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	CLIENT: SRGE	SHEET: 1 of 28
	JOB: REFERENCE BASIC DESIGN	
DDP	TITLE: HANG-OFF ADAPTOR SPECIFICATION	 ES

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DATE	Mar 30, 2021								
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1. INTRODUCTION

1.1. Scope of this Document

This Technical Specification establishes the main parameters for Hang-Off Adaptor (HOA) supplying and describes the criteria for manufacturing, inspection and acceptance tests.

1.2. SYSTEM DESCRIPTION

The HOA is a component to connect riser top connector to Support-Tube.

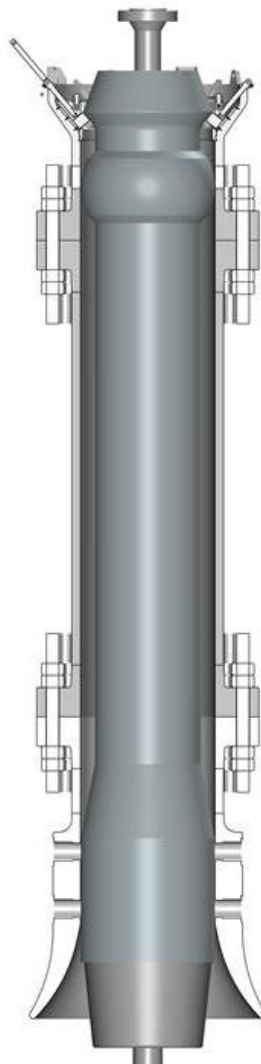


Figure 1 – Hang-Off Adaptor

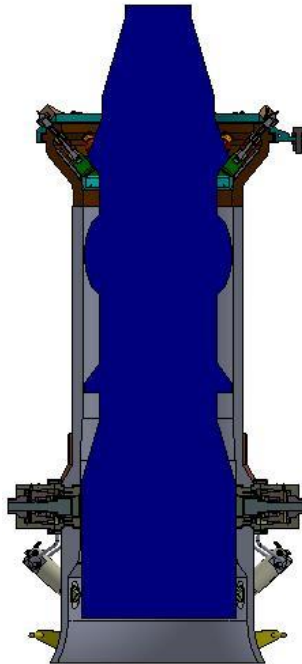


Figure 2 – Unified Diverless Support Tube Assembly main parts for rigid riser

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

BSDL	Diverless Bell mouth(Boca de Sino Diverless)
CONTRACTOR	Company that runs the services or manufacturing contract of a FPU and hires the SUPPLIER to perform the services for manufacturing of the Riser Modular Support Tube
Dummy HOA	Mechanical part used to simulate the rigid riser top termination on Factory Acceptance Tests
FAT	Factory Acceptance Test
FEA	Finite Elements Analysis



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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
NDT	Non-Destructive Testing
PARTIES	The companies directly involved in the Flexible Joint and Receptacle 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

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QHSE	Quality Health, Security and Environment
Riser	A length of flexible or rigid pipe used to connect the subsea collecting/exporting system to the SPU.
RMoST	Riser Modular Support Tube, is a riser support system for a rigid riser
Supplier	Company responsible for detailed Design and manufacturing the Riser Modular Support Tube
Support–Tube	Generic term that refers to the tubular type of support for risers, namely: BSMF, RMoST or TSUDL. In case of rigid riser connections, the link between the support and the riser requires a HOA.
Top Riser Connector	Top termination that can be FXJ or TSJ
TOT	Top of Taper
TRS	Test Report Sheet
TSUDL	Unified Diverless Support Tube (TSUDL) is a riser support system for a rigid and flexible riser

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 Detailed Engineering
[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-DE-3010.1M-1519-140-P56-005	Hang-off Adaptor for Riser Modular Support Tube - External Profile

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[4]	I-ET-0000.00-0000-290-P9U-003	FLEXIBLE JOINT AND CONICAL RECEPTACLE SPECIFICATION
[5]	I-ET-0000.00-0000-290-P9U-004	TITANIUM STRESS JOINTS SPECIFICATION
[6]	I-ET-3010.00-1200-956-P4X-002	General Painting
[7]	I-ET-3010.00-1200-956-P4X-003	Thermal Spray Coating Application of Aluminum
[8]	I-ET-0000.00-0000-970-PSQ-001	Procedure and Personnel Qualification and Certification

