PETROBRAS	**TECHNICAL SPECIFICATION**	N **I-ET-3000.00-1519-291-PAZ-005**	
	CLIENT:		SHEET 1 de 17
	PROGRAM:		-
	AREA: **SUB**		
SUB/ES/DCT	TITLE: **DESIGN REQUIREMENTS**		**NP-1**

INDEX OF REVISIONS

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0	ORIGINAL

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DATE	18/12/2019							
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EXECUTION	Walter (UQ9R)							
CHECK	Eder (CSN8)							
APPROVAL	Lancelotti (CXAX)							

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This Technical Specification is part of I-ET-3000.00-1519-291-PAZ-001 – Flexible Pipe Technical Specification. Please refer to the Flexible Pipe Technical Specification for instructions, definitions and abbreviations.

1. Loads and Load Effects

1.1. General

1.2. Definition of Load Cases

1.3. Load Combinations and Conditions

The manufacturer shall carry out installation feasibility analysis of product(s), including the evaluation of their stability during the laying phase. For structures to be installed empty, the manufacturer shall design the flexible pipe for the accidental bore flooding.

The installation and recovery analysis shall comply with the load cases and requirements presented in I-ET-3010.00-1500-960-PPC-006 – Structural Analysis of Flexible Pipes.

The installation methods currently used by Petrobras and associated requirements are presented in I-ET-3000.00-1500-942-PMU-001 – Installation methods.

The manufacturer shall perform the installation analysis considering the installation vessels specified in the project-specific purchasing documentation. If foreseen on the contract, a new installation vessel may be considered or if a modification to a given installation vessel occurs during the contract validity, the new Technical Specifications will be timely supplied and shall be considered by manufacturer for verification of pipe structures. Any intended modification or refurbishment of vessel/equipment proposed by the manufacturer shall be submitted to the purchaser.

In addition, the manufacturer shall provide the crushing curves considering the tensioner and, when applicable, the laying wheel. The manufacturer shall construct the permissible crushing load graphics according to the laying vessel characteristics supplied with the project specific data and with ET-3000.00-1500-290-PMU-004 – Requisitos para Confecção de Curvas de Aperto de Dutos Flexíveis e Umbilicais.

The manufacturer shall also carry out the connection analysis of the flexible pipe to the subsea equipment according to ET-3010-1500-941-PLR-004 considering the data and limits informed in the project specific data.

The manufacturer shall consider that flexible pipes and accessories can be laid in both directions. Exceptions on this requirement may be accepted if the flexible pipe design feasibility depends on the adoption of only one laying direction.

The manufacturer shall design and supply products that can be installed, handled, reeled, unreeled and recovered, at least, 4 times during the specified service life. The manufacturer shall design the products in such a way that they can install them anywhere, providing they are not subjected to more severe conditions than the design values.

Structural, local and global, analysis shall comply with the requirements from I-ET-3010.00-1500-960-PPC-006 – Structural Analysis of Flexible Pipes.

1.4. Design Load Effects

2. Pipe Design Methodology

The design methodology shall be verified and certified by and IVA. IVA role in methodology certification is further described in document I-ET-3000.00-1519-291-PAZ-003 – Flexible Pipe Certification Requirements.

The manufacturer is also responsible to make the Design Methodology Verification Report and certificate (Type Approval) of the Top Bend Stiffener and Buoyancy Modules Suppliers available, for review by Petrobras representatives in the local offices of the manufacturer (in Brazil).

Design methodologies shall be considered validated (for a validated envelope of product designs) only if there is sufficient evidence that the behavior predicted by the manufacturer's design tools are confirmed through a comprehensive scope combining prototype tests and analysis.

Depending on test results and the status of the methodology validation, safety factors or utilization factors more restrictive than those specified in API may be required for design. Safety factors less restrictive than those required in API are not accepted.

The manufacturer shall demonstrate that the predictions and tests consider the design methodology uncertainties and the capability and variations of the manufacturing processes. Sound statistic analysis must be included in the documentation to confirm that the test results and design tool predictions are representative.

3. Pipe Structure Design

For any flexible pipe structure, the manufacturer shall design the pipe to withstand seawater annulus flooding throughout the whole life cycle of the flexible pipe without violating the limit utilization factors defined in Table 8 of API 17J. The risers shall be designed so that, after the specified service life, the design still complies with the fatigue safety factors required herein, considering that the annulus flooding happened during installation.

