PETROBRAS	**TECHNICAL SPECIFICATION**	No.: **I-ET-3010.00-1519-140-P56-001**	
	CLIENT: BUZIOS		SHEET: 1 of 41
	JOB: HIGH CAPACITY FPSO		
	AREA: BÚZIOS		
DDP	TITLE: **UNIFIED DIVERLESS SUPPORT TUBE**		P
			ES

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INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL
A	Single (action hydraulic cylinder) replaced by double in 6.2.3 and reference [19]- Riser Supports P&ID - is included

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	Mar 18, 2021	Jun 11, 2021							
DESIGN	ES	ES							
EXECUTION	BF5Q	BF5Q							
CHECK	BERL	TS8H							
APPROVAL	CLZ2	CLZ2							

INDEX

1. INTRODUCTION

1.1. Scope of this Document

This Technical Specification establishes the main parameters for Unified Diverless Support Tube supplying and describes the criteria for manufacturing, inspection and acceptance tests.

1.2. SYSTEM DESCRIPTION

The Unified Diverless Support Tube (TSUDL) is a riser support system for a rigid and flexible riser (figure 1). The design shall allow pull-in operations with minimal diver assistance. The figures 2-3 illustrate TSUDL for a rigid riser system and flexible riser, respectively.

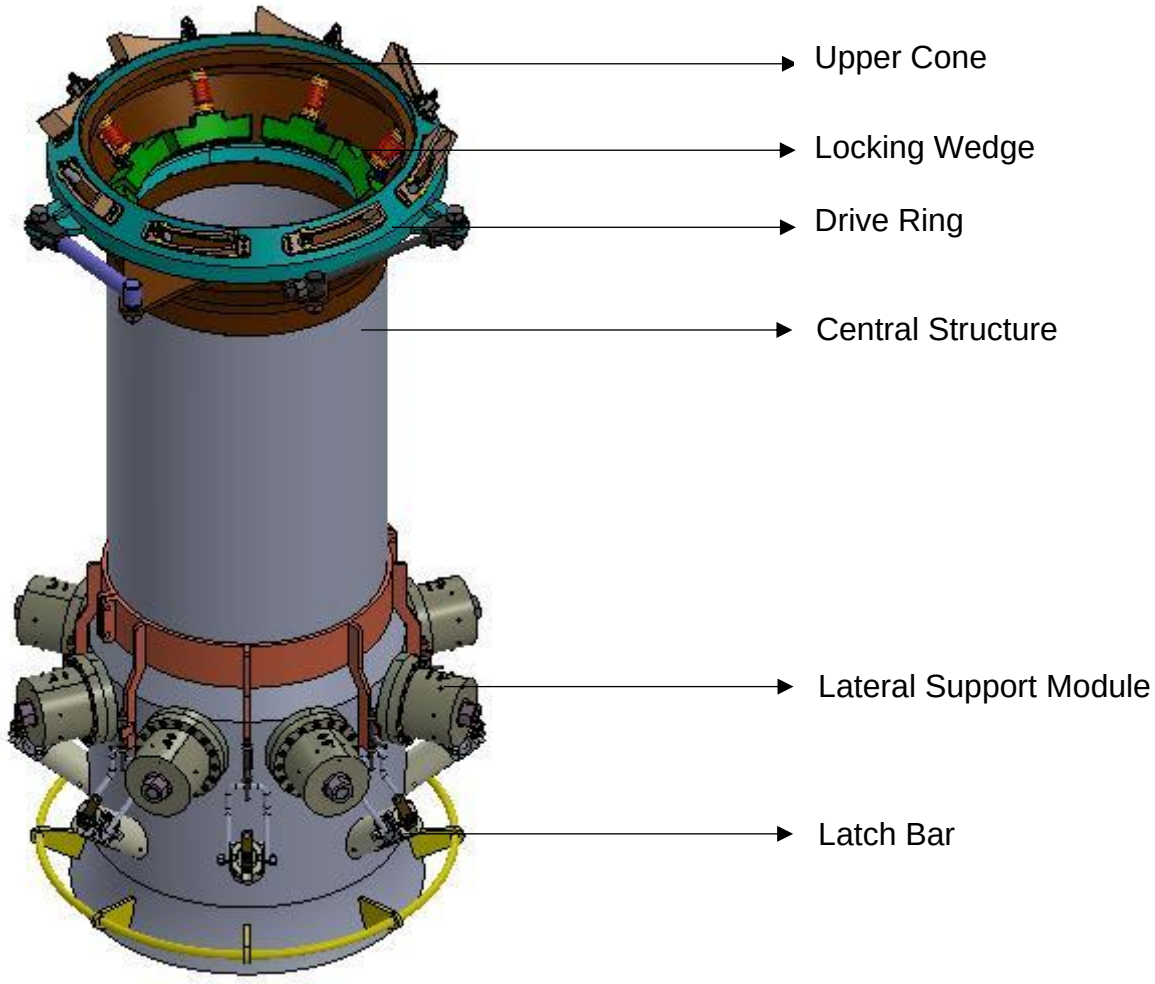

Figure 1 – Unified Diverless Support Tube Assembly main parts

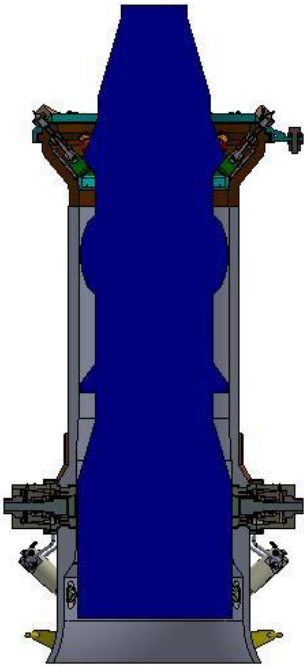

Figure 2 – Unified Diverless Support Tube Assembly main parts for rigid riser

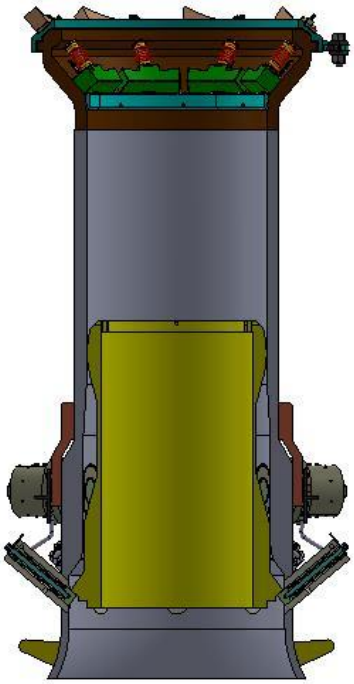

Figure 3 – Unified Diverless Support Tube Assembly main parts for flexible riser

The complete detailed TSUDL Feed Design is presented on I-LI-3010.00-1300-270-P56-001 (ref [3]), which includes the following main subcomponents on ref [4] to ref. [10]

1.2.1. Upper Cone

Component with mechanisms for locking the rigid riser top termination and supporting the riser top tension, connected to the Central Structure.

1.2.2. Locking Wedge

Forged sliding components responsible for bearing the rigid riser weight. On pull-in operations, it slides up due to direct contact with the Hang-Off Adaptor and returns for the bearing load position due to gravity and spring force. For pull-out operations, it slides up with the Drive Ring mechanism

1.2.3. Drive Ring

Rotating component, connected to the top of the Upper Cone, providing an automatic and simultaneous retraction of all Locking Wedge´s.

1.2.4. Latch Bar

Sliding component used to lock and secure Cap DL-SI on TSUDL for flexible riser connection.

1.2.5. Central Structure

Main cylindrical structural part that integrates all other TSUDL subcomponents for riser connection: Upper Cone welded on the upper part, Latch Bars and Lateral Support Modules on the lower part.

1.2.6. Lateral Support Module (MTL)

Sub-assembly responsible for providing lateral stabilization of the top riser termination, in which the riser shearing 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.

