PETROBRAS	**TECHNICAL SPECIFICATION**	N	I-ET-3010.00-1200-200-P4X-003
	CLIENT: SRGE		SHEET: 1 of 17
	JOB:		- -
	AREA:		
SRGE	TITLE: **MATERIALS, DESIGN, CONSTRUCTION AND ASSEMBLY OF FRP PIPING**		INTERNAL
			ESUP

MICROSOFT WORD / V.2010 / I-ET-3010.00-1200-200-P4X-003_F.DOCX

INDEX OF REVISIONS

R E V .	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	REVISED WHERE INDICATED
B	ITEM 2.2.; 8.2.7, 9.2.1, 9.2.3. and 9.2.4 REVISED ACCORDING TO CLARIFICATION NOTICE DUE BIDDERS QUESTIONS
C	REVISED WHERE INDICATED
D	REFERENCE DOCUMENTS REVISED
E	REVISED WHERE INDICATED
F	GENERAL REVISION

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	DEZ/26/19	MAY/26/20	OCT/28/20	MAR/12/21	APR/16/21	SEP/20/22	JUN/07/24		
DESIGN	ESUP	ESUP	EEA	EEA	EEA	EEA	EEA		
EXECUTION	MMARROIG	MMARROIG	CJH4	CJH4	CJH4	CXDI	UQG9		
CHECK	ESTEVES	ESTEVES	CJW2	CJW2	CJW2	CJW2	CXDI		
APPROVAL	GONZALEZ	GONZALEZ	U32N	U32N	U32N	U32N	CJH4		

1 SCOPE

This technical specification sets the requirements for materials, design, fabrication and installation commissioning and pre-operation of fiber-reinforced plastics (FRP) piping systems on FPSO units, including the piping specs and inside all module packages.

2 REFERENCE AND ADDITIONAL DOCUMENTS

All equipment and components shall comply with the requirements of this technical specification and references stated below. All equipment parts and details not complying with any of these requirements shall be informed on a “Deviation List”. Otherwise, they will be considered as “Agreed”, and so required.

As a general guideline, in case of conflicting requirements between this technical specification and other cited references, the most stringent shall prevail. If necessary, the PACKAGER / MANUFACTURER / SUPPLIER may revert to PETROBRAS for clarification.

The package manufacturer (packager) shall follow these specifications as well as any other supplier for this project.

2.1 CLASSIFICATION

SELLER / MANUFACTURER shall perform the work in accordance with the requirements of Classification Society. The Type Approval shall contain the intended service for the proposed material for all components.

Other requirements beyond Classification Society requirements stated here shall be followed.

SELLER / MANUFACTURER is responsible for submitting to the Classification Society all documentation in compliance with stated Rules.

2.2 REFERENCE DOCUMENTS

- ASME B31.3 - Process Piping.
- ASME B16.5 – Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard.
- ASME B16.47 - Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard
- ASME BPCV - Section V – Nondestructive Examination.
- ASTM D2583 – Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.
- ASTM D3567 – Standard Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings.
- ASTM D4024– Standard Specification for Machine Made “Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting Resin) Flanges.
- ASTM D5421 – Standard Specification for Contact Molded “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Flanges.
- ASTM F1173 - Standard Specification for Thermosetting Resin Fiberglass Pipe Systems to Be Used for Marine Applications
- EN 13121-2 - GRP tanks and vessels for use above ground Part 2: Composite materials Chemical resistance
- IMO A.753 - Guidelines for the Application of Plastic Pipes on Ships

- ISO 14692:2017 - Petroleum and Natural Gas Industries: Glass-Reinforced Plastics (FRP) Piping (parts 1 to 4).
- ISO 17024 – Conformity Assessment: General Requirements for Bodies Operating Certification of Persons.

2.3 ISO 9712– NON-DESTRUCTIVE TESTING: QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL.GOVERNAMENTAL REGULATION

- NR-13 Caldeiras, Vasos de Pressão, Tubulações e Tanques Metálicos de Armazenamento (Boilers, Pressure Vessels, Piping and Metalic tanks).
- NR-26 Sinalização de Segurança (Safety Signaling).
- NR-37 Saúde e Segurança em Plataformas de Petróleo (Platforms Health and Safety).

Brazilian Government regulations are mandatory and shall prevail, if more stringent, over the requirements of this specification and other references herein.

