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INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	Original Issue – Based on ET-3000.00-1514-270-PAZ-001=C, ET-3000.00-1514-270-PAZ-002=C, and ET-3000.00-1514-270-PAZ-003=0 requirements
A	Inclusions and modifications are highlighted in yellow

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	30/12/2020	08-Mar-21							
DESIGN	EECE/EES	EECE/EES							
EXECUTION	UT6N	UT6N							
CHECK	C5DR	BTLL							
APPROVAL	UP65	UP65							

CONTENTS

1. INTRODUCTION

1.1. SCOPE

1.1.1. This specification is based on guidelines requirements set forth by the international standards ISO 13628-4 (ref. [16]), ISO 13628-15 (ref. [19]) and API RP 17R (ref. [20]). Its purpose is to complement, reaffirm, clarify and modify specific requirements of these codes related to subsea connector systems to be applied to Vertical Connector Modules (VCMs), Horizontal Connector Modules (HCMs) and Pivotable Vertical Connector Modules (PCMs) for use with flexible lines (first or second end installation) and also for horizontal rigid spools (applicable only for HCMs), setting out uniform details of normative requirements, enough to standardize understandings between PETROBRAS, CONTRACTORS and SUPPLIERS, as well as to provide specific data to allow the application of these systems.

1.1.2. Subsea connector systems for tie-in with rigid pipelines by means of vertical diverless rigid spools are outside the scope of this specification. For these systems ref. [1] shall be followed. Subsea connector systems designed to be tied-in with diver assistance are also outside the scope of this specification.

1.2. APPLICABILITY

1.2.1. This specification applies to subsea connector systems used in subsea end-connections to flexible pipelines or umbilicals with VCMs, HCMs, and PCMs. The abbreviation CM is used throughout this specification to refer to VCMs, HCMs, and PCMs indistinguishably.

1.2.2. Additionally, this specification can also be used to horizontal diverless rigid spool applications with HCMs.

1.2.3. The basic connector systems components, which are within the scope of this Technical Specification, are:

a. Vertical Connection Module (VCM) / Horizontal Connection Module (HCM) / Pivotable Vertical Connection Module (PCM).
   i. Outboard hub
   ii. Subsea connector
   iii. Soft landing system
   iv. Gooseneck
   v. ROV intervention panel
   vi. Back seal test circuit

b. Inboard hub.

c. Landing porch.

d. Guide system.

e. Seal system.

f. Electrical connection system.

g. Tooling
   i. Connection tool
   ii. Stroke / Pull-in / Pull-down tool
   iii. Ring gasket replacement tool

iv. Inboard hub cleaning tool

h. Bases
   i. Transportation skid
   ii. Test base

i. Caps
   i. Block cap
   ii. Test cap
   iii. Protection cap

NOTE: All definitions are described in section 2.2 herein.

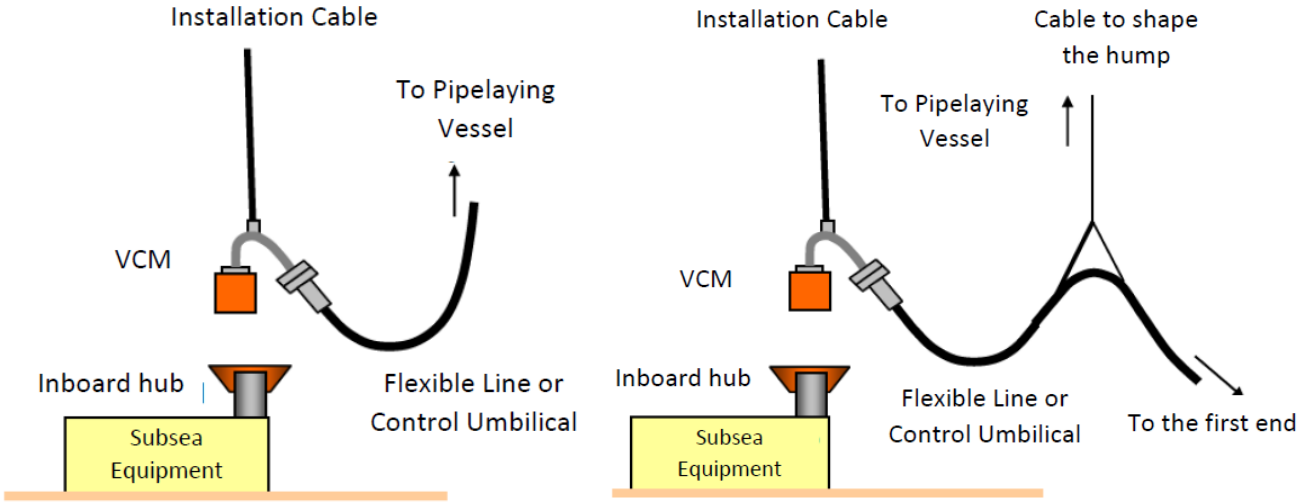


Figure 1 - First (left) and second (right) end connection

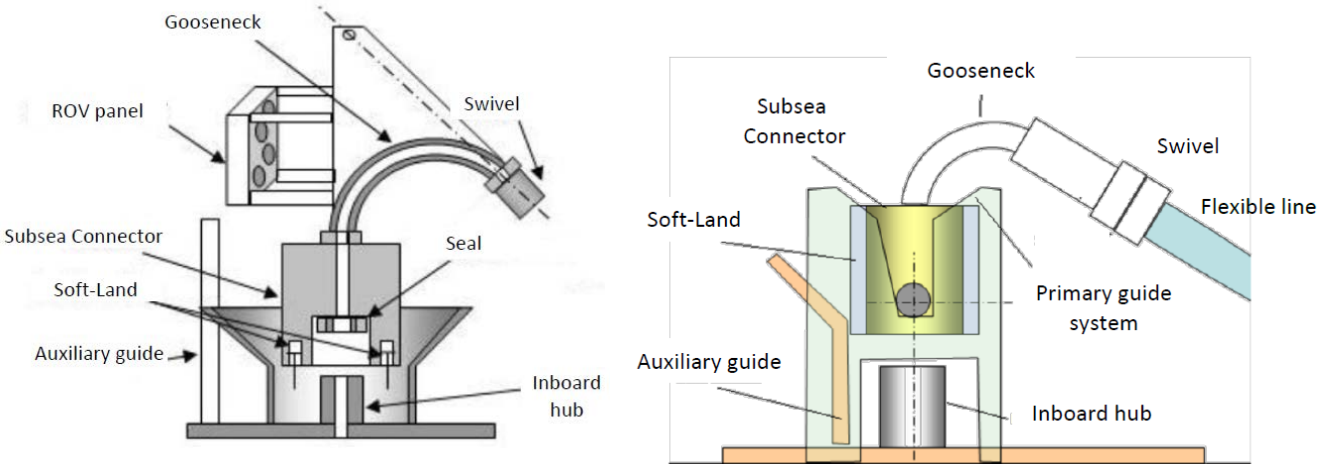


Figure 2 – VCM (left) and PCM (right) main components (illustrative)

2. TERMS AND DEFINITIONS

2.1. VERBAL TENSES

2.1.1. The following definitions apply to the use of the content within this document:

a. “Shall” - is used to indicate that a provision is mandatory.

b. “Should” - is used to indicate that a provision is not mandatory but is recommended as good practice.

c. “May” - is used to indicate that the adoption of a provision is based on the discretion of the user of this Technical Specification.

d. “Shall not” - Forbidden action or requirement.

2.2. DEFINITIONS

2.2.1. All terms defined in ISO 13628 parts 1 (ref. [15]), 4 (ref. [16]), and 15 (ref. [19]), and API RP 17R (ref. [20]) apply, in addition to the following:

2.2.2. **Back Seal Test Circuit**
Hydraulic circuit that allows testing the seal integrity without applying pressure to the equipment bore.

2.2.3. **Block Cap**
Component of the subsea connector system that substitutes the connector and, when latched onto the subsea equipment’s hub, intends to contain its internal piping pressure, isolating it from the external environment and turning it able to operate the pipeline for an indefinite time in this condition.

2.2.4. **Certification**
Third-party issue of a statement, based on a decision following review, that fulfillment of specified requirements has been demonstrated related to the products, processes, or systems. Review shall, in this context, mean verification of the suitability, adequacy and effectiveness of selection and determination activities, and the results of these activities, regarding fulfillment of specified requirements by an object of conformity assessment (based on ref. [25]).

2.2.5. **Connector Module (CM)**
It is the main component of the Subsea Connector System, attached to the end of the flexible flowline or umbilical or to the spoolpiece of the horizontal diverless rigid spool.

This Technical Specification describes three types of Connector Modules:

a. Vertical Connector Module (VCM): applicable to vertical tie-in with flexible lines or umbilicals (Figure 2 - left).

b. Horizontal Connector Module (HCM): applicable to horizontal tie-in with flexible lines or umbilicals and horizontal diverless rigid spools.

c. Pivotable Vertical Connector Module (PCM): applicable to vertical tie-in with flexible lines or umbilicals (Figure 2 - right).

The CM is made up of a subsea connector, soft landing system (as applicable), ROV panel and parts of the guide system.

NOTE: The abbreviation CM is used in this specification to refer to VCM, PCM or HCM.

2.2.6. **CONTRACTOR**
Company directly awarded by PETROBRAS to supply components, structures, and/or part or whole subsea system. CONTRACTOR may award sub-suppliers to deliver part of the scope of work.

2.2.7. **Diverless**
Any operation performed with remote operated vehicle and/or tool, without assistance of diver.

2.2.8. **Diverless Horizontal Rigid Spool**
Comprises one rigid spoolpiece and two HCMs (one module at each end of the spoolpiece). Sometimes the diverless horizontal rigid spool is denominated “spool” in this specification.

2.2.9. **First and Second End connection**
Flowline subsea connection to subsea equipment performed before or after the pipelaying on the seabed, respectively.

2.2.10. **Funnel Down**
Component of the guide system shaped as a cone downwards, positioned at vertical Connector Modules.

