PETROBRAS	TECHNICAL SPECIFICATION	N°:	I-ET-0000.00-0000-210-P9U-003
	CLIENT: PETROBRAS		SHEET: 1 of 11
	JOB: RIGID OFFSHORE PIPELINES		CC:
	AREA:		PROJECT:
DENGE	TITLE: **MINIMUM REQUIREMENTS FOR POLYMERIC LINERS FOR WATER INJECTION SUBSEA PIPELINES**		EDA / EDR

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CONTENT

1 OBJECTIVE AND SCOPE

1.1 OBJECTIVE

1.1.1 The objective of this Technical Specification is to specify the minimum requirements for "tight fitting" polymeric liner systems, as defined by ref. [15], to be used at water injection subsea rigid pipelines. This type of liner is characterized by the interference between the liner and the case pipe due to mechanical interference, e.g., the liner's outer diameter is greater than linepipe's inner diameter.

1.1.2 The minimum requirements herein specified are applicable for material selection, design, manufacturing, insertion, qualification, pipeline installation, and operation of polymeric liners.

1.1.3 This specification is applicable to flowlines and risers in steel lazy-wave configuration of water injection subsea pipelines.

1.2 SCOPE

1.2.1 The scope of this Technical Specification includes liners constituted of high density polyethylene for subsea water injection pipelines. Other materials and uses are not scope of this document.

1.2.2 The scope also includes the connection systems.

1.2.3 The scope includes the development of a risk analysis at start of project listing all critical aspects related to HDPE system and possible mitigations to be implemented.

1.3 TERMS AND ABBREVIATIONS

1.3.1 The terms and abbreviations used in this Technical Specification are in accordance with [1], [12] and [13].

1.3.2 Table 1 presents additional terms and abbreviations used within this Technical Specification.

Table 1 - Additional terms and abbreviations.

CONTRACTOR	Company responsible for the engineering design, procurement, construction, and installation of the scope herein included.
CRA	Corrosion resistant alloy.
HDPE	High density polyethylene.
MDS	Material data sheet.
MFR	Melt mass-flow rate.
ND	Nominal diameter.
PEX	Crosslinked polyethylene.
PIG	Pipeline inspection gauge.
Pipe String	Set of line pipes joined by welding.
PQT	Pre-qualification trial.
PLP	Polymeric Lined Pipe
Procurement	All phases related to the material supply, including quotation, purchase order, material follow up, inspection, tests, insurance, freight and delivery to site.
RFI	Request for information.
SLWR	Steel lazy-wave riser.
Stalk	Pipe string fabricated for reel-lay installation method.
Verify / Verification	To review and issue comments to be implemented by CONTRACTOR.

1.4 REFERENCES

1.4.1 CODES, STANDARDS AND RECOMMENCED PRACTICES

[1] API SPEC 15LE, SPECIFICATION FOR POLYETHYLENE LINE PIPE (PE), 2022.

[2] ASTM D638, STANDARD TEST METHOD FOR TENSILE PROPERTIES OF PLASTICS, 2014.

[3] ASTM D790, STANDARD TEST METHODS FOR FLEXURAL PROPERTIES OF UNREINFORCED AND REINFORCED PLASTICS AND ELECTRICAL INSULATING MATERIALS, 2017.

[4] ASTM D1238, STANDARD TEST METHOD FOR MELT FLOW RATES OF THERMOPLASTICS BY EXTRUSION PLASTOMETER, 2020.

[5] ASTM D1505, STANDARD TEST METHOD FOR DENSITY OF PLASTICS BY THE DENSITY-GRADIENT TECHNIQUE, 2018.

[6] ASTM D1693, STANDARD TEST METHOD FOR ENVIRONMENTAL STRESS-CRACKING OF ETHYLENE PLASTICS, 2021.

[7] ASTM D2240, STANDARD TEST METHOD FOR RUBBER PROPERTY – DUROMETER HARDNESS, 2015.

[8] ASTM D3350, STANDARD SPECIFICATION FOR POLYETHYLENE PLASTICS PIPE AND FITTINGS MATERIALS, 2021.

[9] ASTM D3418, STANDARD TEST METHOD FOR TRANSITION TEMPERATURES AND ENTHALPIES OF FUSION AND CRYSTALLIZATION OF POLYMERS BY DIFFERENTIAL SCANNING CALORIMETRY, 2021.