2.4 DESIGN SPECIFICATIONS

DR-ENGP-I-1.15	COLOR CODING
I-ET-3010.00-1200-956-P4X-002	GENERAL PAINTING
I-ET-3010.00-1200-970-P4X-004	NON-DESTRUCTIVE TESTING REQUIREMENTS FOR METALLIC AND NON-METALLIC MATERIALS
I-ET-3010.00-1200-200-P4X-116	REQUIREMENTS FOR BOLTED JOINTS ASSEMBLY AND MANAGEMENT
I-ET-3010.00-1200-970-P4X-003	REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION

2.5 PROJECT SPECIFICATION

[PIPING SPECIFICATION FOR TOPSIDE]

[PIPING SPECIFICATION FOR HULL]

[METOCEAN DATA]

[MOTION ANALYSIS]

[REQUIREMENTS FOR PIPING STRESS AND DYNAMICS ANALISYS]

[MINIMUM REQUIREMENTS FOR PIPING MECHANICAL DESIGN AND LAYOUT]

[REQUIREMENTS FOR PIPING SUPPORT]

2.6 CONFLICTING REQUIREMENTS

2.6.1 In case of conflicting information between this Technical Specification (ET) and other specific PETROBRAS' document (data sheet) the specific PETROBRAS' document shall prevail.

2.6.2 In all cases of conflict between this specification and applicable documents listed herein, the more stringent requirements shall prevail. In such cases, SELLER shall inform PETROBRAS of the conflict and seek clarification.

2.6.3

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

For the purposes of this specification, the terms and definitions given in ISO 14692-1 are applied. In addition, consider the following definitions:

SUPPLIER or MANUFACTURER: manufacturer of FRP pipes and fittings that, necessarily, shall be technically responsible for the construction, assembly and installation of piping system and responsible for elaborating or approving flexibility analysis and supporting of piping systems.

FABRICATION or CONSTRUCTION: spool fabrication, including all steps since raw material receiving until spool testing.

INSTALLATION or ASSEMBLY: spools field installation in hull or modules. Includes all steps since spool receiving until pre-operation.

3.2 ABBREVIATIONS

FRP - Fiber Reinforced Plastic/Polymer (the same as GRP).
GRP – Glass-reinforced Plastic/Polymer.
RT – Radiographic Testing.
UT – Ultrasonic Testing.
ITP- Inspection and Test Plan.
NDT – Non-Destructive Testing (same as NDE).
NDE – Non-Destructive Examination.
UV – Ultraviolet radiation

4 MATERIALS

4.1 FABRICATION PROCESS

4.1.1 Pipes and fittings shall be manufactured by filament winding of fiberglass rovings impregnated with resin, following ISO 14692 - Part 2. For fittings, semi-automatic or part manual processes (as contact moulding) may be accepted.

4.2 PIPE AND FITTINGS MATERIAL REQUIREMENTS

4.2.1 External liner

4.2.1.1 The external layer shall consist of pure resin, the same used in structural layer, or have a polyester veil for improved protection. It shall contain dark pigment (with carbon black) or be without pigmentation, in order to be painted.

4.2.1.2 The formulation of this layer shall contain additives for 30 years life UV protection.

4.2.1.3 This outer liner shall have at least 0.5 mm thick.

4.2.2 Structural layer

4.2.2.1 This layer shall be made of selected thermosetting resin reinforced with fiberglass type

E or E-CR. The same resin shall be applied to the internal liner and chemical barrier (if applicable). This layer shall be free of pigments.

4.2.3 Chemical/ corrosion barrier

4.2.3.1 The chemical barrier shall be used only for aggressive fluids (acidic and base solutions, or other chemical compounds, like sodium hypochlorite and other biocides). In these cases, the total barrier shall be at least 2.5 mm thick, considering EN 13121-2.

4.2.3.2 Different chemical barriers material and thicknesses may be applied but its suitability shall be demonstrated by qualification tests on pipes, fittings and flanges. The results of these tests shall be approved by BUYER.

4.2.4 Internal liner

4.2.4.1 The resin rich internal liner shall have a resin content of at least 70%. It shall be reinforced with type C glass or polyester fibers veils.

4.2.4.2 This liner shall have at least 0.5 mm thick and be free of pigments and other additives.

4.2.4.3 For chemical products lines the use of liner is mandatory, besides the chemical barrier.

4.2.5 Additives

4.2.5.1 The epoxy resin shall be pigmented with dark colours, which contain the carbon black pigment, as secondary protection to ultraviolet radiation. The lack of pigmentation is also an option, to facilitate inspection.

4.2.5.2 It is mandatory that all vinyl-ester pipes and fittings have, in their outer layers, the anti-UV additive in sufficient concentration, considering life cycle of 30 years.

4.2.6 Electrical properties

4.2.6.1 All FRP pipes and fittings shall be electrically continuous as per ISO 14692, so all liners and layers shall attend to this requirement. The way to reach this property will depend on each manufacturer development. All FRP piping shall be specified for use in hazardous area.

4.2.6.2 The electrical resistivity shall be calculated according to ISO 14692 – part 2 – Item 7.3.1 or ASTM F1173. The volumetric electrical resistivity (inside to outside) requirement for GRP piping shall not exceed 10^3 Ωm. The surface electrical resistivity (outside to outside) shall not exceed 10^5 Ω/m.

4.2.7 Fire resistance and reaction properties.

4.2.7.1 Unless specified, all FRP pipes, fittings and joints shall comply with the fire endurance and fire reaction properties requirements of ISO 14692 and IMO A.753 qualification program for L3 pipes.