2. DEFINITIONS

2.1. General

For the purposes of this document, the following terms and definitions apply. Other terms and definitions can be found in reference documents and standards.

2.2. Definitions

CONTRACTOR	Company that runs the services or manufacturing contract of an FPU and hires the SUPPLIER to perform the services for manufacturing of the Unified Diverless Support Tube
Dummy HOA	Mechanical part used to simulate the rigid riser top termination on Factory Acceptance Tests
Dummy CAP	Mechanical part used to simulate the flexible riser top termination on Factory Acceptance Tests
FAT	Factory Acceptance Test
FEA	Finite Elements Analysis
FPSO	Floating Production Storage and Offloading
FPU	Floating Production Unit – is a ship or a semi-submersible platform for oil and gas production. The FPSO is a type of FPU
GA	General Assembly (Drawing)
HOA	Hang-off Adaptor
ITP	Inspection and Test Plan
MTL	Lateral Support Module
NDT	Non-Destructive Testing
PARTIES	The companies directly involved in the HOA and TSUDL design and fabrication, with power to propose modification over design and manufacturing aspects. By definition they are: PETROBRAS, CONTRACTOR and SUPPLIER
Pull-in	Riser transfer operation from installation ship to the FPU

Pull-out	Riser removal operation.
PETROBRAS	PETRÓLEO BRASILEIRO S.A. – PETROBRAS Where referred to in this Specification, it means both the Company itself and its employees authorized to communicate with CONTRACTOR or SUPPLIER
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QHSE	Quality Health, Safety and Environment
Riser	A length of flexible or rigid pipe used to connect the subsea collecting/exporting system to the FPU.
ROV	Remotely Operated Vehicle
TSUDL	Unified Diverless Support Tube
Supplier	Company responsible for detailed Design and manufacturing the Unified Diverless Support Tube
TRS	Test Report Sheet

3. REFERENCE DOCUMENTS AND STANDARDS

All equipment supplied under the scope of this Specification shall be in conformance to the latest editions of the design codes, standards, and PETROBRAS' documents listed hereafter in this section. In addition to these references, Project Specification shall be considered and shall take precedence to this Specification and references cited herein.

3.1. Petrobras's References

Ref. n°	Document number	Title

[1]	--- (1)	Project Technical Specification for Hull Structural Requirements
[2]	--- (1)	Project Material Requisition/ Data Basis

(1) Project reference number to be informed within a Project Document List, to be released during BID phase.

3.2. Petrobras's References

Ref. n°	Document number	Title
[3]	I-LI-3010.00-1300-270-P56-001	Unified Diverless Support Tube Part List
[4]	I-DE-3010.00-1300-270-PPC-004	Upper Cone
[5]	I-DE-3010.00-1300-270-PPC-002	Central Structure
[6]	I-DE-3010.00-1300-270-PPC-007	Drive Ring
[7]	I-DE-3010.00-1300-270-PPC-061	TSUDL HANG-OFF ADAPTOR
[8]	I-DE-3010.00-1300-279-P56-373	Cap DL
[9]	I-DE-3010.00-1300-279-PPC-306	Latch Bar
[10]	I-DE-3010.00-1300-279-PEK-004	Lateral Support Module
[11]	I-ET-3010.00-1200-956-P4X-002	General Painting
[12]	I-ET-3010.00-1519-140-P56-002	Unified Diverless Support Tube Factory Acceptance Test Procedure
[13]	I-ET-3010.00-1519-140-PPC-001	Wear Bushing for Unified Diverless Support Tubes
[14]	I-ET-3010.00-1200-956-P4X-003	Thermal Spray Coating Application of Aluminum
[15]	I-ET-3010.00-1500-274-PLR-001	Riser Top Interface Loads Analysis
[16]	I-ET-0000.00-0000-970-PSQ-001	Procedure and Personnel Qualification and Certification
[17]	I-ET-3010.00-1300-850-PEK-001	Control and Monitoring System for Riser Supports
[18]	I-DE-3010.1Y-1352-140-P4X-007	LOWER RISER BALCONY
[19]	I-DE-3010.00-1300-850-PEK-001	Riser Supports P&ID

3.3. American Petroleum Institute (API)

Ref. n°	Document number	Title
[20]	API RP 2A-WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
[21]	API SPEC 6A	Specification for Wellhead and Christmas Tree Equipment
[22]	API RP 17G	Design and Operation of Subsea Production Systems
[23]	API 2RD	Dynamic Risers for Floating Production Systems
[24]	API RP 2X	Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Ultrasonic Technicians
[25]	API 20F level BSL 2	Corrosion Resistant Bolting for Use in the Petroleum and. Natural Gas Industries

3.4. American Society of Testing and Materials (ASTM)

Ref. n°	Document number	Title

[26]	ASTM A370	Standard Tests Methods and Definitions for Mechanical Testing of Steel Products
[27]	ASTM A517	Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
[28]	ASTM A578	Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
[29]	ASTM B841	Standard Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits
[30]	ASTM A703M	Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
[31]	ASTM A707M	Standard Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service

3.5. American Society of mechanical Engineers (ASME)

Ref. n°	Document number	Title
[32]	ASME Section VIII, Division 1	ASME Boiler & Pressure Vessel Code
[33]	ASME Section VIII, Division 2	ASME Boiler & Pressure Vessel Code
[34]	ASME Section IX	ASME Boiler & Pressure Vessel Code
[35]	ASME PCC 1-2010	Guidelines for Pressure Boundary Bolted Flange Joint Assembly

3.6. American Welding Society (AWS)

Ref. n°	Document number	Title
[36]	AWS D1.1	Structural Welding Code

3.7. Other Documents

Ref. n°	Document number	Title
[37]	EN 473	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment
[38]	EN ISO 13628-7	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems
[39]	ISO 2859	Sampling Procedures for Inspection by
[40]	ISO 8501	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness;
[41]	ISO 8504	Preparation of steel substrates before application of paints and related products – surface preparation methods
[42]	ISO 9001	Quality management systems – Requirements
[43]	ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
[44]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons

[45]	ISO/IEC 17020	Conformity assessment – Requirements for the operation of various types of bodies performing inspection
[46]	ISO GUIDE 65	General Requirements for Bodies Operating Product Certification Systems;
[47]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons;
[48]	SSP-SP1	Solvent Cleaning;
[49]	SSPC-SP10	Near-White Metal Blast Cleaning

3.8. References and Standards for services in Brazil

In addition to the standards in section 3.1, to perform services in Brazil, the SUPPLIER shall meet the requirements in the following documents and standards in their latest revisions, unless otherwise indicated.

Ref. n°	Document number	Title
[50]	ABENDI NA 018	"Qualificação e certificação de pessoas em teste por pontos" (Qualification and certification of persons for chemical spot testing);
[51]	ABNT NBR 15218	Critérios para qualificação e certificação de inspetores de pintura industrial" (Industrial paint inspectors - Rules for qualification and certification);
[52]	ABNT NBR 16278	Inspeção de fabricação — Qualificação e certificação de pessoas para o setor de petróleo e gás" (Manufacturing inspection — Qualification and certification of personnel for the oil and gas sector)
[53]	ABTN NBR 5426	Planos de amostragem e procedimentos na inspeção por atributos" (Sampling Procedures for Inspection by Attributes);
[54]	ABNT NBR NM ISO 9712	Ensaios não destrutivos – Qualificação e certificação de pessoal" (Non-destructive testing – Personnel qualification and certification)
[55]	PETROBRAS N-1859	"Qualificação de Consumíveis de Soldagem" (Qualification of Welding Consumables)
[56]	PETROBRAS N-2301	"Elaboração da documentação técnica de soldagem" (English - Elaboration of technical documents for welding);
[57]	PETROBRAS PP-5EN-00008	Ensaio não destrutivo – qualificação de pessoal" (Non-destructive testing – personnel qualification)
[58]	ABNT NBR 14842	"Critérios para a qualificação e certificação de inspetores de soldagem" (Criteria for welding inspector qualification and certification)
[59]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons;

4. DOCUMENTATION

4.1. Bidding documentation

4.1.1. Before proposal delivery, the Contractor shall inform conflicting data present in PETROBRAS drawings. If any problem is identified during the manufacturing phase, the solution taken by Contractor SHALL NOT penalize PETROBRAS at any circumstance.