[10] ASTM D3895, STANDARD TEST METHOD FOR OXIDATIVE-INDUCTION TIME OF POLYOLEFINS BY DIFFERENTIAL SCANNING CALORIMETRY, 2019.

[11] ASTM F2620, STANDARD PRACTICE FOR HEAT FUSION JOINING OF POLYETHYLENE PIPE AND FITTINGS, REV. A.

[12] DNVGL-ST-F101, SUBMARINE PIPELINE SYSTEMS, 2017.

[13] DNVGL-ST-F201, DYNAMIC RISERS, 2018.

[14] ISO 9080, PLASTICS PIPING AND DUCTING SYSTEMS – DETERMINATION OF THE LONG-TERM HYDROSTATIC STRENGTH OF THERMOPLASTICS MATERIALS IN PIPE FORM BY EXTRAPOLATION, 2012.

[15] NACE SP0304, DESIGN, INSTALLATION, AND OPERATION OF THERMOPLASTIC LINERS FOR OILFIELD PIPELINES, 2016.

[16] ISO 4427 (ALL PARTS), PLASTICS PIPING SYSTEMS FOR WATER SUPPLY AND FOR DRAINAGE AND SEWERAGE UNDER PRESSURE — POLYETHYLENE (PE), 2019.

[17] ASTM D 2837, STANDARD TEST METHOD FOR OBTAINING HYDROSTATIC DESIGN BASIS FOR THERMOPLASTIC PIPE MATERIALS OR PRESSURE DESIGN BASIS FOR THERMOPLASTIC PIPE PRODUCTS, 2022.

[18] ISO 21307, PLASTICS PIPES AND FITTINGS — BUTT FUSION JOINTING PROCEDURES FOR POLYETHYLENE (PE) PIPING SYSTEMS, 2017.

[19] I-ET-0000.00-0000-274-P9U-001, SLWR DETAILED STRUCTURAL DESIGN REQUIREMENTS, REV. G.

[20] I-ET-0000.00-0000-210-P9U-004, WELDING AND NDT OF SUBMARINE RIGID PIPELINE, RISERS, AND PIPELINE COMPONENTS.

[21] RT TIA TMEC 11/2024, *LINER POLIMÉRICO PARA DUTO RÍGIDO SUBMARINO (DRS) – RISER DE INJEÇÃO DE ÁGUA (IA)*.[1]

[1] PETROBRAS use only, shall not be shared without PETROBRAS system.

2 MATERIAL REQUIREMENTS

2.1 The requirements presented in this section apply to the liner material. These requirements apply exclusively for systems based on the use of HDPE and are in accordance with [1], [15], and [16]. This specification is not applicable to PE-RT and PEX.

2.2 Requirements related to metallic materials such as CRA possibly used in connectors are not addressed by this Technical Specification, although is assumed that suitable and qualified materials are adopted as needed.

2.3 CONTRACTOR shall select the proper HDPE material to suit project's design lifetime, operating temperature, maximum temperature, operating pressure, maximum operating pressure, fluid characteristics, weather conditions in Brazil, and any other boundary condition that CONTRACTOR deems applicable. For qualification purposes, material must be in accordance with API/ASTM standards ([1], [8] and [17]) or in accordance with ISO standards ([14] and [16]). At lease the requirements specified for PE4710 (API/ASTM) and PE100 (ISO) shall be fulfilled.

2.3.1 As an initial approach, CONTRACTOR shall consider 60 ˚C as operating temperature and 70 ˚C as design temperature. The actual values shall be confirmed by PETROBRAS in a case-by-case approach.

2.4 As recommended by Section 3.3.3 of [15], the mechanical properties of the HDPE shall also be measured after reaching equilibrium in the fluid environment so that the effects of absorbed chemicals present in the fluid can be measured and reported.

2.4.1 This requirement may be dismissed if there is traceable and irrefutable evidence that service fluid is not expected to have a significant effect on the material. Sufficient data demonstrating compatibility shall be issued to PETROBRAS analysis and approval.

2.5 Liner materials shall be selected based on mechanical properties and chemical resistance information supplied by polymer manufacturer within the MDS. Published chemical compatibility tables such as PPI TR-19 'Chemical Resistance of Thermoplastics Piping Materials' may be utilized to provide comparisons and assess for potential impacts in a preliminary basis. In this case, CONTRACTOR shall submit technical documentation to PETROBRAS analysis and approval.