4.2.7.2 Modified L3, L2 or L1 pipes, according to any other condition considered in ISO 14692-2 (Annex H), may be applied, if required and approved by BUYER, as long as certified by Type Approval.

4.2.8 Minimum structural thickness

4.2.8.1 The total thickness of FRP pipe is defined as the sum of the thickness of the structural layer, with the inner or internal liner, the chemical barrier layer (if applicable) and the outer or external liner.

4.2.8.2 The structural calculations shall be according to ISO 14692-2 and consider only the structural layer as thickness for calculations.

4.2.8.3 The minimum structural thickness shall be 5.0 mm, for diameter equal or larger than 100 mm (4"); and 3.0 mm for diameters 1" to 3".

4.2.9 Manufacturing materials

4.2.9.1 The recommended manufacturing materials for pipes and fittings depend on the fluid being transported, according to Table 1. BUYER is responsible for the final decision of materials to be used.

Table 1 – Required materials for pipe manufacturing as a function of service fluid.

SERVICE	STRUCTURAL LAYER	CHEMICAL BARRIER (minimum 2.0 mm) (note 4)	INNER LINER (minimum 0.5 mm)	EXTERNAL LINER (minimum 0.5 mm)
Aerated Sea Water (SW) Injection Water (IW) Ballast Water (BW) Industrial Water (W) Others Waters	Bisphenol A Epoxy resins (DGEBA) (note 1), reinforced with fiberglass (type E ou E-CR).	-	Bisphenol A Epoxy resins (DGEBA) (note 1), reinforced with conductive veil.	same resin + anti-UV additive for 30 years
Fire Water (FW) (note 3) Produced Water (PCW)	Bisphenol A Epoxy resins (DGEBA), reinforced with fiberglass (type E ou E-CR).	-	Bisphenol A Epoxy resins (DGEBA) (note 1), reinforced with conductive veil.	same resin + anti-UV additive for 30 years
Sodium Hypoclorite (CN) Biocides, DBNPA (CNI)	Epoxy vinylester resin (bisphenol A or brominated) reinforced with fiberglass (type E-CR). (note 2)	Epoxy vinylester resin (bisphenol A or brominated) reinforced with fiberglass (type E-CR). (note 2)	Epoxy vinylester resin (bisphenol A or brominated) reinforced with conductive veil. (note 2)	same resin + anti-UV additive for 30 years
Note 1: Curing agents, aromatic or aliphatic cycle, must be used for epoxy resin. An alternative is the use of vinylester resin. In special cases, other resins and curing agents may be used if approved by PETROBRAS.				
Note 2: The cure of vinyl ester resin for use with sodium hypoclorite should be with BPO/DMA (no cobalt). A postcure shoud be applied and the chemical barrier shall be a minimum of 2.5 mm (2.0 mm plus 0.5 mm liner).				
Note 3: Fire water systems in FRP (ring main and wet/dry deluge) are only permitted for fixed platforms in Petrobras. The fire integrity level (L1, L2, L2W, L3 or LWD) shall be designed for each part of the system.				
Note 4: Different chemical barriers materials and thicknesses may be applied but its suitability shall be demonstrated by qualification tests on pipes, fittings and flanges. The results of these tests shall be approved by PETROBRAS.				

5 DESIGN

5.1 The flexibility of FRP pipping systems shall be performed in accordance with I-ET-REQUIREMENTS FOR PIPING STRESS AND DYNAMICS ANALISYS. The supports used shall be based on typical supports and ISO 14692.

5.2 The SELLER shall perform dimensional and flexibility analysis of the supports and pads. The flexibility analysis report shall be performed or approved by the SUPPLIER.

5.3 Supports for GRP piping shall be designed to ensure that they cannot damage the piping elements: a 3 mm minimum thick elastomer or thermoplastic lining shall be inserted between the metal collars and the pipes.

5.4 Valves and pumps in a GRP piping system shall be supported separately.

5.5 Flanges interface between FRP and metallic piping materials (change of spec) shall

have at least a rest support.

5.6 The SELLER shall perform measures of alignment, spacing, verticality, leveling, inclination and curves angle of the various sections of pipe system. Design standards of the pipe system as ISO 14692 shall be respected, as well as standards for fabrication and properties of pipes and fittings.

5.7 Risk of overpressure due to surge effect and water hammer shall be considered in the design. When such a risk exists design shall incorporate an analysis of dynamic forces. Care shall be taken in the design to avoid air pockets, special attention for the slope from vessel trim. Where necessary piping system shall incorporate a mean of limiting the risk of water hammer (surge/pressure control system, overpressure protection, non-slam axial check valves etc.).

5.7.1 This evaluation is mandatory for piping systems of industrial water connected to heat exchanger.

5.7.2 The limit for overpressure shall not be greater than pipe spec rating, not considering what is stated in item 5.5 from ISO 14692-3.

5.8 To minimize water hammer occurrence, butterfly and gate valves shall be preferentially selected. The design shall follow ISO 14692 parts 3 and 4.