4.1.2. CONTRACTOR shall present the chosen SUPPLIER 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.

4.1.3. CONTRACTOR shall present the outline design and manufacturing plan, from raw material supply up to the hull integration.

4.1.4. CONTRACTOR will be responsible for the SUPPLIER contract and must assure to comply with all PETROBRAS requirements.

4.2. Manufacturing documentation

4.2.1. Ref. [3] provides only a preliminary design. SUPPLIER shall detail the concept, including and not restricted to: structural analysis (item 17), 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 (item 13.2.2), pre-selected materials, manufacturing process, or any other detailing issue for final manufacturing drawings.

4.2.2. SUPPLIER shall generate its own drawings according to its manufacturing methodology, and shall submit them to PETROBRAS for analysis and approval.

4.2.3. Contractor shall be attentive to the revision of the manufacturing drawings provided by the Supplier. In case of doubts, PETROBRAS shall be consulted.

4.2.4. The SUPPLIER shall only start manufacturing the UNIFIED DIVERLESS SUPPORT TUBE after approval of manufacturing drawings by the Contractor.

5. GENERAL REQUIREMENTS

5.1. Material Selection

5.1.1. All equipment and material manufactured and/or supplied under this 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 requirement, the selected materials shall comply with ref. [20].

5.1.2. CONTRACTOR shall verify all critical components material described in drawings list ref. [3]Contractor may suggest a different material for these components, however it shall be submitted to PETROBRAS approval.

5.1.3. 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.

5.1.4. The origin of all materials used in the manufacture shall be clearly identified. SUPPLIER shall submit any required material manufacturing process details, tests, examinations, inspections, and acceptance criteria for review by PETROBRAS.

5.1.5. The selection of the materials is a responsibility of SUPPLIER 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 service life, as per Project specifications;
- Corrosion protection;
- Wear losses, including deleterious effects on the surface topography and its consequences on fatigue or corrosion-fatigue life, due to relative movement and contact (e.g. fretting) of the parts according to Item 5.2.

5.1.6. The compatibility between all materials shall be checked. Materials shall not be affected by galvanic corrosion reactions and may be required to be welded to other specified metallic pieces where necessary.

5.1.7. Inspection criteria shall consider as a minimum the requirements as specified for the FPU.

5.2. Material Selection for Parts and Components under Wear

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

5.2.2. 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;

5.2.3. 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 Wedges must be adequately superior to the adjacent parts.

5.2.4. Wear bushings shall be designed according to ref. [13]

5.3. Castings

5.3.1. CONTRACTOR/SUPPLIER shall specify the material requirements for the castings. The casting requirements shall be documented in a written specification complete with chemistry, material properties, toughness testing, test coupon locations, inspection requirements, repair provisions, and NDE requirements. Where the engineering design considers varying criticality based on location in the casting, these areas shall be identified on drawings or material specifications. PETROBRAS will review and approve casting specifications.

5.3.2. SUPPLIER shall clearly define the methodology for quality control of the castings to insure all castings provide the required material properties.

5.3.3. As a minimum Castings shall comply with ref. [30].

5.4. Forgings

5.4.1. SUPPLIER may elect to use forged material for in lieu of castings. The material shall be selected to have good weldability, strength, and toughness when welded to steel plate (e.g. EH36 type). The forgings shall be forged to a near net shape, rough machined, heat treated, and final machined. The SUPPLIER shall document a written specification complete with chemistry, material properties, toughness testing, test coupon locations, inspection requirements, and NDE requirements. The forging supplier shall provide an MPS detailing the material, forging processing with reduction ratios, 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.

5.5. CONTRACTOR’s Responsibility

5.5.1. Contractor shall evaluate SUPPLIER quality control system, ensuring compliance with PETROBRAS requirements.

5.6. SUPPLIER’s Responsibility

5.6.1. SUPPLIER shall furnish all labor, consumables, tools, equipment, and materials other than those explicitly identified as supplied by PETROBRAS required to manufacture, test and deliver. SUPPLIER shall perform all required operations for Design, manufacture, inspection, testing and handling.

5.6.2. Nothing contained in this Specification or omitted from it shall be construed as relieving the SUPPLIER 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.

5.6.3. SUPPLIER 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.

5.6.4. 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.

5.6.5. PETROBRAS furnished Drawings and Specifications shall be checked by SUPPLIER immediately upon receipt, and SUPPLIER shall promptly notify PETROBRAS of any discrepancies therein.

5.6.6. For any requirement in question by SUPPLIER, it shall be SUPPLIER'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.

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

5.6.8. SUPPLIER shall provide all reasonable facilities to PETROBRAS' inspectors, without extra charge, to satisfy the inspector that product is being manufactured in accordance with PETROBRAS's 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' Specification, then SUPPLIER may demonstrate to PETROBRAS that the product still satisfies the design requirement. If SUPPLIER is unable to prove this to PETROBRAS' satisfaction, then the manufacturing and/or testing procedure shall be repeated until compliance is demonstrated. All such remedial Work shall be performed at SUPPLIER's cost.

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

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

5.6.11. All costs, including taxes are to the SUPPLIER account in undertaking the responsibilities.

5.6.12. 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.

5.7. Units of Measurement

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

6. DESIGN REQUIREMENTS

6.1. General

Controle and monitoring system for TSUDL shall respect the requirements of ref.

6.1.1. SUPPLIER 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 (Section 6 of the present Specification), the Hull Structural Requirements defined on FPU documentation and ref. [38]. In case of any conflict identified PETROBRAS shall be consulted. This documentation shall be comprised of written reports, in accordance with PETROBRAS standards, and the electronic input and output files of the finite element analysis.

6.1.2. The Design adopted by SUPPLIER based on the requirements set in this document and relevant specifications shall conform to specific general design requirements stated in this section. As a minimum, the TSUDL meet the function as outlined in section 6.

6.1.3. SUPPLIER shall fully 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 for the Project-specific service conditions shall remain.

6.1.4. Commercial local analysis packed accepted are Abaqus and Ansys.

6.1.5. Design methodology reports and analysis results reports shall be submitted by SUPPLIER and approved by PETROBRAS before start of fabrication. Design revision cycles, including proprietary documents when necessary, can be requested by PETROBRAS under SUPPLIER premises, as per Section 5.5.

6.1.6. CONTRACTOR 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 design code for each failure mode.

6.1.7. The TSUDL fabrication shall be subject to the scrutiny, inspection, verification, qualification, and documentation in accordance with SUPPLIER and industry standards as set in this specification and Project documentation;

6.1.8. The TSUDL shall successfully pass the Factory Acceptance Tests defined in ref. [12] and SUPPLIER's approved procedures;

6.1.9. Pad eyes and other lifting devices used for general handling of the equipment shall be designed in accordance with internationally accepted code (e.g. ref. [38]);

6.1.10. Control and monitoring system of TSUDL shall be according to ref. [17];

6.1.11. Welding to lower riser balcony shall be carried out through an intermediate plate supplied together with TSUDL from factory in order to prevent distortion inside the TSUDL. The intermediate plates shall comply with ref. [18] and with their specific top and azimuth angle. The Plate tolerance design is a supplier responsibility.

6.2. Upper Cone

6.2.1. The design requirements applicable to 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;
  - If the fatigue assessment on Structural Calculation considers a post weld heat treatment, this procedure shall be documented as outlined on 19.2.1.2
- 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 service life;
- Offshore installation aids (guides) shall be designed to facilitate the installation of the Hang-off system during offshore installation.

6.2.2. The Upper Cone internal profile and overall length shall be in accordance with the reference design selected standard HOA type as ref. [7].