2.2.11. **Funnel Up**
Component of the guide system shaped as a cone upwards positioned at the subsea structure.

2.2.12. **Guide System**
A system which purpose is to guide the CM during its landing into the inboard hub or landing base / porch, providing the necessary alignment to allow full connection of the connector with the hub.

2.2.13. **Flexible Pipe**
Pipeline composed by several layers from different materials, with lower bending stiffness when compared to a rigid pipeline with similar dimensions.

2.2.14. **Forced coupling system**
System capable to properly couple the PCM even under residual line loads.

2.2.15. **Gooseneck**
Steel pipe bent that is part of the VCM or PCM where the interface (by flange or swivel) for the flowline is made.

2.2.16. **HCM landing porch**
Guiding structure responsible for the vertical landing and coupling of the HCM on the subsea equipment.

2.2.17. **Hot Stab**
Type of hydraulic connector, operated by ROV, that performs the hydraulic connection among the ROV and the CM and their tools.

2.2.18. **Inboard Hub**
Component of the Subsea Connector System, resident at the subsea structure or termination base of a rigid pipeline, flexible line or umbilical to which the CM will be connected.

2.2.19. **Lifting device**
Component or structure where the installation cable is connected and designed to withstand its loads.

2.2.20. **Material Requisition (RM)**
Project document intended for the procurement of materials that establishes all technical requirements and complementary instructions necessary for this objective. It lists all attachments that composes the scope of supply, such as Technical Specifications, Project Description, Technical Standards, Drawings, Data Sheets, etc.

2.2.21. **Pipelines**
Transport pipelines and production/service injection flowlines, rigid or flexible, installed on the seabed.

2.2.22. **PIG**
Pipeline inspection gauge component that is displaced inside the flowline for purposes of cleaning or internal inspection.

2.2.23. **Protection Cap**
Component of the subsea connection system that it is not pressure containing. It intends to protect the hub against accidental damage on the sealing areas, drop of objects inside the hub and prevent calcareous deposits when latched on subsea equipment's hub.

2.2.24. **Prototype**
Component or equipment piece manufactured on an individual basis in order to perform design qualification tests.

2.2.25. **Qualification**
Testing using a prototype or production unit, if appropriate, in order to verify that the design meets all premises, including product life cycle conditions (testing, installation, operation, intervention and decommission). PVT is also used to refer to qualification in this specification. See also "Validation".

2.2.26. **Ring Gasket Replacement Tool**
Device operated by ROV used to replace the ring gasket, without the need to retrieve the CM to sea level.

2.2.27. **ROV Panel**
Interface panel used for operation and intervention via ROV.

2.2.28. **Seal Plate**
Plate where the gaskets are mounted onto, allowing them to be handled concomitantly.

2.2.29. **Seal System**
System used to stablish a leak tight sealing between the subsea connector and inboard hub. This system may be made up of a seal plate and gaskets.

2.2.30. **Soft Landing System**
System that allows the final landing of vertical CMs to be smooth, preventing damages to the interfacing sealing elements between the subsea connector and the inboard hub.

2.2.31. **Spoolpiece**
Piping accurately fabricated with sections of rigid linepipes (straight sections and bends).

2.2.32. **Subsea Connector**
Component responsible for locking the CM to the inboard hub, as well as for energizing the ring gasket.

2.2.33. **Subsea Connector System**
System made up of a connector module, inboard hub, sealing and guide systems used to connect flowlines to subsea structures, including associated tools, bases and caps, needed for the fabrication, tests and installation of the Subsea Connector System.

2.2.34. **Subsea Structure / Equipment**
System made up of components to be installed underwater for use in subsea oil and gas production or transportation in offshore fields.

2.2.35. **SUPPLIER**
Company responsible for the design and manufacturing of the CM.

2.2.36. **Stroke tool**
Tool / mechanism used to displace the HCM forward to the inboard hub.

2.2.37. **Swivel**
Component intended to interconnect a subsea flowline to equipment such as a subsea connector system or structure. Its main function is to allow relative rotation between the pieces of equipment attached to its both ends while they are being launched (installed), in order to ensure the correct alignment of the equipment whist keeping its sealing and pressure containing capacity.

2.2.38. **Technical Specification**
Document that contains technical requirements that CONTRACTOR and its sub-suppliers shall fulfill.

2.2.39. **Test Base**
Portable base provided with a hub and porch (as applicable) that allows landing, coupling and testing the CM locking mechanisms and the sealing system in the conditions forecasted for the installation (similar structural components and inclination when compared to the inboard hub of the subsea structure).

2.2.40. **Test Cap**
Temporary component of the subsea connection system that is specified to be used during the hydro-test and (pre)commissioning of the pipeline.

2.2.41. **Third-Party Conformity Assessment Body**
Body or person that is independent of the person or organization that provides the object, and or user interests in that object that performs conformity assessment services (see ref. [25]).

2.2.42. **Tools**
Any device or equipment piece used to install, lock, unlock, uninstall, and test the CM.

2.2.43. **Transportation Skid**
Base used to transport the CM (onshore and offshore), protecting it against possible damages.

2.2.44. **Validation**
Confirmation that the operational requirements for a specific use or application have been fulfilled through the provision of objective evidence

NOTE: Typically, validation is achieved by qualification testing and/or system integration testing.

2.2.45. **Verification**
Confirmation that specified design requirements have been fulfilled, through the provision of objective evidence

NOTE: Typically, verification is achieved by calculations, design reviews, and hydrostatic testing.

2.3. ABBREVIATIONS

1.	BAP	WCT Production Base ("*Base Adaptadora de Produção*", in portuguese)
2.	CM	Connector Module
3.	CoG	Center of Gravity
4.	CRM	Corrosion Resistant Material
5.	DRS	Diverless Rigid Spool
6.	FAT	Factory Acceptance Test
7.	HCM	Horizontal Connector Module
8.	ID	Internal Diameter
9.	MDR	Master Document Register
10.	MEG	Mono Ethylene Glycol
11.	PCM	Pivotable Vertical Connector Module
12.	PETROBRAS	Petróleo Brasileiro S.A.
13.	PLET	Pipeline End Termination
14.	PSL	Product Specification Level
15.	PVT	Performance Verification Test
16.	OD	Outside Diameter
17.	RM	Material Requisition ("*Requisição de Material*")
18.	SS	Stainless Steel
19.	SIT	System Integration Test
20.	SMYS	Specified Minimum Yield Strength
21.	SWL	Safe Working Load
22.	UV	Ultraviolet
23.	VCM	Vertical Connector Module
24.	WCT	Wet Christmas Tree

3. REFERENCES

3.1. DOCUMENT PRIORITY AND CONFLICTS

3.1.1. The documents listed in sections 3.2 and 3.3 below are essential for the use of this TECHNICAL SPECIFICATION. The documents listed in section 3.4 are complementary.

3.1.2. For dated references, only the mentioned edition/revision applies. For undated references, the latest edition of the referenced document (including any amendments), in force when the contract between PETROBRAS and CONTRACTOR was awarded, applies.

3.1.3. Specifically, for API and ISO equivalent standards, CONTRACTOR shall consider the most updated edition between them.

3.1.4. In case of conflict between this TECHNICAL SPECIFICATION and any other document, the following precedence order prevails (decreasing order):

a. The Contract Terms celebrated between PETROBRAS and CONTRACTOR.

b. The RM from PETROBRAS, which makes reference for this Technical Specification.

c. This Technical Specification.

d. PETROBRAS documents listed in section 3.2.

e. Codes and Standards listed in section 3.3.

f. Documents indicated in section 3.4.

3.2. TECHNICAL SPECIFICATIONS

Ref.	Designation	Title
[1].	I-ET-3000.00-1500-24A-PEK-001	Subsea Connector Systems for Diverless Rigid Spool
[2].	ET-3000.00-1521-600-PEK-001	*Projeto de Interfaces para Operaçoes com ROV*
[3].	ET-3000.00-1500-940-PEK-001	*Projeto de proteção catódica para equipamentos submarinos*
[4].	ET-3000.00-1500-251-PEK-001	*Fixadores em Aço Baixa Liga de Alta Resistência para Aplicação Submarina*
[5].	ET-3000.00-1500-251-PEK-002	*Rastreabilidade de Fixadores de Alta Resistência para Utilização Submarina*
[6].	ET-3000.00-1500-29B-PMU-001	*Fixadores de ligas resistentes à corrosão para utilização em umbilicais submarinos*
[7].	I-ET-0000.00-0000-431-P9U-002	Wet Thermal Insulation for Subsea Equipment
[8].	ET-3000.00-1500-600-PEK-007	*Envelope de Cargas Combinadas Admissíveis de Módulos de Conexão Submarina*
[9].	I-ET-3000.00-1500-270-PEK-002	Subsea Swivel Requirements
[10].	ET-3000.00-1500-610-PEK-002	*Eslingas e Skids para Transporte de Equipamentos Submarinos*
[11].	I-ET-3000.00-1500-24A-PEK-002	Test Requirements for Subsea Connector Systems for Diverless Rigid Spool

Ref.	Designation	Title
[12].	ET-3000.00-1520-612-PEK-001	*Dispositivo de Manuseio e Tombamento de Módulos de Conexão Submarina de Dutos e Umbilicais*

3.3. ESSENTIAL CODES AND STANDARDS

Ref.	Designation	Title
[13].	N-2037	*Pintura de equipamentos submersos em água do mar*
[14].	ISO 10423 API 6A	Wellhead and Christmas Tree Equipment
[15].	ISO 13628-1 API RP 17A	Design and operation of subsea production systems – General requirements and recommendations
[16].	ISO 13628-4 API 17D	Subsea Wellhead and Tree Equipment
[17].	ISO 13628-8 API RP 17H	Remotely Operated Vehicle (ROV) Interfaces on Subsea Production Systems
[18].	ISO 13628-9 API RP 17M	Remotely Operated Tool (ROT) Intervention Systems
[19].	ISO 13628-15 API 17P	Subsea Structures and Manifolds
[20].	API RP 17R	Recommended Practice for Flowline Connectors and Jumpers
[21].	DNVGL-RP-B401	Cathodic Protection Design
[22].	DNVGL-RP-O501	Managing Sand Production and Erosion
[23].	API RP 14E	Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems
[24].	DNV-RP-D102	Failure Mode and Effect Analysis (FMEA) of Redundant Systems

3.4. COMPLEMENTARY REFERENCES

Ref.	Designation	Title
[25].	ISO 17000	Conformity assessment – Vocabulary and general principles
[26].	ANSI/NACE MR0175 ISO 15156	Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons

4. SERVICE CONDITIONS

4.1. The design shall comply with ISO 13628-15 (ref. [19]) and ISO 13628-4 (ref. [16]), clause Design and Performance Requirements, as well as with the specifications for the following items, which complement the general service conditions and standardize details of the listed requirements.