5.9 All fittings, with diameter below 40”, shall be solid (one-piece), not mitered. Mitered fittings are only permitted for 40” diameter and higher.

5.10 The sea water lift system shall be equipped with automatic air brake valves, to eliminate air automatically when starting up the system. This requirement is valid for the entire sea water inlet system, sea water filters downstream and not only the sea water lift pump system.

5.10.1 The air break valves shall be calculated according to the volume of the system.

5.10.2 It shall be issued a procedure for start up the system considering eliminating the air trapped and equalizing pressure without water hammer. The system shall neither start up dry nor with trapped air. If there are some parts not yet commissioned that causes air to be trapped, it shall be foreseen, and the trapped air shall be eliminated.

5.10.3 FRP lines isometrics shall indicate all joints selected for UT/RT application, as per item 10.3.1. Those shall be submitted for BUYER approval before issued for fabrication.

6 PERSONNEL QUALIFICATION

6.1 Personnel qualification, following ISO 14692-4 shall be provided for pipe fitters/bonders/laminators, supervisors and inspectors.

6.2 The SELLER shall submit evidence of theoretical and practical training of pipe fitters/bonders/laminators previously the start of the project.

6.3 Training shall be provided by the pipe manufacturer and shall contain general aspects of composite pipes, specific aspects for SUPPLIER product (manufacturer, diameter, and pressure class), and the types of joints to be used in the current project. The course shall consist of theoretical and practical part, meeting the minimum requirements of ISO 14692 - Part 4.

6.4 The basics topics of the course are:

a) Terminology, types of pipes, manufacture/fabrication, applications.

b) Material properties and engineering requirements.

c) Health, environment and safety.

d) Joining methods and procedures, including typical defects and failure modes.

e) Procedures for measuring electrical continuity.

f) Transport, handling and storage.

g) Installation.

h) Repairs.

i) Quality assurance and control, including methods of inspection.

j) Practical training in pipe joining (adhesive bonding, laminated, and flange connections). This activity may be conducted as part of the supplier-specific course, if appropriate.

6.5 All professionals shall be certified by independent certification bodies, national or international ones, according to ISO 14692. A third part organization (as Classification Society) shall comply, and stamp certificates issued by SUPPLIERs as training and test party.

6.6 Certification involves application of tests for pipe fitters/bonders/laminators, inspectors and supervisors after training by a third part (which may be the SUPPLIER) before beginning of installation.

6.7 There shall be a SUPPLIER Supervisor and a SELLER Inspector, who shall have 24 months proven experience in construction of FRP piping system and in the specific project unions / joint types. Besides SELLER inspector, at least one SUPPLIER Supervisor shall be present on site FULL TIME.

6.8 Every SELLER team involved in the assembly and erection (installation) of the FRP piping system shall consist of at least 60% of experienced staff in this type of material. Previous experience should consider the type of joint, pipe diameter, pressure class and manufacturer. (Ex: previous experience with bonded joints does not apply to laminated joints and vice-versa).

7 STORAGE, PRESERVATION AND HANDLING

7.1 The SELLER is responsible for the storage and preservation and shall submit, in conjunction with the SUPPLIER, for PETROBRAS approval a storage and preservation procedure for pipes, fittings and consumables in accordance with Annex B of ISO 14692-4.

7.2 The storage facilities shall be in accordance with of ISO 14692-4 and SUPPLIER specific requirements. Facilities shall consider specific locations for segregated materials. Environmental conditions in the consumables storage room (resins, adhesives, catalysts, etc.) shall be controlled and monitored.

7.3 It shall be designated by the SELLER an inspection and preservation team with available and trained regarding FRP piping materials and consumables.

7.4 Storage shall use wooden sleepers or pallets, or other appropriate devices, in order not to damage the pipes or pipe coatings regarding to environmental degradation, kneading, warping, damage by impact, moisture, dust or chemical contamination.

7.5 The pipes and fittings cannot be arranged directly on the floor, rails or concrete floors.

7.6 Pipes, fittings, flanges and pre-assembled sections shall have end protections. If these components are stored in open area, the pipes shall be covered by canvas that promotes UV radiation protection.

7.7 Auxiliary materials or consumables such as resins, adhesives, paints, catalysts, chemicals in general, elastomeric sealing rings (O-rings), flange gaskets, fibrous reinforcements (mat, fabrics and roving) and lubricants shall be stored in accordance with manufacturer's recommendations in their original packaging whenever possible, protected from the sunlight, dust, humidity and heat. Expiring dates shall be managed.

7.8 The SELLER shall submit, in conjunction with SUPPLIER, a procedure for shipping and handling of pipes and fittings for BUYER approval. The transport and handling of composite pipe items shall follow the guidelines of ISO 14692-4 and SUPPLIER specific requirements. The SELLER is responsible for the handling and transportation in accordance with approved procedure.

