 3 minutes after reaching and stabilizing the set pressure.
4) A pressure of at least 100% operating pressure must be applied, i.e., 5000 psi or more for at least 3 minutes after reaching and stabilizing the set pressure.

**Acceptance Criteria:** There must be no leaks in the system at any of the stages.

**Note:** Pressure, start time and end time of steps 3 and 4 must be recorded.

3. **Operational Test**

As the nominal actuation pressure is 5000 psi, the actuator must be capable to function with a maximum of 4500 psi. Then, in this case, it will have 10% of operating pressure, or 10% * 5000 psi = 500 psi of clearance to accommodate any increases in friction that may arise over time.

FPU CONTRACTOR/SELLER shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) A pressure of up to 90% operating pressure must be applied (up to 90% * 5000 psi = 4500 psi) and the actuator must reach the fully open position.
4) Step 3 must be repeated at least 3 times.

**Note:** It is important that the entire actuation, opening and return pressure curve be mapped.