2.6 CONTRACTOR shall consider the necessity of performing fluid chemical compatibility tests as per Section 3.7 of [15]. Specific conditions and tests procedures shall be submitted to PETROBRAS for verification and approval.

2.7 Raw material manufacturer and pipe manufacturer shall issue a quality certificate containing at least MFR, melting point and thermal stability per batch of material. Yield strength and elongation, break strength and elongation and modulus, thermal stability, pressure test,

carbon content and dispersion (if non-masterbatch system), ovality, toe-in/circumferential reversion on extruded pipe material per batch manufactured. The data required in Sections 2.4 and 2.6 of this Technical Specification shall be included in the Design Report issued by CONTRACTOR.

2.8 CONTRACTOR shall select the liner material considering at least: operational temperature, design temperature, operational pressure, design pressure, characteristics of transported fluids (e.g. composition, dissolved gas content, solid content), and all loads that the polymeric liner may be subject during fabrication, installation, and operation.

2.9 CONTRACTOR shall supply documentation to demonstrate that selected material has an extensive track record of use in similar conditions, e.g., temperature, pressure, chemical characteristics of transported fluid, of the intended use.

2.10 CONTRACTOR shall specify the additional requirements it deems necessary to guarantee the suitability of selected material. The additional requirements shall be included in the quality certificate of raw material and / or pipe.

3 MINIMUM REQUIREMENTS FOR DESIGN, MANUFACTURING, AND INSERTION OF LINER

3.1 DESIGN

3.1.1 The design of the polymeric liner shall be performed in accordance with Sections 4 and 5 of [15].

3.1.2 The design shall also consider the requirements presented on Section 5 of [1] and requirements of Section 2.

3.1.3 The design shall consider all relevant loads from manufacturing, insertion, installation, and operation phases. Specific requirements and conditions related to the operation of the pipeline shall be clearly addressed.

3.1.3.1 The design of liner for risers shall consider additional loading cases and effects, as applicable. The vertical stability of liner as a consequence of liner's self-weight and creep effect, for example, and collapse resistance during shutdown/shut-in cycles shall be assessed.

3.1.4 All calculation shall be performed through analytical spreadsheets or finite element analysis. A design report shall be issued by CONTRACTOR and submitted to PETROBRAS for review and approval.

3.1.5 The design of the polymeric liner shall be integrated to the pipeline design. Applicable requirements from [12], [13] and [19] shall be fulfilled.

3.1.6 The associated fatigue of pipeline and liner caused by HDPE insertion, pipeline installation and operation shall be properly addressed during design phase.

3.1.6.1 The fatigue assessment of the liner shall consider the effects of operational and design temperature in liner material's properties.

3.2 HDPE PIPE MANUFACTURING

3.2.1 The polymeric liner shall be constituted of extruded pipes manufactured in accordance with Section 6 of [1] or in accordance with [16].

3.2.2 Polymeric pipes containing defects (e.g., wrinkles, porous, die swell marks, etc.) shall not be used.

3.2.2.1 The pipe section containing the defect shall be removed and the remaining length of the pipe may be used.

3.2.2.2 Repairs on polymeric pipes are not accepted.

3.2.2.3 Reprocessing of the defective pipe section (e.g., milling for re-extrusion) is not accepted. The pipes shall be manufactured using virgin material only.

3.2.3 Pipes manufacturing parameters such as extrusion temperature, screw rotation speed, extrusion pressure, material flow rate, quenching temperature, and quenching duration shall be continuously monitored and recorded.

3.2.4 A quality program for pipe manufacturing shall be adopted as per Section 7 of [1] or in accordance with [16].

3.2.5 If joining of pipes is necessary, the extruded pipes shall be joined by heat fusion – butt fusion – as per [11] or [18].

3.2.5.1 After cooling, external and internal fusion beads shall be trimmed off. After trimming, the butt fusion area shall be visually inspected to guarantee that no defects were created during trimming operation.

3.2.5.2 Defects such as cold weld, lack of fusion, porous, misalignment between pipes, etc. are not acceptable. In this case, the defective section shall be removed, and the butt fusion shall be redone.