Long term properties of all materials used in the flexible pipe, including degradation curves and corrosion rates, shall be considered in the design.

Flexible pipe body, end fitting and accessories shall be designed to withstand the loads deriving from any and all phases of the flexible pipe life cycle. Structural design shall comply with the requirements from I-ET-3010.00-1500-960-PPC-006 – Structural Analysis of Flexible Pipes.

Whenever fugacity, instead of partial pressure is used for the purpose of design and material selection, the manufacturer shall duly justify the applicability of fugacity regarding the targeted failure mechanisms.

Collapse analyses shall consider all phases of the life cycle and any source of ovalization, including bending, squeeze and residual ovalization caused prior to operation. If a given pipe design cannot withstand collapse at the design water depth at the operational MBR, the manufacturer shall limit the pipe MBR to a suitable value and demonstrate that the installation, operation and retrieval of such pipe is feasible.

Armor buckling analysis, radial and lateral, shall consider all phases of the life cycle of the flexible pipe. If a given pipe design cannot withstand the buckling loads at the design water depth at the operational MBR, the manufacturer shall limit the pipe MBR to a suitable value and demonstrate that the installation, operation and retrieval of such pipe is feasible.

Structural and fatigue analyses shall demonstrate that utilization factors, related to maximum strain of pipe polymeric layers, comply with criteria found herein and in API 17J. The analysis shall include the strain analysis of the internal pressure sheath of the installed flexible pipe system under the leak test conditions for the design water depth.

When sacrificial layers are employed adjacent to the internal pressure sheath, collapse analysis shall evaluate the pressure build up between the layers considering also the gases absorbed by the polymer and permeated and accumulated between adjacent layers. The analysis shall take into account the Project-specific internal fluid and depressurization rates. If no depressurization rate is informed, the manufacturer shall define the limit.

The manufacturer shall have a validated design methodology to calculate the maximum pressurization and depressurization rates. Alternatively, the manufacturer may use limit values based on fullscale testing.

The interface of any layer sealed in the end fitting (outer sheath or intermediate sheath) shall be designed in such a way that the every annulus space may be subjected to integrity tests up to the maximum pressure, in the factory, before pipe delivery. The interface of any layer sealed in the end fitting shall also be designed in such a way that any of the annulus spaces may be vented during recovery.

The friction factor between the extra external protective layer and any underneath layer shall be in such a way that no slide will occur during pipe installations, retrievals and re-installations.

The manufacturer shall be able to calculate the stresses and strains on the wires as received and generated by the spooling and manufacturing process and throughout the flexible pipe life cycle. Analysis against failure modes and mechanisms shall consider the history of stresses and strains whenever relevant.

The manufacturer shall provide results of structural stress/strain, fatigue and service life analyses of pipe ancillary components (e.g. bend stiffener and buoyancy modules), accessories (e.g. connectors and bend restrictors), end fitting, and hang-off. Flexible pipe accessories and ancillary equipment shall be designed considering the load cases applicable to the flexible pipes. The requirements from API 17L1 apply.

3.1. Design Criteria

The limit loads and consequential stresses shall be based on the limitations imposed by any of the pipe body layers or end fittings, including connector, or ancillary equipment.

Unless otherwise specified, the maximum and minimum values shown in the project-specific data are the actual limits expected for the field operation. It is up to the manufacturer to evaluate these values and design the flexible pipes with the appropriate safety margins.

The manufacturer may design the pipe for the intended maximum differential pressure, i.e. using the effects of the external pressure in the design of the flexible pipe, including accessories and ancillary components. This option does not apply to failure modes related to external pressure. Even if this design option is being used, the manufacturer shall also consider the effects of the absolute internal pressure for instance, in material selection, internal pressure sheath deformation calculations, sealing systems, permeation and fatigue. The flexible pipe design structure shall comply with the maximum differential design pressure for the maximum and minimum specified design water depths and associated maximum design pressures.

The manufacturer shall define, for each structure, the maximum and minimum operating water depth, considering the maximum differential design pressure and the maximum design pressure.

The manufacturer shall design the pipe for the buckling failure modes considering the pipe MBR. If there is any limitation in the bending radius, at any point in the flexible pipe life cycle, the manufacturer shall clearly demonstrate the cause for such limitation and present a handling, installation, operation and retrieval analysis demonstrating that the design is feasible and no risks are added to these operations.

