PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-290-P9U-005	
	CLIENT: E&P		SHEET: 1 de 54
	JOB: GENERAL		-
	AREA: GENERAL		-
DP&T	TITLE: TITANIUM PULL IN TUBE SPECIFICATION		SUB/ES/EDD/EDR
			-

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL
A	INCLUDED: Definitions and Abbreviations; References; Dummy Adaptor Cap in Scope of Supply, Table 4.1; Functional requirements for Adaptor Cap (sec. 5.2), Steel Transition Spool (sec. 5.3), Hang-off Assembly (sec. 5.4), TRMS (sec. 5.7) and installation and pre-commissioning (sec. 5.8); Material Requirements, sec 6; Interface loads limits, sec. 7.2.1; Length adjustment, sec 7.3.2; Thermal Analysis, sec. 7.9; Qualification of TRMS, sec. 12.1.3; Drawings, sec. 13.4. ALTERED: Description of the Hang-off parts, Figure 1.2; Functional requirements for Compact Flange (sec. 5.5); Lower Balcony dimensions, sec. 7.3.4; Design Loads Matrix, Table 7.1; Additional steel corrosion protection, sec 7.16; Qualification scope of metallic parts, sec. 12.1.1;. EXCLUDED: References DNVGL-RP-F111 and ISO-12736; External coating qualification, sec. 12.1.2 (requirements transferred to ref. [5]); List of reports to be delivered in bidding phase in case of direct purchase (out-of-scope), sec. 13.2; Lifting test requirements, sec. 13.7. GENERAL REVISION of the text or clarity.
B	INCLUDED: Requirement for definition of the center of rotation of TiPT in the Support–Tube, sec. 5.2; Hydrotest ("Temporary 1") design case, Table 7.1; Reference to the inspection manual of sec. 13.3 (Deliverable) in sec. 7.12 and sec. 7.11; Information on lateral and angular offset of std. flange, sec. 13.4. ALTERED: TiPT system description, sec. 1.3; term "optional" to "optative" (supplied items) and note for confirmation of supply, Table 4.1; TRMS sensors type, position and cabling requirements, sec. 5.7; some steel parts' material specifications in Material Requirements, Table 6.1; Interface load limits description, sec. 7.2.1; Length adjustment requirements, sec. 7.3.2; Way to report the Standard Flange elevation, lateral and angular offset when short distance between URB and LRB is specified, sec. 7.3.3; Name of the load category "Temporary" to "Temporary 2" (Installation), and renumbered all the design cases, Table 7.1; renumbered sections 12.1.1 and 12.1.2; Notes and requirements of metallic parts qualification, sec 12.1. EXCLUDED: FBG and IMU in Pup Piece with cabling from the TiPT Scope of Supply, sec. 1.3 and sec. 4.1; Adaptor Cap requirement, sec. 5.2; Provisions for qualification of new system\ part concepts different from those described in sec. 1.3, sec. 12; Section 12.1; Qualification of TRMS cabling underneath coating, sec. 12.2.1. GENERAL REVISION of the text or clarity.
C	INCLUDED: Explanation on Pup Piece's TRMS sensors Scope of Supply, sec. 5.7; New acceptable material specification for the tubular section of the Steel Transition Spool, in material requirements Table 6.1; Requirements for steel pipe material for TiPT tubular sections, sec. 8; Explanation on qualification and PQT Scope of Work, as well as the Note 1 and the Table 12.1, in sec. 12.1. ALTERED: Titles of ref. [2] and [3] in project's reference list sec. 3.1; Reference for FBG quantities, Table 4.1; Renumbered notes in sec. 12.1. EXCLUDED: Abbreviation for PPT, sec. 2.2; "Project Management" section 13.5 (entirety). GENERAL REVISION of the text or clarity.
D	INCLUDED: Definition of "Standard Flange", sec. 2.1; abbreviation for "MLP", "MPQT" and "SIT", sec. 2.2; Reference for Project Interface Specification [3], Adaptor Cap Guide Drawing [9], TRMS specifications [13] and [14], High-strength Low-Alloy Steel fastener (in English) [16], CRA Clad Pipe [17] and (Riser) Cathodic Protection Design [20] in sec. 3; Electrical Isolation Kit (for the Standard Flange) and External Coating Repair Kit with applicable Notes 3, 4 and 7 within the Scope of Supply, Table 4.1; Requirement for Electrical Isolation of the Hang–off, sec. 5.4; Instruction on FEA analysis and coating material selection in sec. 5.6; Installation and Post Pull–in Inspection requirements, sec. 5.8; Material requirement for Steel Spacer Pipe and tubular section of the Transition Spool Section, Table 6.1; Requirement for protective potential limit at riser top, sec. 7.1–ix; Inspection and Maintenance requirements, sec. 7.11 and 7.12; Temporary FPU heel angle and increased excursion for pull–in, sec. 7.14; Section 7.16, on Steel Spacer Pipe (option); Section 11.1, on System Integration Test (SIT); APPENDIX I. ALTERED: Updated numbers for DNV references, sec. 3.3; Renumbered subitems of sections 5.1 to 5.5 and 5.7; Title of section 5.8; Limiting temperature of 80°C for the use of "sweet–service" titanium alloys, in line with ISO 15156–3; Tags for load combination "ALS4" and "ALS5", now in line with [11], Table 7.1; Order of sec. 7.11 and 7.12; Renumbered section on "Steel Parts Corrosion Protection", sec. 7.17; Renumbered subsection of sec. 11; Renumbered references along the text due to exclusions. EXCLUDED: Several references not directly used in this document, sec. 3; Normal gasket ring, studs and nuts in the Scope of Supply (substitute by Electrical Isolation Kit of gasket/ studs/ nuts), Table 4.1; Paragraph in sec. 13. GENERAL REVISION of the text or clarity.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	07/08/2020	17/12/2020	01/04/2021	19/04/2021	10/10/2022	
EXECUTION	TS8H	TS8H	TS8H	TS8H	TS8H	
CHECK	TS8H	UP86	CSOE/UT6L	CSOE/UT6L	UP86	
APPROVAL	CLZ2	CLZ2	CLZ2	CLZ2	CLZ2	

TABLE OF CONTENTS

1. INTRODUCTION

1.1. SCOPE OF THIS DOCUMENT

The purpose of this specification is to define the minimum functional and technical requirements for the design, material selection, manufacture, inspection, testing and delivery of Titanium Pull in Tube to connect rigid risers to the FPU hang–off.

This document shall be read in conjunction with all documents listed in Section 3.

Additional or amended functional requirements for TiPT can be found within the Project documentation. In general, the TiPT is intended to be connected into Support–Tube type riser supports (BSN, BSMF, BSDL, RMoST, TSUDL, others). The project detailed scope of supply, information on the *Support–Tube*, the *Upper I–Tube* and interface with the FPU, definition of the type of top connection, coating specification, monitoring system, operating conditions, fluids composition and other Project related data are also defined in project documentation [1] to [8].

This Specification also intend to be used either for newbuilt or retrofit to existing FPU, with the specific requirements for each case clearly stated herein.

1.2. PROJECT DOCUMENTATION AND RESPONSABILITIES

The TiPT design, procurement and installation is set to be within CONTRACTOR's scope of work (full EPCI). The contractual relationships are between CONTRACTOR and SUPPLIER, and between CONTRACTOR and PETROBRAS, and thus the interface between the TiPT, steel riser and FPU supports is entirely within CONTRACTOR scope. The definitive inputs for component design are a CONTRACTOR responsibility. CONTRACTOR is also responsible for issuing its own version of the documents [2] and [4], as well as a TiPT specification, to SUPPLIER, in compliance with the PETROBRAS documentation.

Its highlighted that PETROBRAS may also issue in the bidding process the documents of [4], based on the results of the Basic Design, and information on the FPU interfaces with TiPT. These documents may be used in part or in whole as reference for preliminary sizing during the bidding phase, under CONTRACTOR responsibility, as the riser configuration to be defined by the CONTRACTOR may not be the same configuration defined by PETROBRAS in the basic design.

The definition of the final component datasheet, with definitive interface loads, is under CONTRACTOR responsibility. PETROBRAS has no responsibility for changes in design due to differences between PETROBRAS and CONTRACTOR's datasheets.

Scope of supply in this technical specification is amended by Material Requisitions/ Data Bases regarding definition whether it includes or not any optional parts, as per section 4.1.

1.3. SYSTEM DESCRIPTION

A Titanium Pull in Tube Stack–up shall include from bottom up: a *Pup Piece* that may be a regular riser pipe or a forged tapered beam (in special cases), welded (likely onshore) with a *Steel Compact Flange* with prolonged neck extension, a *Lower Titanium Stress Joint (LTSJ)* properly sized to withstand the imposed riser loads, an *Upper Titanium Stress Joint (UTSJ)* with a cylindrical section which interfaces with the Support–Tube through an *Adaptor Cap/ Trumpet* while absorbing a permanent fixed deflection to align the TiPT with the Upper I-Tube, a *Titanium or Steel Spacer Pipe* section formed by several tubular forgings (undefined quantity, but should be as low as possible) connected by integral Compact Flanges to each other and to a *Steel Transition Spool*, attached to the *Upper I-Tube* through an *"End–Fitting"* termination mounted on a *Hang–off Assembly*, with a *Standard Flange* to interface with the FPU top closing pool and with installed sensors (FBG) for riser monitoring.

Figure 1.1 presents a general view of the TiPT *Stack–up*, with the major elements labelled for reference and introducing some terminologies used in this document.

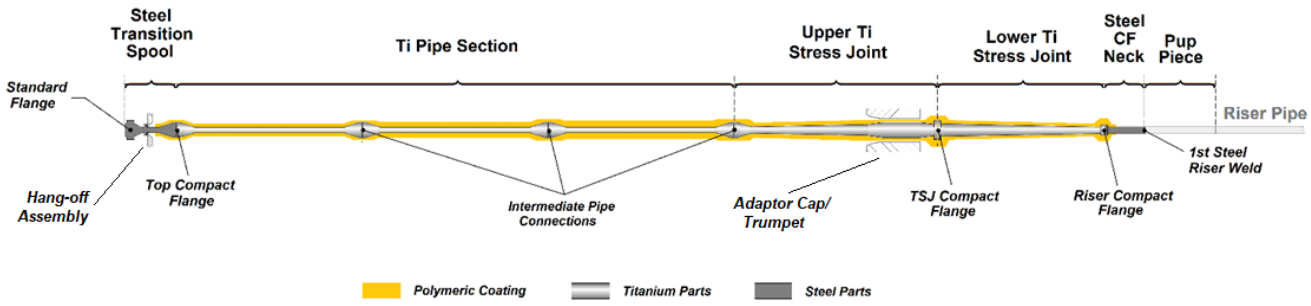


Figure 1.1 – General Schematic View of the TiPT *Stack–up* and Its Main Sections.

The function of the *Titanium Pull–in Tube* is to:

i. Support the riser, while keeping its own integrity and that of the FPU support and riser system at designed conditions during all service life;

ii. Provide an articulated interface between the FPU and the riser, to allow for relative angular motion between the FPU and the riser, while providing adequate flexibility to limit the transference of loads (mainly bending moments) in the top area of the riser and to the lower balcony structure;

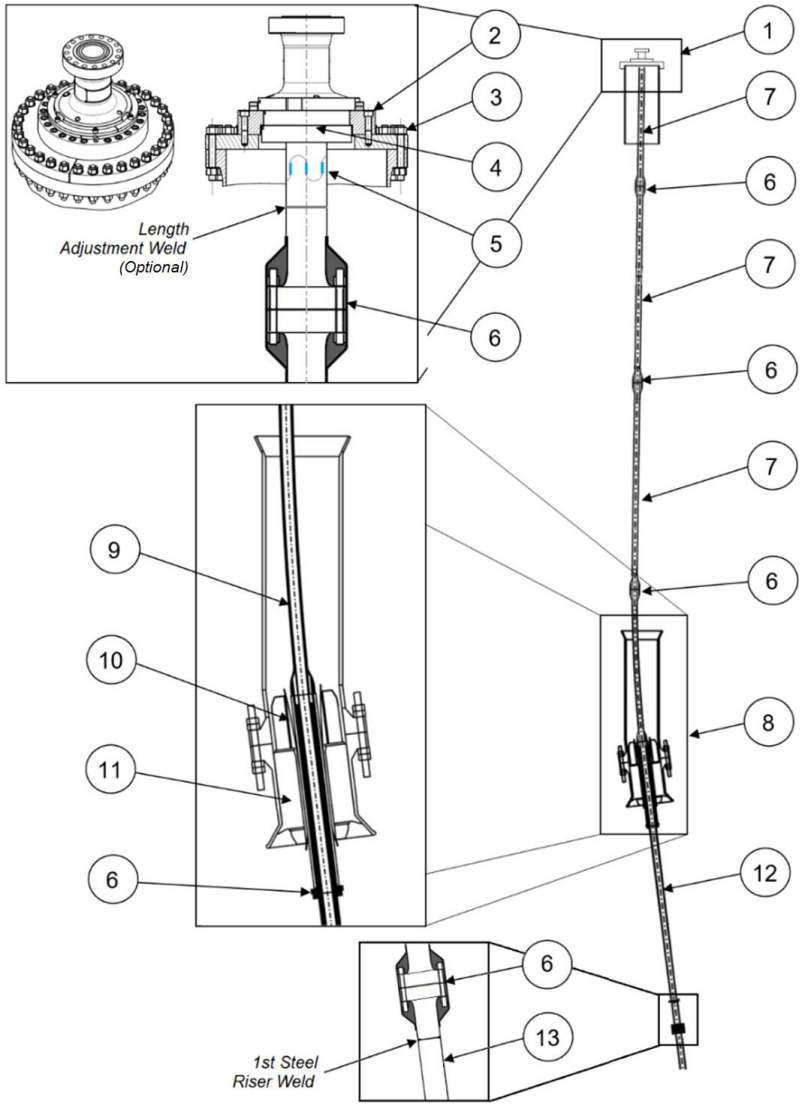
iii. Provide an interface between the riser and the FPU piping for fluid transportation in the maximum operating condition of pressure and temperature;

iv. Allows pigs to be transported between FPU piping and the riser;

v. Connect the riser to temporary installation equipment (ex: pig launch and receiver or pull–in head) during pull in and commissioning activities;

The Main Parts that compose the scope of supply for the TiPT are shown in Figure 1.2.