7.9 The handling shall be carried out carefully avoiding any impact. It is recommended that the pipe, fittings and spools sections to be loaded and unloaded individually. Pipes and fittings shall be transported by suitable trucks and protected to prevent slip and abrasion between each other.

7.10 Factory spools shall be kept in original container transport, protecting pipe ends and joints, to final assembly in the field. Pre-assembled parts shall not be stacked or placed on surfaces that may cause harm (rocks, for example).

7.11 For load lifting it shall be used only proper synthetic fiber straps (e.g., polyamide or polyester) or canvas. Chains, ropes, steel cables, clamps or any other material that may damage the FRP shall not be used or used with protective materials.

7.12 Standard pipe lengths and spools shall be raised up in at least two support points, ensuring the weight is well balanced. Attention shall be taken to ensure that polyamide or canvas lifting belts are always placed around the larger sections of pipe. If necessary, extension bar and additional lifting belts shall be used to prevent bending.

7.13 Lifting cranes are generally used for pipe loading and unloading. If a forklift is used, the forks should be covered with some kind of padding, such as rubber or plastic. Forks should never be put inside the pipe unless a special pipe handling tube is used which can be attached to the forklift.

8 DELIVERY/RECEIVING INSPECTION

8.1 The SELLER, with SUPPLIER approval, shall submit to PETROBRAS approval a delivery inspection procedure for pipes, fittings and all consumables to be used in the project as per ISO 14692-4.

8.2 The SELLER delivery inspection team shall have proper and documented qualification / training and be sized to meet the demand of expected materials delivery

inspection.

8.3 Before unloading the pipes, fittings and consumables at site, the SELLER INSPECTION shall check all documentation and perform the visual inspection, according to ISO 14692-4. The state of preservation and storage of pipes, fittings and prefabricated spools during transport shall be checked regarding the protection of pipes and fittings edges, stacking, moorage, fixing and support of the materials on the transport vehicle.

8.4 The SELLER shall perform the delivery inspection (pipes, fittings and consumables) ensuring that they are in compliance with the applicable material requisition (RM), i.e. type, quantity, qualified pressure, nominal sizes, minimum thickness and specific contract requirements, etc. and considering the applicable technical specification (ET), material certificates, reports of manufacturing test.

8.5 The site facilities shall be appropriate and consider specific locations to segregated materials. Measuring instruments used for the material delivery inspections shall be verified and present calibration certificated within the period of validity.

8.6 The defect types, acceptance criteria and corrective actions, related to materials delivery inspection shall be in accordance with ISO 14692-4. In addition, imperfections such as kneading, warping, blistering, excessive peeling, pores, and degradation spots are not accepted.

8.7 All materials used for construction of the piping system shall be properly identified and shall be from the same SUPPLIER or nominated and approved by the SUPPLIER.

8.8 All materials shall be re-inspected prior to spools fabrication and installation in order to find possible damages caused during the storage period.

8.9 Dimensional inspection of pipes and fittings shall be performed according to standards defined at piping specification from manufacturer.

8.10 An electrical conductivity testing shall be performed according to ISO14692-2 at each lot of incoming material. This test may be executed in SUPPLIER's/manufacturer's site delivery inspection. The reports shall be sent for SELLER and BUYER approval.

8.11 Total thickness measurement to verify thickness shall be performed at both pipe and fittings middle and ends. The thickness measurement may be performed using by ultrasound, calibrated caliper or Pi tape.

9 SPOOL FABRICATION AND INSTALLATION

9.1 GENERAL REQUIREMENTS

9.1.1 The SELLER shall ensure the correct application of materials, joints assembly, inspection and testing. The SUPPLIER shall provide training, test, tutoring and supervision of assemblers in all phases of installation and integrally supervise the work. The SELLER, under consulting and supervision of SUPPLIER, shall ensure proper implementation of installation, repair, and field modifications procedures, subjecting such procedures and proposed changes to the approval of BUYER. The SELLER shall submit all technical decisions during installation to the SUPPLIER and BUYER.

9.1.2 The first prefabricated joint of each bonder shall be pressure tested according to item 10.5.2 prior to further bonding. If any joint fails, the next three joints shall be pressure tested. If another joint

fails, the bonder must be re-qualified or relieved from further bonding duties. Testing shall be witnessed by BUYER. This is applicable only for bonders working for the first time in Petrobras projects.

9.1.3 The services of fabrication, assembly, curing, cleaning, inspection, and testing of systems and components of FRP piping shall be executed according to procedures prepared in accordance with the standards considered in the Contract, Technical Specifications and in accordance with the requirements under applicable BUYER Safety Standards. At least the project specifications listed at item 2 shall be considered.

9.1.4 SELLER shall submit for BUYER approval a spool fabrication and field installation procedure in accordance with ISO 14692-4.

9.1.5 The SUPPLIER shall issue a document I-MC specific for the calculus memory for the adhesive and laminated joints strength.

9.1.6 The local conditions for safety, organization and cleaning shall be at satisfactory levels and according to BUYER HSE policy. Team workers shall be wearing all personnel protection equipment (PPE) necessary to perform the task safely.