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

- Upper Cone shall be inherently fail-safe. In the event that a complete fail 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 over the top cone components during the shipyard construction.
- The Design shall consider a 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 ref. [3] and ref. [17])

- Upper cone hydraulic cylinder is a double action hydraulic actuator installed on TSUDL as shown in Figure 4 and ref. [19] that provide means for remote control to unlock BSDL-SI during diver less pulling operation.
- Upper cone hydraulic actuator is responsible primarily for retracting locking wedges, usually on pull-out or preparation for pulling. Pulling operation does require hydraulic actuation since locking wedges device operates mechanically and automatically by hang off adaptor direct contact and movement.
- On pull-in operations, prior to Hang-Off Adaptor connection, it is expected to have contact between the FPU pull-in Cable 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 provides 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 (ex: chamfer, fillets), which area reduction shall be validated on Structural Calculation (section [17]) for a proper rigid riser weight bearing.
- ROV mode of operation is also available by screw rod device as shown in Figure 4.

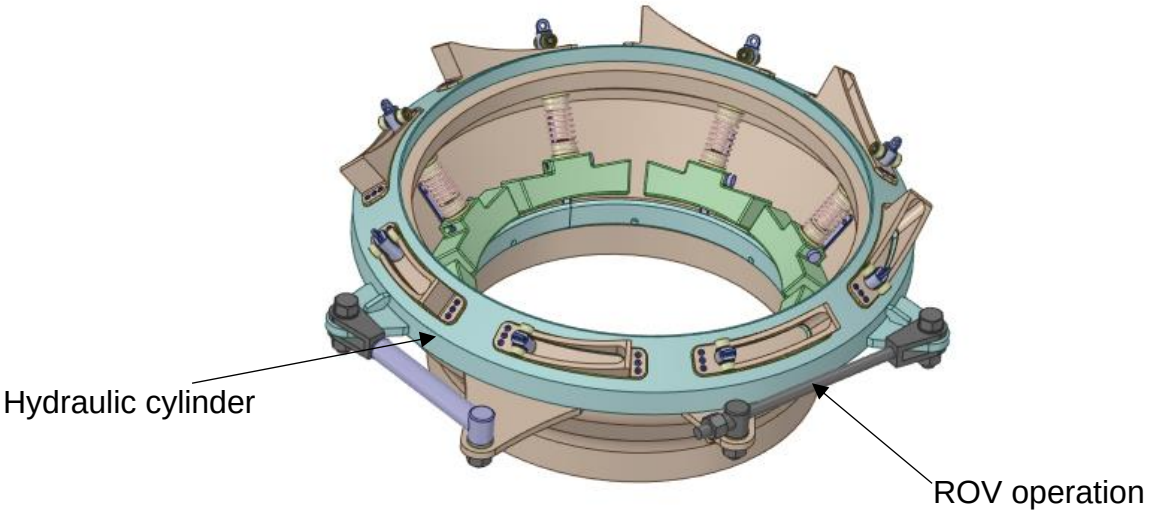

Figure 4 – Upper cone assembly

6.2.4. Upper cone hydraulic cylinder technical requirements:

6.2.4.1. Hydraulic maximum operation Pressure: 5000psi

6.2.4.2. Hydraulic Test Pressure: 5500psi

6.2.4.3. Hydraulic fluid: 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) as listed: MacDermid HW443, MacDermid HW525P or Castrol Transaque DW

6.2.5. External Environment: Sea Water

6.2.5.1. Maximum sea water temperature: 30°C

6.2.5.2. Minimum sea water temperature: 20°C

6.2.6. 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 following corrosion resistance alloys:

6.2.6.1. UNS N07725 Max 35 Rc

6.2.6.2. UNS S31266

6.2.6.3. UNS C17000

6.2.7. Minimal Spring force: 3 x rod hydraulic force due to pressure produced as a result of hydrostatic column in umbilical considering 30m and fluid density (see 6.2.4.3)

6.2.8. Spring material shall be INCONEL 718 with hardness limited to 35HRC

6.2.9. Sealing shall be full compatibility with all of the water-glycol based hydraulic (see 6.2.4.3)

6.2.10. Minimum hydraulic cylinder force shall consider, at least, cylinder spring reaction, wedges springs reactions, wedges weight and all friction forces associated and be able to complete stroke at 3000 psi.

6.2.11. Maximum hydraulic cylinder force shall be limited to 20 kN. Note: this limit is defined to prevent unintentional unlocking of 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 section 17.

6.2.12. Design operational life: 30 years

6.2.13. Design locking and locking cycles: 10

6.2.14. Stress analysis shall be performed and allowable stress shall be considered according to API 6X.

6.2.15. Scope of supply include detailed design, procurement, construction, assembly, FAT.

6.2.16. Hydraulic actuator manufacturing, quality control, storing and shipping shall comply with API6A considering PSL 3.

6.2.17. Performance Requirements level PR2 shall be fulfilled.

6.2.18. Manufacturing and quality control data book 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.

6.3. Central Structure

6.3.1. The design requirements applicable to the Central Structure shall include, but not be limited to the following:

- 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 service life;
- The Central Structure shall incorporate any features needed for handling during assembly into SPU hull;

6.4. Latch Bar Mechanism

6.4.1. The design requirements applicable to the Latch Bar Mechanism shall include, but not be limited to the following:

- 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.

6.4.2. Th Latch Bar Mechanism be in accordance with the reference Cap-DL design as ref.[8].

6.4.3. 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. In the event that a complete fail 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 a unlock mechanism with a Handler, which has been optimized for diving operations. In order to perform a diverless pull-out operation, the final design shall consider an optimized ROV interface, as the preliminary conceptual drawing outlined below.

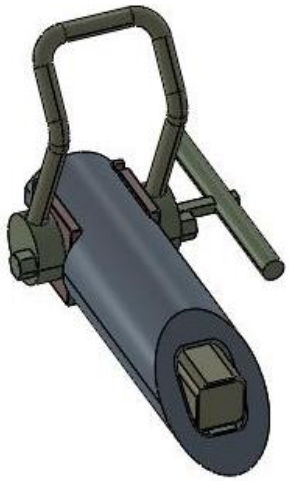

Figure 5 – Latch Bar Mechanism

6.5. MTL

6.5.1. Functional requirements

6.5.1.1. The lateral support module (MTL) comprises 8 radially arranged assemblies as shown in Ref. [3], including components that move towards hang off adaptor surface at pull-in's final stage driven by hydraulic cylinders and keep its position in order 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.

6.5.1.2. MTL components shall be retractable by both hydraulic pressure and ROV actuation to release HOA and clear TSUDL inner space for pullout operation.

6.5.1.3. Alternative MTL designs may be proposed during FPSO BID process subject to Petrobras approval based on fulfilling the functional and design requirements, track record and qualification reports.

6.5.1.4. 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
- complying to 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 20m hydrostatic column from lower balcony to main deck;
- MTL design shall have enough clear space and reaction plates for torque tools ref. [10];
- Fitting sealings type shall comply with ISO 8434-2(JIC 37) standard

6.5.1.5. As a minimum, the MTL shall be designed to meet the functional characteristics outlined below:

- Maximum Gap: 10 mm (defined as difference between minimum Hang Off Adaptor diameter and maximum TSUDL diameter)
- Design Loads: Anticipated maximum individual MTL load according to Petrobras FEED studies are 2700kN and 1600kN on accidental and extreme conditions for each MTL respectively. This load condition is preliminary and shall be detailed as section 17.
- Hydraulic maximum operation Pressure: 5000psi
- Hydraulic Test Pressure: 5500psi
- Hydraulic fluid: 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)
- External Environment: Sea Water
- Maximum sea water temperature: 29,25°C
- Minimum sea water temperature: 20,76°C
- MTL components shall be electrically insulated from TSUDL cathodic protection as a mean to activate copper based alloys biofouling inhibition as well as preventing calcareous layer formation.
- 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 ref. [25] level BSL 2 and ref. [10].
- Wedge locking washers shall be used to prevent loosening of bolts.
- Minimal Spring force: 2,5 x rod hydraulic force due to pressure produced as a result of hydrostatic column in umbilical considering 20m and fluid density.
- Design operational life: 30 years
- Design locking and unlocking cycles: 5

6.5.1.6. As a minimum, the MTL shall be designed to meet the functional characteristics outlined below:

- 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

6.5.2. MTL description

6.5.2.1. MTL is illustrated in Figure 2 that is part of drawing I-DE-3010.00-1300-279-PEK-004 that has full description of components. MTL should be actuated after riser Hang Off Adaptor is already seated on top cone.