For information, the APPENDIX I presents a graphical description of the various mitigation considered in the TiPT design to overcome the hydrogen embrittlement at titanium parts, comprising the design, qualification, inspection & maintenance, and monitoring aspects with links to the related requirements presented herein this specification and its references.



Part	Description
1	*Upper I–Tube (OoS) and Hang–off*
2	*Split Stopper*
3	*Split Hang-off Flange*
4	*Steel Transition Spool (“End Fitting”)*
5	*Fiber Bragg Gratting, with cabling and dry-mate connector (TRMS)*
6	*Compact Flanges*
7	*Titanium or Steel Spacer Pipes*
8	*Riser Support–Tube (OoS)*
9	*Upper Titanium Stress Joint*
10	*Trumpet*
11	*Adaptor Cap*
12	*Lower Titanium Stress Joint*
13	*Pup Piece*

Figure 1.2 – TiPT General Assembly and Its Main Parts.

NOTE: The TiPT configuration depicted in Figure 1.2 shall be observed, although the final design of its parts may vary according to SUPPLIER design.

2. DEFINITIONS AND ABBREVIATIONS

2.1. DEFINITIONS

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.
SUPPLIER	The organization that constructs the TiPT parts and provides it under a Purchase Order directly to the PETROBRAS or through the CONTRACTOR for riser EPCI Contract
SUB–SUPPLIER	The Party supplying a material or service to the SUPPLIER.
CONTRACTOR	The company responsible for the engineering, procurement, construction and Installation of riser system for the Project.
PARTIES	The companies directly involved in the *Titanium Pull–in Tube* specification, design, fabrication and installation, with power to propose modification over design and manufacturing aspects. They are: PETROBRAS, CONTRACTOR and SUPPLIER.

Cutback	Uncoated area defined in terms of length at the end of the *Lower CS Compact Flange* or *Pup Piece* which is required to prevent damage to the coating system when the TIPT is welded together with the pipe sections.
EPCI	Contracting mode where the CONTRACTOR is responsible for the detailed engineering, procurement of some or all the riser components, construction, installation and commissioning of riser system.
End–fitting	End component of the TiPT, which is a part of the *Steel Transition Spool* that provides the rigid connection of the TiPT with the *Hang–off Assembly*.
Hang–off (Assembly)	Structure that is bolted to the Upper I–Tube on the URB of the FPU, where the TiPT is locked and far most of the riser tension will be applied. For this specification it is composed of the *Hang–off Split Flange* and *Stopper*.
Monolithic	Refers to a single forged part without welds or other means of permanent connection along the forging.

Pre–commissioning	Activities performed by CONTRACTOR after the pull–in of each rigid riser, to verify the integrity, and condition the pipeline (specified fluid, pressure, etc. – see [1]) for handover.
Project	Scope of activities performed by the PARTIES to design, construct and install the riser system for a specific field and host FPU.
Requisition	A formal written request for supply of equipment or materials for a specific Project.
(TiPT) Stack–up	Refers to the tubular, interconnected TiPT parts (steel and titanium sections) from *Pup-Piece* (or Steel CF Neck) to the *Transition Spool*. The *Stack–up* may be supplied segmented due to handling, transportation and\or installation limitations.
Standard Flange	Termination device, being an integral part of the *Transition Spool*, that interfaces with the FPU's Closing Spool. The specification of this flange is given in Project documentation (see sec.4.1).
Support–Tube	Generic term that refers to the Project's support installed at the LRB. Support–Tubes can be BSN, BSMF, BSDL, RMoST and TSUDL. The specific *Support–Tubes* of the Project is defined in [3] and [7].
Titanium Pull–in Tube (TiPT)	Refers to the entire equipment to be supplied, in its installation configuration. See section 1.3 for definition and details of the constituent parts.
Upper I–Tube	Pipe guide section located in the URB, which provides the support for the TiPT, Flexible or Umbilical risers.
Work	All tasks to be performed by the SUPPLIER under the Purchase Order for any specific Project, including all duties and obligations undertaken by the SUPPLIER.

Shall	Indicates a mandatory requirement.
Should	Indicates a preferred course of action.
May	Is used where alternatives are equally acceptable.

2.2. ABBREVIATIONS

The following abbreviations are used in this document:

ALS	Accidental limit state
AUT	Automatic ultrasonic test
BSDL	*Diverless bellmouth (por.: boca de sino "diverless")*
BSMF	*Multifuctional bellmouth (por.: boca de sino multifuncional)*
BSN	*Conventional bellmouth (por.: boca de sino "convencional")*
CNC	Computer numerical control
COG	Centre of gravity
CP	Cathodic protection
CRA	Corrosion resistant alloy
CS	Carbon steel
CTOD	Crack tip opening displacement test
CVN	Charpy v–notch
DBM	Design basis and methodology
ECA	Engineering critical assessment
ELI	Extra low interstitials
FAT	Factory acceptance test
FEA	Finite elements analysis
FJC	Field joint coating
FOAK	First of a kind
FOS	Factor of safety
FPU	Floating production unit. In general meaning herein this specification, it is understood as the larger structure where the hang–off system in attached
GA	General assembly (drawing)
HAZ	Heat–affected zone
HIC	Hydrogen induced crack
HSE	Health, safety and environment
ID	Internal diameter
ITP	Inspection and test plan
JIP	Joint industry project
L.A.S.T.	Lowest anticipated service temperature
LRB	Lower riser balcony
MIP	Manufacturing inspection procedure
MLP	Mechanically Lined Pipe
MPQT	Manufacture Procedure Qualification Tests (Ti and Steel forgings)
MPS	Manufacturing procedure specification

NCR	Nonconformity report
NDT(NDE)	Non-destructive test (non-destructive examination)
OD	Outer diameter
OOS	Out of scope of work\ supply for CONTRACTOR
P/N (S/N)	Part number (serial number)
PAUT	Phased array ultrasonic test
PEEQ	Equivalent plastic strain
PEP	Project execution plan
PO	Purchase order
POD	Probability of detection
PQT	Procedure qualification trial (coating application)
PT	Liquid penetrant test
QA	Quality assurance
QC	Quality control
QHSE	Quality health, security and environment
QTS	Qualification test sample
RA	Arithmetic average value of a filtered surface roughness profile
RMOST	Riser modular support tube
RP	Return period
RT	Maximum height of the roughness profile (range)
SCF	Stress concentration factor
S.I.	International system of units *(fre. Système international)*
SMYS	Specified minimum yield stress
SMTS	Specified minimum tensile stress
SSC	Sulfide stress cracking
SIT	System Integration Test
SWT	Smith–watson–topper model
TSA	Thermal sprayed aluminum
TIPT	Titanium stress joint
TSUDL	Diverless universal support tube *(por.: tubo suporte universal "diverless")*
ULS	Ultimate limit state
UNS	Unified numbering system
URB	Upper riser balcony
UT	Ultrasonic test
VME	Von mises equivalent stress
WPQT	Welding procedure qualification test

3. REFERENCES

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 with respect to this specification and references cited herein.

3.1. PROJECT DOCUMENTS

Ref. n°	Document number(1)	Title
[1]	---	Project Technical Specification for Detailed Engineering
[2]	---	Project Design Basis
[3]	---	Project Interface Specification(2)
[4]	---	Project Input Data Sheet for Titanium Stress Joint Design
[5]	---	Project Coating Assessment Specification
[6]	---	TRMS Material Requisition
[7]	---	Project Support–Tube Drawing(2)
[8]	---	Project Metocean Data

(1) Project reference number to be informed within a Project Document List, to be released during bidding phase.
(2) Project selected *Support–Tube* and specific drawings of itself and its accessories to be informed during Project bidding phase.

3.2. PETROBRAS'S REFERENCES

Ref. n°	Document number	Title
[9]	I-DE-3000.00-1300-279-P56-001	Support–Tube Adaptor Cap for TiPT – Geometry Reference Guide
[10]	I-ET-0000.00-0000-290-P9U-004	Titanium Stress Joint Specification
[11]	I-ET-0000.00-0000-274-P9U-001	SLWR Detailed Structural Design Requirements
[12]	I-ET-3000.00-5529-850-PEK-003	TiPT Riser Monitoring System (TRMS) – Full Scope
[13]	I-ET-3000.00-5529-850-PEK-008	TiPT Riser Monitoring System (TRMS) – Riser Scope for FPU Hull side Conduit Cabling
[14]	I-ET-3000.00-5529-850-PEK-009	TiPT Riser Monitoring System (TRMS) – Riser Scope for FPU Hull side Umbilical Solution
[15]	ET-3000.00-1500-941-PMU-003	Padronização de Acessórios para Kit Pull–in
	~~I-ET-0000.00-6000-970-PSQ-001~~	[EXCLUDED]
[16]	I-ET-3000.00-1500-251-PEK-001	High-Strength Low-Alloy Steel Fasteners for Subsea Applications
	~~ET-3000.00-1500-251-PEK-001~~	[EXCLUDED]
	~~ET-3000.00-1500-251-PEK-002~~	[EXCLUDED]

[17]	I-ET-0000.00-0000-219-P9U-002	CRA CLAD Pipe Requirements
[18]	I-ET-0000.00-0000-219-P9U-004	CRA Weld Overlay Clad Pipe Requirements
[19]	I-ET-0000.00-0000-210-PSQ-001	Alternative Flaw Acceptance Criteria of Submarine Rigid Pipeline and Riser Welds
[20]	I-ET-0000.00-0000-940-P9U-001	Cathodic Protection Design
[21]	SwRI Project No. 18.16696	JIP SwRI Final Report. “Fatigue and Fracture Performance Evaluation of Welded Ti 29 Tapered Stress Joints". 2015.

3.3. DET NORSKE VERITAS (DNV)

Ref. n°	Document number	Title
[22]	DNV–ST–F101	Submarine Pipelines Systems
[23]	DNV–ST–F201	Dynamic Risers
[24]	DNV–RP–F108	Assessment of flaws in pipeline and riser girth welds
	~~DNV–RP–F201~~	[EXCLUDED]
[25]	DNV–RP–C203	Fatigue Strength Analysis of Offshore Steel Structures DnV Recommended Practice
	~~DNV-RP-A203~~	[EXCLUDED]
[26]	DNV–ST–E271	DNV Standard for Certification No. 2.7-1 Offshore Containers

1.1.