3.3. American Petroleum Institute (API)

Ref. n°	Document number	Title
[9]	API RP 2A-WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
[10]	API SPEC 6A	Specification for Wellhead and Christmas Tree Equipment
[11]	API RP 17G	Design and Operation of Subsea Production Systems
[12]	API 2RD	Dynamic Risers for Floating Production Systems
[13]	API RP 2X	Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Ultrasonic Technicians

3.4. American Society of Testing and Materials (ASTM)


Ref. n°	Document number	Title
[14]	ASTM A370	Standard Tests Methods and Definitions for Mechanical Testing of Steel Products
[15]	ASTM A517	Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
[16]	ASTM A578	Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
[17]	ASTM B841	Standard Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits
[18]	ASTM A703M	Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
[19]	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
[20]	ASME Section VIII, Division 1	ASME Boiler & Pressure Vessel Code
[21]	ASME Section VIII, Division 2	ASME Boiler & Pressure Vessel Code
[22]	ASME Section IX	ASME Boiler & Pressure Vessel Code
[23]	ASME PCC 1-2010	Guidelines for Pressure Boundary Bolted Flange Joint Assembly

3.6. American Welding Society (AWS)

Ref. n°	Document number	Title
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[24]	AWS D1.1	Structural Welding Code
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3.7. Other Documents

Ref. n°	Document number	Title
[25]	EN 473	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment
[26]	EN ISO 13628-7	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems
[27]	ISO 2859	Sampling Procedures for Inspection by
[28]	ISO 8501	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness;
[29]	ISO 8504	Preparation of steel substrates before application of paints and related products – surface preparation methods
[30]	ISO 9001	Quality management systems – Requirements
[31]	ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
[32]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons
[33]	ISO/IEC 17020	Conformity assessment – Requirements for the operation of various types of bodies performing inspection
[34]	ISO GUIDE 65	General Requirements for Bodies Operating Product Certification Systems;
[35]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons;
[36]	SSP-SP1	Solvent Cleaning;
[37]	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
[38]	ABENDI NA 018	“Qualificação e certificação de pessoas em teste por pontos” (Qualification and certification of persons for chemical spot testing);
[39]	ABNT NBR 15218	Crítérios para qualificação e certificação de inspetores de pintura industrial” (Industrial paint inspectors - Rules for qualification and certification);
[40]	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)



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[41]	ABTN NBR 5426	Planos de amostragem e procedimentos na inspeção por atributos" (Sampling Procedures for Inspection by Attributes);
[42]	ABNT NBR NM ISO 9712	Ensaio não destrutivo – Qualificação e certificação de pessoal" (Non-destructive testing – Personnel qualification and certification)
[43]	PETROBRAS N-1859	"Qualificação de Consumíveis de Soldagem" (Qualification of Welding Consumables)
[44]	PETROBRAS N-2301	"Elaboração da documentação técnica de soldagem" (English - Elaboration of technical documents for welding);
[45]	PETROBRAS PP-5EN-00008	Ensaio não destrutivo – qualificação de pessoal" (Non-destructive testing – personnel qualification)
[46]	ABNT NBR 14842	"Critérios para a qualificação e certificação de inspetores de soldagem" (Criteria for welding inspector qualification and certification)
[47]	ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons;

4. GENERAL REQUIREMENTS

4.1. Material Selection

- 4.1.1. All equipment and material manufactured and/or supplied under this Specification shall be new, of proven Design, 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. [9].
- 4.1.2. SUPPLIER shall be responsible for the selection of the materials. 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.
- 4.1.3. 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.
- 4.1.4. 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;

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- 4.1.5. The compatibility between all materials shall be checked. Materials shall not be affected by galvanic corrosion reactions and can be required to be welded to other specified metallic pieces where necessary.
- 4.1.6. Inspection criteria shall consider as a minimum the requirements as specified for the FPU.
- 4.1.7. 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;
- 4.1.8. 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;
- 4.1.9. 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.