6.5.2.2. Hydraulic actuation mode for HOA locking at pull-in operation

6.5.2.2.1 Hydraulic fluid is pressurized into cylinder inlet chamber that consists the inner space inside parts 17 - cylinder external tube, 14 - cylinder internal tube and 12 – piston in order to move the following part towards hang off adaptor:

18 – Nut
9 – Mandrel
12 – Piston
19 – Mandrel Ring
20 - Rod Cover
8 - Cage
3 – Shoes

6.5.2.2.2 The moving parts mentioned (18, 9, 12, 19, 20, 8 and 3) will be stopped when reaching hang off adaptor at any position in stroke (max 10mm). After component 8-cage stops by reaching HOA, 9-mandrel is forced to keep moving

towards 9-cage and resulting in 3-shoes moving outwards by tapered surface sliding inside inner 3-shoes surface. Low taper angle, 2,86° (1/20 in radius), provides self-holding feature to mechanism.

6.5.2.3. Hydraulic actuation mode for MTL retract and HOA unlocking at pull-out operation

6.5.2.3.1 Hydraulic fluid is pressurized into cylinder retract inlet to do opposite movements as described in 6.5.2.2:

6.5.2.4. ROV actuation mode for HOA locking at pull-in operation

6.5.2.4.1 ROV hydraulic torque wrench (see for ref. RSL14h308) is positioned over 18-nut. Torque reaction pins (1) are placed on 17-cylinder external tube to provide anti-rotation support for torque wrench.

6.5.2.4.2 Rotating 18-Nut clockwise will drive the following components towards HOA:
9 – Mandrel
12 – Piston
19 – Mandrel Ring
20 - Rod Cover
8 - Cage
3 – Shoes

6.5.2.4.3 When reaching HOA the same way as described in 6.5.2.2.2 the 8-cage will stop moving but 9-Mandrel will keep moving and 3-shoes will be forced over 7-Load Ring.

6.5.2.4.4 ROV mode of operation may be used ad back up mode of operation in the case of hydraulic actuation failure. Also, ROV mode of operation may be used to increase load capacity since previous analyses performed by Petrobras resulted in following data:

Operation Mode	Load capacity (kN)
Hydraulics	1700
ROV	3000

6.5.2.1. ROV actuation mode for HOA locking at pullout operation

6.5.2.1.1 Rotating 18-Nut counter clockwise will retract the same components described in 6.5.2.4.2.

6.5.3. MTL materials selection

6.5.3.1. Bio fouling prevention shall be considered in MTL materials selection mainly in space surrounded by 7-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 stablishes the following material to be used in 7-Load ring, 8-Cage, 3-Shoes and 9-Mandrel:

ASTM B570 - UNS No. C17000 (CuBe)

6.5.3.2. Copper based alloys anti-fouling features can only be achieved without cathodic protection. For that reason as electrical isolating component is placed between 7-load ring and TSUDL wall. The isolating material shall be selected also with adequate mechanical properties to MTL loads. Also stiffness and time independent properties shall be considered when selecting isolating material in order to prevent bolt loosening due to pretension loss and its deleterious effect on bolt fatigue behavior. For example, viscoelastic behavior as expected for polymer based materials shall be avoided for isolating component.

6.5.3.3. Spring (21) shall be designed to prevent unintentional MTL actuation due to hydrostatic head considering umbilical 30m from lower balcony to FPSO deck level. Anti-fouling material shall be selected for spring so that CuBe is required also for spring.

ASTM B570 - UNS No. C17000 (CuBe)

6.5.3.4. Other MTL components shall be Corrosion Resistant Alloys considering required mechanical properties and corrosion resistance with no cathodic protection premises. The following materials are considered pre-approved for MTL components UNS N07725 - Max 35 Rc (INCONEL® 725) UNS S31266; ASTM A182 - F58.

6.5.4. MTL scope of work:

6.5.4.1. SUPPLIER is required to provides detailed design for MTL FEED studies

6.5.4.2. SUPPLIER is required to perform a Design Validation test by subjecting a complete MTL assembly under sea water during at least 6 months to verify its functionality and load capacity prior to start the production of the MTLs. A Design Validation test report shall be issued. The validation shall be completed up to 12 months after the Notice to Proceed.

6.5.4.3. Scope of supply includes procurement, construction, assembly, FAT. of MTLs and two units of Hydraulic Torque Wrenchs as specified in detailed design (see ref. [10] for type example).

6.5.4.4. Hydraulic actuator manufacturing, quality control, storing and shipping shall comply with API 6A considering PSL 3.

6.5.4.5. Performance Requirements level PR2 shall be fulfilled.

6.5.4.6. Manufacturing and quality control data book 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.

6.5.4.7. Hydraulic lines cleanness shall be from 6B through 6F fromSAEAS4059 or according to ISO 4406 class 17/15/12 (formerly NAS 1638 Class6).

6.5.4.8. Design data shall be considered as follows:

6.5.4.9. Factory acceptance test pressure: 5000 psi

6.5.4.10. Minimum temperature: 20°C

6.5.4.11. Maximum temperature: 30°C

6.5.4.12. Maximum external pressure: 20m water column

6.5.4.13. Full compatibility with all the water-glycol based hydraulic control fluids listed: Mac Dermid HW443, Mac Dermid HW525 Por Castrol Transaque DW;

6.5.4.14. Design operational life: 30 years and 50 cycles.

6.5.4.15. Each MTL assembly shall be load tested with, at least, 2700 kN prior to TSUL assembly.

6.5.4.16. Each MTL hydraulic cylinder shall be hydrostatic tested with at least 5500 psi prior to TSUL assembly.

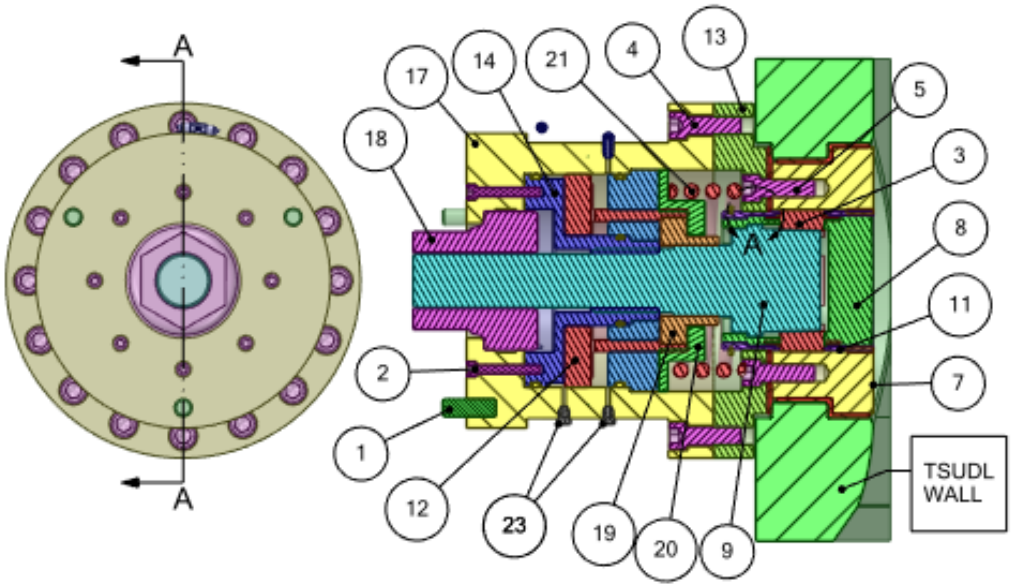

Figure 6 – MTL Assembly Drawing

7. UNIFIED DIVERLESS SUPPORT TUBE IDENTIFICATION AND TRACEABILITY

7.1. Traceability

7.1.1. Codification and traceability procedures shall be in accordance with ref. [42] plus the following requirements:

7.1.2. Alphanumeric codes for traceability shall be punctured in materials using low-stress punches.

7.1.3. Each equipment shall receive a unique codification to allow tracing back to its own inspection and test reports.

8. PROTECTION AND PACKING

8.1. General

8.1.1. UNIFIED DIVERLESS SUPPORT TUBE shall be delivered packed to ensure the integrity of the parts, in particular the mobile locking devices.