3.2.5.3 Cooling time before application of any load shall be clearly defined in the Design Report and respected during manufacturing procedure.

3.3 LINER INSERTION

3.3.1 The liner insertion shall be performed considering the requirements and recommendations of Section 6 of [15].

3.3.2 CONTRACTOR shall issue a detailed insertion procedure and submit it to PETROBRAS verification. The procedure shall describe all relevant steps, imposed loads and necessary equipment to perform the insertion. The procedure shall also contain drawings of main steps performed during liner insertion.

3.3.3 CONTRACTOR shall perform the insertion procedure without damaging the polymeric liner. In case of damaging the polymeric liner, the affected section shall be removed. Repairs on polymeric liner are not accepted.

3.3.4 CONTRACTOR shall inspect the inner surface of the linepipe case (metallic pipe / stalk) to avoid damages on liner due to case irregularities (e.g., weld spatter, debris). The recommendations provided at Section 6.2.7 of [15] are considered good practices and shall be accomplished.

3.3.5 The use of a lubricant for insertion is acceptable since it does not jeopardize the performance of the lined pipeline during installation and operation. In this case, the use of lubricant shall be considered at the design, especially for thermal expansion, axial buckling analyses and gripping and liner and steel pipe.

3.3.6 Liner stresses level shall not exceed the manufacturer’s recommended maximum in any circumstances.

3.3.7 During insertion, all relevant parameters such as pulling tension, diameter reduction ratio, etc., shall be continuously monitored and recorded.

3.3.8 The liner shall be properly anchored into the case pipe / stalk in order to allow the pipeline installation and to prevent the liner displacement (axial buckling) due to high operation temperatures. The gripping force necessary to support all loads imposed by installation shall be determined at the design phase and confirmed at the PQT.

4 MINIMUM REQUIREMENTS FOR CONNECTION SYSTEM AND LINED PIPELINE OPERATION

4.1 CONNECTION SYSTEM

4.1.1 The design of the connection system shall consider all relevant loads which the pipeline may be submitted to during installation and operation phases. Specific requirements and conditions due to its intended use shall be clearly addressed.

4.1.2 CONTRACTOR shall issue a design report of the connection system for PETROBRAS verification and approval.

4.1.3 Connection system design report shall also address special connections, e.g., connections between lined pipeline and PLET, lined pipeline and flange, etc.

4.1.4 The connection system shall guarantee that no transported fluid will get in contact with the steel host pipeline. Special attention shall be addressed to fluid permeation at polymeric liner edge within the connector.

4.1.5 The connection system shall be suitable to pigging operations during pre-commissioning and operational phases. The system shall withstand at least loads imposed by high density foam pigs and interference pigs used for cleaning the pipeline and caliper pig used during pre-commissioning.

4.1.6 CONTRACTOR shall issue for PETROBRAS verification a detailed drawing of the connection system. Selected materials for each component of the connection system (e.g., connector body, interference ring, heat shield, etc.) shall be clearly indicated / specified.

4.1.7 CONTRACTOR shall also issue for PETROBRAS verification an installation procedure of the connection system including all relevant steps and necessary equipment. CONTRACTOR may opt to include this procedure in the liner installation procedure.

4.2 LINED PIPELINE OPERATION

4.2.1 The entire polymeric liner system (e.g., liner, case pipe and connectors) shall be suitable to requirements of operational phase. The system shall be suitable to chemical composition of transported fluid, pipeline design temperature and pipeline design pressure.

4.2.2 The entire polymeric liner system shall be suitable to pigging during operational phase. The system shall withstand at least loads imposed by high density foam pigs and interference pigs used for cleaning the pipeline.

4.2.3 CONTRACTOR shall inform PETROBRAS of any special procedure demanded for properly and safe operation of polymeric lined pipeline.

5 MINIMUM QUALIFICATION REQUIREMENTS

5.1 GENERAL

5.1.1 The polymeric liner system shall be qualified through a project specific PQT.

5.1.2 The PQT encompasses the material selection, liner design, liner insertion, prototype manufacturing, prototype operation, small scale and full-scale evaluations as described throughout following sections.

5.1.3 All PQT activities herein mentioned shall be witnessed by a PETROBRAS representative or by a CERTIFY AUTHORITY assigned by PETROBRAS.