3.4. AMERICAN PETROLEUM INSTITUTE (API)

Ref. n°	Document number	Title
	~~API STD 1104~~	[EXCLUDED]
[27]	API RP 2RD	Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
	~~API SPEC 6A~~	[EXCLUDED]
	~~API 5L~~	[EXCLUDED]

3.5. NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE)

Ref. n°	Document number	Title
[28]	ISO 15156-3	Materials for use in H2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys
[29]	NACE TM 01-77	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments

3.6. AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM)

Ref. n°	Document number	Title
	~~ASTM A388M~~	[EXCLUDED]

	~~ASTM E1290~~	[EXCLUDED]
	~~ASTM E709~~	[EXCLUDED]
	~~ASTM E2375~~	[EXCLUDED]
[30]	ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials
	~~ASTM B348~~	[EXCLUDED]
	~~ASTM B861~~	[EXCLUDED]
[31]	ASTM B381	Titanium and Titanium Alloy Forgings
	~~ASTM B499~~	[EXCLUDED]
	~~ASTM E797~~	[EXCLUDED]
[32]	ASTM A194	Standard Specification for Carbon Steel, Alloy Steel, and Stainless-Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
[33]	ASTM E1820	Standard Test Method for Measurement of Fracture Toughness
	~~ASTM G1~~	[EXCLUDED]
[34]	ASTM E466	Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
[35]	ASTM E647	Standard Test Method for Measurement of Fatigue Crack Growth Rates
	~~ASTM E1220~~	[EXCLUDED]

3.7. AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

Ref. n°	Document number	Title
	~~ASME Section VIII~~	[EXCLUDED]
[36]	ASME Section V	ASME Boiler & Pressure Vessel Code, Section V: Non-destructive Examination
	~~ASME Section IX~~	[EXCLUDED]

3.8. OTHER STANDARDS

Ref. n°	Document number	Title
[37]	EN ISO 13628-7:2006	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems
[38]	EN 1779	Non-destructive testing. Leak testing. Criteria for method and technique selection
[39]	ISO 13679	Petroleum and Natural Gas Industries – Procedures for Testing Casing and Tubing Connections

[40]	BS 7910	Guide to methods for assessing the acceptability of flaws in metallic structures
	~~AMS 2380~~	[EXCLUDED]
	~~SAE AMS 2801B~~	[EXCLUDED]
	~~SAE AMS 2750~~	[EXCLUDED]
	~~AMS 2645H~~	[EXCLUDED]
	~~AMS 3156~~	[EXCLUDED]
[41]	ISO 17782	Petroleum, petrochemical and natural gas industries — Scheme for conformity assessment of manufacturers of special materials
[42]	ISO 27509	Petroleum and natural gas industries. Compact flanged connections with IX seal ring
	~~ISO 9712~~	[EXCLUDED]
	~~ISO 15549~~	[EXCLUDED]
	~~ISO 17643~~	[EXCLUDED]
	~~ISO 20339~~	[EXCLUDED]
[43]	NORSOK Standard L–005	Compact Flanged Connections

3.9. CONFLICT OF INFORMATION AND DOCUMENT APPROVAL

In the event of any conflict between this specification or any other specification and associated requisition forms, or with any of the applicable codes and regulations arise, written clarification shall be sought from PETROBRAS before proceeding with the Work. SUPPLIER shall provide PETROBRAS with a written request of clarification. PETROBRAS' decision shall be final regarding interpretation of requirements.

All deviations to this specification and other referenced specifications or attachments listed in this specification shall be made in writing and shall require written approval by PETROBRAS prior to the execution of the Work.

The Stress Joint shall be designed and manufactured in accordance with the regulations applicable for service offshore Brazil.

4. GENERAL REQUIREMENTS

4.1. MATERIAL SUPPLIED

In general terms, it is anticipated that the supplied Titanium Stress Joint will consist of the basic components listed in Table 4.1 (to be confirmed within the contractual documents).

Table 4.1 – Scope of Supply (Breakdown).

Item	Description	Application	Qty per Type
1	**Titanium Pull in Tube Stack-up.**	Permanent Equipment	[2]
1.1	Lower Titanium Stress Joint Monolithic Titanium Body (UNS R56404 ELI/ UNS R56407 ELI) W\ Integral Compact Flanges in both ends.		
1.2	Upper Titanium Stress Joint Monolithic Titanium Body (UNS R56404 ELI/ UNS R56407 ELI) W\ Integral Compact Flanges in both ends.		
1.3	Titanium Spacer Pipe (UNS R56404 ELI/ UNS R56407 ELI) w\ Integral (unwelded) Compact Flanges in both ends. (Note 1)		
1.4	Steel Transition Spool terminated in an integral Standard Flange.		
1.5	Lower CS Compact Flange w/ weld prepped neck.		
2	**Adaptor Cap (Steel) to Interface with Support–Tube.**(Note 2)	Permanent Equipment	[2]
2.1	Steel Cap, with split holder and fuse cables (installation aid items), see sec. 5.8.		
2.2	Trumpet (steel) internally coated, installed into the Adaptor Cap.		
3	**Hang–Off Assembly.**	Permanent Equipment	[2]
3.1	Split Hang–Off flange w\ bolts and nuts (electrically isolated(Note 3)).		
3.2	Split Stopper w\ bolts and nuts electrically isolated(Note 3) (may be part of the Split-Flange).		
3.3	Flange electrical insulation gasket kit for final topside spool assembly (consisting of isolating gasket/sleeves/washers plus steel bolts and nuts) (Note 4).		
4	**Steel Pup Piece for riser first weld**(Note 5)	Permanent Equipment	[2], [6]
5	**FBG Attached to the Transition Spool for top load and temperature measurement.**	Permanent Equipment	[6]
6	**Other Supply Items.**		
6.1	Dummy End Fitting (Mock–up) Simulating the interface flange with the FPU, for adjustment of the FPU closing spool (Elevation "A", Figure 8.1).(Note 6)	Construction Accessories (Optative Item)	Confirmation of Supply Qty. in [2]
6.2	Dummy Adaptor Cap (Mock–up) simulating the same part of the TiPT set, for coupling/ assembly verification of this part into the specified Support–Tube of the FPU in the yard. This accessory may be required only for Newbuilt FPU.	Construction Accessories (Optative Item)	Confirmation of Supply Qty. in [2]
6.3	Handling pull-in/pull-out device w\ seal ring, bolts and nuts.	Handling Accessories (Optative Item)	Confirmation of Supply Qty. in [2]
6.4	External Coating Repair kit.(Note 7)	Installation Contingency (Repair)	(NOTE 7)
~~6.4~~	~~Gasket rings for final topside spool assembly~~	~~Permanent Equipment (Optative Item)~~	~~Confirmation of Supply Qty. in [2]~~
~~6.5~~	~~Studs and nuts for final topside spool assembly~~	~~Permanent Equipment (Optative Item)~~	~~Confirmation of Supply Qty. in [2]~~

NOTE 1: Alternative material for the *Spacer Pipes* may be proposed by CONTRACTOR and submitted to PETROBRAS for approval. Requirements of sec. 7.16 shall be observed.

NOTE 2: Steel *Adaptor Cap* with cathodic protection system (anodes), to interface to the internal surface of the Project selected Support–Tube.

NOTE 3: Electrical isolation system for the *Hang–off Assembly* shall be provided, as per sec. 5.4.

NOTE 4: Electrical isolation kit for the *Standard Flange* connection with the FPU's closing spool flange shall be provided, as per sec. 5.3.

NOTE 5: A steel riser pipe or a forged tapered pipe (exceptional case) to be preferably factory welded to the *Riser Compact Flange* by SUPPLIER. The *Pup Piece* shall have the same material requirement of the riser pipe in term of dimension (pipe ends) and metallurgy.

NOTE 6: Mock–up to be used by FPU constructor for top closing spool adjustment in the yard during construction. This mock–up shall be provided with a blind flange with the same specification as the TiPT interface *Standard Flange* per [3] (including N_2 test port if specified). The mock–up shall be able to withstand a leak test for the topside hard pipe, with the same pressure of the riser hydrostatic test (according to [2]). This accessory may be required only for newbuilt FPU.

NOTE 7: Repair kit to be used in case damage occur in the external isolation coating of the TiPT after pull–in. The specification of the material to be used shall be detailed (commercial designation, types, etc.). Quantity of the main repair product in the kit, for instance polymeric tape, shall be agreed with PETROBRAS. Any tools specially designed for these repairs shall be included within the kit, and a repair manual shall be provided (see section 7.12).

4.2. MATERIAL SELECTION

All equipment and material supplied under this Specification shall be new, of proven design, and in accordance with sound engineering fabrication and manufacturing practice. It is preferred to use existing designs or modifications that have been already accepted.

SUPPLIER shall be responsible for the selection of the materials. All materials shall be suitable for the intended service. The selected materials shall be in accordance with the relevant applicable codes, standards and specifications and be able to meet the requirements defined in [2].

The origin and manufacture 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 and approval by PETROBRAS.

SUPPLIER shall select the materials in accordance with the:

- 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 control;
- Environmental conditions (mediums in contact with TIPT).

The compatibility between all materials shall be checked. Materials shall not be affected by galvanic reactions and can be welded to other specified metallic pieces where necessary. In particular, the adequacy of the compact flange pairs and the nearest steel pipe sections are critical. Requirements can be found in section 7.16 and within Project Specification.

If SUPPLIER intends to consider the weld overlay or the metallurgical CRA layer contributing to the strength of the dynamic steel parts (*Steel Compact Flange* and *Pup Piece*), additional requirements of the DNV Report for JIP Lined and Clad Pipelines, Phase 3 - Design and Construction of Lined and Clad Pipelines [18], and Appendix A.3 of [22], shall be fulfilled.

Additional criteria for weld overlay are presented on section 8.6 of [10].

4.3. SUPPLIER'S RESPONSIBILITIES

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 the *Titanium Pull–in Tube* in a safe manner per the agreed schedule. SUPPLIER shall perform all operations required for design, manufacture, inspection, testing, handling and shipping.

Nothing contained in this specification or omitted from it shall be construed as relieving the SUPPLIER of the obligation to supply the TiPT 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.

SUPPLIER shall develop a written Manufacturing Plan/Procedure, which includes a Quality Control Plan, which shall be submitted to PETROBRAS for approval prior to the manufacture.

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 prior to commencement of manufacturing.

PETROBRAS furnished drawings and specifications shall be checked by SUPPLIER immediately upon receipt, and SUPPLIER shall promptly notify PETROBRAS of any discrepancies therein.

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 of Work or continuation of Work.

SUPPLIER shall allow PETROBRAS reasonable access to all areas concerned with design, manufacture, inspection and testing during all times while Work is being performed for this order.

SUPPLIER shall provide all reasonable facilities to PETROBRAS inspectors, without charge, to satisfy the inspector that product is manufactured in accordance with this Specification. Such facilities shall include, but not limited to, office equipment and telecommunication equipment. CONTRACTOR shall perform a complete visual inspection at the place of manufacture prior to shipment, and upon the receipt of the TIPT at the construction site. If any inspection or testing reveals details not in accordance with this Specification, then SUPPLIER may demonstrate to PETROBRAS that the product still satisfies the design requirement. If SUPPLIER is unable to demonstrate this to PETROBRAS's satisfaction, then the manufacturing and/or testing procedure shall be repeated until compliance is demonstrated. All such remedial work shall be performed at SUPPLIER's cost.

SUPPLIER shall furnish all data generated during the design cycle of the *Titanium Pull–in Tube* including the results of the numerical analyses that will be carried out in order to fulfill the design requirements. This documentation shall be comprised of written report, in a layout defined by the PETROBRAS, and the electronic input and output files of the finite element and ECA analysis.

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

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

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

Deviations from this Specification are not permitted. All proposed changes or modifications to this Specification shall be submitted in writing for PETROBRAS approval. Approved changes shall be incorporated into a revised, approved purchase specification. Disclaimers are not permitted.

4.4. PRODUCT QUALIFICATION

SUPPLIER shall demonstrate the qualification of the product for the intended service. Refer to section 12 for qualification requirements of TiPT components.

4.5. UNIT OF MEASUREMENTS

All data shall be reported in primary S.I. units; however, customary US units may also be reported for reference only.

5. FUNCTIONAL REQUIREMENT

5.1. TIPT ASSEMBLY

i. The TiPT shall be design and sized in a way to guarantee that its titanium portion will be composed by monolithic pieces. Weld on titanium parts shall be avoided;

ii. The TiPT shall provide a secure attachment of the riser to the hull under all specified load conditions;

iii. The TiPT *Stack–up* shall fit together so that under load there is no relative movement between mating parts;

iv. The TiPT shall transfer all specified load conditions without gross yielding, buckling or failing during the specified service life;

v. During a catastrophic event, the TiPT design shall provide that failure is likely to occur in the riser pipe rather than the TiPT or hull structure;

vi. The TiPT shall be designed to withstand a constant hydrostatic pressure at specified installation maximum water depth, including pre-abandonment if required, for a minimum of twelve (12) months;

vii. The TiPT shall provide electrically isolating barriers between the riser and the FPU, at the *Support–Tube*, the *Hang–off Structure* and the closing spool flange, to prevent FPU cathodic (impressed) current from reach the titanium parts and the riser CP from draining into the hull structure;

viii. The TiPT, mainly in the interface with dissimilar metallic parts, shall be protected from galvanic potential to prevent the formation of hydrides. Special attention shall be taken at the Compact Flanges connections;

ix. The TiPT flanges shall maintain a leak tight connection under all specified load conditions using a metal HX seal ring as the primary pressure barrier;

x. The TiPT flanges shall provide a fatigue resistant, quasi-static connection, mostly isolating the bolts of dynamic loadings as defined in sec. 5.5;

xi. The TiPT flanges shall be designed to avoid yielding of the titanium material for all combinations of make-up and operational loads;

xii. The TiPT *Standard Flange* shall be designed to withstand to riser installation loads (transfer and pull–in).

xiii. The TiPT should be totally assembled, tested and coated in the factory prior shipping. However, if for any limitation in installation, handling or transportation, the TiPT may be segmented into smaller subassemblies and integrated in the yard or in the installation vessel.