9. MATERIALS AND COMPONENTS

9.1. General

9.1.1. SUPPLIER shall provide material certificates of raw materials used in UNIFIED DIVERLESS SUPPORT TUBE manufacturing to be included in the databook, as in item 19 of this Specification.

9.2. Ferrous Materials

9.2.1. Ferrous materials for manufacture the UNIFIED DIVERLESS SUPPORT TUBE and its parts shall be certified by a classification society.

9.3. Thermally Pretreated Steels

9.3.1. Parts manufactured with thermally pretreated steels may need heat treatment after welding and/or machining to ensure that its mechanical properties will remain unaltered. SUPPLIER shall contact the SUPPLIER of the steel to specify the appropriate heat treatment.

10. PROCEDURE AND PERSONNEL QUALIFICATION

Personnel qualification of Weld, NDT and dimensional inspectors shall comply with ref. [16].

10.1. General

10.1.1. ALL complete joint penetration welds shall be inspected by means of ultrasonic examination.

10.1.2. All welds and surrounding area of base metal shall pass through magnetic particle inspection. Partial NDE is not allowed.

10.1.3. Qualification of NDE Inspectors shall be according to AWS doc. ref. [36], API doc. ref. [24] and PETROBRAS Specification ref. [16]

10.2. Procedures

10.2.1. Ultrasonic testing of welds shall conform to AWS doc. ref. [36], API doc. and PETROBRAS Specification ref. [16].

10.2.2. Magnetic Particle testing shall conform to API doc. ref. [24]

10.3. Acceptance Criteria

10.3.1. The acceptance criteria for ultrasonic inspection and testing of complete Joint penetration welds shall be API doc. ref. [24] Criteria Level A.

10.3.2. The acceptance criteria for magnetic particle inspection shall be ASME Section VIII Division 1, Appendix 6 doc. ref. [32]. Local grinding of the weld to enhance interpretation of examination results shall be carried out as determined necessary by SUPPLIER.

10.3.3. Radiographic testing of welds is not required by this specification. If required by CONTRACTOR or SUPPLIER, testing shall conform to AWS doc. ref. [36].

11. WELDING

11.1. General

11.1.1. All welds shall be in accordance with ref. [36].

11.2. Qualification

11.2.1. The welders and welding procedures shall be qualified and certified in accordance with item 10 of this technical Specification.

11.3. Welding Consumables

11.3.1. Consumables used in Brazil shall be certified by the Product Certification Body (OCP) as a Conformity Assessment Body (OAC) accredited by INMETRO under the *Sistema Brasileiro de Avaliação de Conformidade* (SBAC), according to PETROBRAS N-1859. When used abroad, they shall be certified by an OCP accredited by INMETRO or a foreign OCP that complies with ISO GUIDE 65. In this case, the consumable trademark does not comprise an essential variable in the qualified procedures. In case the welding consumables are not certified by the OCP, the change in consumable trademark, even if this does not modify its classification, results in the requalification of the welding procedure.

11.3.2. Once the consumables with suffix G are not certifiable by OCP, their use shall be limited to situations in which there is no specific classification to optimize a characteristic required for welding of a given material. If their application is required, the Welding Procedure Specification (WPS) and Welding Procedure Qualification Record (RQPS) shall contain trademark, specified chemical composition of deposited weld metal, specific toughness requirements (testing temperature and impact energy), and post-weld condition (as welded or treated).

In addition, it shall have lot control, according to AWS A5.01 Schedule J. The welding of that consumable shall be used only with previous approval of Contractor. The respective lot certificates shall present the values specified and accepted by Contractor. For use of consumables generically classified (which means, equivalent to suffix “G”) with Specification different from AWS, such as, for example, of European standard (EN) or standard ISO, (only allowed when provided in the design standard of equipment), the same requirements described herein for suffix “G” consumables of Specification AWS shall be met.

12. MANUFACTURING INSPECTION

12.1. General

12.1.1. The Contractor shall maintain a fabrication inspector during manufacturing process of the TSUDL.

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

12.1.3. Inspections shall be performed in accordance with specific procedures and shall include at least the activities listed in 12.2 to 12.8.

12.2. Inspection and Tests Plan – ITP

12.2.1. Contractor 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 Supplier.

12.2.2. SUPPLIER shall send the ITP for Contractor approval respecting the contractual terms.

12.2.3. The ITP is a document within the Supplier’s Quality Plan that follows the standards set by quality management standards, which shall contain at least:

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

b. Identification of intervention type that will be performed by Supplier's personnel and by Contractor's inspection representative throughout the manufacturing cycle (document verification, monitoring point, an observation point, and holding point);

c. Indication of procedures, technical specifications, and standards for each activity;

d. Acceptance criteria for all features and quality requirements of each activity, including activities carried out at sub-supplier facilities;

e. Identification and preparation of quality records, citing the record type applicable to each activity.

12.3. Preparation and cutting

12.3.1. Verify if parts to be cut are identified in accordance with item 7.1 of this Technical Specification.

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

12.3.3. Verify if parts dimensions are in accordance with drawings.

12.4. Pre-assembly

12.4.1. Verify if the traceability of the parts is in accordance with item 7.1 of this Specification and belong to the same assembly.

12.5. Non-destructive tests

12.5.1. All procedures and personnel used in NDT shall be qualified and certified in accordance with item 10 of this technical Specification.

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

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

12.6. Tensile and Impact Tests

12.6.1. An addition latch bar shall be supplied to prepare 2 (two) samples for the tensile tests and 2 (two) samples for the impact tests. See Figure 5 and ASTM A370 for samples dimensions.

12.6.2. Similar to item 12.6.1, an additional Locking Wedge shall be supplied to prepare 2 (two) samples for tensile testes and 2 (two) samples for impact tests, which sample position shall be obtained near from part surface, similar as outlined on Figure 5.

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

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

12.6.5. The results shall be part of Data Book, as in item 19 of this specification.

12.6.6. Tensile Tests

12.6.6.1. The yield strength, tensile strength, stretching and area reduction shall be obtained by tensile test.

12.6.6.2. 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 strength shall comply with the detailed design.