4.2. Forgings


4.2.1. SUPPLIER may elect to use forged material for the basket 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 a 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.

4.3. CONTRACTOR’s Responsibility



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

4.4. SUPPLIER’s Responsibility

4.4.1. SUPPLIER shall furnish all labor, consumables, tools, equipment, and materials other than those explicitly identified as supplied by PETROBRAS required to

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- manufacture, test and deliver. SUPPLIER shall perform all required operations for Design, manufacture, inspection, testing and handling.
- 4.4.2. Nothing contained in this Specification or omitted from it shall be construed as relieving the SUPPLIER of the obligation to supply the HOA 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.
- 4.4.3. 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.
- 4.4.4. 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.
- 4.4.5. PETROBRAS furnished Drawings and Specifications shall be checked by SUPPLIER immediately upon receipt, and SUPPLIER shall promptly notify PETROBRAS of any discrepancies therein.
- 4.4.6. 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.
- 4.4.7. 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.
- 4.4.8. 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.
- 4.4.9. Equipment used for the manufacture shall be of proven Design and in good operating condition.

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- 4.4.10. Methods employed shall be in accordance with prudent engineering, fabrication and construction practice.
- 4.4.11. All costs, including taxes are to the SUPPLIER account in undertaking the responsibilities.
- 4.4.12. 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.

4.5. Units of Measurement

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

5. DESIGN REQUIREMENTS

5.1. General

- 5.1.1. SUPPLIER shall furnish all data generated during the design cycle of the HOA, including the results of the numerical analyses that will be carried out to fulfill the design requirements of this Section. 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.
- 5.1.2. SUPPLIER shall fully demonstrate the adequacy and the reliability of the HOA 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.
- 5.1.3. Commercial local analysis packages accepted are Abaqus and Ansys.
- 5.1.4. 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 4.3.
- 5.1.5. 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, complimentary 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.
- 5.1.6. The HOA 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;
- 5.1.7. The HOA design shall consider: there is not a deviation sheave in all FPSO slots to assist riser pull-in procedure.

5.2. Dimensions

- 5.2.1. Ref. [3] provides drawings. SUPPLIER shall detail the concept, including and not restricted to: structural analysis (item 16), general geometric dimensioning and tolerance considering surface coating thickness, pre-selected materials, manufacturing process, or any other detailing issue for final manufacturing drawings.
- 5.2.2. All loads results from riser top connector shall be applied in TOT, as indicated below.

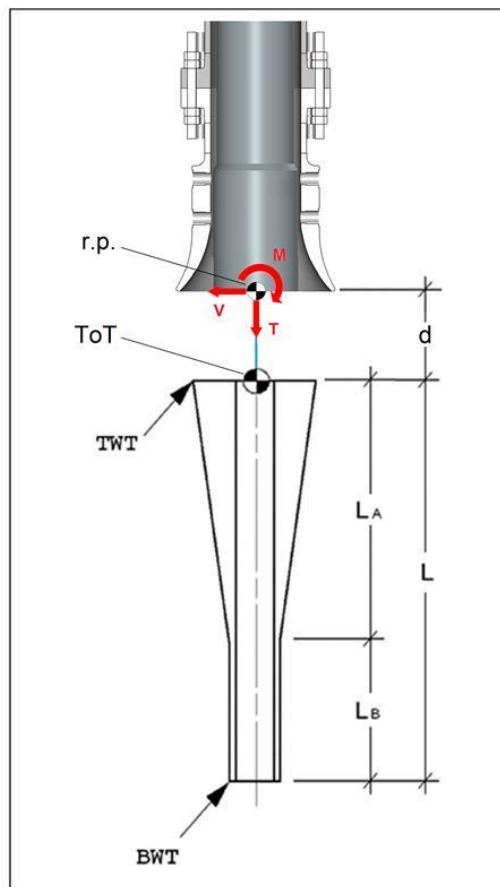




Figure 3 – Applied forces point

5.3. Interface Load

The interface loads shall be defined as described in Ref [4] or [5] based on loads cases matrix.