Additionally to the MBR, the manufacturer shall calculate the Natural Bending Radius. The Natural Bending Radius shall be considered in the flexible pipe design analyses.

The flexible pipe design shall also comply with the bending, tension, and torsion applied during the reeling and unreeling processes during manufacturing, handling and installation. Special requirements regarding reeling and handling of flexible pipes shall be clearly stated in the Operating Manual.

3.2. Design Requirements for Pipe Layers

3.2.1. Internal Pressure Sheath

The design methodology shall account for the protrusions of the selected internal pressure sheath polymer into the carcass and pressure armors gaps. Furthermore, the thickness of the internal pressure sheath shall be such that no excessive deformation or creep into the gaps of the surrounding layers will induce cracks or defects in the internal pressure sheath.

This analysis shall include the effects of long term exposure to internal pressure and temperature, creep, swelling, ageing, temperature and pressure cycles and fatigue. The design of the Internal Pressure Sheath shall always consider the bore to be saturated with water. The manufacturer shall have a validated design methodology covering these aspects for each type of polymer used.

If PVDF is selected, the manufacturer shall adopt unplasticized PVDF, as per API RP 17B definition. PVDF pipes shall be designed and manufactured to comply with maximum allowed surface roughness and potential stress concentration factors in the interface with the surrounding layers. Other types of PVDF shall be considered as new materials.

Especially for the PVDF, the manufacturer shall demonstrate that the design and manufacturing criteria is adequate to avoid cracks in the Internal Pressure Sheath throughout the flexible pipe life cycle. Therefore, the manufacturer shall have a validated design methodology covering these aspects.

If polyamide is selected (PA-11 or PA-12), the manufacturer shall consider the minimum CIV of 1.1 dl/g for flowlines and 1.2 dl/g for risers. The manufacturer shall have evidences demonstrating that the design predictions are accurate.

The Internal Pressure Sheath material shall account for the possible ingress in the gaps of the Pressure Armour and of the Carcass. The analysis regarding the ingress of Internal Pressure Sheath material in the gaps shall account for water and CO_2 exposure, decompression cycles, volume change and the dynamic effects of bending as a minimum.

3.2.2. Outer Sheath

The external protective sheath shall not constitute a second annulus where pressure build-up may occur. The space between the outer sheath and external protective sheath shall be vented or open to the external environment.

The friction factor between the extra external protective layer and any underlying layer shall be such that no slide will occur during pipe installations, retrievals and re-installations. Whenever necessary, the external protective sheath shall be fixed at the end fitting interface.

Friction behavior of the Outer Sheath shall be documented and used in the flexible pipe design. The flexible pipe design shall account for friction between the Outer Sheath and underlying and overlying layers, as well as between Outer Sheath and External Protective Sheath. If any additives, materials or manufacturing aids are used between the Outer Sheath and External Protective Sheath, they shall be accounted for in the flexible pipe design.

Pipes designed to work with flooded insulation layers, i.e. pipes that have a sealed sheath beneath the insulation and a non-sealed sheath above the insulation, are not required to have an External Protective Sheath.

Outer Sheath and External Protective Sheath shall be designed considering weather and UV exposure during long-term storage onshore, in Brazil, prior to the operating service life. A period of at least 4 years shall apply. For risers, the design shall assume that, regardless of the section, the outer sheath can withstand sunlight exposure throughout the flexible pipe life cycle.

The minimum thickness of the outer sheath and the external protective sheath, shall be as indicated in Table 1 below:

Table 1: Minimum thickness of outer sheath and external protective sheath

Structure ID (in.)	Minimum Thickness (mm)
2.5	4.5
4	5.5
6 to 7	7.0
8	8.5

9 to 10	10.0
11 to 12	11.5
14 to 15	14.5
16 to 17	15.0

The minimum thickness values indicated above may be increased whenever the manufacturer deems necessary in the design. Smaller values may be accepted provided that the design does not increase the risk of annulus flooding and that it is previously accepted by the purchaser.