5.2. ADAPTOR CAP AND TRUMPET

i. The *Adaptor Cap* shall provide a secure attachment of the TIPT assembly to the hull under all specified load conditions, according to the reference *Support–Tube* drawings [7] and interface data informed within [3]. Reference drawing with additional orientation for Adaptor Cap design is present in [9].

ii. A trumpet shape, internal profile, shall be designed in view of the expected curvature of the UTSJ while in contact with the *Trumpet*. Material compatibility of contacting pair shall be assessed to reduce the contact friction in this region.

iii. Trumpet material shall avoid direct electric contact between titanium and steel parts during specified service life and accidental conditions.

iv. The *Adaptor Cap* shall transfer all specified load conditions without buckling or failing during the specified service life. A certain plastic deformation at the *Adaptor Cap* is acceptable in accidental cases, as per section 7.6. The Trumpet shall not present great deformation on steel parts that could cause crease to appear at the contact region.

v. The trumpet length and radius and the TiPT interaction will define load center reference point directly related to the FPU Support load transfer.

5.3. STEEL TRANSITION SPOOL

i. This part shall consist of an integral *Standard Flange*, to interface with the FPU closing spool, an *"End– Fitting"*, which holds the TiPT at the Hang–off, a tubular section, to provide enough area for FBG sensors installation and enable length adjustment when intended, and the *Top Compact Flange*, to connect to the remain of the TiPT *Stack–up*.

ii. The *"End–Fitting"* feature shall provide the locking of the *Steel Transition Spool* both upward and downward, designed to withstand the riser tension and the mounting loads (shear, moment) at the *Hang–off Flange*, but also a catastrophic disruption of the riser resulting in a sudden upward force proportional to the end cap effect of the riser.

iii. The *Standard Flange* shall be electrically isolated from closing spool flange by mean of commercial insulation kit compactible with the specified flange of the FPU's closing spool, in terms of standard, size, ring groove type and pressure rating. The closing spool flange specification, or in certain cases the electrical insulation gasket kit specification, is presented in ref. [3].

iv. Limitation on the total length of the *Transition Spool* shall be observed to allow its unimpeded passage through the *Support–Tube* during the pull–in, as per sec. 5.8.

v. The optimization of the shape of the UTSJ cylindrical section should be performed seeking to promote a reduction in the lateral and axial loads due to the coupling (alignment) during final stages of the pull–in. Some non-particular form of "hourglass" in this section may reduce the magnitude of the binaries.

5.4. HANG–OFF ASSEMBLY

i. *Split Hang–off Flange* shall follow the design of the respective *Upper I–Tube*, as presented within the interface data provided in [3].

ii. Electrical isolation system, that isolates the TiPT's *"End–fitting"* from the hull (*Upper I–Tube*), shall be provided. Such system shall isolate the TiPT by mean of non-conductive barriers (e.g., G-10 glass epoxy "isolating rings", ceramic epoxy painting, etc.) designed to withstand the bearing/ compressive stress at hang-off contacting surfaces, and isolation kit for the studs and nuts, consisting of isolating sleeves and washers (or painting) as outlined in Figure 5.1, which is a schematic view only (actual system selected by CONTRACTOR may differ from this representation). The chosen electrical isolation system shall be submitted to PETROBRAS for review.

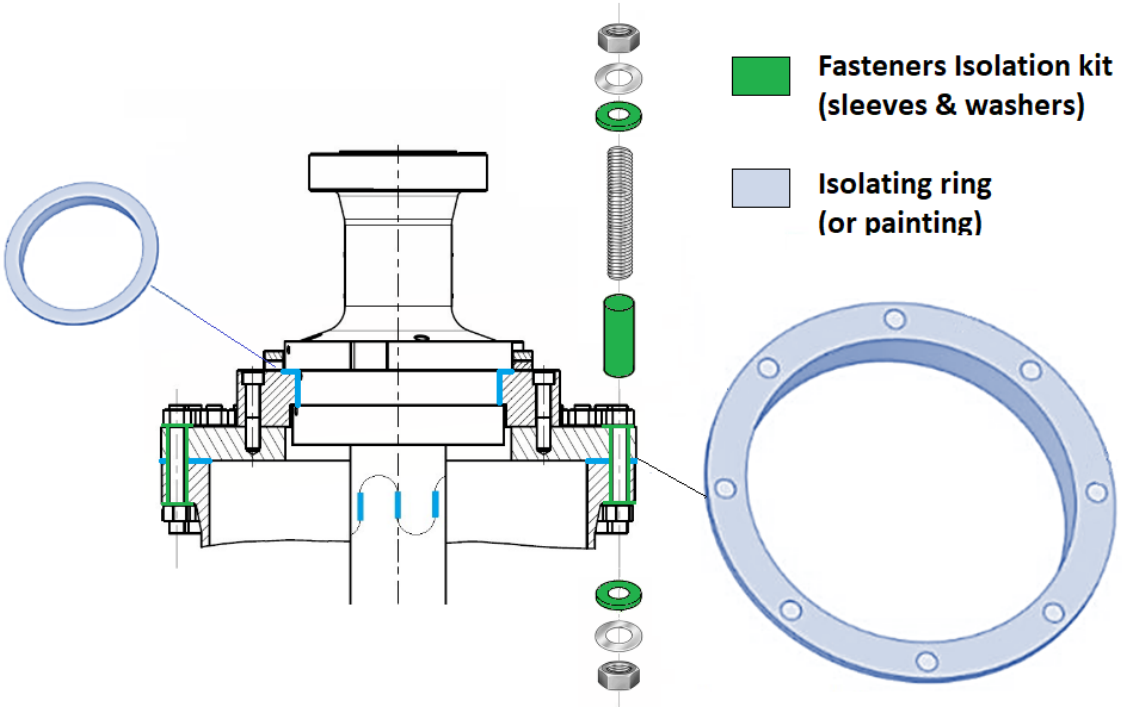


Figure 5.1 – Electrical Isolation System for the *Hang–off Assembly*. (Schematic View Only)

5.5. COMPACT FLANGES

i. SUPPLIER shall provide the data sheet of the selected compact flanges, as per [43], for the interfaces with the FPU spool and with the riser. Information includes commercial\standard designation (or detailed drawing for modified design), material, sealing type, qualified loads envelope capacity. Seal ring type shall be type HX.

ii. Integral compact flange shall be sized per strength capacity calculation of annex A of [42]. SUPPLIER should use the maximum tension, associated with the design pressure, that leads to 100% of the pipe capacity (1.0VME), per [39]. This is a conservative approach for flange design instead of using the final Project calculated loads and load cases. Very limited plastic strain (PEEQ) may occur at titanium flange by this approach, and in this case, SUPPLIER shall submit a request to PETROBRAS for approval.

iii. The functionality of the seal for the workloads shall be checked up to the pipe capacity (1.0VME) and shall guarantee the average contact pressure at primary sealing area to be at least two times the flange pressure rating per [37] annex H.4.

iv. The TSJ flanges shall provide a fatigue resistant connection by limiting the increase of bolt nominal stress in no more than 5% as defined in [42], due to the riser dynamic loadings. The 95% balance of the bolt stress shall be carried in the pre-loaded flange faces.

v. Thicker wall at the top of the *Steel Compact Flange* neck, associated with a longer, tapered section neck should be considered, if large loading (extreme and fatigue) is applied in this part. Especially if such loads put the TSJ close to SUPPLIER's monolithic *Stress Joint* length limit.

vi. At least FEA half–models of the Compact Flange shall be employed, to capture bending behavior.

vii. High strength steel studs may be considered for lower stress fatigue non–critical flanges (e.g., one of the *Spacer Pipes'* compact flanges), upon PETROBRAS approval.

viii. Compact Flange assembly, torquing and pre-loading procedure shall be prepared and submitted to PETROBRAS review. Procedure for yard or offshore assembly and tightness test shall also be submitted for review in case of segmented *Stack–up*.

ix. Electrical isolation of the titanium studs shall be guaranteed in any loading condition during all service life of this component (see also sec. 7.1–ii).

5.6. EXTERNAL COATINGS

External coatings shall be used on 100% of the exposed surface of titanium parts to afford complete electrical isolation of titanium parts from the electrolyte, and galvanic shielding from steel components to which the TiPT will be connected in service.

SUPPLIER shall comply with the requirements for the external coating and tests (PQT, pre-production and production phases) of titanium and steel parts presented in [5].

For risers with maximum operating temperature closer to the selected material limit, a thermal analysis, as instructed in section 7.9, shall be done to determine the temperature profile through the polymeric coating thickness to be compared with the material qualified limit.

FEA focusing on estimate the coating loading (contact pressure) with adequate accuracy shall be performed. The passage during pull–in and operation scenarios shall be included, with the regular pipe (*Spacer Pipes*) and protrusions (*Compact Flange* and UTSJ) simulated. The coupling of the cylindrical section of the UTSJ and the *Trumpet* in the last steps of the pull–in shall be included, considering also the recommendations given in sec. 5.3–v (shape optimization) and sec. 7.14 (use of temporary heel angle at FPU).

The selection of the coating material, for the atmospheric and tide variation portions of the Spacer Pipes, shall also take into account the possible harmful effects of direct exposition to UV ray, saltwater splashes and industrial ozone-rich atmosphere.

The *Trumpet* inner diameter shall be coated with a polymer layer compatible with the TiPT (UTSJ) coating, in view of reduced friction wear between the two coatings. The material selection shall be backed by bench tests and validated by a functional test as per the TiPT section of [5].

A coating repair procedure shall be prepared for all the TiPT regions, per sec 7.12. Repair kit shall be provided prior to the installation, as per Item 6.4 of Table 4.1, to be used by PETROBRAS in case of damage during pull–in.

5.7. TIPT RISER MONITORING SYSTEM (TRMS)

The TiPT parts to receive the TRMS sensor and quantities to be monitored are as follow, per [6]:

i. The *Steel Transition Spool* shall be equipped with calibrated FBG sensors for top loads and temperature measurement, installed on the section shown in Figure 1.2.

ii. Calibrated FBG sensors (loads, temperature) and accelerometers (angles) shall be installed onto the *Pup Piece*.

iii. Cathodic potential differential measurement shall be included within the monitoring quantities.

iv. The set of FBG sensors shall include in any case the monitoring of temperature on TiPT metal surface, for reading corrections.

The detailing of the monitoring system requirements is given in the TRMS specification [12], [13] or [14], depending on the presence of cabling and cabling facilities at the hull side of the Project's FPU (none, pre-installed conduit cabling or pre-installed umbilical respectively). The applicable TRMS specification for the Project is informed in the TRMS Material Requisition [6].

5.8. INSTALLATION, PRE–COMISSIONING AND INSPECTIONS

Pull–in head and its associated accessories shall be dimensionally compactible with the Project selected *Support–Tube* [6]. The diameter and the length of these pull in accessories attached to the top of TiPT shall be such that allow the passage of the pull–in rigging and the *Transition Spool* through the *Support–Tube* without getting stuck in the support or inducing excessive bending moment on the top of TiPT including the *CS Compact Flange*. CONTRACTOR shall perform a "clear pass study" (geometric), simulating the steps of the passage of the *Transition Spool* and pull–in head through the *Support–Tube* and included within de Design Report.

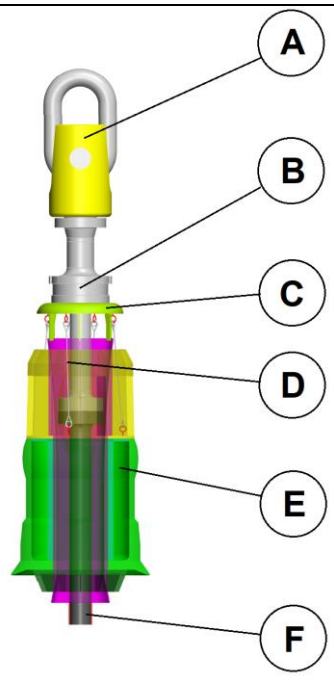
Prior to the beginning of the TiPT passage through the *Support–Tube* during the pull–in, the *Adaptor Cap* shall be attached to the *Transition Spool* by mean of a holder and fuse cables with a holder. Guidelines of [15] and [9] shall be observed.

Pre-commissioning of the riser with TiPT is performed from the FPU top side, at the URB. Surrounding space around the *Upper I–Tube* and a description of the facilities is informed in [3] and its sub-references.