4.2. The values of the variables of the items described below, which make up the service conditions specified for the application, are defined in the RM or in its referenced documents:

a. Design pressures.

b. Maximum and minimum design temperatures.

c. Composition of fluids carried by the flexible line or umbilical.

d. Environmental data and water depth.

e. Control and chemical injection fluids, if applicable.

f. Maximum and minimum design hydraulic pressures.

g. Minimum design life.

h. Maximum flexible line or umbilical loads.

i. Maximum rigid spool loads and dimensions, if applicable.

5. DESIGN AND FUNCTIONAL REQUIREMENTS

5.1. GENERAL

5.1.1. Product Specification Level

5.1.1.1. Pressure containing/controlling components of the connection systems herein defined shall comply with the PSL (as defined in ref. [14]) specified in the RM. In case it is not specified in the RM, it shall be considered PSL 3G.

5.1.2. Operation

5.1.2.1. The system shall be operated with no diver assistance and no guiding cable (guideline) for installation of the flexible line (both for first and second end installation) or rigid spool, as applicable.

5.1.2.2. The CM shall be designed without considering the use of a heave compensation system during its landing onto the subsea structures, unless clearly stated otherwise in the RM.

5.1.2.3. CONTRACTOR and/or SUPPLIER shall submit to PETROBRAS, in the technical proposal, an installation and recovery procedure. Such document shall detail all installation steps (CM handling on vessel, flexible line x CM connection for first and second end or rigid spool installation, overboarding, subsea approaching to subsea structure for tie-in, soft-landing actuation, tooling actuation, locking, and procedures for the recovery operation). The

installation and recovery procedure shall present the facilities required for the CM handling and operation, such as, padeyes to topple the connector module for flexible line connection.

5.2. CONNECTOR MODULE

5.2.1. Interface with Spoolpiece / Gooseneck or Subsea Structure Piping

5.2.1.1. The type (if flanged or welded) and dimensions of the interface between gooseneck / spoolpiece and flowline / umbilical, as well as between the inboard hub and the subsea equipment piping are defined in the RM.

5.2.1.2. If the interface is welded, sample rings of the material shall be provided for the purpose of welding qualification, as applicable. Quantities of rings and dimensions are provided in the RM.

5.2.2. Interface for ROV Operations

5.2.2.1. General requirements for the design of interface used in ROV operations, including tooling, are defined in the RM. All requirements of ref. [2] shall be followed, as well as those from ISO 13628-8 (ref. [17]).

5.2.2.2. All ROV actuation interfaces using either hot stabs or control valves shall allow free access for a workclass ROV.

5.2.2.3. All receptacles for hot stab shall be supplied with an associated dummy stab. Hot stab parking places shall also be provided for each receptacle. Unless otherwise mentioned in the RM, the dummy hot stab shall have a D-type handle.

5.2.2.4. All ROV interfaces shall be concentrated on a panel placed in accordance with the subsea equipment requirements where the CM will be installed.

5.2.2.5. The CM shall have, at minimum, two (02) lock/unlock indicators. VCM and PCM shall have also two (02) extended/retracted soft-land indicators.

5.2.2.6. The indicators shall be 90° apart from each other. Different angles may be proposed by CONTRACTOR and/or SUPPLIER for prior PETROBRAS approval. They shall be accessible to ROV visualization and provide a clear visual indicator to allow knowing if the alignment condition is proper for the soft-land retraction or stroking tool actuation. Visual indicators shall be stiff enough to prevent incorrect indications due to deformations. Instrumentation tubing shall not be used as indicator. The design of the visual indicators shall be approved by PETROBRAS.

5.2.2.7. General symbols, signals (turn direction, n° of turns, torque values, etc.) and arrangement of visual indications for operation by ROV shall follow the requirements stated in the RM and ref. [2].

5.2.2.8. Following symbols for functions and positions shall be used as ROV visual indications:

F	Closed
A	Open
T	Locked
D	Unlocked
PP	Parking place
SL	Soft landing
ST	Back seal test

5.2.2.9. A drawing showing the arrangement of the ROV interfaces and visual indications shall be issued for PETROBRAS evaluation. All instrumentation shall be protected against eventual clashes with the ROV or during deck operations.

5.2.3. Gooseneck

5.2.3.1. SUPPLIER shall submit a load chart presenting the allowable set of loads (tension, shear, bending on flange as well as gooseneck bore pressure) acting the interface flange, according to the RM requirements. In case, there is no orientations in the RM for this subject, SUPPLIER shall fulfill the requirements from ref. [8] to create the load chart.

5.2.4. Weak Point

5.2.4.1. A point (or region) with lower mechanical resistance shall be foreseen in design for the gooseneck or on the fasteners that bolt it to the VCM / PCM, in order to guarantee the structural integrity of the subsea equipment, the hub and the connector, in case of accidental loadings such as, excessive tension from the flowline.

5.2.4.2. In case of a weak point rupture, the contingency unlock shall remain fully operational.

5.2.4.3. The weak point shall be clearly marked and identified to ease its inspection.

5.2.4.4. Although the HCM is capable to rotate with respect to a horizontal axis that allow the HCM pivoting in case of flowline lifting movements, this does not guarantee the subsea equipment integrity for an accidental load after locking. For this condition, a weak point between the HCM and the flowline is the optimal choice, but for safety reasons, the main goal is to guarantee the subsea equipment integrity (for e.g., BAP x wellhead and BAP x WCT connections). Therefore, the SUPPLIER shall consider a weak point for the connection system.

5.2.5. Gooseneck angle

5.2.5.1. The gooseneck angle at the interface end with the flexible line shall be 45° or 60° in relation to the vertical.

5.2.6. Bending Radius

5.2.6.1. The gooseneck bending radius shall be suitable for pigging operations. The minimum radius shall be defined in the RM.

5.2.6.2. The requirement above is also applicable for the horizontal spool pieces for HCM application.

5.2.7. Internal Diameter

5.2.7.1. The inboard hub and CM internal diameters are defined in the RM.

5.2.7.2. In case of different internal diameters along the inboard hub and/or the outboard hub, a minimum 1:5 transition in radius shall be used. Unless otherwise stated in the RM, this transition shall be located, if possible, close to the ring gasket.

5.2.8. Minimum height from the flowline interface flange to the seabed

5.2.8.1. With the VCM / PCM locked in the inboard hub, the minimum distance from the interface flange with the flexible line (gooseneck or swivel) and the seabed, shall be in accordance with the flowline loads informed in the RM for the specific gooseneck angle.

5.2.8.2. For the HCM, when it is landed on the porch, the final loads from the flexible shall be calculated based on the height between the interface flange and the seabed, which will depend on the exit angle, additional system features as defined by the SUPPLIER, and flowline and accessories properties. The loads informed in the RM are preliminary, due to the fact that the final design loads rely on specific system characteristics from each SUPPLIER. To turn the ROV operations viable, the minimum height shall not be lower than 1.5 m, even if there is no interference between the sag part of the catenary and the seabed.

5.2.9. Maximum dimensional envelope

5.2.9.1. Unless otherwise specified in the RM, the CM shall have a maximum envelope of 4 m x 4 m x 4 m.

5.2.10. CM Lifting Point

5.2.10.1. The CM lifting point shall consider the CM weight, the flexible line loads and accessories during installation and retrieval and allow the connector module alignment inside the limits of the guiding system (self-orientation).

5.2.10.2. A bolt type anchor shackle shall be considered for the lifting point, which shall be supplied mounted in the CM. Other structures with a similar shackle geometry or interfaces for the installation cable may be proposed for PETROBRAS approval. The calculation report performed by CONTRACTOR to select/define the specific shackle for the CM installation and retrieval shall be presented for PETROBRAS approval.

5.2.10.3. The shackle shall have its own cathodic protection system, in accordance with the project design life specified in the RM and shall have certification and traceability tag, following the standard also defined in the RM.

5.2.10.4. It shall be considered enough room to, if necessary, disassemble the shackle for the make-up of complementary accessories used by the vessel for CM and flowline laying.

5.2.10.5. The CM drawings shall indicate the shackle stoppers positions and its travel distance.

5.2.10.6. In order to extend the equilibrium load range for which the VCM can be verticalized, mainly for first end installation, the VCM shall have, at least, one additional padeye, aligned with the vertical projection of the flange for flexible connection, as an additional lifting point for verticalization for a second equilibrium load (see Figure 3).

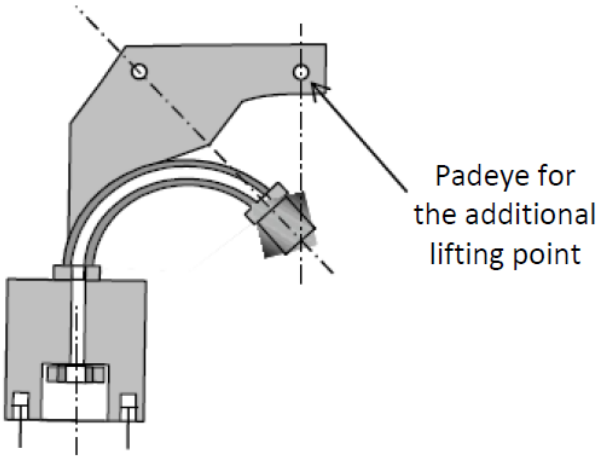


Figure 3 - Additional lifting point for verticalization under secondary equilibrium loads

5.2.10.7. In case of HCM, it is allowed the use of different lifting points to comply with a flowline loading range.

5.2.10.8. The CM shall be supplied with additional padeyes and lifting points for its handling with tag lines and/or slings, in land and onboard the pipelaying vessel in a safe way. The handling padeyes shall be positioned in a way to allow the VCM or PCM toppling, whenever required, for connection with the flexible line. It shall not be considered the use of slings for the CM handling.