The interface loads results shall be evaluated on the indicated reference point in figure 3, after that the interface loads shall be compare to the limit loads informed in ref. [2].

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6. HOA IDENTIFICATION AND TRACEABILITY

6.1. Traceability

- 6.1.1. Codification and traceability procedures shall be in accordance with ref. [30] plus the following requirements:
- 6.1.2. Alphanumeric codes for traceability shall be punctured in materials using low-stress punches.
- 6.1.3. Each equipment shall receive a unique codification to allow tracing back to its own inspection and test reports.

7. PROTECTION AND PACKING

7.1. General

- 7.1.1. HOA shall be delivered packed to ensure the integrity of the parts, in particular of the mobile locking devices.

8. MATERIALS AND COMPONENTS

8.1. General

- 8.1.1. SUPPLIER shall provide material certificates of raw materials used in HOA manufacturing to be included in the databook, as in item 19 of this Specification.

8.2. Ferrous Materials

- 8.2.1. Ferrous materials for manufacture the HOA and its parts shall be certified by a classification society.

8.3. Thermally Pretreated Steels



- 8.3.1. 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.

9. PROCEDURE AND PERSONNEL QUALIFICATION

Personnel qualification of Weld, NDT and dimensional inspectors shall comply with ref. [8].

9.1. General

- 9.1.1. ALL complete joint penetration welds shall be inspected by means of ultrasonic examination.
- 9.1.2. All welds and surrounding area of base metal shall pass magnetic particle inspection. Partial NDE is not allowed.
- 9.1.3. Qualification of NDE Inspectors shall be according to AWS doc. ref. [24], API doc. ref. [13] and PETROBRAS Specification ref. [8]

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9.2. Procedures

- 9.2.1. Ultrasonic testing of welds shall conform to AWS doc. ref. [24], API doc. and PETROBRAS Specification ref. [8].
- 9.2.2. Magnetic Particle testing shall conform to API doc. ref. [13]

9.3. Acceptance Criteria

- 9.3.1. The acceptance criteria for ultrasonic inspection and testing of complete Joint penetration welds shall be API doc. ref. [13] Criteria Level A.
- 9.3.2. The acceptance criteria for magnetic particle inspection shall be ASME Section VIII Division 1, Appendix 6 doc. ref. [20]. Local grinding of the weld to enhance interpretation of examination results shall be carried out as determined necessary by SUPPLIER.
- 9.3.3. Radiographic testing of welds is not required by this specification. If required by CONTRACTOR or SUPPLIER, testing shall conform to AWS doc. ref. [24].

10. WELDING

10.1. General



- 10.1.1. All welds shall be in accordance with ref. [24].

10.2. Qualification

- 10.2.1. The welders and welding procedures shall be qualified and certified in accordance with item 9 of this technical Specification.

10.3. Welding Consumables

- 10.3.1. 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.
- 10.3.2. 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

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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.

11. MANUFACTURING INSPECTION

11.1. General


- 11.1.1. The Contractor shall maintain a fabrication inspector during manufacturing process of the HOA.
- 11.1.2. All inspection records and results shall be included in the databook.
- 11.1.3. Inspections shall be performed in accordance with specific procedures and shall include at least the activities listed in 11.2 to 11.7.

11.2. Inspection and Tests Plan – ITP

- 11.2.1. 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.
- 11.2.2. SUPPLIER shall send the ITP for Contractor approval respecting the contractual terms.
- 11.2.3. 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.

11.3. Preparation and cutting

- 11.3.1. Verify if parts to be cut are identified in accordance with item 6.1 of this Technical Specification.

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- 11.3.2. Verify if materials certificates correspond to the specified ones in the drawings.
- 11.3.3. Verify if parts dimensions are in accordance with drawings.

11.4. Pre-assembly

- 11.4.1. Verify if the traceability of the parts is in accordance with item 6.1 of this Specification and belong to the same assembly.

11.5. Non-destructive tests

- 11.5.1. All procedures and personnel used in NDT shall be qualified and certified in accordance with item 9 of this technical Specification.
- 11.5.2. Visual Inspection - All welds shall be inspected in 100% (both sides) of their extension to check aspect and continuity.
- 11.5.3. Liquid penetrant inspection – All welds shall be inspected in 100% of their extension.