9.1.7 The types of unions/joints are limited to: laminated joint ("butt-and-strap joint", "butt-and-wrap joint"), bonded/adhesive joints (spigot and bell) and flanged joint, depending on the application and design requirements.

9.1.8 Flanged joints are mandatory between joints of different materials/piping specs (i.e. metallic and FRP flanged joints).

9.1.9 FRP joints shall be spot (5%) inspected by radiographic testing (RT) and/or ultrasonic testing (UT) according to I-ET-3010.00-1200-970-P4X-004 – NON-DESTRUCTIVE TESTING REQUIREMENTS FOR METALLIC AND NON-METALLIC MATERIALS. The inspected joints shall be those considered critical joints in flexibility and support analysis as well as surge analysis, when applicable, plus other selected joints by BUYER.

9.1.10 The decision on the criticality of the joints (for NDT's application – UT and/or RT) is responsibility of the designer (SELLER) when considering the flexibility and surge analysis. The final project with identification of each critical joint shall be submitted for BUYER approval. BUYER reserves the right to define the critical joints, if necessary, and those other to complete the amount of 5% of joints.

9.2 SPOOLS FABRICATION AND ASSEMBLY

9.2.1 Professionals involved in spools fabrication shall be qualified and the SELLER’s responsible for installation shall be involved in all stages of the work.

9.2.2 The criteria used for spooling shall consider as minimum: joints, fittings, dimensions, maximum weights and accessory position. It shall be minimized the use of connections and installation of fittings in field, prioritizing the assembly of spools during fabrication or pipe-shop in SUPPLIER’s site.

9.2.3 All materials transported from the storage area to the pipe shop shall go through inspection for integrity assessment.

9.2.4 The coupling devices for bonded/adhesived joints shall be described in the spool fabrication and installation procedures.

9.2.5 All joints (bonded or laminated) shall be fully supported, clamped, and braced to ensure that no movement occurs during the curing process.

9.2.6 The joining procedure shall be qualified by the SUPPLIER and approved by BUYER. The same procedure shall be used for pipe joining in pipe shop and field. Each fabrication or assembly

step shall be checked and inspected by the SELLER's INSPECTION, according to specific items for each type of joining.

9.2.7 Finished spools shall be inspected regarding visual defects and dimensions, alignments between different components and applied material, meeting the specified tolerances. The inspection shall be performed by a qualified inspector.

9.2.8 At least 10% of the prefabricated spools shall be pressure tested prior to the final installation at 1.5 times the pressure rating for a minimum period of one hour. In case of failure, re-testing shall be performed according to the requirement of ISO 14692-2. For hydrotesting non-flanged end spools, appropriate plugs shall be used (Figure 1).

Figure 1 – Examples of plugs for hydrotesting non-flanged end spool pieces.

9.2.9 The handling and movement of prefabricated components to its final installation site shall meet the specific procedure of the SUPPLIER in accordance with item 7 of this technical specification. All openings' parts shall be protected or capped.

9.2.10 All flanged joints and bolted connections shall be assembled as per the requirements of I-ET-3010.00-1200-200-P4X-116 – REQUIREMENTS FOR BOLTED JOINTS ASSEMBLY AND MANAGEMENT and following SELLER's procedure, based on SUPPLIER's torque table for specific component.

9.2.11 Bolts, gaskets and lubricants to be used shall always be in accordance with the approved

design and assembly procedure.

9.3 JOINTS REQUIREMENTS

9.3.1 Adhesive Bonded Joints

9.3.1.1 The assembly procedure shall contain a specific item for the execution of adhesive bonded joints. It shall be a qualified bonding procedure (Bonding Procedure Specification), in accordance with ISO 14692-4.

9.3.1.2 A mock-up joint, representative of the scope of work, shall be adhesive bonded in accordance with the qualified procedure and fully tested at the beginning of the spool fabrication or field installation.

9.3.1.3 During the bonding process, the assembly inspector shall control and record at least the following items: fitters/bonders identification, material traceability (including adhesive), ambient conditions (e.g. relative humidity, temperature, direct incidence of sunlight), integrity of the ends of pipes, surface preparation. The recommendations of pipe manufacturer regarding bonding shall be observed.

9.3.1.4 Visual inspection and nondestructive testing shall be performed after complete curing of the adhesive. The acceptance criteria for visual inspection shall be in accordance with ISO 14692-4.

9.3.2 Laminated Joints

9.3.2.1 The assembly procedure shall contain a specific item for the execution of laminated joints. It shall be a qualified procedure (Lamination Procedure Specification) in accordance with ISO 14692-4.

9.3.2.2 A mock-up joint, representative of the scope of work, shall be laminated in accordance with the qualified procedure and fully tested before at the beginning of the spool fabrication or field installation.