Post pull–in visual inspection of the TiPT *Stack–up* is mandatory. Although this is usually OOS, an Inspection Manual shall be prepared with the participation of the PARTIES. Post pull–in cathodic potential differential measurement (riser anodes) shall be performed by CONTRACTOR. See section 7.11.

CONTRACTOR shall provide instructions for the assembly of *Hang–off* and assist PETROBRAS during pull–in activities in the FPU. The verification of the passage of the *Stack–up* through the *Adaptor Cap* and Trumpet, and the assembly of the *End–fitting* into the *Split Flange* and *Stopper* shall be tested during SIT (section 11.1).

Typical top TiPT section, in its configuration with accessories prior to the pull–in, is depicted in Figure 5.2.



Part	Description
A	*Pull–in Head (“Bull Nose”)*
B	*Steel Transition Spool*
C	*Split Holder (Installation Aid)*
D	*Fuse Cables (Installation Aid)*
E	*Adaptor Cap*
F	*Titanium Spacer Pipe*

Figure 5.2 – Top TiPT Section and Adaptor Cap with Installation Aid Devices.

6. MATERIAL REQUIREMENTS

Table 6.1 provides the TIPT material requirements by component. Alternative materials or modifications to industry specification shall be reviewed and approved by PETROBRAS.

Table 6.1 – TIPT Component Material Requirements.

Component	Material	Code(1)	SMYS/ spec.	Remarks(2)
LTSJ, UTSJ, Spacer Pipes	Titanium	ASTM-B381-GR29(1) ASTM-B381-GR23(3)	758 MPa 758 MPa	For "sour–service", per ref. [28] For "sweet–service" per ref. [28] and ≤ 80°c
Spacer Pipes (option)	Steel forging	ASTM-A707 L5	---	Acceptable material/ grade.(1)
	Steel pipe	Ref. [17][18], see sec. 7.16		Inlay of CRA shall be considered, as per section 7.17.
Steel Compact Flanges	Steel forging	ASTM-A707 L5	≥ 450MPA	Acceptable material/ grade.(1) Inlay of CRA shall be considered, as per section 7.17.
Transition Spool	Steel forging	ASTM-A707 L5	≥ 450MPA	Acceptable material/ grade.(1)(5) Inlay of CRA shall be considered, as per section 7.17.
	(Steel pipe)(5)	Ref. [17][18](5)		
Hang–off Assembly	Steel plates	ASTM-A36 or EN 10225	--- S420	Acceptable materials/ grades.(1)
Adaptor Cap & Trumpet	Steel forging	ASTM-A694	F52	Acceptable materials/ grades.(1)
	Plate	EN-10025	S355J2	
TiPT Studs & Nuts	Titanium	ASTM-B381-GR29/23	793 MPa	Property after heat treatment. Other material\ grades may be proposed for PETROBRAS approval.
Tie-in Spool Studs(4)	Steel	ASTM-A193-GRB7	724 MPa	
Tie-in Spool Nuts(4)	Steel	ASTM-A194-GR2H	1205 MPa	Proof load per [32]
Compact Flange Seal Ring	Nickel	ASTM-B564	414 MPa	Alloy UNS N06625, Xylan coated

(1) Any modifications to these materials/ grades shall be submitted to PETROBRAS approval prior to the manufacture. The Ti alloys listed herein are base case. However alternative Ti alloys may be specified, since pre-qualified, as per the requirements of sec. 6.1 of [9].
(2) According to supplier specification. Calculation notes shall demonstrate the adequacy of the choice.
(3) For material severity class defined as "0", according to NACE [28] AND riser operating temperature below 80°C.
(4) Studs and nuts shall comply also with PETROBRAS specification of [16].
(5) Integral all forged piece as base case. However, combination of forgings (extremities) and pipe segment welded together may be considered.

Additional material selection guideline for steel and titanium components of the TiPT shall follow sec. 6.1 of [10].

7. DESIGN REQUIREMENT

7.1. GENERAL

SUPPLIER shall design and construct the TIPT to accommodate the specified values for angular rotation, axial loads, temperatures, and pressures for the specified service life within allowable stress limits specified in [27]. PETROBRAS will provide the riser design basis covering the entire riser system including the TIPT, as per Section 3.1.

The design requirements applicable to the riser and TiPT shall include, but not be limited to the following:

i. The TIPT design shall conform to the chemistry of fluids passing through the risers. The TiPT shall be designed for sour service per [28] requirements, if sour service is expected as per [2].

ii. Titanium studs of the Compact Flanges shall be electrically isolated from the flange (Ti and CS), for instance by mean of thin, high-strength (compressive) coating applied on the face of the nuts in contact with the flanges, and dielectric sleeves installed in the holes in the annular space between the studs and the flange. If high strength steel studs are approved to be used, then electrical contact with the CS side of the flange shall be guaranteed, as per section 7.16.

iii. The TIPT shall transfer all loads at their maximum design limits without gross yielding, buckling, collapsing, or failing during the specified service life.

iv. The *Stress Joint* lower connection *Pup Piece* shall be designed to be compatible with the riser pipe, both in term of material and dimension.

v. The TIPT shall be designed to interface with the Project selected *Support–Tube*, per [7] considering the prescribed tolerances. The limit of interface loading on the *Support–Tube* and on the *Hang–off* shall also be regarded, as per section 7.2. This is especially important for installation into existing FPUs, where the supports may have been designed in view of another type of riser top connection. Newbuilt FPUs are customarily designed for greater interface loads, typical of optimized riser configuration with TiPT.

vi. The TIPT shall accommodate the riser cyclic load without failure for a fatigue life greater than the Project service life factored by 10. The combined fatigue life will include contributions due to installation and wave induced fatigue. SUPPLIER shall get approval from PETROBRAS regarding parameters, techniques, and programs used for the FEA and fatigue analysis prior to starting either FEA or fatigue analysis.

vii. The fabrication of the TiPT shall be subject to inspection, verification, qualification, and documentation in accordance with PETROBRAS's and industry standards.

viii. The TiPT assembly shall successfully pass the factory acceptance testing (FAT), as well as dimensional and visual inspections as per section 11. Tests specification and criteria shall be submitted to PETROBRAS comment prior to the stars of FAT.

ix. CONTRACTOR shall guarantee the protective potential at the riser top steel section (riser anode potential) to be positive to -850mV, as per [20].

x. SUPPLIER shall submit a complete Design Report and drawings (as per sec. 13.4) to PETROBRAS for review and approval.

7.2. INTERFACES

7.2.1. INTERFACE LOADS LIMITS

The CONTRACTOR–calculated TiPT induced extreme loads on the *Support–Tube* and on the *Upper I–Tube* shall be constrained by the limiting reaction loads informed in [3]. The reference points for the load applications are also indicated. These reference points are considered specifically for this verification, and any correction on the loads (load transference) shall be done if CONTRACTOR consider different points for load generation.

For resistance evaluation to cyclic loadings, CONTRACTOR shall generate loading histograms that shall be below (less damaging) than the *Support–Tube* and *Upper I–Tube* fatigue limiting loading histograms provided in [3], at the reference points for load application, as well as the respective Weibull fitted distribution parameters. The limiting cyclic loads in [3] will typically reflect previously performed fatigue checks in the Support-Tube/Upper I-Tube critical details of Basic Design TiPT loads.

Further explanation on how to generate and compare the TiPT loadings to the limiting loads of the FPU structures are given in [3].

7.3. DIMENSIONS

7.3.1. GENERAL

In case different internal diameters are specified for the riser bore and for the top connection spool (FPU interface) in [3], a smooth 1 : 5 slope diameter transition shall be provided, in the *Steel Transition Spool*.

7.3.2. LENGTH ADJUSTMENT

The adjustment of TiPT total length shall be made based on as-built drawings or metrology between the LRB and URB, considering also the curvilinear length of TiPT *Stack–up*. One of the *Spacer Pipes* or the *Steel Transition Spool* may be constructed with different length or may a cut-to-length and girth weld adjustment of the *Steel Transition Spool* be provided, for each riser position.

The UTSJ cylindrical (interfacing) section shall be prolonged to apart the *Stress Joint* compact flange and its coating from interfere with the *Adaptor Cap* bottom during pull–in and operation due to relative movement between structure and the TiPT, settlements or deformation of the LRB, unintentional overpull during pull–in and other effects. A minimum distance “d” shown in Figure 7.1 shall be defined by CONTRACTOR. Printed scale should be put on the prolonged section of the

UTSJ nearest to the Compact Flange and on the Transition Spool underneath the *End-Fitting*, to aid pull-in and pos pull-in monitoring and inspection.

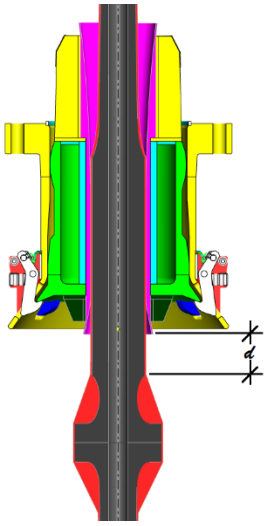


Figure 7.1 – Clearance Between UTSJ Compact Flange and Adaptor Cap.

7.3.3. UPPER BALCONY

The specified interface flange elevation "A" above the *Upper I–Tube* flange (to the raised face of the *Standard Flange*), are given in [3] for each TiPT position (see Figure 7.2). SUPPLIER/ CONTRACTOR shall consider these values on the TIPT design, and inform PETROBRAS, during clarifications in bidding phase, if this requirement cannot be fulfilled.

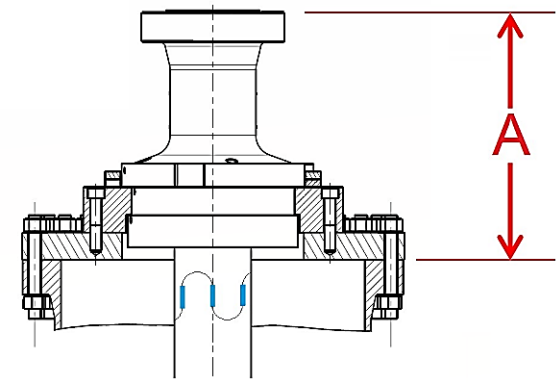


Figure 7.2 – Standard Flange Elevation "A" Above Upper I–Tube.

In case short distance between URB and LRB is specified, the top parts of TiPT may not have enough flexibility to provide a vertical connection and an angular offset with vertical may be required for the *Transition Spool* as shown in Figure 7.3, if stated so in [3]. Only in this case, CONTRACTOR shall define and report to PETROBRAS the elevation "A", the lateral offset "B" and angular offset "θ" of the top of the standard flange with respect to the I-Tube centerline.

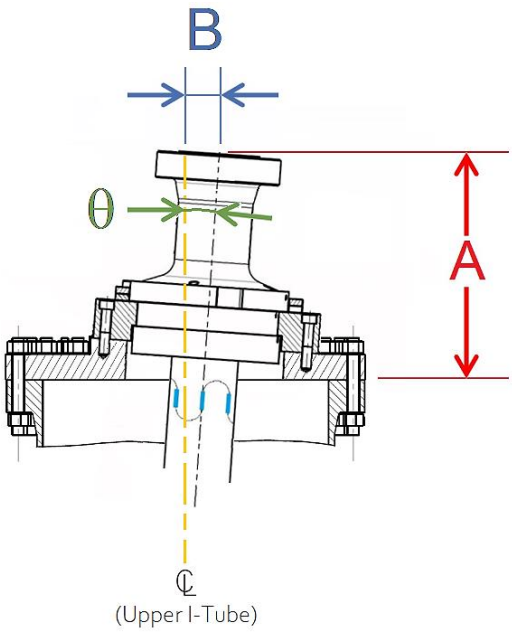


Figure 7.3 – Standard Flange Position w.r.t. the Upper I–Tube – Angular Offset, in Riser Plane.

7.3.4. LOWER BALCONY

The Adaptor Cap shall match with the dimensions of the Project selected *Support–Tube Dummy Adaptor Cap* present in [3]. Any modification on the external profile of the Adaptor Cap from the Dummy Cap drawing, if needed, shall be approved by PETROBRAS. Fabrication tolerances of the external profile of the TIPT and contacting areas of the Trumpet including coatings shall be considered. Interference/assembly study shall be performed.

The design of the LTSJ shall assure free rotation of the lower Extension (without contact with the FPU Hull Structure) over the maximum Project specified angular deflection.

Dummy cap may be required to be supplied, if so stated in [2]. This construction accessory is used to verify the compatibility of the SUPPLIER designed Adaptor Cap with the internal diameters of the actual FPU Support–Tube, through a drift pipe testing. If modification on the external profile of the Adaptor Cap was considered, then the supply of Dummy Cap is mandatory.