11.6. Dimensional

- 11.6.1. Verify if dimensions are in accordance with the drawings.
- 11.6.2. Dimensional control inspectors shall be qualified in accordance with item 9 of this technical Specification.

11.7. Availability of documents for inspection

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



11.8. Nonconformities

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

12. CORROSION PROTECTION

12.1. General

- 12.1.1. Corrosion protection of the HOA shall be accomplished with a combination of protective coating and cathodic protection.
- 12.1.2. The HOA shall be painted with marine epoxy coating as per PETROBRAS Specification ref. [6]. Top coat color shall be specified by PETROBRAS.
- 12.1.3. At least the contacting surfaces of the HOA shall be coated with TSA in accordance with ref. [7]. The effectiveness of the proposed system shall be well documented and tests shall demonstrate the efficiency of the system.

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- 12.1.4. All coatings and coating procedures used by SUPPLIER or SUB-SUPPLIERS are subject to the PETROBRAS's review and approval.
- 12.1.5. The HOA main parts shall include 3.75 mm of corrosion allowance per side exposed to seawater.

12.2. Cathodic Protection

- 12.2.1. The HOA cathodic protection is provided by the electrical contact with the main hull structure, which is provided by the impressed current from the SPU.
- 12.2.2. Electrical continuity between all components must be tested after assembly

12.3. Painting

- 12.3.1. SUPPLIER shall observe that parts whose drawings present the indication "DO NOT PAINT" are not to be either painted or electrically isolated ref. [6].
- 12.3.2. Painting procedure shall comply with item 12.4.1 or paint manufacturer specification. In case of divergence, paint manufacture specification shall be used, observing the thickness specification for each layer and final thickness.

12.4. Final thickness

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

12.5. Final Painting

- 12.5.1. The HOA shall be delivered with the paint free of defects.
- 12.5.2. For the FAT, HOA shall be painted with the last layer of paint applied (antifouling). If any HOA 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.
- 12.5.3. 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 12.4 of this Specification.
- 12.5.3.1. 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 HOA shall be retested.



12.6. Anti-friction coat

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

13. DUMMY HOA

13.1. General

- 13.1.1. Only one Dummy HOA must be manufactured for testing. The Design is going to be defined by PETROBRAS after the kickoff meeting and as ref. [3].

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14. FACTORY ACCEPTANCE TESTS – FAT

14.1. General

- 14.1.1. The HOA shall be tested individually to verify their mechanical functioning.
- 14.1.2. All tests are Supplier's responsibility.
- 14.1.3. 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.
- 14.1.4. A PETROBRAS representative shall witness all tests. This representative will be responsible for approving or rejecting the HOA FAT.
- 14.1.4.1. For HOA 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 HOA will be available for FAT.
- 14.1.4.2. For HOA 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. MODIFICATIONS AND ADJUSTMENTS

- 15.1.1. The SUPPLIER can implement small changes in the HOA'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.
- 15.1.2. The changes or corrections mentioned in 15.1.1 will only be implemented after Contractor approval.
- 15.1.3. The document approved shall be included in the databook.

16. STRUCTURAL CALCULATION

16.1. General

- 16.1.1. 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 limits defined by ref. [2] and criteria defined by ref. [26].
- 16.1.2. If the calculous indicate small structural changes, the design modification requirement shall only be implemented after PETROBRAS approval.
- 16.1.3. Design methodology and acceptance criteria shall be in accordance with an internationally recognized code such as API RP 17G ref. [11]. Other design codes or methodology previously validated by Contractor may be accepted after PETROBRAS approval.

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16.2. Finite Element Analysis



- 16.2.1. Finite element analysis shall be used to establish structural, buckling, and fatigue performance of the HOA.
- 16.2.2. 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.
- 16.2.3. Applied boundary conditions shall be clearly indicated in model sketches and/or in finite element plots.
- 16.2.4. Mesh sensitivity analysis shall be performed to ensure that accurate results are predicted. Mesh density convergence checks shall be presented in the reports.
- 16.2.5. The sensitivity of the calculation model and the parameters utilized in the model shall be examined.