5.3. GUIDE SYSTEM FOR CM

5.3.1. This sub-section specifies alignment and geometrical requirements for the guiding system for CM. Guidance systems and values other than those defined below may be accepted upon Petrobras analysis during the clarifications phase, prior to the submittal of technical proposals.

5.3.2. The guiding systems shall allow the CM to:

a. Land.

b. Couple – without getting stuck due to the complacent movements from the flowline.

c. Stroke / Soft-land the connector forward the inboard hub after the pipelaying of a few meters of flowline to uncouple the vessel motions, but still under residual loads from the flowline (applicable to HCM).

d. Lock – Also under the residual loads from the flowline. When applicable the stroking tool / forced coupling tool is used to force the coupling with the inboard hub.

5.3.3. The use of composite material for the funnel / guiding system may be proposed by the CONTRACTOR and/or SUPPLIER, subject to approval by PETROBRAS, in order to reduce weight. Other solutions for funnel design such as using tubing and fins may also be proposed.

5.3.4. Coupling

5.3.4.1. The CM shall be landed vertically and able to couple. For VCM or PCM the couple shall be done vertically and for HCM it shall be horizontally. The guide system shall assure primary alignment between the VCM or PCM and the inboard hub and between the HCM and the landing porch.

5.3.4.2. The guiding structure shall be able to align, land and lock the CM with up to six degrees (6°) or higher initial vertical misalignment relative to the inboard hub or landing porch (see Figure 4).

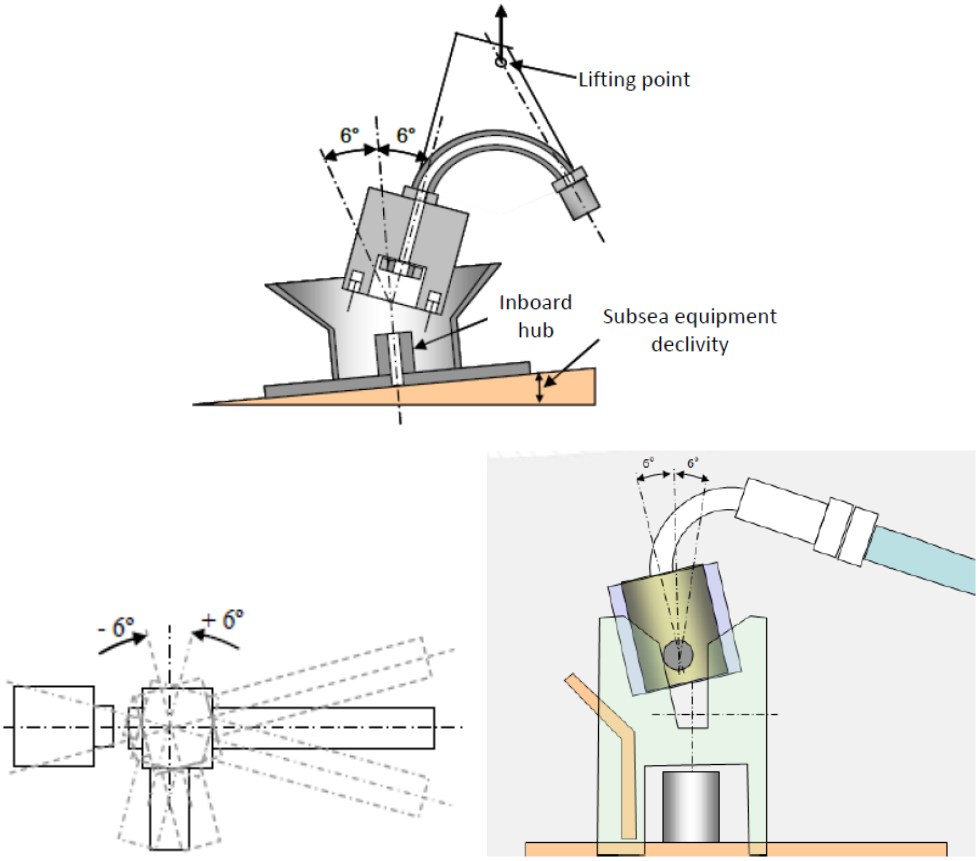


Figure 4 - Vertical misalignment for VCM, HCM and PCM, respectively

5.3.4.3. Unless otherwise specified in the RM, the VCM Guide Systems may be of the type funnel-up or funnel-down (or landing porch for HCMs) and shall allow the VCM / HCM to self-align, land, couple and lock with an initial angular misalignment on the horizontal plane of up to ± 30º for VCMs / PCMs and ± 20º or higher for HCMs (see Figure 5), with respect to the central axis of the flowline azimuth.

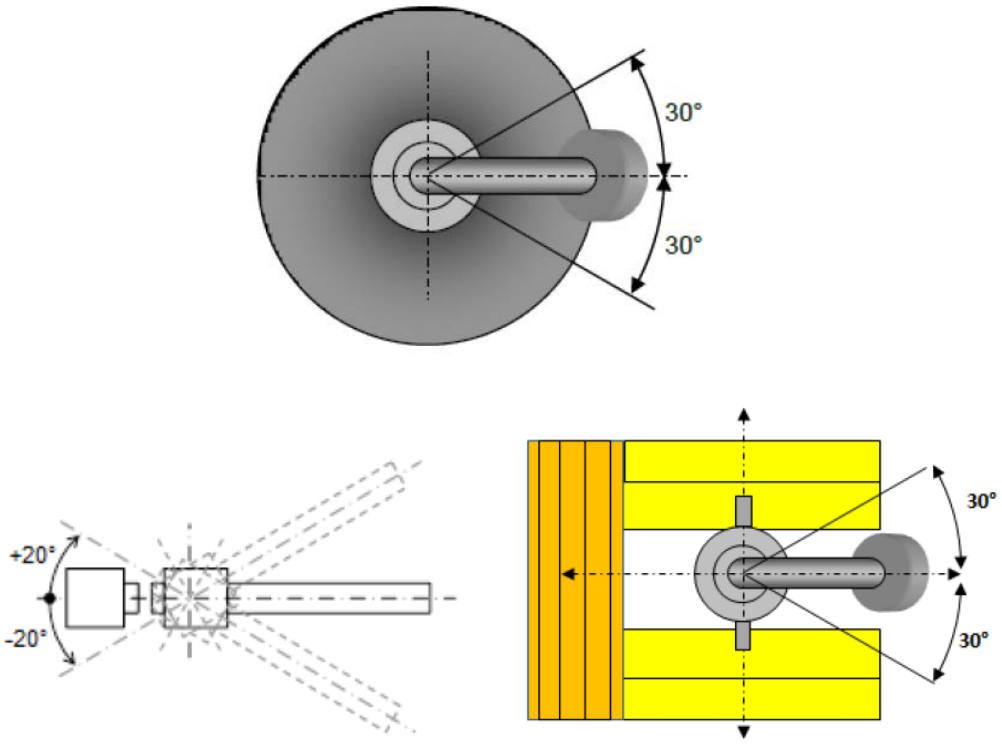


Figure 5 - Horizontal misalignment for VCM, HCM and PCM, respectively

5.3.4.4. The CM shall be designed to land, couple and lock onto the inboard hub or landing porch under the influence of the flexible line load cases defined in section 5.5.

5.3.4.5. The PCM, by its specific features does not require verticalization for landing under the influence of flowline loads. The primary guiding system shall be able to guide it for the auxiliary guiding system and the couple and lock vertically on the inboard hub.

5.3.4.6. The VCM / PCM shall possess a soft-landing system, as detailed in section 5.4.10, that shall be maintained actuated during the VCM / PCM landing. It shall be taken as design premise that the CM will be landed and coupled with a vertical speed equal to 0.1 m/s or lower for installation with heave compensators. For the installation scenario without heave compensators the vertical speed shall be considered as 1 m/s or higher.

5.3.4.7. For HCM coupling the connector shall stay at a safe distance from the inboard hub, which is defined by the SUPPLIER.

5.3.4.8. Prior to stroking tool actuation in HCM applications and prior soft land actuation for PCMs, the CM shall be able to rotate around a horizontal axis to allow the module pivoting in case of lifting movements from the flowline due to pipelaying vessel motions. This rotation shall not transfer bending moment loads to the HCM / PCM structure. In case of high tension loads, the guide system shall allow the uncoupling of the HCM / PCM from its porch at an angle defined by the SUPPLIER and informed to PETROBRAS. Additionally, a stopper shall be foreseen to limit the HCM / PCM rotation to fall, keeping the HCM / PCM in the final position to start the stroking movement / soft-landing between the connector and the inboard hub and the pipelaying until it is possible to lock the HCM / PCM safely.

5.3.5. Uncoupling

5.3.5.1. The CM shall be designed to be released from the inboard hub, after unlocking, when pulled from cable with a force of maximum 3 times (3x) the vertical load of the CM (CM weight plus the vertical component of the external loads such as flexible line and accessories).

5.3.5.2. The VCM shall be considered misaligned by up to 3 degrees (3°) to the vertical in this scenario, and the uncoupling shall not consider the actuation of the soft landing system. However, the soft-land system shall allow the preliminary separation between the VCM and the inboard hub keeping this separation without an ROV continuous actuation.

5.3.5.3. The HCM / PCM shall be capable of uncoupling from the guide system due to flowline movement during the horizontal / vertical subsea disconnection, respectively.

5.3.5.4. Both the technical proposal and the design manual shall include drawings that confirm the system features required as detailed above.