7.3.5. WELDED SECTION WITH THE STEEL RISER

The Pup Piece riser end dimension and tolerances shall be considered in view of welding requirements (Hi-Lo), and coating requirements (coating cutback characteristic) of the riser pipe.

7.4. DESIGN LOADS

From the global riser analysis and environmental conditions, PETROBRAS or CONTRACTOR will provide the riser interface loads at the Stress Joint termination locations, including maximum tension, maximum bending moment (or bending angle with respect to the center of rotation in the *Support–Tube*), and fatigue tension/ angle histograms, as required.

SUPPLIER then shall size the TIPT according to the load cases provided by PETROBRAS or CONTRACTOR and return with the size and critical section locations along the TIPT (taper transition), so the abovementioned histograms can be correctly informed. SUPPLIER shall provide also the interface load (i.e., reacting moment on the hang–off), and the TIPT and Adapter Bushing geometry, as 3D CAD model, and the exact position of the point of application of forces to PETROBRAS to subsidize the design of the hang–off design.

7.5. LOADING CASES

Table 7.1 indicates the minimum set of design cases to be considered in the structural design of titanium and steel parts from each TiPT type for the Project. The reference [2] summarizes all these load cases. The responsibilities about the emission of the final data set for TIPT design is presented on section 1.2. The complete set of load combinations for riser global analysis is listed in [11].

TABLE 7.1 – DESIGN LOADING CASE MATRIX FOR TIPT.

Design Case	Load Category	Description	Load Combination from Riser Global Analysis, [11]	Design Loads	Cf (1) [27]
1	Temporary 1	Hydrotest	ULS1	[2]	1.35
2	Maximum Operating	10 Years Return Period Storm	ULS3		1.0
3	Extreme 1	100 Years Return Period Storm	ULS2		1.2
4	Extreme 2	1 Year Rp. Incidental Pressure	ULS4		1.2
5	Extreme 3	10 Year Rp. One Mooring Line Broken(2)	ALS2		1.2
6	Survival 1	100 Year Rp. One Mooring Line Broken(2)	ALS1		1.5
7	Survival 2	1 Year Rp. Flooded Hull Compartment(3)	ALS3		1.5
8	Temporary 2	Installation(4)	-		1.2
9	Abnormal 1	10 Years-Rp, with Loss of Buoyance Modules	ALS5		1.2
10	Abnormal 2	100 Years-Rp, with Loss of Buoyance Modules	ALS4		1.2
11	Fatigue (Sec. 7.8)	Fatigue Conditions (Wave with Associated Annual Current Distribution)	-		N/A

(1) The Cf factor is the design case factor used to calculate allowable stresses, as per [27]. Load categorization may vary depending on chosen design code.
(2) Load category to account for the maximum FPU drift.
(3) Load category to account for the maximum accidental top angle.
(4) Installation cases to be defined by CONTRACTOR, following also the provisions of section 7.14. Max. allowable installation water depth according to [2].

The selection of load cases to be analysed, for the design case 1 to 4 of Table 7.1, shall be performed in accordance with section 7.1 of [11]. One plot of “Tension x bending moment” shall be presented for each load category of Table 7.1 and shall include all results from global analysis and the selected load cases in order to demonstrate that the selected ones are representative of the whole set of results. At least the load cases with the maximum resultant bending moment and the maximum tension values shall be selected (with the respective associated tension and angle values).

Additional load case(s) other than those cases listed in Table 7.1 may be included, to account for any specificities of a given Project. Any Project extra load case condition will also be clearly defined within Project documentation in [2].

For newbuilt FPU, the prescribed mounting angle tolerance of the *Support–Tube*, defined in [3], shall be considered as an additional permanent deflection of the TIPT, and shall be considered in a conservative form.

Any difference from *Support–Tube* angles and those of the riser (top and azimuth angles) shall be considered by CONTRACTOR in global analysis models.

Appropriate fluid combination (pressure and temperature), as per flow profiles informed within [2], shall be considered in each load category of Table 7.1. More than one combination should apply, and SUPPLIER shall evaluate the most relevant combinations according to its design methodology.

7.6. DESIGN CRITERIA

TIPTs typically have D/t ratios below 10 as well as concentrated stresses in locations along the taper. The use of elastic stress analysis and stress classification per [27] to demonstrate structural integrity can produce non-conservative results in these sections. A complete finite element analysis shall be made of all components that contribute to TIPT strength capacity and sealing capability.

Annex D of [37] provides guidelines for finite element analysis and establishes TIPT design criteria for both elastic and elastic-plastic stress analysis for steel parts. Plastic deformation on titanium parts shall not be considered.

In addition to comparing the TIPT stresses to the allowable criteria for the riser design load cases, it may also be useful to compare riser limit loads to the ultimate capacity of the hang-off system to ensure a systematic and controlled failure sequence during a catastrophic event. For example, during a catastrophic event the riser should be designed to fail before the hang-off system or hull structure reach ultimate capacity. The design of riser hang-off structures is not specifically covered by current industry codes. However, the ultimate capacity methodology given in [37] Annex D may

be applied. For example, ultimate capacity of the *Adaptor Cap* may be defined as any of the following (derived from guidelines in [37] Annex D.2.4):

- Principle strain exceeds 2% across entire primary structural section;
- Equivalent plastic strain exceeds 10% or $0.5x\left(1-\frac{\sigma_y}{\sigma_u}\right)$ at any point in the structural section;
- Global structural instability, excessive receptacle deformation or plastic collapse is reached.

7.7. FATIGUE REQUIREMENTS

- SUPPLIER shall furnish the TIPT stress concentration factors to be applied in the riser global model, with the respective calculation sheets.
- SUPPLIER shall submit to PETROBRAS the intended criteria to be used for fatigue analysis (fatigue curves) for titanium and steel parts.
- Supplier pre–qualified titanium fatigue design curves may be used, following PETROBRAS review and approval as per section 12. In case SUPPLIER design titanium S–N curve is not present or not approved for use in the Project, the base case curve from the JIP [21] shall be employed, valid for both sweet\ sour service, internal\ external fibber, for base metal section only, and for grade 23 and 29. Such curve is defined by $N \times \Delta\sigma^6 = 2.87 \times 10^{19}$ (with $\Delta\sigma$ in MPa), and was raised with constant load amplitude at R = 0.1.
- Lower weld S–N curves in air from [25] may be used, if possible, given the stress levels, seeking to make UT inspections more feasible.
- The design S–N fatigue life calculated for the TIPT shall exceed the specified Project service life factored by a FoS of 10.
- Storm waves contribution on TIPT and riser welds fatigue life shall be included within the fatigue analyses. The most damaging extreme waves at the Top of Taper section, for each return period, shall be selected and included among the operational fatigue waves, as per section 7.1.2 of [11].

7.8. FATIGUE ANALYSIS

CONTRACTOR shall determine fatigue life and generate stress histograms for the critical sections along the TIPT. These sections are project specific and shall be defined on the project's TIPT general arrangement drawings. These reference sections shall be located at the top of taper, the

start of taper, the Ti Compact Flange and steel weld sections. The corresponding SCF on the outer surface shall be calculated by FEA for each of these sections.

NOTE: During bidding phase of EPCI contracts, PETROBRAS may provide stress histograms based on Basic Design analysis, in the format and for assumed critical section positions given in [2]. These histograms consider wave-wind-current combination at Project location and may include "storm conditions" and extreme current events, to subsidize preliminary assessment. SUPPLIER may use these histograms and positions as references to interpolate the static and cyclic stresses to the corresponding TIPT geometry to be pre-dimensioned for the Project. The responsibility for the emission of final fatigue data is according to section 1.2.

For critical, non-welded sections of the TiPT parts, without significant residual stresses, SUPPLIER may propose a method for compensate for the stress ratio variation (R–ratio) along the sections, as per sec. 2.5 of [25], the SWT method or other. Stress reduction method shall not be employed for clod formed tubular sections with residual tensile stresses due to the fabrication process. The method, along with any detailed material (empirical) fatigue parameters, coefficients and exponents used shall be submitted to PETROBRAS approval.

7.9. THERMAL ANALYSIS

The thermal analysis to determine the temperature at the Isolation polymeric coating shall take into account the appropriate fluid combination (pressure and temperature), as per flow profiles informed within [2], per each Load Category of Table 7.1.

For the submerged portion of the TiPT, the seawater temperature shall be given by sec. 7.1 of [8] (“Vertical Distribution of Sea Water Temperature”), considering i) for extreme analyses, the maximum seawater temperature (Tmax) at the first level informed (closest to sea surface) and ii) for long term analyses (if required), the average seawater temperature (Tavg) also at the first level informed. For emerged portion (permanently or temporarily) the absolute maximum air temperature shall be given by sec. 3.4 of [8] (“Air Temperature, Characteristics Monthly Values”).

Thermal properties of the conveyed fluid of ref. [2] shall be used.

7.10. ECA REQUIREMENTS

SUPPLIER shall perform a fatigue assessment based on fatigue crack growth calculations so that maximum initial defect height size left after fabrication and non-destructive testing would not grow to a critical size during service life. A ECA procedure shall be elaborated according to [19], [23], [24], [27] and [40] and submitted to PETROBRAS for approval. The target life for the fracture mechanics evaluation of TIPTs shall be the design service life, as per [2], factored by:

- a DFF_{ECA} of 5 where the assumed initial defect can be reliably derived from PoD 90%|95% and sizing error of the NDT in place according to [19] and [22];

- a DFF_{ECA} of 10 where the assumed initial defect is the expected value of defects (mean) according to [23] and there is limited practical trials on NDT reliability.

Maximum initial defect height sizes depend on flaw length. Detected flaws shall be evaluated considering NDT acceptance criteria and sizing error. Non detected flaws shall be evaluated considering NDT capabilities with a postulated full-circumferential flaw. SUPPLIER shall inform the critical sections where the tension-angle histograms should be informed. Both static and cyclic loading information from the riser global analyst will be provided by PETROBRAS. Tension-angle histograms will be generated with enough fine blocks (bin size) at small values of tension and angle. SUPPLIER shall generate by each section the stress blocks derived from the histograms to be provided by PETROBRAS within [2].

7.11. POST–INSTALLATION AND IN–SERVICE INSPECTION

PARTIES shall work together to generate an Inspection and Maintenance Manual (sec. 13.3), for post–installation and periodic inspection, confirming the integrity of the TiPT and TRMS components and upkeeping of the electrical isolation of the *"End Fitting"* from the FPU, during the service life of the field.

Especially, the inspection procedure for the external polymeric coating shall be detailed for all the regions – atmospheric portion, temporarily and permanently submerged sections and occluded portion (directly, by partial pull–out, and indirectly by TRMS' cathodic potential measurement). The Inspection and Maintenance Manual shall include a cleaning procedure of the isolating coating (for periodic inspections), and a list of possible coating damages patterns caused as a result of the pull–in activities and in operation.

Post–installation cathodic potential differential measurement (riser anodes) shall be performed by CONTRACTOR, up to the top section of the riser, beneath the titanium section of the TiPT, as per instruction of [20].

7.12. MAINTENANCE AND PRESERVATION

The *Titanium Pull–in Tube* shall not require intervention for maintenance or repair during the specified service life, other than the repair of the external coating.

The procedure for eventual repair of damages in the external isolation coating, considering both immediately after installation and during service life, shall be qualified and included in the Inspection

and Maintenance Manual. Contingency material for repair during installation shall be provided (see Table 4.1).

Instructions aiming to guarantee the preservation of the TiPT parts shall be included. Especially for the atmospheric and tide variation portions of the *Spacer Pipes* (preservation against harmful effect in sec. 5.6, where applied), and the steel *Hang–off Assembly* (preservation against rust and corrosion control of steel parts, as painting touch up).

The riser shall be partially removable (partial pull–out) and re–installable, for inspection purpose (Trumpet and UTSJ region). The TiPT shall meet this requirement and PARTIES shall work together to generate a procedure for such operation, per sec. 13.3.

The TiPT shall be capable of passing inspection pig as per section 7.13.2.

7.13. PIGGING REQUIREMENTS

TiPT design shall consider following requirements related to pigging:

- Enable riser cleaning with foam-pigs, brush pigs and magnet-pigs in order to remove residues, according to pre-commissioning procedure;
- Enable riser gauging, consisting of the passage of a bi-directional calliper or pig with gauging plate, as defined in design;
- Enable pigging operations in two directions;
- Internal diameter transitions may be required by PETROBRAS and will be defined in Contractual Documents. In this case, the provisions of section 7.3 shall be considered.
- The TiPT shall neither be damaged nor loose its sealing properties because of the pig passage.

NOTE: The TIPT itself will not be subjected to internal inspection with pig but is required to allow unimpeded passage of the various types of pig as stated above. The in-service pig launcher/ receiver will be installed on the top side of the FPU, therefore no disassembly of spool on the TIPT side will be required.

