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|  PETROBRAS | TECHNICAL SPECIFICATION | | | | Nº I-ET-0000.00-0000-217-P9U-004 | | | | | |
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| | AREA: | | | | PROJECT: | | | | | |
| ENGENHARIA | TITLE: OFFSHORE INTERNAL AND EXTERNAL FBE FIELD JOINT COATING | | | |  | | | | | |
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1. INTRODUCTION



- 1.1. To establish the applicable minimum requirements for the anticorrosive coating applied to internal and external girth welds surface, with fused bonded epoxy (FBE), of Offshore Pipelines, operating at temperatures between - 15 °C and 90 °C.
- 1.2. The OFFSHORE internal and external FBE Field Joint Coating consists of a system of:
 - a) Internal - A layer of Fusion Bonded Epoxy (FBE) applied by means of a fluid air unit depositing fluidized powder onto the heated steel surface;
 - b) External - Dual layer Fusion Bonded Epoxy (FBE) applied by means of fluid air units depositing fluidized powder onto the heated steel surface.
- 1.3. The Field Joint Coating (FJC) shall present a good performance during the project design life after it has been subjected to the installation process.
- 1.4. All materials and processes shall be qualified and tested prior to coating application, as described in Clauses 8, 10 and 11.

2. SCOPE

- 2.1. This document specifies minimum requirements to perform FBE girth weld coating to Dual layer FBE coated pipeline. The contractor shall prove that his equipment, materials and coating procedures result in a quality of end product, as specified in Clause 5.
- 2.2. The technical qualification for the material shall include simulated service tests, laboratory tests and full scale tests to assure the required properties as specified in Clause 6. Contractor shall supply Procedures and Inspection and Test Plan (ITP) for all tests to be performed during all phases of project.
- 2.3. The qualification tests listed in this specification shall be performed by Contractor at his expenses and the report shall be issued to PETROBRAS for approval. PETROBRAS will witness the application process and qualification tests.
- 2.4. This technical specification lists and describes the tests to be performed during pre-qualification, pre-production and production phases in accordance with the status of each coating system.

3. GENERAL



- 3.1. The system shall combine the high bond-strength and high anticorrosion properties of FBE coating with the high mechanical properties performance of FBE Dual Layer. Maximum design temperature is 90°C.
- 3.2. Applicator shall support the offered field joint coating system by submitting certificates of tests conducted by an independent national or international testing laboratory, complete details of tests conducted, methods, standards used and results in conformity with properties requirements as specified in Clause 6.



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- 3.3. The requirements of this Technical Specification shall prevail against the requirements of Standards listed in Clause 4.
- 3.4. Applicator shall, at his expense, carry out coating procedures trials for operational and installation phases to prove that the field joint material has the required properties as defined in applicable technical specifications.
- 3.5. The procedures and ITP shall be in accordance with this document and submitted to PETROBRAS for approval prior to the beginning of the works.
- 3.6. A quality system should be applied to assist compliance with the requirements of this document.
- 3.7. Applicator shall be responsible for complying with the requirements of this document. It shall be permissible for the purchaser to make any investigation necessary in order to be assured of compliance by the applicator and to reject any material which does not comply.
- 3.8. All the stages described in this document will be followed and witnessed by PETROBRAS' eventual or permanent inspection. This inspection could be done by certifying companies or duly qualified professionals indicated by PETROBRAS.
- 3.9. Inspection documents shall be in accordance with ISO 10474. The type of certificate of compliance shall be defined in the purchase order.
- 3.10. FJC reports shall identify each field joint by a unique number for identification purposes and shall record material batch number for traceability. Test results shall be linked to the field joint number or repair on which they were performed. Records shall be maintained on a shift and daily basis.
- 3.11. The certificates of compliance signed by the applicator (and the inspector, if applicable) shall be transmitted to the purchaser at a frequency defined in the purchase order. Cumulative production records shall be maintained daily.
- 3.12. Purchaser and the end user shall have the right to inspect applicator's records at any time during the period of the contract.