5.3.6. Free obstacle distance around the hub

5.3.6.1. The minimum free obstacle diameter to allow a maximum horizontal movement of the VCM or PCM shall be equal or greater that 1 m plus:

a. Outside funnel diameter – funnel down.

b. Inner funnel diameter – funnel up.

5.3.6.2. The subsea structure limits and other surrounding parts for the HCM landing porch, as well as, the guiding structure for another surrounding HCM shall be beyond the HCM limits considering a horizontal movement of 300 mm in radius with respect to its final landing position.

5.3.7. Guide System Angle

5.3.7.1. If using a funnel or other tilted guiding plane, it shall be designed to guarantee that the angle formed between the funnel generatrix / tilted plane and the horizontal plane is equal or higher than 45º.

5.3.8. Guide System Capture Diameter

5.3.8.1. The guide system shall be able to guide the CM to full landing on the hub or porch, considering possible horizontal movement within a 300 mm radius with regard to the final landing position (see Figure 6), as well as considering the loads involved and functional landing and coupling requirements.

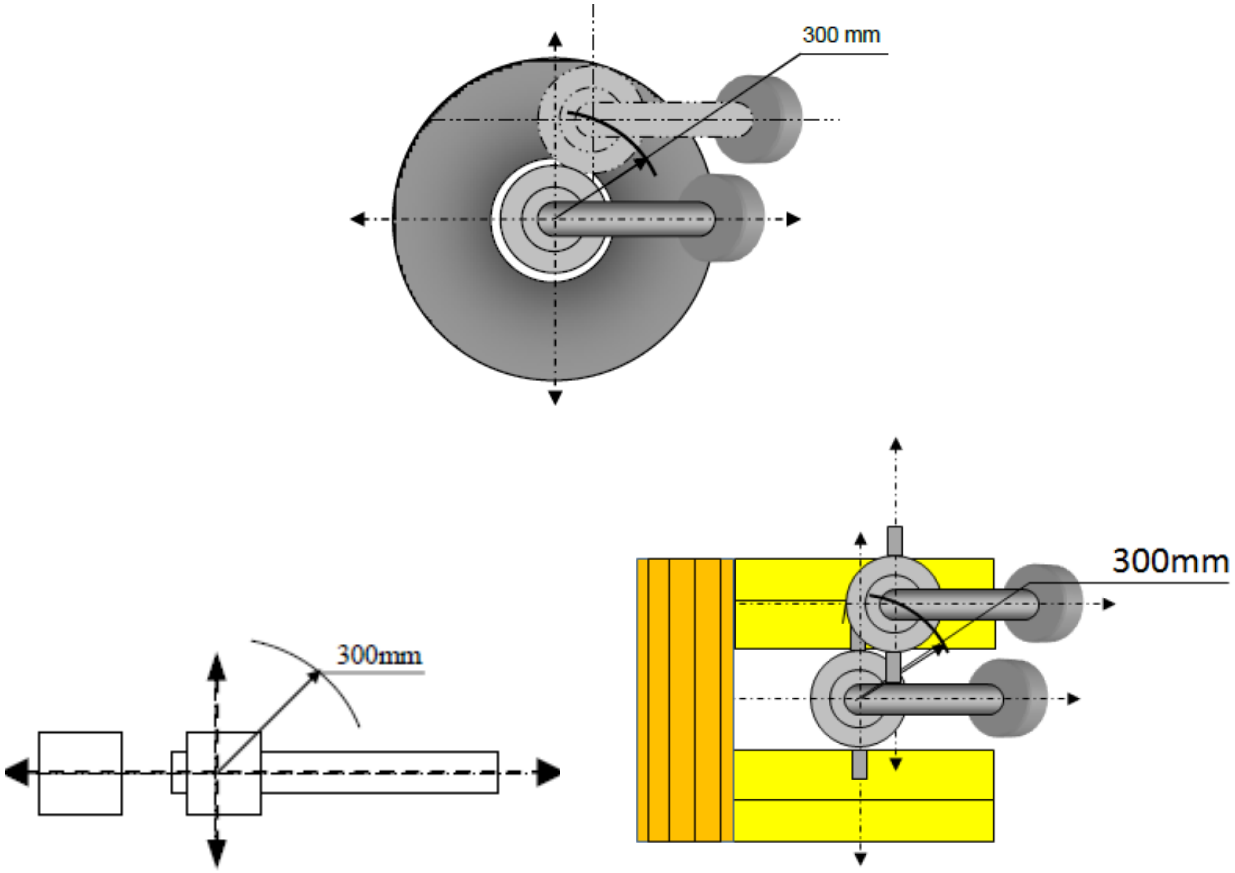


Figure 6 - Guide system capture diameter for VCM (w/ funnel up), HCM and PCM, respectively

5.3.9. Auxiliary Guide System

5.3.9.1. In case of obstacles that limit the horizontal movement of the VCM for purposes to place it inside the funnel capture area, these obstacles may be inside the minimum free obstacle diameter. However, they shall be placed in the opposite side of the gooseneck end. The minimum height for the auxiliary guide system shall be 2 m, using the reference below, and take into account the vertical movement amplitude:

a. Top of the hub for funnel down.

b. Top of the funnel for funnel up.

5.4. FUNCTIONS

5.4.1. The CM and/or their tools shall have the following main functions, which shall be clearly marked (see also marking requirements in section 8):

a. Stroking the connector to the inboard hub, using an ROV operated tool or by a resident device in the connector (applicable to HCM).

b. Connector lock and unlock.

c. Contingency unlock (emergency release).

d. Soft landing.

e. Back seal test. Optionally, the back seal test function may be integrated on the inboard hub for HCM applications.

f. Swivel energize and de-energize (as applicable).

5.4.2. The CM shall have all functions hydraulically actuated and shall be integral, i.e., the hydraulic circuit shall be part of the CM and not of an external tool. Exception for the stroking tool for HCM application (see 5.4.1.a).

5.4.3. Lock

5.4.3.1. The CM connector shall remain locked and assure sealing under all load conditions without using external means, including hydraulic pressure, external loads, connection tool or use of springs (see also 5.4.4).

5.4.3.2. In order to provide a more efficient landing and locking under flowline loads, the PCM shall have a pull-down system for forced coupling.

5.4.4. Secondary Lock

5.4.4.1. The use of a secondary lock feature is NOT mandatory, if the connector system design can assure that the connection and the sealing integrity and tightness are maintained under all design conditions during the entire design life, including cyclic loading.

5.4.5. Unlock

5.4.5.1. While in the unlocked position, the connector and/or its connection tool shall assure that it remains unlocked during the lowering of the CM without using hydraulic pressure or external loads.

5.4.6. Secondary Unlock

5.4.6.1. The secondary unlock feature is a function intended to provide another hydraulic unlock function for redundancy, if needed, to disconnect the system. Secondary unlock is required only if the design of the primary unlock function does not allow the disconnection under all working conditions.

5.4.7. Contingency Unlock

5.4.7.1. An emergency mechanical unlocking method shall be provided as contingency, whose operation shall be performed by ROV. If a tool is needed to perform the contingency unlock operation, it shall be hydraulic and able to be supported, handled and operated by ROV. If such a tool is anticipated, it shall be part of the scope of supply (quantities to be defined in the RM).

5.4.7.2. The contingency unlock system shall not rely on the VCM / PCM gooseneck structure to its actuation (it shall be able to operate even in case of the gooseneck rupture).

5.4.8. Stroking mechanism

5.4.8.1. The mechanism to stroke the HCM forward the inboard hub shall be capable to function considering the reactive loads from this stroking, including the friction forces from the

connection system moving parts. The stroking force capacity shall be, at least, five times (5x) the required design load. This stroking mechanism may be integrated to the HCM or as removable tool suitable for ROV transportation and operation.

5.4.9. Back-Seal Test

5.4.9.1. The CM shall be provided with hydraulic circuits resident in the CM or, optionally, in the inboard hub to perform the back-seal test, after the connector is locked by using the PETROBRAS standard hot stab operated by ROV.

5.4.9.2. Unless otherwise elsewhere stated, the system tightness shall be possible to be monitored by a pressure gage located at the ROV and/or at the CM.

5.4.9.3. The seal test system shall be capable to verify the system outboard x inboard hub tightness without relying on flowline internal pressurization.

5.4.9.4. The seal test system shall take into account the hydrostatic pressure and the ambient water temperature. The seal test chamber shall have the smallest feasible volume, keeping the metal x metal sealing as close as possible from the seal test (elastomeric) sealing.

5.4.10. Soft-Landing System

5.4.10.1. The VCM / PCM shall be provided with a soft-landing system (if this function is not provided by a specially designed, ROV operated pull-in, pull-down or connection tool, see 5.11), so that the final landing is performed, under the influence of the VCM / PCM installation loads, without damaging the ring gasket. The integrity of all sealings shall be kept during all VCM / PCM operations for its design life.

5.4.10.2. This system shall remain extended during DRS landing, keeping the ring gasket away from the inboard hub until final landing.

5.4.10.3. The soft-landing system shall be designed to allow preliminary separation, if needed, between the VCM and the hub during recovery of the spool, keeping this separation without continuous ROV actuation. Alternatively, this operation may be performed by using the pull-in, pull-down or connection tool (see 5.11).

5.5. CM LOAD CAPACITY

5.5.1. The capacity of the CM and its connector to withstand loads maintaining the sealing integrity shall be higher than the load capacity of the attached piping / spoolpiece for all possible load combinations.

5.5.2. The loads to be considered are:

a. Pressure

b. Bending moment

c. Tension / compression

d. Shearing, and

e. Torsion

5.5.3. The preliminary flowline loads to be considered in the CM design will be informed in the RM.

5.5.4. The CM shall be designed considering a safe operation for its installation and retrieval within an operational window with heave equal to 1.5 m or higher.

5.5.5. The CM shall be able to start the installation lowering in an upside-down position (connector facing upwards), without any damages for the CM and without any need to lock the connector.