7.13.1. CONVENTIONAL PIG

The TiPT shall be capable of passing disc-type (Mandrel / Solidcast) pigs equipped with wire brushes. SUPPLIER shall review the TiPT design based on the overall design criteria and demonstrate to PETROBRAS's satisfaction that this can be achieved.

SUPPLIER's evaluation shall consider the dimension, material and operation of typical disc-type pigs and the minimum pig length required for the pig to pass through the TiPT without losing its seal.

7.13.2. INSPECTION PIG

The TiPT shall be capable of passing inspection pigs (ultrasonic or magnetic type inspection pig for CS riser inspection) in both directions.

7.14. INSTALLATION

SUPPLIER shall assist PETROBRAS during preparation of the TiPT installation and handling procedure. SUPPLIER shall review CONTRACTOR's installation and handling procedures.

The selected Installation method (S–, J– or reel–lay), and operational limitation, if any, will be informed by PETROBRAS within Project documentation. SUPPLIER shall inform if additional equipment (e.g. protective shrouds) will be required. PETROBRAS will arrange with the PARTIES a review of the Installation Procedures as they relate to the TIPT.

Additional FPU displacements may be considered during pull–in: increased excursions due to reduced mooring tension (Newbuilt) and application of temporary heel angle to facilitate the passage of the TiPT *Stack–up* through the support (reduce pull–in overload). The values of the installation offset and of the maximum allowable heel angle per FPU is informed in [3].

PETROBRAS, or CONTRACTOR directly, will supply all relevant details of the installation plans and requirements to SUPPLIER for review and comment regarding suitability for use with TiPT operational parameters. These details may include the following:

- General installation procedures;
- Commissioning details for the TiPT and riser;
- Pre-commissioning pig receiver dimensions;
- Special tool requirements and transfer/ pull in rigging characteristic for installation;
- Requirement for TiPT mock-ups (optional).

7.15. CONNECTION AND WELDING

The attachment of the riser to the TIPT *Extension* (*Lower CS Compact Flange* or steel *Pup Piece* if any) shall be a butt weld connection (CONTRACTOR scope). SUPPLIER shall assure that the

TIPT termination's material and dimensions, including any internal CRA layer and external coating, are compatible with the mating riser components in accordance with the Project Basis [2].

SUPPLIER shall support weld qualification *of the interface weld between the Lower CS Compact Flange* and the *Pup Piece* or the riser pipe by providing material certificates and material samples of the forged steel *Compact Flange*, if *Pup Piece* is not included within SUPPLIER scope as per [2]. Additional weld requirement of [1] and related documents shall be observed.

NOTE 1: SUPPLIER shall not be responsible for performing the weld between the TIPT termination (*Lower CS Compact Flange* neck or *Pup piece*) and the riser pipe.

NOTE 2: The weld test rings should be supplied as prolongation of the same forging of the *Lower CS Compact Flange*, but it may be supplied from a separate forging, provided that the forging material is from the same heat, undergoing the same manufacturing process, and heat-treated together with the steel *Compact Flange*.

7.16. STEEL SPACER PIPES (OPTION)

The use of steel pipes or steel forging for the Spacer Pipes, in lieu of titanium forgings, is allowed. In this case, the following requirements shall be observed:

i. Hot Rolled Bonded Clad Pipe (metallurgical clad pipe) as per [17] and Weld Overlaid clad Pipe (WoL Clad Pipes) as per [18] are accepted. Steel Spacer MLP pipes shall not be used.

ii. Steel forgings components shall be considered as risers components, as per [23], and must follow [17] requirements. In this case, Appendix A of [17] is mandatory.

iii. The permanent strain shall be evaluated and reported, and fatigue evaluation shall follow [23] accordingly.

iv. The severe Splash Zone corrosion shall comply with item 7.1.3.4 of [23] (Guidance Note), which is mandatory.

7.17. STEEL PARTS CORROSION PROTECTION

For the TiPT *Stack–up* steel parts (*Transition Spool* and *Steel Compact Flanges*), the requirements of section 7.15 of [10] shall be applied.

Additionally:

- For the *Hang–off Assembly*, the requirements for external protective coating of [5] shall apply;
- For the *Adaptor Cap*, in addition to the protective coating specified in [5], anodes shall be included to mitigate possible unavailability of the FPU cathodic protection system, and if prolonged period of exposure under water, disconnected from the FPU, is expected (e.g. long deployment period prior to pull–in).
- In case Steel Spacer Pipe is used, UNS N06625 alloy inlays shall be applied in a minimum length of 10 meters from the flange interface with the UTSJ, for any inner diameter, when un-cladded carbon steel riser is specified, to provide a galvanic buffer between the titanium and carbon steel.

8. MANUFACTURING REQUIREMENTS

Titanium parts requirements for Chemical Composition, Ingot Melting, QTS, Heat Treatment and Mechanical Properties, as well as Steel parts requirements for Forged Material, QTS and CRA Weld Overlay on forged pieces shall follow the requirements of section 8 of [10]. Requirements for pipe material for tubular section, shall follow [2].

9. INSPECTION AND MATERIAL TESTING OF TITANIUM PARTS

Titanium parts requirements for Tensile Testing, Fracture Toughness Testing, Micro and Macrostructure Evaluation, Chemical Compatibility Test for Conveyed Fluids and Non-destructive Examinations, as well as Tests Certification and Documentation shall follow the requirements of section 9 of [10].

10. INSPECTION AND MATERIAL TESTING OF STEEL PARTS

Requirements for Inspection and Material Testing of Steel Parts shall follow all the requirements of section 10 of [10].

11. COMPONENT TESTING REQUIREMENTS

All components shall pass visual, ultrasonic, and liquid penetrant inspection in accordance with SUPPLIER and this specification prior the assembly of the TIPT. In additional, final visual inspection shall be done on the assembled equipment for conformance to PETROBRAS approved drawings.

All assembly and testing shall be done according to a Company approved Inspection Test Plan (ITP) to ensure quality and safety standards are met.

11.1. SYSTEM INTEGRATION TEST (SIT)

The integration of the detached parts of the TiPT (i.e., the *Adaptor Cap/ Trumpet* and the *Hang–off Assembly*) with the *Stack–up* shall be verified for the dimensional adequacy of the coated parts (gaps), using the actual parts and fully coated. The SIT shall verify at least:

i. The unimpeded passage of the *Trumpet* along the TiPT *Stack–up*, all the way to the UTSJ cylindrical section (All Unities).

ii. The assembly of the *Transition Spool* (*End–fitting*) into the *Split Flange/ Split Stopper* (aligned), with the isolation ring/ painting (FoaK).

11.2. FACTORY ACCEPTANCE TEST

Before the final release and packaging, the TiPT will undergo final testing and review to assure all pertinent aspects of the design and fabrication are following both the PETROBRAS's specifications and SUPPLIER's design and production requirements.

SUPPLIER shall propose a factory acceptance test program for PETROBRAS acceptance to be carried out in detail on the TiPT. The factory acceptance test program will include as a minimum requirement the steps outlined in hereunder and shall accomplish the following goals:

- Demonstrate compliance with performance requirements described in this Specification and SUPPLIER design and test specification.
- Detect any unit that fails to meet required performance levels and reject them for release unless the non-conformance can be eliminated through re-qualification or mutual written consent from the PETROBRAS.

The factory acceptance test program shall be performed in all manufactured TiPT, and shall include as a minimum requirement the steps outlined in hereunder:

- Dimensional check of main, interfacing dimensions;
- Electrical isolation of all titanium studs of the Compact Flanges;
- Electrical isolation test of the external coating;
- Leak test of the assembled Compact Flange, as per sec. 4.6 of [43] and [38];
- Hydrostatic test (as detailed in section 11.2.1).
- TRMS signal continuity test, as per the Project applicable TRMS specification [12], [13] or [14].

SUPPLIER Factory Acceptance Testing (FAT) specification shall include test conditions, procedures, measurements to be taken, and acceptance criteria specifically for the TiPT to be manufactured. The FAT specification shall be reviewed and approved by PETROBRAS prior to initiation of factory acceptance testing.

11.2.1. HYDROSTATIC PRESSURE TEST

Hydrostatic testing, as part of the FAT, shall be performed on the assembled TiPT *Stack–up* to demonstrate function and integrity. Hydrostatic testing is not required for individual parts. If any part of the Stack–up needs to be disassembled for any reason, the leak test of the disassembled connections and the hydrostatic test shall be repeated.

Internal hydrostatic tests of the TiPT shall be performed at 1.5x of the Project design pressure specified in [2] and prior to delivery. Agreement shall be obtained with PETROBRAS's representative that pressure stabilization has occurred before proceeding with the hold period of the pressure test. Test duration for all tests shall be a minimum of thirty (30) minutes after pressure stabilization. All components shall be visually inspected for leaks throughout the test period. The test shall be performed in air to allow visual inspection.

Tests shall be performed with end caps installed on both ends of the riser Stress Joints. Following the completion of the test, SUPPLIER shall be responsible for removing the end cap and the associated heat-affected zone (HAZ) from the lower end of the Extension, leaving a clean straight edge ready for beveling, or testing flange.

The fluid media shall be city tap water (fresh water) and the test temperature shall be ambient (outside approx. 20°C). The acceptance criteria for a successful test shall be no pressure drop due to leakage. A pressure drop of 0.5% of the hydrostatic test pressure due to ambient temperature fluctuation is permitted. Pressure recorders and charts shall be utilized.

11.2.2. TEST DOCUMENTATION

Internal pressure test reports shall include, but not necessarily be limited to, the following information:

- Detailed description of test equipment with diagram of test hook-up, and test procedures;
- Test temperature records;
- Test pressure records;
- Test equipment calibration certificates;
- Test results and interpretation;
- Dead weight Pressure Test records.

Calibration certificates (valid within the previous 6 months) shall be supplied for the temperature recorder, the pressure recorder, and the dead weight tester.

11.3. DIMENSIONAL AND VISUAL INSPECTION

All components shall be dimensionally and visually inspected prior to delivery. Rework or modifications shall not be allowed without PETROBRAS approval. All products and forgings shall be visually inspected with 100% surface coverage of all accessible surfaces to be free from visible laps, cold shuts, cracks, porosity, slag, excessive scale, and other surface imperfections.

11.3.1. DIMENSIONAL INSPECTION

Pipe sections shall be dimensionally inspected or, each end and at the approximate center location for compliance to the PETROBRAS approved. Flanges shall also be dimensionally inspected for compliance to the approved drawing. Reports detailing the actual dimensions shall be provided as part of the MPS.

11.3.2. VISUAL INSPECTION

Pipe, flanges and weldments shall be 100% visually inspected on the entire OD and accessible ID surfaces. Any abnormalities, local grind-outs, etc. shall be recorded and documented. This applies even if the area is within the dimensional tolerances. The relative location, length, width and depth of each abnormality shall be recorded. External polymer cover shall be 100% visually inspected for damage as crack or cuts. Repair of the damaged area, if any, is mandatory.

11.3.3. FASTENERS

Fasteners shall be 100% visually inspected and dimensionally inspected to PETROBRAS approved drawing by the SUPPLIER, as per [16].

12. QUALIFICATION AND MPQT OF TITANIUM PULL IN TUBE

The following tests, considered a minimum requirement for acceptance of the titanium parts, shall be performed before TiPT supply, unless otherwise stated below.

12.1. METALLIC PARTS

The test matrix for titanium base material is presented in Table 12.1, comparing the tests required to be performed prior to the start of Work ("Qualification") and those required to be performed during the Work, as part of MPQT of titanium forgings.

Table 12.1 – TIPT Titanium Base Material Qualification.

	Tests	ASTM-B381-F29 ASTM-B381-F23 (NOTE 1)		OTHER TITANIUM ALLOYS (NOTE 6)	
		Qualification	MPQT	Qualification (NOTE 6)	MPQT
a)	Corrosion test, as per the method A of [29]	No	Yes (NOTE 2)	Yes	Yes (NOTE 2)
b)	Chemical compatibility assessment with Project fluids (NOTE 3)	No	Yes	Yes	Yes
c)	Tensile test at higher temperature, to determine the de–rating of material properties of yield strength, tensile strength and E–modulus	No	Yes (NOTE 2)	Yes	Yes (NOTE 2)
d)	S-N fatigue testing, as per [34]	No (NOTE 4)	No	Yes	No
e)	Fracture toughness test, as per [33], and section 9	No (NOTE 4)	No	Yes	No
f)	FCG test, as per [35]	No (NOTE 4)	No	Yes	No
g)	Chemical composition (material certificate) as per [31] (NOTE 5)	No	Yes	Yes	Yes
h)	Micrography/ macrography, per sec. 9	No	Yes	Yes	Yes
i)	Tensile test, as per [30] (min. yield strength @0.2% offset, min. tensile strength, % min. elongation, calculated elastic modulus). Additional test requirements per sec. 9. Acceptance criteria per [31]	No	Yes	Yes	Yes
j)	Bend test, as per [36]	No	Yes	Yes	Yes
k)	Density	No	Yes	Yes	Yes

NOTE 1: For top riser material severity class defined as "0", according to NACE [28].