5.1.4 Before starting of any qualification activity, CONTRACTOR shall issue to PETROBRAS verification a PQT proposal containing all boundary conditions (e.g., host pipe inner diameter, installation method, operating and design temperatures, operating and design pressures, etc.), all required evaluations and tests, and all applicable acceptance criteria.

5.1.5 CONTRACTOR shall issue a PQT Report for PETROBRAS verification at completion of all requirements herein specified.

5.2 DESIGN AND MATERIAL SELECTION

5.2.1 Prior to the start of any practical PQT activity, CONTRACTOR shall issue to PETROBRAS verification a Design Report in accordance with the requirements defined in Section 3 of this Technical Specification. The specific scenario to be considered will be defined by PETROBRAS as demanded.

5.2.2 The design report shall also contain all material data from Section 2 of this Technical Specification. A CERTIFY AUTHORITY representative must have witnessed all tests. Tests certificates shall have the CERTIFY AUTHORITY representative official stamp.

5.2.3 Due to the specificity of the requirements from Sections 2.4 and 2.6, CONTRACTOR shall envisage the necessity of performing these tests instead of presenting historical data. All material supplied shall be tested certified by manufacturer.

5.3 LINER INSERTION AND PIPE STRING MANUFACTURING

5.3.1 CONTRACTOR shall issue to PETROBRAS verification a Liner Insertion Procedure containing all relevant information as specified in Section 3.3 of this Technical Specification.

5.3.2 The feasibility of the proposed procedure shall be demonstrated through a full-scale trial. CONTRACTOR shall define the minimum host pipe / liner length and any other variable to guarantee the validity of the trial.

5.3.3 The full-scale trial shall include all relevant steps, e.g., liner manufacturing (joining of polymeric pipes through heat fusion), diameter reduction, parameters control / register, connection system installation, etc.

5.3.4 CONTRACTOR shall consider the pipe string to be manufactured with steel case pipes ID as agreed with PETROBRAS and demonstrate that the steel pipe welding process do not impose damages to HDPE.

5.3.5 The pipe string shall contain at least one connection system in such a position that allows the evaluation of the system when submitted to relevant tests described within Section 5.4.

5.4 FULL-SCALE EVALUATIONS

5.4.1 A pipe string containing at least one connector shall be submitted to full-scale tests to demonstrate that the system is fit for purpose. Full scale tests shall consider the PLP itself and its intermediate and end connections. At least the following full-scale tests shall be

performed:

5.4.1.1 Full-scale fatigue test;

5.4.1.1.1 For all PLP pipelines fatigue sensitive sections or whenever specified by project documents, full-scale fatigue tests shall be performed according to APPENDIX A of ref. [20] to validate the required girth weld and polymeric liner/connector fatigue endurance, regardless DNV-RP-C203 curve specified.

5.4.1.2 Full-scale bending test;

5.4.1.2.1 For risers to be installed by reel-lay method, all the specimens to be tested shall be submitted to full scale bending cycles (representative strain level as specified per design) prior to fatigue full scale tests. The number of simulated reeling/ unreeling cycles shall be representative of reel-lay spooling and installation/contingency methodology.

5.4.1.3 Full-scale vertical stability test;

5.4.1.3.1 CONTRACTOR shall demonstrate that liner is stable when submitted to vertical loads (e.g., due to self-weight) in start of life and end of life conditions (e.g., after exposed to transported fluid and after creep of liner's material).

5.4.1.4 Full-scale pigging test;

5.4.1.4.1 CONTRACTOR shall demonstrate that the pigging (high interference and caliper pig) does not damage the HDPE.

5.4.1.5 Hydrotest / sealing test;

5.4.1.5.1 CONTRACTOR shall consider the annulus pressure monitoring during test. Pressure and duration of hydrotest shall be informed by PETROBRAS on a case-by-case basis.

5.4.1.6 Pressure cycling test (liner collapse);

5.4.1.6.1 CONTRACTOR shall consider full and partial shutdown/shut-in cycles as specified for the project.

5.4.1.6.2 Pressures to be considered shall be informed by PETROBRAS on a case-by-case basis.

5.4.2 CONTRACTOR shall issue to PETROBRAS verification detailed full-scale tests procedures. The procedures shall include all relevant steps and proposal of acceptance criteria.

5.4.3 The pipe string shall be desiccated for visual inspection at the completion of the full-scale evaluations.