5.5.6. For the horizontal rigid spool loads for HCM application, the design loads will be defined by the DRS design.

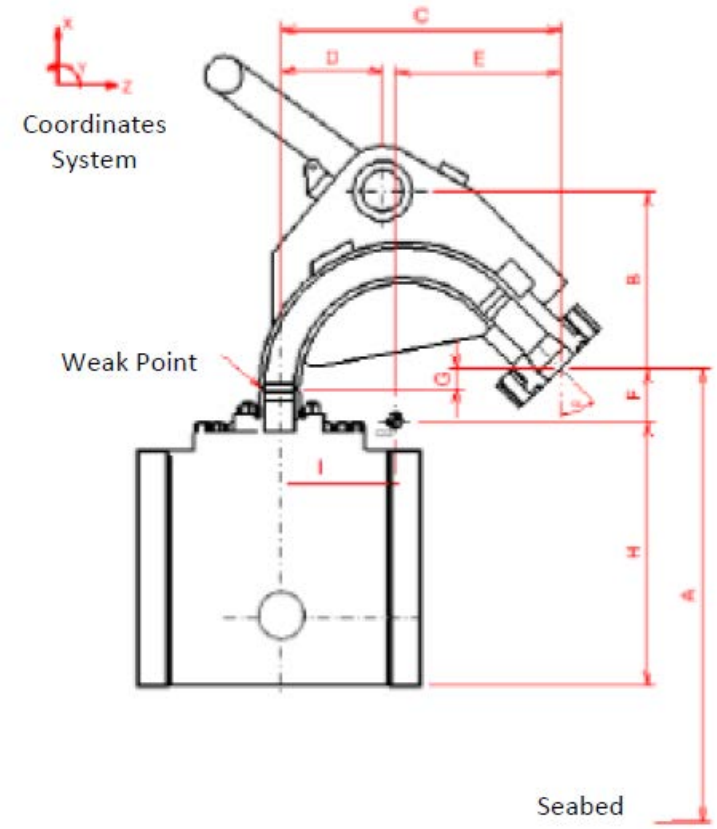
5.5.7. CONTRACTOR and/or SUPPLIER shall consider in the design of the CM that the flexible line catenary may be out of the CM plane. This implies that not all CM design loads are aligned with this plane. These loads outside the CM plane will be informed in the RM, when applicable.

5.5.8. After the CM basic design, considering the preliminary loads, CONTRACTOR and/or SUPPLIER shall submit to PETROBRAS the information regarding the weight, main dimensions, and CoG of the CM, as per the model below (Table 1), for assessment and possible adjustment of the preliminary loads, if required.

a. CONTRACTOR and/or SUPPLIER shall indicate these loads used in the basic design.

b. In case, the new loads imply in modifications of the CM or the subsea structure, this verification process shall be re-done.

c. Where applicable, the data from the spreadsheet model above (weight and dimensions referenced to CoG) shall consider the influence from the shackle weight (cases with and without it).



Project			
Flowline function			
Dimension	**Description**	**Value**	**Unit**
α	Gooseneck angle		degrees
A	Distance from the CM flange to seabed after installation as designed		mm
B	Vertical distance from padeye to flange		mm
C	Horizontal distance from flange to CM weak point		mm
D	Horizontal distance from padeye to CM weak point		mm
E	Horizontal distance from flange to CM CoG		mm
F	Vertical distance from flange to CM CoG		mm
G	Vertical distance from flange to CM weak point		mm
H	Vertical distance from CoG to connector bottom surface		mm
I	Horizontal distance from the CoG to Y axis		mm
	CM submerged weight		kg

Table 1 - Spreadsheet model for CM basic data (dimensions and weight)

5.5.9. Loads to design the CM equilibrium for first and second end installation.

5.5.9.1. These are the loads on the interface flange with the flexible line (gooseneck flange or swivel flange, as applicable) when the CM is imminent to coupling. However, for design purposes of these catenary loads, including the influence of the flowline accessories (vertebrae and end fitting), the flange height to the seabed is considered as 10 m from the hub for VCMs / PCMs and coupled on the porch for HCMs.

5.5.9.2. In such condition, the VCM / PCM shall be designed to stay verticalized, i.e., without vertical misalignment. The maximum allowable tolerance for vertical misalignment when the VCM / PCM is subjected to the equilibrium loads informed by PETROBRAS is one degree (1°).

5.5.9.3. The VCM / PCM shall be capable of landing until the moment it is possible to start the soft-landing function, when subjected to the equilibrium loads, without the necessity of any adjustments in the flowline laying operation. It is considered that the same loading is applicable for both first and second end tie-in.

5.5.9.4. For HCM scenario, the guiding system shall be designed to keep its landing position as per its design, i.e., within the allowable misalignment design requirements, when subjected to these loads. It shall also be able to couple on the landing porch and lock in the inboard hub, providing its sealing.

5.5.9.5. It is understood that the PCM / HCM loads are the same for both first and second end connection.

5.5.10. Loads for structural design

5.5.10.1. These are the highest loads on the interface flange with the flowline line (gooseneck flange or swivel flange, as applicable). The CM shall be designed to withstand these loads maintaining its structural integrity. Such loads may present the bending moment acting on the interface flange in lifting or lowering direction and occur in the following situations:

a. CM landed on the hub or porch with the flexible line still suspended by the pipelaying vessel (first end connection)

   i. In this scenario, the pipelaying vessel motions can transfer an extreme load condition for the CM interface flange and/or the landing porch, due to the fact that the flexible line is suspended by the vessel (first end connection) or by the line hump (second end connection).

   ii. Usually, the VCM or PCM is not yet locked in the inboard hub, but there are cases when the VCM can be locked.

   iii. For HCM applications, it is considered that the extreme condition occurs at the first end connection. Thus, the HCM will be subjected to a maximum bending moment in the lifting direction of the flange. At this condition, the HCM is not locked yet on the hub, because the stroking tool actuation to move the connector towards the hub will be performed only after the flowline is laid on the seabed.

b. CM landed on the hub or porch with the flexible line touching the seabed (first end connection)

   i. In order to minimize the time duration of the VCM in the suspended line condition, with dynamic and random loadings from the pipelaying vessel due to the wave motions, it is recommended that immediately after the VCM landing on the hub, some length of line (few meters) is laid on the seabed, even before beginning the soft-landing actuation. Therefore, under these loads, the VCM

should be able to complete its landing, with the soft-landing system, lock on the inboard hub and seal.

ii. The flowline may present an extreme loading condition at the CM x flowline interface flange and at the landing porch / guiding structure as well, with a bending moment in the lowering direction.

c. HCM stroking to the inboard hub, with the HCM landed on the porch and the flowline laid on the seabed

i. In this scenario, the flowline applies a loading at the HCM x flowline interface flange with opposite reaction to the stroking movement considering the maximum stroke reported by the SUPPLIER. The set of loads informed by PETROBRAS does not take into account the friction forces among the connection system components, which shall be assessed by the SUPPLIER.

d. CM on the beginning of subsea lowering on second end

i. In this scenario, the flexible line is suspended by the CM and, then, this will apply a tension load in the CM x line interface flange equal to the suspended flowline weight associated with the dynamic amplification from the pipelaying vessel motions.

e. Operation and test

i. In this condition the loads applied to the CM x line interface flange, hub and porch are caused by the flowline and its accessories when the line is laid on the seabed and subjected to a maximum pressure equal to the hydrostatic test pressure, i.e., 110 % of the maximum operation pressure as defined for the project and informed in the RM.

f. VCM / PCM on the beginning of subsea lowering on first end

i. The VCM / PCM is suspended by the flexible line in this situation and, hence, subjected to the loads acting on the VCM / PCM x line interface flange, due to the equilibrium configuration for this scenario. In other words, these loads are caused by the suspended VCM / PCM self-weight and by the dynamic amplification from the pipelaying vessel (see Figure 7).

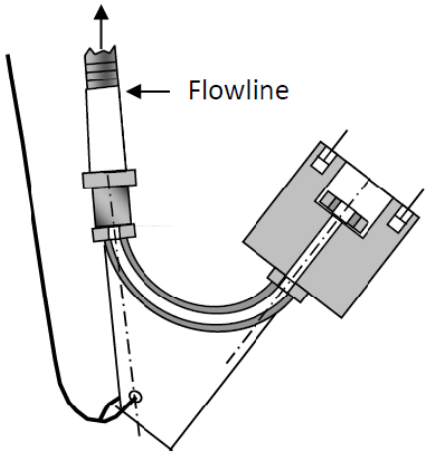


Figure 7 – Beginning of lowering for first end connection

5.6. SUBSEA CONNECTOR

5.6.1. The connector design shall allow coupling, locking and sealing between the CM and the hub when submitted to installation loads (both first and second end or rigid spool), in addition to withstanding the design loads and other premises (e.g., misalignments), without deformations such that would affect performance or not meet other requirements of this specification.

5.6.2. The connector shall be of the following type:

a. Hydraulic connectors with integral hydraulics similar to subsea wellhead connectors.

5.6.3. The latching mechanisms of the connector may be of the following types:

a. Collet fingers.

b. Locking dogs.

5.6.4. Hydraulic connectors with the C-Ring type actuation shall not be used.

5.6.5. Connector with Hydraulic Actuation

5.6.5.1. The connector shall possess integral hydraulics, constituted of single toroidal chamber or multiple cylinders actuator, as long as the maximum CM dimensions are met (as specified in the RM or other contractual document).

5.6.5.2. Hydraulic actuation shall be done by using a standard PETROBRAS hot stab via ROV.

5.6.6. Hydraulic circuit for CM functions

5.6.6.1. The locking / unlocking, soft-landing, seal test and swivel energize / de-energize functions shall have resident hydraulic circuits in the CM. To ease the operation, the CM hydraulic circuit shall be on a stainless-steel plate (or other CRM approved by PETROBRAS) attached to the panel. Only the seal test hydraulic circuit may have fittings.

5.6.6.2. The hydraulic tubing shall be made from AISI 316L SS seamless tubing. The diameter and the fittings shall be according to the RM requirements. Fitting connections are not allowed in hydraulic circuits for umbilical interface.