NOTE 2: these tests may be waived if already performed prior to the start of Work, at SUPPLIER discretion.

NOTE 3: these may basically be weight-loss corrosion tests for the main conveyed fluids and for the chemicals intended to be injected into the risers, as per the requirements of section 9. For titanium alloys grade F29 ELI, the chemical compatibility test is not required prior to the start of Work.

NOTE 4: the fatigue related tests, d) to f), may be waived, for unwelded forgings of titanium grade 29 ELI or grade 23 ELI, and in this case the curves qualified by PETROBRAS (JIP coordinated by SwRI [21]) shall be employed.

NOTE 5: Weight percentile composition of main alloy elements shall be informed, as well as other residual elements with concentration level greater than 0.1% (individual) or 0.4% (total). In addition, the report shall include the percentile composition of the following interstitial elements: carbon, oxygen, nitrogen, hydrogen and iron. Other elements may be also reported at the discretion of SUPPLIER.

NOTE 6: For other titanium alloy not framed in grade F29 (UNS R56404) ELI and grade F23 (UNS R56407) ELI (for maximum design temperature up to 80°C), all tests a) to k) shall be performed prior to the BID.

The parameters to be used to assess the similarity between the Project proposed and the qualified alloys shall be the results of tests g) to k), which shall be performed as part of MPQT and therefore for whatever alloy is selected.

12.2. EXTERNAL POLYMERIC COATING

Requirements for coating qualification are presented in [5], for titanium and steel parts in the scope of supply.

All materials used in the fabrication of the TiPT shall be successfully submitted to qualification testing in accordance with accepted standards or approved SUPPLIER procedures. PETROBRAS shall have access to the material test results for verification prior to commencement of production operations.

PETROBRAS acceptance of previous qualification to be presented by SUPPLIER, as well as proposed qualification programs for the Project does not waive SUPPLIER\CONTRACTOR from the responsibility to deliver products perfectly fitted for the Project service, based on Project specification and any other information provided by PETROBRAS.

13. QUALITY CONTROL AND REPORTING

This section defines the quality assurance requirements to be observed in performance of the procedures defined by this specification.

~~Quality is a prime consideration for ensuring the structural integrity of the TiPT. Inspection of parts of the TiPT in service may not be possible and removal of the riser to repair or replace any TiPT Parts would be extremely costly. SUPPLIER shall demonstrate to PETROBRAS's satisfaction that a quality system is in place to ensure that the TiPT will be manufactured per this specification.~~ [EXCLUDED]

Quality management procedures will be routinely performed in every phase of design and manufacture in accordance with the Quality System Manual. Internal quality standards will comply with ISO 9001.

SUPPLIER shall provide details on its Quality Assurance Program to PETROBRAS prior to issuance of a PURCHASE ORDER.

13.1. QUALITY PLAN AND QUALITY CONTROL PLAN

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.

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.

The criteria of material SUB-SUPPLIER conformity of [41] shall also be observed.

SUB-SUPPLIERs shall also refer to document "QHSE Management for Suppliers / Subcontractors".

13.2. REPORTS AND RECORDS

Records will be maintained to sufficiently document the performance of each operation required by this specification and to identify all materials used in the processing. These records will be formal documentation (MIPs) containing manufacturing and quality control sign offs for each step of the process. These records are available to the PETROBRAS upon request and are retained by

SUPPLIER for a certain period as Contract Specifications (length of time to be confirmed by PETROBRAS prior to award of contract).

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

- QA/QC procedures; to be submitted to PETROBRAS for review prior to 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;
    - NDE Procedures;
    - FAT Procedures;
    - Document Control Procedures;
    - Traceability Plan;
    - Non-conformance Procedure including examples of report form to be utilized.
- Design Basis and Methodology (DBM) to be submitted to PETROBRAS for review prior to start 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 of the main TiPT Parts;
    - Chemical composition and mechanical properties of titanium and steel components (yield strength, tensile strength, percent elongation, area reduction and other required properties);
    - Component material lists and descriptions, including designation of any Proprietary material, whose technical specification may be revised by PETROBRAS in SUPPLIER premises;
    - List of Design Drawings to be provided;

- Design calculations and reports for each element to be provided.

The final documentation of the detailed design shall include:

- Qualification Dossier, covering the items in section 12;
- Design Basis and Methodology;
- Design Report;
- Material compatibility (galvanic) assessment (if not included within the Deign report);
- Chemical Compatibility Report (with respect to PETROBRAS injected fluid data informed within [2]), and alerts to other harmful fluids and concentrations for the selected titanium alloy, listed or not listed in [2], based on SUPPLIER experience;
- Manufacturing Procedure Specification (MPS) to be submitted to PETROBRAS for review prior to 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;
  - Compact Flange assembly, torqueing and pre-loading;
  - Factory acceptance testing.
- Inspection and Maintenance Manual, as pe section 13.3;
- General assembly drawings of TIPT and mock up drawings, as per section 13.4;
- Inspection and test reports, records, and procedures as defined by this Specification;
- As-built drawings or as-built dimensional reports;

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.

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

Design calculations and reports of the TiPT and its parts shall be issued to PETROBRAS for review prior to the manufacturing.

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

All non-conformity reports, including concession requests, shall be submitted to PETROBRAS for review.

13.3. INSPECTION AND MAINTENANCE MANUAL

PARTIES shall work together generate an inspection and maintenance manual for the Titanium Pull in Tubes, to be issued by CONTRACTOR as part of the final documentation of the Project.

This manual shall present any inspection and repair procedure necessary to avoid the TiPT failure during the whole specified project operational life, as per description given in sections 7.11 and 7.12.

All necessary tools, materials, inspection methodology, acceptance criteria and inspection interval shall be present in this manual, for each necessary inspection.

A list of possible harmful fluids (chemical compatibility) and critical operational limits (temperature, electrical potential of the CP system of the FPU, etc.) shall be included as cautions.

13.4. DRAWINGS

Prior to start of manufacture, the General Assembly drawings of the TIPT shall be supplied to PETROBRAS for review. Subsequent revisions to drawings shall also be issued to PETROBRAS for review, as they are prepared. GA drawings for both TIPT shall include the following minimum information:

- Overall dimensions and tolerances of length and diameters (after coating);
- View of the *Hang–off Assembly* and the *Transition Spool* in the final position, showing:
    - Dimensional details of the top *Standard Flange* and test port (if required), indicating also the elevation “A” of Figure 7.2 and the lateral and angular offset of the flange as per Figure 7.3, if present;
    - Detail of location and the specification of the electrical isolating system used (see sec. 5.4–ii).
- View of the interface with the Project selected *Support–Tube*, showing:
    - View of the bent TiPT, with the *Adaptor Cap* and *Trumpet* into the *Support–Tube* contour (as per [7]);

- Axial distance (clearance) between the *TSJ Compact Flange* and the Adaptor Cap and Trumpet;

- Distance from the *Riser Compact Flange* face to the riser end ("1st weld");
- Details of the TiPT polymeric coating thicknesses and layers;
- Position of the CoG (in air and in water);
- Total weights;
- Material identification and source part number;
- Details of handling attachments;
- For segmented TiPT *Stack–up*: also include the length of each segment and detail view of the field joint coatings between them.

When required SUPPLIER shall provide a detailed drawing with tolerances of the *Dummy End–Fitting* and *Dummy Adaptor Cap* (mockups) to PETROBRAS for review.

Final documentation shall also include detailed drawings for the following individual TiPT Parts: UTSJ and LTSJ (final machined forgings), the *Split Hang–off Flange* (with the *Split Stopper* if present), and the Adaptor Cap subsystem with the Trumpet.

13.5. TRACEABILITY AND MARKING

13.5.1. RAW MATERIAL

Traceability of components shall be established during fabrication, verified at receiving inspection, and shall be fully documented throughout the entire manufacturing process.

The forger shall have an established material traceability plan. Each forging shall be given a unique serial number. The serial number shall be traceable to the heat number and heat treat batch number. Full traceability shall be maintained with respect to the following, as applicable: Heat, Ingot, Heat-Treat Sequence or lot.

13.5.2. PRODUCT MARKING

The TiPT must be stamped for permanent identification, including identifying features such as size, rating, and SUPPLIER's assigned serial number. Additional marking for riser tagging may be required by PETROBRAS, wherefore SUPPLIER shall seek PETROBRAS concordance with the product marking.

NOTE: SUPPLIER may use an individual mark (P/N or S/N) for each fabricated item. This mark, transferred on the associated documentation, allows guaranteeing the traceability.

13.5.3. MANUFACTURING OPERATOR AND INSPECTOR MARKING

On all kind of document (manufacturing or test router, report or ITP), the person who will handle the task shall affix his own mark and signature.

13.6. HANDLING, STORAGE AND SHIPPING

Storage and handling procedures shall provide for techniques and protections to avoid mechanical and weather damage. Lifting and support of the TIPT shall be done in a manner that avoids concentrated loads or single point lifts. Schematic drawing of the support points, lifting points and transport crate shall be included within the handling, storage and shipping procedure.

TIPT systems shall be shipped via steel shipping skids or fully boxed steel beam truss baskets for offshore shipment. Pad eyes and lifting sets shall be designed per [26].

The TiPT skid shall be clearly marked by paint stencil to identify the contents by size, serial number, CoG and lifting points. The TiPT shall be protected against moisture/corrosion or any foreseeable industrial atmosphere degradation of the polymer cover, if it may be stored in an open air, unprotected area.

13.7. DOCUMENTATION REQUIREMENTS (DATA BOOK)

Copy of a final report for each manufactured TIPT shall be submitted to PETROBRAS for review and approval prior to final acceptance. This report shall contain Purchase Order number, part number, dash number, serial number, actual weight, all material certifications, dimensional verification, test results and on-site verification of current visual examination compliance by site inspectors and surveyors, and shall certify that the product was manufactured and inspected in accordance with the requirements of applicable drawing(s) and this Specification.

Additional documentation shall be submitted in accordance with [2].

SUPPLIER shall submit a detailed description of the manufacturing process.

SUPPLIER shall document the design with drawings and calculations.

All tests and clarifications required for the design acceptance and the evaluation of the TiPT and receptacle shall be submitted.

SUPPLIER shall submit the quality control procedures for PETROBRAS review and approval.

SUPPLIER shall submit document stating all deviations to this Specification.

13.8. INSPECTION AND TEST PLAN

This section concerns the product fabricated by SUPPLIER as well as the product purchased by SUPPLIER.

At the beginning of the Project, within the contractual deadlines, the Inspection and Test Plans (ITP) for all stablished items shall be issued for PETROBRAS comments. SUPPLIER shall obtain with PETROBRAS all self-assigned Inspection points (mainly Hold and Witness points) before the start of the manufactures.

All testing procedures are subject to both internal (SUPPLIER) and external (PETROBRAS or PETROBRAS's representative) Quality Control oversight and verification. PETROBRAS approved procedures shall be issued with reasonable advance before the start of manufacture.

The same document shall be used by the SUPPLIER and its SUB–SUPPLIER.

The following ITP shall be produced:

- Forgings and material testing ITPs;
- Machining ITP(s);
- Weld and Heat treatment ITPs (if permitted);
- NDE ITP
- Coating/ painting ITP;
- Cladding ITP(s) (inner surface cladding and sealing surfaces);
- Titanium and Steel Parts ITP (assembly, final painting, FAT and other tests, etc.).

The ITP sums up the inspection points, applied by:

- SUB-SUPPLIER;
- SUPPLIER;
- PETROBRAS and CONTRACTOR;
- 3rd Party Inspection.

The ITP shall be submitted for PETROBRAS review. All PETROBRAS holding and witnessing points shall be confirmed prior to start of manufacturing.

The inspection points are defined hereafter:

Table 10.1 – Inspections Points and Definitions

Inspection Level	Definition
H: Hold Point	A point at which work cannot progress beyond, until the activity has been witnessed or written approval has been given by the parties who have designated the hold point.
W: Witness Point	A point where the opportunity to witness shall be given to the parties who have designated the witness.
W1: FoaK	A Witness Point limited to the First of a Kind event.
M: Monitor Point	Activity surveillance on a random basis to verify compliance with contract specifications and procedures.
R: Review Point	Evaluation of Project generated documentation.

Contractual aspects of the inspections (including notification for inspection issuing deadline and notification date revision) shall adhere to the Contractual Guidance for Quality Management, as per [1].

APPENDIX I – HYDROGEN INDUCED CRACK DUE TO CP SYSTEMS – LAYERS OF SAFETY