9.3.2.3 During the lamination process, the assembly inspector shall control and record at least the following items: fitters/bonders identification, material traceability, ambient conditions (e.g. relative humidity, temperature, direct incidence of sunlight), integrity of the ends of pipes, surface preparation and laminations dimensions. The recommendations of pipe manufacturer regarding bonding shall be observed.

9.3.2.4 The preparation and mixing of the resin and hardener shall be performed according to the manufacturer recommendations and procedure.

9.3.2.5 Laminated joint curing process shall be checked for the time of heat application, if applicable (blankets, furnaces, blowers, others), heating curve, gel time and cure time, even if the cure takes place at room temperature.

9.3.2.6 The degree of cure of the laminated joint shall be checked after full cure using Barcol hardness test (ASTM D2583). Visual inspection and other nondestructive tests shall be performed after complete curing of the resin. A visual inspection shall be carried out considering the acceptance criteria of ISO 14692-4.

9.3.3 Flanged Joints

9.3.3.1 The assembly procedure shall contain a specific item for the execution of flanged joints. It shall be a qualified procedure (Flanged Joint Procedure Specification) in accordance with ISO 14692-4 and pipe manufacturer’s flange torque table.

9.3.3.2 For joints between FRP and other material pipe spec or equipment, a backing flange shall be used. The gasket shall be according to piping spec.

9.3.3.3 The SELLER's assembly procedure for flanged joints shall detail the maximum torque and sequencing of flange screws, in accordance with ISO 14692-4 and pipe manufacturer's flange torque table.

9.3.3.4 Flanged joints shall be backing flange type or integral flange type according to the pipe specification. It is not allowed to replace one type for another. It shall be followed the pipe spec. Flanges are the weakest part of the system considering the occurrence of cracks in the neck area.

9.3.4 Repairs

9.3.4.1 The SELLER shall issue a repair procedure indicating the repair method to be used for each type of defect. The repair shall follow ISO 14692-4. The repair method employed shall fully restore the specified properties of the pipe, evaluated through hydrostatic testing and visual inspection.

9.3.4.2 No repairs shall be performed on the inner surface of the pipe or fittings. In this case, replacement of the pipe or component shall be performed.

9.3.4.3 The repair shall guarantee the type approval certificate, including fire resistance and electrical conductivity.

10 NON-DESTRUCTIVE TESTING (NDT) AND HYDROSTATIC TESTING

10.1.1 GENERAL REQUIREMENTS

10.1.2 The SELLER shall execute the following tests for FRP piping systems: visual inspection, dimensional inspection, Barcol hardness, electrical conductivity, radiographic and/or ultrasonic testing, hydrostatic testing, and leak testing. The procedures shall comply with the requirements of I-ET-3010.00-1200-970-P4X-004 NON-DESTRUCTIVE TESTING REQUIREMENTS FOR METALLIC AND NON-METALLIC MATERIALS.

10.1.3 All joints assembled in field, factory or "pipe-shop" shall be identified and recorded in the logbook, with the minimum relevant information according to ISO 14692-4. It shall be registered and identified in the joint if it is considered critical or not and if it was inspected by radiography and/or ultrasonics.

10.1.4 All joints between pipes, fittings, and flanges, whether performed in the factory, "pipe-shop" or field, shall be inspected by a certified or qualified assembly or NDT/NDE inspector, in accordance with this Technical Specification.

10.1.5 Any NDT, including visual inspection, Barcol hardness, ultrasonic testing, radiographic testing, and others shall be performed prior to hydrostatic testing. The visual inspection shall be carried out in the joints, compulsorily, before, during and after sealing and hydrostatic tests.

10.1.6 In case of base material defect identified, the repair is only accepted under previous SUPPLIER evaluation and approval of repair procedure.

10.2 SAMPLING

10.2.1 When sampling test is indicated (random examination), a percentage of the number of joints within the specified lot shall be selected, and the whole bonded / laminated length of the selected joint shall be inspected.

10.2.2 A LOT is defined as the total number of joints bonded / laminated during a period (not greater than three months), grouped by material specification (trademark), and by fitters/bonders and process (type of joint). Therefore, a LOT may only contain:

- Joint from the same material.

- Joints with similar manufacturing process.

10.2.3 Pipe shop joints (for the fabrication of spools) and on-site joints (for the field assembly of piping) shall be grouped in separated lots.

10.3 CRITICAL JOINTS

10.3.1 Spot NDT inspection (5% of all joints) shall be performed in the critical joints plus those indicated by Petrobras, if necessary. The decision on the criticality of the joints is responsibility of the SUPPLIER, but it is recommended to observe the following criteria in precedence order:

a) Adhesive-bonded or laminated joints in lines with higher axial stresses (subjected to fatigue), detected during flexibility analysis.
b) Field joints (mainly closure joints).
c) Elbow type fittings.
d) “T” type fittings.
e) Adhesive-bonded or laminated joints close to valves.
f) Adhesive-bonded or laminated joints close to pumps.
g) Adhesive-bonded or laminated joints close to equipment.
h) Weld neck flange joints for B23H pipe spec.