12.6.7. Impact Test

12.6.7.1. Charpy tests shall be performed at -10 ºC (minus ten degree Celsius).

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

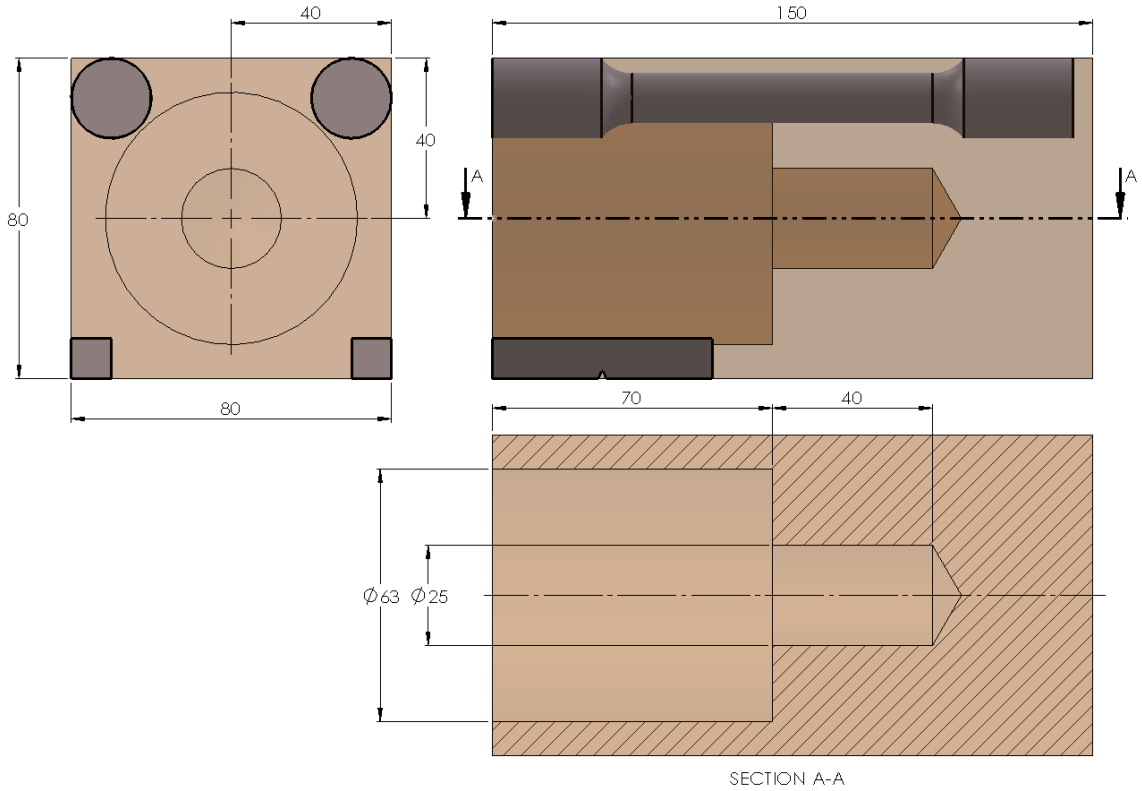

Figure 7 – Position for extraction of tensile and impact tests samples on the addition Latch bar

12.7. Dimensional

12.7.1. Verify if dimensions are in accordance with the drawings.

12.7.2. Dimensional control inspectors shall be qualified in accordance with item 10 of this technical Specification.

12.8. Availability of documents for inspection

12.8.1. The SUPPLIER shall always keep available for the inspectors the ITP, procedures, technical standards, and other documents necessary to perform the inspection and interpretation of results.

12.9. Nonconformities

12.9.1. All non-conformities records shall be part of the data book, as in item 19 of this Specification.

13. CORROSION PROTECTION

13.1. General

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

13.1.2. The TSUDL shall be painted with marine epoxy coating as per PETROBRAS Specification ref. [11]. Top coat color shall be specified by PETROBRAS.

13.1.3. The CONTRACTOR will touch up the coating at the interface to the hull structure.

13.1.4. At least the contacting surfaces of the TSUDL shall be coated with TSA in accordance with ref. [14]. The effectiveness of the proposed system shall be well documented, and tests shall demonstrate the efficiency of the system.

13.1.5. All coatings and coating procedures used by SUPPLIER or SUB–SUPPLIERs are subject to the PETROBRAS's review and approval.

13.1.6. The TSUDL main parts shall include 3.75 mm of corrosion allowance per side exposed to seawater.

13.2. Cathodic Protection

13.2.1. The UNIFIED DIVERLESS SUPPORT TUBE cathodic protection is provided by the electrical contact with the main hull structure, which is provided by the impressed current from the SPU.

13.2.2. 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.

13.2.3. Electrical continuity between all components must be tested after assembly

13.3. PAINTING

13.3.1. SUPPLIER shall observe that parts whose drawings present the indication "DO NOT PAINT" are not to be either painted or electrically isolated ref. [11].

13.3.2. Painting procedure shall comply with item 13.4.1 or paint manufacturer specification. In case of divergence, paint manufacture specification shall be used, observing the thickness specification for each layer and final thickness.

13.4. Final thickness

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

13.5. Final Painting

13.5.1. The UNIFIED DIVERLESS SUPPORT TUBE shall be delivered with the paint free of defects.

13.5.2. For the FAT, UNIFIED DIVERLESS SUPPORT TUBE shall be painted with the last layer of paint applied (antifouling). If any UNIFIED DIVERLESS SUPPORT TUBE 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.

13.5.3. 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 item 13.4 of this Specification.

13.5.3.1. If necessary, the paint shall be touched up only in parts that do not require disassembly of the locking mechanisms. If SUPPLIER needs to disassemble the locking mechanisms, the UNIFIED DIVERLESS SUPPORT TUBE shall be retested.

13.6. Anti-friction coat

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

14. DUMMY HOA & DUMMY CAP

14.1. General

14.1.1. Only one Dummy HOA and Dummy Cap must be manufactured for testing all the UNIFIED DIVERLESS SUPPORT TUBE. The Design is going to be defined by PETROBRAS after the kickoff meeting and as ref. [7].

15. FACTORY ACCEPTANCE TESTS – FAT

15.1. General

15.1.1. The TSUDL shall be tested individually to verify their mechanical functioning.

15.1.2. All tests are Supplier’s responsibility.

15.1.3. A member of Quality Control department of the SUPPLIER 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.

15.1.4. A PETROBRAS representative shall witness all tests. This representative will be responsible for approving or rejecting the UNIFIED DIVERLESS SUPPORT TUBE FAT.

15.1.4.1. For TSUDL manufactured in Brazil, the Contractor shall notify Petrobras, at least 10 (ten) calendar days in advance or as defined in the terms of the contract, the date when the TSUDL will be available for FAT.

15.1.4.2. For TSUDL manufactured abroad, the Contractor shall inform Petrobras, at least 30 (thirty) calendar days in advance or as defined in the terms of the contract, the date when the equipment will be available to be tested.

15.2. FAT Procedure

15.2.1. The FAT Procedure shall be submitted to PETROBRAS analysis and approval.

15.2.2. This procedure shall observe at least the requirements listed on ref. [12] and [13].

16. MODIFICATIONS AND ADJUSTMENTS

16.1.1. The SUPPLIER shall not machine the Locking Wedges to force the contact with the Dummy HOA. The shape and angles of the Locking Wedges shall not be changed from the dimensions and tolerances shown in the manufacturing drawings approved by the Contractor.

16.1.2. The SUPPLIER 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 the Contractor.

16.1.3. The SUPPLIER can implement small changes in the TSUDL's Design to make it appropriate to their manufacturing process or to correct small non-conformities. In this case, the SUPPLIER shall submit a written document to Contractor describing the problem and the proposed solutions. Contractor shall inform PETROBRAS about these changes.

16.1.4. The changes or corrections mentioned in 16.1.3 will only be implemented after Contractor approval.

16.1.5. The approved document shall be included in the databook.

17. STRUCTURAL CALCULATION

17.1. General

17.1.1. Contractor 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 by ref. [15], ref. [38] and the specific riser configurations defined by the project.

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

17.1.3. Design methodology and acceptance criteria shall be in accordance with an internationally recognized code such as API RP 17G ref. [22]. Other design codes or methodology previously validated by Contractor may be accepted after PETROBRAS approval.

17.2. Finite Element Analysis

17.2.1. Finite element analysis shall be used to establish structural, buckling, and fatigue performance of the TSUDL.

17.2.2. 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.

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

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

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

17.1. FEA methods to evaluate plastic collapse capacity

17.1.1. There are different ways of estimating the plastic collapse capacity of a component using FEA:

- elastic analysis;
- limit analysis;
- elastic-plastic analysis.

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

17.2. Elastic analysis

17.2.1. Finite element analysis shall be used to establish structural, buckling, and fatigue performance of the TSUDL. Service criteria whenever applicable shall be also evaluated to avoid excessive deformation that may compromise the proper functionality of all components, and the moving parts of the TSUDL. (ref. Sect. 5.2.4.3 of ref. [33]).