5.6.6.3. The connections between the umbilical hoses and the CM shall be concentrated on a plate and positioned 25 mm away from each other to allow the proper tightening of the connection nuts. All hydraulic hose functions shall be clearly identified.

5.6.6.4. The electrical connectors between the umbilical and the CM (dry mate connection) and the electrical connector between the CM and the subsea equipment (wet mate connection) shall fulfill the requirements from the RM and the Technical Specification for control system. The electrical connector between the CM and the subsea equipment shall be coupled only after the CM is completely landed and locked in the inboard hub.

5.6.6.5. The electrical connectors shall be protected against impact loads during installation, intervention, and recovery.

5.6.6.6. Regarding hoses and electrical harness routing, it shall be foreseen a minimum straight length of 200 mm for termination purposes. Therefore, no obstacle shall be in a distance lower than this value, to guarantee the ease of access for field assembling. Special attention shall be paid for the minimum bending radius (as per RM requirements) to avoid any damage during installation.

5.6.7. Sealing Areas between Connector and Inboard Hub

5.6.7.1. The sealing areas shall be made with CRM. Care shall be taken to avoid the galling effect and calco-magnesian deposits between the sealing area and the ring gasket.

5.6.7.2. The sealing areas shall be protected against impact loads during installation, intervention, and recovery.

5.6.7.3. Unless otherwise informed in the RM, the sealing chamber for the seal test should be as minimum as feasible and the elastomeric sealing as close as possible to the metal-metal sealing.

5.6.7.4. In case of damages to the sealing areas between the subsea structure and the CM, its design shall anticipate the use of a modified ring gasket for contingency sealing.

5.6.7.5. Unless otherwise mentioned in the RM, the requirements in this section are also applicable for elastomeric sealing.

5.7. RING GASKET

5.7.1. The ring gaskets shall be made or overlaid with CRM. The design, material and hardness selection are responsibility of the SUPPLIER and shall consider only the possibility of elastic deformations. The qualification tests shall be performed to prove that the hub and connector sealing areas are not damaged, jeopardizing the sealing function.

5.7.2. Only metal-metal, bi-directional ring gaskets are allowed for primary sealing of the seal system.

5.7.3. The sealing system shall be designed considering the service conditions defined in the RM.

5.7.4. Elastomeric material shall not be used as secondary sealing, in case it is not possible to test, at any situation, the metal-metal sealing. Moreover, it shall be demonstrated that there is no interference of the elastomeric seal in this sealing.

5.7.5. The ring gaskets shall be protected against impact loads during installation, intervention and recovery.

5.7.6. The ring gasket installation in the connector seal area shall be made by means of fasteners. SUPPLIER shall submit a drawing exhibiting these gasket assembling details, making it clear how it is installed in the sealing area. Other assembling methods may be proposed for PETROBRAS approval.

5.8. SWIVEL

5.8.1. Unless otherwise mentioned in the RM, the CM shall have a swivel for connection with the flowline. The swivel shall be connected to the CM by means of weld or flanged connection.

5.8.2. The swivel shall absorb any induced torsion caused by the flowline to guarantee a maximum vertical misalignment of 4° (four degrees) for the VCM / PCM, with respect to the catenary plane and to allow the HCM to land in its porch. The induced torsion shall also include loads outside the CM plane, as described in item 5.5.7. This requirement shall be verified during the FAT.

5.8.3. Unless otherwise mentioned in the RM, the swivel shall fulfill the requirements from ref [9].

5.9. TEST BASE

5.9.1. The test base shall be designed to allow, onboard vessel, the landing, coupling, locking and hydrostatic testing of the connector module. It shall also provide the inclination of the hub up to 6° in relation to the vertical plane in order to simulate the installation / landing conditions for the CM.

5.9.2. The base ends shall be marked with reflective paint, according to ref. [10].

5.9.3. The test base shall have the same stiffness as the structure (PLET, BAP, etc.) that it is simulating. It shall be demonstrated by means of calculation.

5.10. TRANSPORTATION SKID AND SLINGS

5.10.1. The transportation skid shall be made from steel and provided with a device to allow the CM transportation and handling, both onshore and offshore, so that they can always be fixed and protected against impacts.

5.10.2. The skid ends shall be marked with reflective paint, according to ref. [10].

5.10.3. The test base and all auxiliary tools shall possess transportation skids. All skids that will be delivered to PETROBRAS shall be painted and designed for the entire design life of the CM.

5.10.4. The VCM / PCM transportation skid shall be pivotable in order to allow the upright of the VCM / PCM in case it is transported in the horizontal position onto its skid.

5.10.5. The handling of all equipment/components/accessories/tools shall be feasible by padeyes with no necessity of straps. The CM shall possess at least three padeyes with shackles to be connected to tag lines during the CM overboarding / inboarding / tilting with appropriate SWL, especially for the case of inboarding (minimum SWL of 10 ton per padeye). CONTRACTOR shall detail the use of the tag lines at these padeyes during overboarding/inboarding and for the tilting before first or second end connection.

5.10.6. Additional safety requirements for the CM skids handling shall follow ref. [12].

5.10.7. The painting requirements from section 5.17 are also applicable for the skids.

5.10.8. Slings for offshore use shall be designed for both installation and recovery of subsea equipment.

5.10.9. All slings for the CM scope of supply shall meet the requirements from ref. [10]. The sling's quality certificate shall be delivered with the invoice of the CM.

5.11. PULL-IN, PULL-DOWN AND CONNECTION TOOLS

5.11.1. These tools are responsible for the final approximation of the connector towards the inboard hub (pull-in or pull-down tool) and the locking function (connection tool). When non-integral, it shall be retrieved after connection, leaving only passive mechanical hardware subsea. Further references to these tools are given in ISO 13628-9 (ref. [18]), clause 4.5, Tie-in operations, which shall be considered as recommendations.

5.11.2. For stroking tool requirements for HCMs see item 5.4.8.

5.12. SEAL REPLACEMENT TOOLS

5.8.1. The seal replacement tools shall be suitable for ROV operation.

5.13. HUB CLEANING TOOL

5.13.1. The hub cleaning tool shall be operated via ROV during cleaning of the installed subsea structure hub sealing area.

5.13.2. It shall be able to clean the sealing area without damaging any component of the system.

5.14. CAPS

5.14.1. Following subsections define and give specific requirements for the caps which normally are part of the scope of supply of the connector system. Quantities of each cap to be supplied shall be defined in the RM.

5.14.2. Blocking Cap

5.14.2.1. The main objective of the blocking cap is the isolation of the internal bores of the subsea structure during the operational phase of the pipeline when the CM is not connected to the structure.

5.14.2.2. The cap shall be designed to withstand the connector design differential pressure and shall have an unlocking and locking system operated by ROV in order to allow it to be removed and reinstalled.

5.14.2.3. The locking and unlocking of the blocking cap connector may be hydraulically or mechanically actuated, according to item 5.6. It shall have same locking requirements as 5.4.3.

5.14.2.4. The seal system shall be bi-directional, metal-to-metal.

5.14.2.5. The maximum installation and removal angles shall be in accordance with the guide system (see 5.3).

5.14.2.6. The cap shall have a back-seal test function, operated by ROV through hot stab (see 5.4.9).

5.14.2.7. The cap shall have a guide system and other ancillaries needed for installation and removal via cable, assisted by ROV.

5.14.2.8. The blocking cap shall have a cathodic protection system compatible with the equipment design life.

5.14.2.9. The cap connector shall have a contingency mechanical unlocking method. If a mechanical connector is chosen, a cutting tool may be proposed as contingency mechanical unlocking method; in this case, the cutting procedure specification shall be supplied.

5.14.2.10. The blocking cap shall be provided with a flooding device to equalize inner and outer pressure as well as valves and hot stab ports for MEG injection.

5.14.2.11. The blocking cap shall have an interface for transponder (and/or interface for metrology) in accordance with the transponder specification to be provided by CONTRACTOR.

5.14.3. Protection Cap

5.14.3.1. The protection cap shall cover both sealing and locking areas of the inboard hub against impact loads and assure electric contact with it, in order to avoid calco-magnesian deposits.

5.14.3.2. This cap shall be designed with an unlocking and locking mechanism which allows the cap to be transported with the equipment, locked on its hub.

5.14.3.3. The protection cap shall be capable to avoid any internal fluid spills from the bore during the installation. It shall be also provided with a flooding device to equalize inner and outer pressure.

5.14.3.4. It shall also be installable and retrievable by ROV without need of other items, like a crane or winch cable or HCM removal from its porch.

5.14.4. Testing Cap

5.14.4.1. Testing cap allows testing the pipeline and attached subsea structures during the period between the installation of the subsea structure and the CM or the blocking cap.

5.14.4.2. If not required in the RM, CONTRACTOR shall confirm the need of this cap and further requirements.

5.14.4.3. Unless otherwise informed in the RM, the testing cap shall have an interface for transponder (and/or interface for metrology) in accordance with the transponder specification to be provided by CONTRACTOR.

5.14.4.4. The seal system may be resilient (soft).

5.15. CATHODIC PROTECTION

5.15.1. Cathodic protection design shall comply with ref. [3] and ref. [21].

5.16. FASTENERS

5.16.1. Fasteners shall comply with ref. [4] and [5].

5.16.2. In case of fasteners made from Inconel® they shall meet ref. [6] requirements.

5.17. COATING

5.17.1. The CM shall be painted according to item 4.3 of ref. [13] (alternative C). Additional and modified painting requirements (coating assessment) may be presented in the RM and shall also be considered by CONTRACTOR. The sealing areas and/or surfaces with relative movement shall not be painted.

5.17.2. The design of components with coatings based on fluoropolymers shall consider the exposal to UV radiation.

5.17.3. When required, thermal insulation for the CM and its components shall be supplied in accordance with ref. [7]. The thermal insulation shall cover the piping of the CM and its

respective subsea structure. A thermal analysis report shall be submitted by CONTRACTOR for PETROBRAS approval.

5.17.4. Unless otherwise informed in the RM, the following colors shall be used on the CM: white for fixed parts (inboard hub, landing porch, subsea structure, etc.), red or orange for structural padeyes and yellow for removable parts (CM, etc.). Where colors were not specified, annex B orientations from ref. [15] shall be adopted.