16.3. FEA methods to evaluate plastic collapse capacity

- 16.3.1. There are different ways of estimating the plastic collapse capacity of a component using FEA:
 - elastic analysis;
 - limit analysis;
 - elastic-plastic analysis.
- 16.3.2. 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.

16.4. Elastic analysis

- 16.4.1. 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.
- 16.4.2. 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.
- 16.4.3. 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.
- 16.4.4. In using elastic finite element analysis to calculate the HOA plastic collapse capacities, SUPPLIER shall be aware of the following limitations of this approach:

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- 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;

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

16.4.6. For the reasons listed above, the decision to perform elastic finite element analysis to calculate the the HOA 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 HOA, as per sections 16.5 and 16.6 of this Technical Specification.

16.5. Limit analysis

16.5.1. 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.

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

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



16.6. Elastic-plastic analysis

16.6.1. 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.

16.6.2. 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.

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

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

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16.6.5. 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.

16.7. FEA Methods to Evaluate Protection Against Local Failure

16.7.1. Strength verification of the HOA 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.

16.7.2. 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.

16.7.3. 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.

16.8. FEA Methods to Evaluate Protection Against Progressive Collapse

16.8.1. 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 HOA.

16.8.2. 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.[21].



16.8.3. 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. [21]).

16.9. FEA for Fatigue

16.9.1. Fatigue life evaluation of the HOA 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.

16.9.2. When creating FE models for the purpose of 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.

16.9.3. 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

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determined (notch stress method). The geometry of the elements should be carefully evaluated in order 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.

16.10. FEA documentation



16.10.1. 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. 4.4). 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 convergency study results;
- Analysis results;
- Sensitivity analysis;
- Discussion of results;
- Conclusions;
- Any other performed verification.

17. INSTALATION

17.1. SUPPLIER shall provide assistance on request to PETROBRAS and CONTRACTOR during preparation of the HOA, installation onto the Support Tube system and handling procedure. SUPPLIER shall review the riser installation and commissioning procedures to confirm that the HOA design suits the installation induced loads.

17.2. NOTE: The design characteristics of the HOA shall accommodate the installation motions and loading conditions without detrimental effects. All components of HOA shall be checked for load envelop related to each of the installation phases

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(abandonment, recovery, riser transfer, pull-in, etc. according to CONTRACTOR procedure).

- 17.3. SUPPLIER shall also provide a detailed (step by step) procedure for the handling, storage, transportation and preservation of the HOA, and submit to CONTRACTOR and PETROBRAS for review. In case of the acquisition of spare HOA, the preservation procedure shall consider long periods of storage.
- 17.4. In cases where full pre-abandonment is required in the Project, HOA protective kit design and a summary procedure for remote (ROV or automatic) disconnection of the Extension locking system / lay down tool shall be supplied. Track record of supply or qualifications of the lay down tool, considering predicted loads and field water depth, shall be presented in technical proposal at BID stage. Detailed procedure of disconnection and locking system (lay down tool) inspection shall be included within HOA handling and inspection manual.
- 17.5. SUPPLIER shall observe installation, pre-abandonment and recovering requirements for Flexible Joints in ref. [4] or for Titanium Stress Joint in ref. [5] for definition of HOA installation, pre-abandonment and recovering procedures and design.

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".

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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;

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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 14.

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. HOA Drawings

18.4.1. Prior to start of manufacture, SUPPLIER shall generate General Assembly drawings of the subassemblies Upper Cone, Guide Tube and Centralizer, and a General Assembly drawing of the HOA. 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 HOA and each subassembly;
- Total weights of the assembled HOA and of each main subassemblies of Figure 1;

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- Material identification and source part number;
- Details of handling attachments;
- Dimensional details of the assembly flanges;
- Assembly between Upper Cone, Guide Tube and Centralizer, 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 HOA manufactured in Brazil, the Data Book shall be emitted in Portuguese language, unless otherwise requested. For HOA 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, in order 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;

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- 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.