17.2.2. 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 stresses 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 SUPPLIER.

17.2.3. For the FE models where the analysis is 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.

17.2.4. 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.

17.2.5. In using elastic finite element analysis to calculate the TSUDL plastic collapse capacities, SUPPLIER 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;

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

17.2.7. 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 Design Premises document. CONTRACTOR/SUPPLIER 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 17.3 and 17.4 of this Technical Specification.

17.3. Limit analysis

17.3.1. 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.

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

17.3.3. PETROBRAS may require the performance of limit analysis in addition to the elastic one when the presented results of elastic analysis were not conclusive.

17.4. Elastic-plastic analysis

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

17.4.2. 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.

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

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

17.4.5. PETROBRAS may require the performance of elastic-plastic analysis in addition to the elastic one when the presented results of elastic analysis were not conclusive.

17.5. FEA Methods to Evaluate Protection Against Local Failure

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

17.5.2. Design codes usually recommend 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.

17.5.3. 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.

17.6. FEA Methods to Evaluate Protection Against Progressive Collapse

17.6.1. Methods for protection against progressive collapse from repeated loading are found on internationally recognized design codes. SUPPLIER shall follow the recommended procedure of the respective selected codes for the verification of the TSUDL.

17.6.2. 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 section 5.5.6 of ref.[33].

17.6.3. However, if elastic-plastic analysis results are used, then an assessment method compatible with such type of analysis shall be employed instead (e.g. see section 5.5.7 of ref. [33]).

17.7. FEA for Fatigue

17.7.1. Fatigue life evaluation of the TSUDL carried out by SUPPLIER shall include the assessment of both welds and plain material following the rules and procedures of a selected internationally accepted code.

17.7.2. When creating FE models for calculating 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.

17.7.3. 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.

17.8. FEA documentation

17.8.1. The analysis report shall be sufficiently detailed to allow for 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 provisions of sec. 5.6). 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;
- Loads and load sequence;
- Analysis approach;
- Application of safety factors;
- Mesh convergence study results;
- Analysis results;
- Sensitivity analysis;
- Discussion of results;
- Conclusions;
- Any other performed verification.

18. QUALITY CONTROL AND REPORTING

18.1. Quality management system

18.1.1. Each element of the Work shall be executed in accordance with quality management systems that comply with the requirements of CONTRACTOR and PETROBRAS project requirements.

18.1.2. SUB-SUPPLIER shall refer to the document “Project Quality Management Plan”.

18.2. Quality Plan and quality control plan

18.2.1. SUB-SUPPLIER shall produce for SUPPLIER 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 SUB-SUPPLIERS and SUPPLIER.
Project quality control plan (ITP)	Detail quality control plan and control monitoring to be employed during mobilization, acquisition and reporting phases.

18.2.2. All SUB-SUPPLIERs shall address and resolve any audit reports, recommendations and/or corrective action requests issued by the CONTRACTOR to the satisfaction of the CONTRACTOR and of the PETROBRAS.

18.2.3. SUB-SUPPLIERs shall also refer to document “QHSE Management for Suppliers / Subcontractors”.

18.3. DESIGN, Procurement and Fabrication Procedures Reports and Records

18.3.1. The following procedures, reports and records shall be provided to PETROBRAS for review:

18.3.1.1. QA/QC procedures to be submitted to PETROBRAS for review prior to the start of design and production work. The plans and procedures shall include, as a minimum, the following elements:

- Manufacturing ITPs for PETROBRAS to comment (assign inspection points);
- Material and Process Qualification Plan;
- Inspection and Test Reports to be provided including all reports defined in this Specification;
- NDT Procedures;
- FAT Procedures;
- Document Control Procedures;
- Traceability Plan;
- Nonconformance Procedure including examples of a report form to be utilized.

18.3.1.2. Design Basis and Methodology (DBM) to be submitted to PETROBRAS for review before starting of design and production work, as a minimum, includes 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 SUPPLIER facilities;
- List of Design Drawing to be provided;
- Design calculations and reports for each element to be provided.

18.3.2. The final documentation of the detailed Project shall include:

18.3.2.1. Design Basis and Methodology;

18.3.2.2. Design Report;

18.3.2.3. Manufacturing Procedure Specification (MPS) to be submitted to PETROBRAS for review before the start of design and production work, as a minimum, includes the following:

- Procedures including process control plans;
- Testing and Inspection Plan with monitoring points identified;
- Factory Acceptance Testing, as described in section 15.

18.3.2.4. Inspection and test reports;

18.3.2.5. As-built drawings or as-built dimensional reports;

18.3.2.6. Inspection, test records, and procedures as defined by this Specification.

18.3.3. 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.

18.3.4. SUPPLIER shall notify PETROBRAS of any changes in these practices for PETROBRAS review/approval prior to implementation.

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

18.3.6. Nonconformity reports shall be issued to PETROBRAS within the contractual deadline.

18.3.7. All nonconformity reports, including concession requests, shall be submitted to PETROBRAS for review.

18.4. TSUDL Drawings

18.4.1. Prior to start of manufacture, SUPPLIER shall generate General Assembly drawings of the subassemblies Upper Cone, Central Structure, and a General Assembly drawing of the TSUDL. These 04 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 FPU 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 subassemblies of Figure 1;
- 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.

18.5. Project Management

18.5.1. QHSE/PEP Plans - SUPPLIER shall submit a detailed HSE Plan within two weeks of the Purchase Order award and shall provide a comprehensive Project Execution Plan (PEP) within four weeks of Purchase Order award, for PETROBRAS approval. SUPPLIER's PEP shall be designed to achieve all deliveries in line with PETROBRAS's requirements. SUPPLIER shall also submit a Manufacturing Quality Plan detailing all procurement, manufacturing, and inspection processes and activities for PETROBRAS approval within the contractual deadlines.

18.5.2. Organization and Key Personnel - SUPPLIER shall assign key engineering and service personnel to manage and control the Work from the start through to final delivery. Such staff shall not be changed without PETROBRAS approval. Within 02 weeks of receipt of Purchase Order, SUPPLIER shall submit an organization chart defining the reporting structure and shall provide resumes of the proposed key candidates, with others on request, for PETROBRAS approval.

18.5.3. SUPPLIER shall confirm compliance with all the requirements of this document, and the referenced documents during the review of the manufacturing quality plan. Any deviation from the requirements of this document shall be highlighted and forwarded to PETROBRAS for review and approval. In the event of any disparity of information given in this document with any referenced document or standard, written clarification shall be sought from PETROBRAS before proceeding with Design and/or fabrication of the Flexible Joints.

19. DATA BOOK

19.1. General

19.1.1. For TSUDL manufactured in Brazil, the Data Book shall be emitted in Portuguese language, unless otherwise requested. For TSUDL manufactured abroad, the Data Book must be issued in the language defined by the contract.

19.2. Minimum Content

19.2.1. The SUPPLIER shall issue a Data Book of the products, to allow traceability of all parts, containing at least the following items:

19.2.1.1. Certificate of raw materials and tests according to this specification and project standards;

19.2.1.2. Records of heat treatment and tests according to this specification and project standards;

19.2.1.3. Records of Non-Destructive Examinations according to this specification and project standards;

19.2.1.4. Records of FAT according to this specification and project standards;

19.2.1.5. Qualifications of the welding process and welders according to this specification and project standards;

19.2.1.6. Records of dimensional Inspection according to this specification and project standards;

19.2.1.7. Inspection and Tests Plan (ITP) approved by Costumer;

19.2.1.8. Identification and inclusion of all reports issued by Contractor inspection, concerning the released products;

19.2.1.9. Identification and incorporation of critical non-conformities of the SUPPLIER / sub supplier and the corrective actions taken concerning the released products;

19.2.1.10. Drawings of set containing traceability of all essential components of the project, reported in the ITP.

19.3. Distribution

19.3.1. The SUPPLIER shall deliver hard copies along with a copy in electronic media of the Data Book to Contractor.