Note: a) and b) has same precedence to define critical joints.

10.3.2 The scope for selection of critical joints considers those joints above diameter 3” for all FRP specs and above 12” for B22 pipe spec.

10.4 NON-DESTRUCTIVE TESTING (NDT)

10.4.1 The SELLER shall prepare and submit for approval of PETROBRAS a procedure for pressure testing and other for performing nondestructive testing as ultrasonic testing (UT) and/or radiographic testing (RT). These procedures shall be in accordance with ISO 14692- part 4 and ASME BPVC Section V article 1 and 14 (level B – intermediate rigor).

10.4.2 The requested NDT for the joints shall consider the Annex E of ISO 14692-4. Inspection procedures shall be developed by Level 3 Certificated professionals and submitted for review of PETROBRAS.

10.4.3 Before any nondestructive testing, all joints (100%) shall be visually inspected (VT) to assure that the joint is free from visual defects. Dimensional check of the joint and piping assembly shall be applied with tolerances according to ISO 14692-4.

10.4.4 Radiographic (RT) and/or ultrasonic (UT) inspection shall be in accordance with items 9.1.9 and 9.1.10.

10.4.5 NDT (RT or UT) of joints in FRP piping shall be 5% of the total number of joints. The SELLER shall follow the acceptance criteria per ISO 14692.

10.4.6 The results of visual testing, Barcol hardness, leak testing, hydrostatic testing, radiographic testing and ultrasonic testing shall be recorded in specific reports. All tests shall be performed after complete curing of the resin (lamination) or adhesive (bonding).

10.4.7 Barcol hardness test shall be performed at all laminated joints according to ASTM D2583 with at least 4 measurements at each joint, for checking degree of cure.

10.4.8 Electrical conductivity testing shall be performed at all spools according to item 4.2.6, and after final installation for checking field joints electrical resistivity and earthing.

10.4.9 Penalties (Progressive Sampling for Examination) shall be applied to the bonder/fitter

responsible for the defective joint as stated in ASME B31.3. The lot approval, replacement, repair and reexamination shall be as stated in ASME B31.3.

10.5 PRESSURE TESTING

10.5.1 All supports, guides, and anchors shall be installed prior to pressure testing. All adhesive or laminated joints shall be fully cured prior to pressure testing. Bolts of flanged joints shall be made up to correct torque prior to pressure testing.

10.5.2 The SELLER shall submit a hydrostatic and leak tests procedures for approval by BUYER.

10.5.3 The hydrostatic test pressure shall be done at 1.5 times the pipe pressure rating.

Attention: this is not the 1.5 x design pressure. This is an additional requirement from BUYER and shall be followed for the test condition. The reason is to test the system at the maximum allowed pressure for the materials, including gaskets. This increases the safety factor of the system.

10.5.4 It is not allowed to reduce the test pressure, except for open drain systems after the last block valve.

10.5.5 The hydrotest shall be gradually raised over a period of 30 min or longer up the required test pressure is achieved. The test shall be conducted for a minimum hold period of 2 hours during which time the test pressure shall be maintained with ±2.5% of the required test pressure with no test fluid being added or removed during the hold period of the test. The test hold period begins once stable conditions have been achieved.

10.5.6 The leak pressure test shall be performed at 1.1 times the design pressure (Pdes). For systems with elevation variations, the required pressure shall be achieved at the system lower point, in the system higher point the test pressure shall not be more than 1.0 times the design pressure (Pdes). For large elevation variations, the system lower point test pressure may be increased above the required test pressure, however this shall not exceed 1.25 times the design pressure (Pdes).

10.5.7 The leak test minimum hold period shall be sufficient time to inspect all joints and potential leak sources (for piping systems with the joints and other potential leak sources exposed for inspection). It considers a minimum duration of 2 hours.

10.5.8 Hydrostatic and leak tests may be performed with fresh or salt water.

10.5.9 Flanged connections at drain boxes and drain pits shall be temporarily closed to allow hydrotest.

10.5.10 All lines shall be washed before pressure testing. The cleaning shall be performed according to ISO 14692.

11 PAINTING

11.1 The pipes and fittings shall receive, during their manufacture, direct pigmentation in the resin or an external resin liner with anti-UV additive and pigment, with color in accordance with DR-ENGP I-1.15. In case of requirement of painting, the I-ET-3010.00-1200-956-P4X-002 shall be applied.

12 INSPECTION AND TEST PLAN AND REPORTS

12.1 The SELLER shall provide an ITP which includes inspection, spool fabrication and field assembly, for different steps:

a) Raw material control.

b) Spool fabrication parameters.
c) Spool preparation.
d) Field assembly.
e) Tests.

12.2 Final reports shall be established following the size of the whole project or individual assemblies. Final reports shall include:

a) Quality Plan.
b) Assemblies identified on isometrics - bonding or laminations with identification of the fitter who has performed them.
c) Control of joints.
d) Hydrostatic test reports.
e) NDT reports.