The manufacturer shall have a validated design methodology to predict the wear in the outer sheath or external protective sheath. The flexible pipe design shall demonstrate that the outer sheath material and thickness comply with the full service life. The design methodology shall account for:

a) Number and length of cycles in operation;

b) Contact pressure between;

c) Geometry and material properties if the interfaces;

d) The compression forces and the friction between the surfaces in contact;

e) Surface temperature;

f) Presence of seawater in the contact area;

g) Abrasive and mechanical properties of materials in contact;

h) Change of profile of contact areas throughout the riser service life;

3.2.2.1.Outer Sheath Repair

Outer Sheath repair procedure shall ensure that the pipe annulus is watertight. The manufacturer shall demonstrate that the annulus of the repaired pipe will remain water tight throughout its life cycle.

Flexible pipes that required outer sheath repair shall comply with the same requirements applicable to the new pipes, e.g. repair procedure shall not prevent free annulus flow and the External Protective Sheath shall provide proper protection of the Outer Sheath. The repair procedure shall not foresee the need of flushing or corrosion inhibitor injection.

3.2.3. Intermediate Sheath

If a smooth bore pipe is specified for water injection application, a leak proof intermediate sheath, sealed in the end fitting – i.e. anticollapse sheath – shall be applied in order to prevent the collapse of the internal pressure sheath, even if the annulus is flooded (e.g. due to an outer sheath damage).

3.2.4. Internal Carcass

The design of the internal carcass shall also account for the following:

a) stresses caused by crushing loads, combined or not with tension (squeeze loads from the tensile armors),

b) the distance or contact stresses between the pressure armor and the internal pressure sheath,

c) stresses generated by axial elongation and/or bending in the interlocked spirals of the carcass.

The carcass design shall not allow any crack initiation or growth.

The manufacturer shall demonstrate that the pipe design considers all possible sources of carcass ovalization throughout the flexible pipe life cycle, including the effects of bending, crushing and bending over chutes and reels.

The manufacturer shall demonstrate that the pipe design methodology considers the imperfections in the carcass shape in a conservative way. Typical ovality measurement, i.e. using measurements 90° apart, may not represent the most critical aspect of carcass shape.

3.2.5. Pressure Armours

The pressure armors shall be designed for the required hoop strength and shall account for the control of gaps between wires, the prevention of loss of interlock, plastic deformation and residual stress from the manufacturing process and from FAT.

Pressure armor design shall take into account the collapse with minimum specified internal pressure, maximum external pressure and maximum layer ovalization.

Pressure armor shall be designed to withstand the crushing loads combined with tension (squeeze loads from the tension armors), induced by the installation methods and equipment.

For safety reasons, risers shall have an interlocked pressure armor overlying the internal pressure sheath.

For smooth bore pipes or pipes with an Intermediate Sheath designed to prevent collapse, the pressure armor design shall consider the full external pressure acting on the outside of the leak proof intermediate sheath.

3.2.6. Tensile Armours

The manufacturer shall design the flexible pipe in such a way that the torsional balance between the armours shall not lead to the formation of loops, kinks, or buckling of the tensile armors. The maximum allowed pipe rotation under any load case foreseen for the flexible pipe life cycle is 0.6°/m. The allowable pipe twist shall be reduced if its effects lead to other failure modes, such as pipe crushing or lateral buckling.

Tensile armors shall be designed against buckling due to axial compression associated or not to bending and torsional loads. The limits for utilization factor (0.85) of Table 8 of API 17J shall apply if the methodology is calibrated against sufficient data from controlled, instrumented, lab tests. If there is no instrumented lab data to support the methodology – i.e.

methodology based on un-instrumented DIP tests – the maximum utilization factor for the Operation Conditions (Table 8, API 17J) shall be 0.67.

3.2.7. Additional Layers

3.2.7.1.Flexible Pipe External Protection

See item 3.2.2 above.

3.3. End Fitting

For the design of end fittings, the dimensional limitations defined in the project specific documentation shall apply. It shall be considered that flexible pipes and accessories can be laid in both directions. Exceptions on this requirement may only be accepted if demonstrate to Petrobras that the project feasibility depends on the adoption of only one laying direction.

The manufacturer shall design the end fitting so that it may be assembled in the pipe laying vessel if required. The same tolerances and quality control checks from in-factory assembly shall apply to end fittings assembled offshore.

For water injection *smooth bore* pipes, the *end fitting* shall be designed in such a way that the performance of the external sealing system of the *leak proof intermediate sheath* can be checked anytime through a nitrogen pressure test at a pressure of 2 bar. Test port shall be designed for use in factory and also on board of the installation vessel.