5.18. EROSION

5.18.1. When required as per RM, CONTRACTOR shall consider in the CM piping and applicable tools / accessories the effects of erosion as per ref. [22].

5.18.2. The service conditions data required for erosion calculation are presented in the RM. Erosional velocity shall be calculated as per ref. [23] and the erosion rate calculated as per ref. [22].

5.18.3. A detailed calculation report shall be issued by CONTRACTOR for PETROBRAS evaluation, describing the effects of erosion in the subsea connector systems and informing (at minimum): their critical points, erosion rates, geometry factors, thickness & IDs and material properties.

6. TESTING

6.1. GENERAL TEST REQUIREMENTS

6.1.1. Testing requirements for the connector systems are defined in reference [11]. These tests comprehend qualification (PVT), factory acceptance (FAT), and system integration tests (SIT).

6.1.2. CONTRACTOR shall mobilize a Third-Party Conformity Assessment Body representative, recognized by PETROBRAS, to witness the PVT, FAT, and SIT activities, unless otherwise informed in the RM.

6.2. QUALIFICATION TESTS

6.2.1. The subsea connector of the CM and the ring gaskets shall undergo the qualification (PVT), factory acceptance (FAT) and system integration tests (SIT) as per ref. [11] requirements. Interchangeability requirements shall also adhere to ref. [11] requirements.

6.2.2. Additional testing requirements and remarks applicable for CM are presented in the following section 6.3.

6.3. DYNAMIC LANDING, COUPLING AND LOCKING

6.3.1. Dynamic Test Study

6.3.1.1. The SUPPLIER shall present, for PETROBRAS approval, a study to demonstrate the viability for CM landing, coupling and locking on the inboard hub, with the CM subjected to the flexible line loads and considering the allowable misalignments.

6.3.1.2. This study may be performed by means of simulation software for solid surfaces interaction, by analytical calculation solely, or even by reduced scale model tests, considering the similitude theories between model and product, provided that they are previously validated by tests performed in physical equipment and submitted for PETROBRAS approval. This study may be used to define the most critical loading combination for the test.

6.3.2. Dynamic Qualification Tests

6.3.2.1. The dynamic tests for CM landing, coupling, stroking (as applicable), and locking on the hub are part of the CM qualification procedure. These tests shall validate the compliance to the specified design premises for the following scenarios:

a. Two different installation speeds: ≤ 0.1 m/s and ≥ 1 m/s.

b. Flowline loads (magnitudes and directions).

c. Maximum allowable misalignments.

i. Horizontal displacement (≥ 300 mm – Figure 6) for the two main axis, in four directions.

ii. Angular in the horizontal plane (± 30° for VCM / PCM and ± 20° for HCM - Figure 5).

iii. Angular in the vertical plane (± 6° for the two main directions, total of four cases - Figure 4).

d. Stopper function and uncoupling for HCM / PCM, as specified by the SUPPLIER.

e. The capacity to rotate around a horizontal axis that allow the pivoting of the HCM / PCM, simulating the flowline lifting movements without bending load transfer to the HCM / PCM structure. This shall allow the uncoupling from the porch at a defined angle specified by the SUPPLIER.

f. Combination of the scenarios above for the most critical case considered.

6.3.2.2. SUPPLIER shall submit for PETROBRAS approval the qualification test procedure, the device that will simulate the loadings and the calculation report to verify the load values considered. The allowable tolerance between simulated and project loads is a maximum of 20 %, provided the VCM / PCM vertical misalignment is not greater than 2° (two degrees). It is remarked that the operational vertical misalignment between VCM / PCM and inboard hub shall be a minimum of 6° (six degrees), absolute value.

6.3.2.3. The landing shall be performed with the VCM / PCM under equilibrium loads. Before the soft land actuation, the lifting cable shall be without tension (slacked) and the load set shall be changed to the condition of VCM / PCM landed on hub with flexible line laid on seabed. In this condition, the VCM / PCM shall land, couple and lock on the hub, without need to any movement/adjustment of the lifting cable or load variation. Immediately after locking, the back-seal test between VCM / PCM and inboard hub shall be performed.

6.3.2.4. The dynamic tests shall be registered by video and photographs, which shall be part of the qualification report.

6.3.2.5. It is also part of the dynamic tests the contingency unlocking and the uncoupling with the lifting cable vertically misaligned at 3° (three degrees) and maximum tension equal to three times the CM weight (plus the vertical component of the loads from the flexible line and accessories in this condition).

7. INTEGRITY MANAGEMENT

7.1. Same integrity management requirements established for the risers/flowlines and/or subsea equipment, are also applicable for the connection modules and their components for which they are tied in, as per the scope of supply defined in the RM.

7.2. CONTRACTOR shall implement a FMECA in order to identify failure modes' mechanisms and causes and determine critical components, considering all phases of the project (manufacturing, maintenance, installation, operation, decommissioning, etc.). This FMECA study shall be in accordance with the same level of requirements defined for the riser / flowline / subsea equipment associated with the CM and shall be carried out in accordance with ref. [24] and orientations given in section 5.5.4 from ref. [14].

7.3. CONTRACTOR shall propose a plan for both subsea inspection and preservation / maintenance inspection (for storage items), comprising the subsea structures, the CMs and all components of the scope of supply defined in the RM, which shall include, at least:

a. The suggested inspection frequency based on the FMECA results. This proposed inspection frequency shall be previously approved by PETROBRAS.

b. Equipment necessary for inspection plan execution.

c. The acceptance criteria for the recommended inspections.

d. The complete list of components, which shall be replaced at each maintenance event, for all tools that need to go through maintenance and preservation.

7.4. To allow the assessment of the integrity level, life extension and reuse of subsea structures (including their components such as valves, connectors, etc.) and their decommissioning strategy, whenever required during the project design life, CONTRACTOR shall provide the following minimum information to be captured in a dedicated document, which shall be listed in the MDR:

a. Design code used.

b. Material specification for pressure containing parts, identifying if the materials are in accordance with ref. [26] requirements.

c. Material class (from AA to HH) as defined in ref. [14].

d. SMYS @ design temperature.

e. Allowable stress according to the design code.

f. Hardness.

g. OD and ID.

h. Minimum design thickness as per design code.

i. Minimum fabrication thickness for straight piping sections.

j. Minimum fabrication thickness for bends.

k. Corrosion allowance and clad thickness (when applicable).

l. Piping bending radius.

8. MARKING AND TAGGING

8.1. All padeyes shall be painted in red or orange and have their SWL indicated.

8.2. All CMs shall receive a tag to differentiate them from each other and have their tags stamped. The hubs shall also be marked and differentiated.

8.3. The structural capacity for installation shall be marked on the CM.

8.4. Additional requirements for marking and tagging will be defined in the RM.

9. REPORTS, RECORDS AND DOCUMENTATION

9.1. By using this Technical Specification, as a minimum the following documents shall be issued for PETROBRAS information and evaluation, or be made available for PETROBRAS review:

a. Design

i. Scope of Supply drawings.
ii. General Arrangement drawings of each item in the scope of supply.
- ROV interfaces and visual indications arrangement drawing.
- ROV accessibility report.

iii. Detailed drawings of each component of the scope of supply.
iv. Design premises.
v. Design reports (including clearance and tolerance studies).
vi. Load capacity charts.

b. PVT

i. Homologation plan.
ii. Qualification dossier (as applicable).
iii. Qualification procedures.
iv. Qualification report (PVT procedure filled with notes and signatures during tests execution).
v. Certificate of Compliance, when qualification of the items shall be certified by an independent third party.

c. Fabrication

i. Inspection and Testing Plan (ITP).
ii. Databook.
iii. Material certification.

d. FAT

i. FAT procedures.
ii. FAT reports.

e. SIT

i. SIT procedure.
ii. SIT reports.

f. Operation and maintenance

i. Operation, inspection, handling, storage, preservation, and maintenance manual.

g. Installation

i. Installation analysis.
ii. Retrieval analysis (for decommissioning purposes).
iii. Installation procedures and checklists.

10. SUMMARY OF INPUT DATA FOR CONNECTOR SYSTEM SPECIFICATION

10.1. Following list presents the information which is needed when using this technical specification and that are planned to be provided in the RM, in the main equipment specification or by CONTRACTOR.

10.2. If any necessary information is not defined in the RM, the main equipment specification or in any other contractual document, PETROBRAS shall be formally consulted before any implementation by CONTRACTOR. CONTRACTOR shall present for PETROBRAS evaluation a range of values that do not violate any requirement found in the contractual documentation.

a. Design pressures.

b. Maximum and minimum design temperatures.

c. Composition of fluids carried by the flowlines / umbilicals.

d. Environmental data and water depth.

e. Control and chemical injection fluids, if applicable.

f. Maximum and minimum design hydraulic pressures.

g. Internal diameter for the hydraulic circuit.

h. Electrical connector (as applicable)

i. Hoses and electrical harness (as applicable).

j. Minimum design life.

k. Flowline type (flexible line, umbilical or rigid spool)

l. Maximum flowline loads.

m. PSL.

n. Swivel specification

o. Inner diameter of the connector and inboard hub.

p. Minimum flowline bending radius.

q. Dimensional envelope for the connector module.

r. Type and dimensions of interface flange to the flexible line, umbilical or spoolpiece.

s. Quantities and dimensions of rings for welding qualification (if applicable).

t. Quantities of accessories, tools, caps and spares.

u. General requirements for ROV interfaces and visual indications.

v. Cathodic protection requirements.

w. Coating requirements.

x. Additional requirements for material selection and fasteners.

y. Guide System and/or funnel (up or down – if not specified, may be any of the two) types.

z. Additional guide system alignment requirements.

aa. Heave compensation requirements for the CM.

bb. Position of the inner diameter transitions within the inboard and outboard (connector) hub.

cc. Additional requirements for design qualification/validation.

dd. Requirements for the certification and traceability tags for shackle.

ee. Additional manufacture quality control requirements.