The end fitting shall be designed to avoid the ingress of seawater through any of its ports or sealing interfaces. The design shall allow the testing of all vent ports, epoxy injection ports, seal testing ports and sealed interfaces (e.g. between jacket and body) to confirm end fitting suitability to operate at the design water depth.

3.4. Service Life Analysis

3.4.1. Static and Dynamic Applications

For both risers and flowlines, the manufacturer shall establish a maximum time to repair and the service life associated with the event of outer sheath damage leading to aerated seawater in the annulus.

3.4.2. Dynamic Applications

For pipes in the annulus flooded with deaerated seawater condition, the manufacturer may adopt a reduced fatigue safety factor of 3.3 or more for the tensile armors of the top riser provided that:

a) the methodology validation supports the use of lower safety factors; and

b) the top end fitting is accessible from the production unit with the proper access to the annulus.

For water injection pipes, as they are classified in a lower safety class, reduced design fatigue factors may be considered. Single-well water injection risers may use a reduced fatigue safety factor of 3.0. Multiple-well water injection risers may use a reduced fatigue safety factor of 6.0 that may be further reduced to 3.0 if conditions (a) and (b) above are met.

If, due to project specific restrictions, the SpyHole end fitting is not applicable for hydrocarbon carrying pipes, the fatigue safety factor reduction is not allowed.

3.4.3. Fatigue Analysis of Armor Wires in the Pipe Body

3.4.4. Fatigue Analysis of Armor Wires in the End Fitting

3.4.5. Ageing

3.5. Annulus Prediction

The manufacturer shall have a methodology to predict the pipe annulus conditions. This design methodology shall be developed using a theoretical basis and validated through experimental data.

The annulus prediction model shall be capable of calculating the annulus composition, pressure and temperature at any point in the flexible pipe. The model shall also consider the change in annulus pressure over time due to the permeation of fluid into the annulus or due to the external hydrostatic pressure.

The annulus prediction model shall be able to predict the evolution of the condensation in the pipe cross section and along the pipe length. The manufacturer shall be able to demonstrate, based on the annulus condition, the pipe service life and the adequacy of materials against applicable failure modes and mechanisms (e.g. SSCC, HIC, corrosion, corrosion-fatigue or ageing).

The annulus prediction model shall be able to predict multiple phases in the annulus, including supercritical phases. The model shall also be able to predict the eventual segregation or combination of these phases.

The qualification of the annulus prediction model shall include full-scale tests to represent actual pipe conditions in the annulus. The annulus prediction model shall be validated and certified by the IVA. All related documentation shall be available for Petrobras review.

3.5.1. H_2S Consumption

The manufacturer may consider H_2S consumption in the annulus. If it chooses to do so, additional testing shall be done to validate the design premise. Testing details are presented in I-ET-3000.00-1519-291-PAZ-006 – Materials. A specific IVA certificate shall be issued evaluating the H_2S consumption methodology.

3.6. Design Requirements for Ancillary Equipment

This Section presents additional requirements with respect to those found in API Spec 17L1.

3.6.1. Bend Stiffener

Top bend stiffener design shall comply with I-ET-3010.00-1500-960-PPC-011 – General Bend Stiffener Requirements.

3.6.2. Bend Stiffeners Stopper

Bend Stiffener Stopper shall be designed with a reel shape and withstand to the dynamic loads caused by the bend stiffener drop due to installation or operation failures of fasteners (e.g. respectively, wire cables or bell mouth locking device). Stopper design shall consider possible interference with the surrounding risers so that no damage shall arise if clashing occurs.

3.6.3. Bend Restrictors

For the design of bending restrictors, the manufacturer shall consider the normal installation condition, assuming that the pipe bore is fully flooded with seawater during the vertical connection of the flexible pipe to the subsea equipment. After the connection, during the rest of the pipe laying operation, the manufacturer shall consider that there will be no more water entrance or contact between internal and external environments.

If project-specific documentation requires the pipes to be installed with an empty bore, the manufacturer shall consider both scenarios in the design.

In order to allow the bending radius to be estimated during pipe laying, each restrictor segment shall be painted with a different color from the adjacent ones to allow the inspection with the ROV camera to distinguish between each one of them.

3.6.4. Bellmouths

3.6.5. Buoyancy and Ballast Modules

If buoyancy or ballast modules are used, the manufacturer shall demonstrate that the modules and materials are qualified for their design water depth (see below) and comply with all other functional requirements.

Buoyancy modules shall be designed to withstand the operating water depth of the pipe section to which they will be applied. If the project requires the pre-abandonment of the riser, the manufacturer shall design the buoyancy modules considering the depth achieved during this pre-abandonment.

3.6.6. Subsea Buoys

3.6.7. Tethers

3.6.8. Riser and Tether Bases

3.6.9. General Clamping Device Requirements

3.6.10. Subsea Buoy Clamps

3.6.11. Tether Clamps

3.6.12. Piggy-back Systems

3.6.13. Repair Clamps

3.6.14. I/J-tube Seals

3.6.15. Pull-in Heads

3.6.16. Chinese Fingers/Cable Grips

3.6.17. Connectors

The manufacturer shall verify if the connectors specified by Petrobras in the project specific documentation, when combined with the products and accessories to be supplied, comply with the system design and associated rules and referenced standards and submit any necessary design change to Petrobras.

3.6.18. Load-transferring Devices

The hang-off design shall hold the end fitting in place in case of reaction due to an abrupt rupture of the riser top section. The design of the devices shall consider the maximum design pressure combined with the design tension (effects of the rapid tension release).

The hang-off design shall also allow the maintenance of the monitoring system, if any, and an easy connection of the Annulus Venting System according to the project specific documentation.

3.6.19. Mechanical Protection

This section presents some requirements regarding protections added to the product and which are not normally produced in the same manufacturing line of the flexible pipe. The necessity of installation of an anti-abrasive protection is indicated in the project specific documentation.

The anti-abrasive protection against aggressive soils at the TDP region of risers shall be designed in such a way that its assembly on the riser is to be carried out during laying operation. So, anti-abrasive protections fixed over the outer sheath during manufacturing are unacceptable. Whenever anti-abrasive protection is specified, the manufacturer shall supply pre-qualified protection.

For protection of the surrounding risers against outer sheath abrasion between the bend stiffener stopper and their outer sheaths, the manufacturer shall design polyurethane sleeves for assembling in the stoppers considering the loads and conditions from the installation and operation phases.

If specified, the flexible pipe region close to the anchoring collar location shall be protected against abrasion caused by the friction of anchor pile rigging.

The manufacturer shall demonstrate that all proposed protections will comply with the specified service life.

3.6.20. Fire Protection

4. System Design Requirements

4.1. General

As a general rule, risers shall be designed in a free hanging configuration. Exceptions may be accepted if the manufacturer demonstrates that this configuration is not feasible, in this case, lazy wave configuration shall be adopted. The riser configuration design shall comply with the preliminary riser configurations shown in project specific documentation. The manufacturer shall perform riser interference analysis considering the specified riser configuration and project specific data regarding other neighboring risers, tendons, mooring lines, vessel hull and subsea equipment.

For risers, the manufacturer shall submit results of the TDP Displacement Analysis calculated for TDP displacements for all operating conditions. The analysis shall demonstrate that the vertical displacement of the interface between the riser and flowline is null and that the tension load applied to the subsea equipment is null. The manufacturer may propose to increase the riser length and, if necessary to use an anchoring system in the interface between the riser and flowline in order to fulfill these criteria.

Fasteners use that are exposed to any cathodic protection system during the service life and whose fail represent risk of damage to the flexible pipe shall be designed to comply with the requirements of technical specification ET-3000.00-1500-251-PEK-001.

4.2. Corrosion Protection

4.2.1. Galvanic Corrosion

4.2.2. Surface Treatment

All steel surfaces exposed to the external environment shall be prepared and coated in accordance with internationally recognized standards for corrosion protection against all foreseen environmental conditions, unless the material is documented to be corrosion-resistant in the specified environment. The anti-corrosion coating shall also protect end fitting, ancillary components, and accessories against long-term exposure to the weather at the quay side (unprotected area). The anti-corrosion protection shall be designed for the specified service life.

Coatings applied to End Fitting parts, ancillary components, and accessories shall be resistant against abrasion and impacts that typically occur during the flexible pipe life cycle.

Ancillary components, accessories and end fittings shall have their metallic components protected against corrosion on internal and external surfaces, whichever is applicable, in contact with seawater or exposed to marine atmosphere. The following requirements apply:

a) End fittings and connectors:

- Coating for corrosion protection of external surfaces of end fittings and connectors shall be adequate to protect end fittings in severe marine corrosive environments, during storage and service, above and below the seawater or in the sea bottom, for the specified maximum water depth considering that the end fitting may be buried and without any extra cathodic protection.
- The coating shall comply with the requirements of I-ET-3000.00-1500-956-PZ9-001 – Anticorrosive coating for end fitting and connectors. Alternatively, Interdiffused Electroless Nickel Coating can be used for external surfaces, for all pipe functions according to ET-3000.00-1500-950-PMU-001 – Revestimento de níquel químico com tratamento térmico de interdifusão.
- For hydrocarbon carrying pipes, Alloy 625 (UNS No. N06625) weld overlay shall be used for all parts in contact with the internal fluid, including the seal ring groove of flange and the face of the flange.
- For water injection pipes, an alternative coating may be applied in the surfaces in contact with the internal fluid and Alloy 625 (UNS No. N06625) weld overlay shall be used in the seal ring groove and in the face of the flange. The alternative coating shall be previously approved by Petrobras.
- Alloy 625 (UNS No. N06625) weld overlay shall comply with ISO-10423. Seal rings (ref. Figure 8 of API 17B) shall be made of materials adequate to withstand to the internal fluid conditions. The minimum hardness of the seal ring grooves of flanges shall be 220 HB and the flange groove shall be at least 30HB harder than the seal ring.

b) *Bend Stiffener* – see I-ET-3010.00-1500-960-PPC-011 – General Bend Stiffener Requirements;

c) *Bend Stiffener Stopper* shall be painted, as per item 5.1.4.7 of API Spec17D Second Edition and protected with anodes;

d) *Bend Restrictor*: shall be painted, as per item 5.1.4.7 of API Spec17D Second Edition and protected with anodes. Corrosion allowance shall be adopted in order to assure the restrictor function for the specified service life in the event of damaged painting;

e) Anchoring Collars: shall be painted, as per item 5.1.4.7 of API Spec17D Second Edition and protected with anodes;

f) Pulling heads and handling blind flanges: shall be painted, as per item 5.1.4.7 of API Spec17D Second Edition;

g) Seal gaskets (e.g. “O” BX rings) shall comply with ISO-10423 and the material of this component shall be alloy 625 (UNS No. N06625). The maximum hardness of the alloy 625 seal gaskets shall be 190 HB. In case of seal gaskets used only for hydro test and handling purposes, AISI 316L shall be used;

h) Fasteners (stud bolts, nuts, etc.) shall be protected against corrosion on all surfaces in contact with seawater or exposed to marine atmosphere. The galvanic corrosion in seawater caused due to the contact of dissimilar materials shall be taken into account for the selection of materials.

i) *End fitting adapters*: corrosion protection of *end fitting adapters* shall be the same defined above for *end fittings*. The minimum hardness of the seal ring grooves of flanges shall be 220 HB.

4.2.3. Corrosion Allowance

4.2.4. Cathodic Protection

For the flexible pipe system, the manufacturer shall comply with the requirements of ET-3000.00-1500-940-PZ9-001 – Cathodic Protection.

For top bend stiffeners, the manufacturer shall consider the additional requirements defined in I-ET-3010.00-1500-960-PPC-011 – General Bend Stiffener Requirements.

4.3. Thermal Insulation

Thermal insulation, when required, is specified in the project specific documentation.

For the purpose of providing better insulation capacity, pipe concept having a sealed intermediated sheath outside the pressure armor is not accepted by Petrobras (except for water injection pipes), unless the sealed intermediate sheath is external to the outermost tensile armors.

4.4. Gas Venting

The design of the flexible pipe shall allow for permeated gases to be vented. For safety reasons, flexible pipes shall be designed so that any pressure build up between layers is relieved during recovery, i.e. no space in the flexible pipe shall be left pressurized once the pipe is onboard.

Gas venting system is required for both end fittings of all pipe sections. Exceptions may apply if the manufacturer demonstrates that venting through one end fitting is enough or in water injection pipes, where vent valves shall only be installed in the top end fitting of the top riser, in the interface with the floating unit.

Gas venting system shall be designed according project specific documentation. The gas venting system shall comply with service life requirements of the flexible pipe.

4.5. Pigging and TFL Operations

4.6. Fire Resistance

4.7. Routing

4.8. On-bottom Stability