4. REFERENCES

- 4.1. The following referenced documents are required for the application of this document. The way in which these referenced documents are cited determines (in whole or in part) the extent to which they apply.
- 4.2. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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| ABNT NBR 15221-3 | - | <i>Steel Pipes – External Anticorrosion Coating Part 3 – Fusion Bonded Epoxy</i> | |
| ASTM B-117 | - | <i>Standard Practice for Operating Salt Spray (Fog) Apparatus</i> | |
| ASTM D-149 | - | <i>Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies;</i> | |
| ASTM D-257 | - | <i>Standard Test Method for D.C. Resistance or Conductance of Insulating Materials</i> | |
| ASTM D-610 | - | <i>Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces;</i> | |
| ASTM D-695 | - | <i>Standard Test Method for Compressive Properties of Rigid Plastics</i> | |
| ASTM D-714 | - | <i>Standard Test Method for Evaluating Degree of Blistering of Paints;</i> | |
| ASTM D-790 | - | <i>Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials</i> | |
| ASTM D-792 | - | <i>Standard Test Methods for Density and Specific Gravity (Relative Density of Plastic by Displacement)</i> | |
| ASTM D-1525 | - | <i>Standard Test Method for VICAT Softening Temperature of Plastics</i> | |
| ASTM D-2240 | - | <i>Standard Test Method for Rubber Property - Durometer Hardness</i> | |
| ASTM D 2370 | - | Standard Test Method for Tensile Properties of Organic Coatings; | |
| ASTM D-3418 | - | <i>Standard Test Method for Transition Temperatures of Polymers by Differential Scanning Calorimetry</i> | |
| ASTM D-4060 | - | <i>Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser;</i> | |
| ASTM D-4285 | - | <i>Standard Test Method for Indicating Oil or Water in Compressed Air</i> | |
| ASTM D-4541 | - | <i>Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers</i> | |
| ASTM D-4703 | - | <i>Standard Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets</i> | |
| CAN/CSA-Z245.20 | - | <i>External Fusion Bond Epoxy Coating for Steel Pipe</i> | |
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| <p>CAN/CSA-Z245.21 -02 - <i>External Polyethylene Coating for Pipe</i></p> <p>DIN 30670 - <i>Polyethylene Coatings for Steel Pipes and Fittings</i></p> <p>DNV-RP-F111 - <i>Interference Between Trawl Gear and Pipelines</i></p> <p>ISO 8502-3 - <i>Preparation of Steel Substrates Before Application of Paints and Related Products – Tests for the Assessment of Surface Cleanliness – Part 3: Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure-Sensitive Tape Method)</i></p> <p>ISO 10474 - <i>Steel and Steel Products – Inspection Documents</i></p> <p>ISO 11357-6 - <i>Determination of Oxidation Induction Time</i></p> <p>ISO 21809-3 - <i>Petroleum and Natural Gas Industries – External Coatings for Buried or Submerged Pipelines Used in Pipeline Transportation System</i></p> <p>NACE Standard RP-02-74 - <i>High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation</i></p> <p>NACE Nº 2/SSPC-SP10 - <i>Joint Surface Preparation Standard, Near-White Metal Blast Cleaning</i></p> <p>NACE Nº 2/SSPC-SP 1 - <i>Joint Surface Preparation Standard, Solvent Cleaning</i></p> <p>NFA 49-711 - <i>External three-layer polypropylene based coating application by extrusion</i></p> <p>NFA 49-716 - <i>Steel Tubes and Fittings for Onshore and Offshore Pipelines – External Field Joint Coatings</i></p> | | | |
| <p>5. QUALIFICATION REQUIREMENTS</p> <p>5.1. Materials shall meet the requirements of the applied technical specification. Materials shall be re-qualified in case of change in either the raw materials or any other conditions as defined in applicable specification.</p> <p>5.2. The pre-qualification trials for this field joint coating are valid to the specific conditions utilized on the coating application. In case of any change listed below, all the pre-qualification tests shall be repeated:</p> <p>a) Coating materials;</p> <p>b) Surface preparation level (cleanness, roughness);</p> <p>c) Temperature range of coating application;</p> <p>d) Pre-treatment;</p> <p>e) Equipment for application procedure;</p> <p>f) Range of diameters: from 4 to 10.75in; from 10.76 to 20in, from 20.01 to larger;</p> <p>g) Variation in thickness: -30% (negative variation);</p> | | | |
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| <p>h) Variation in thickness of steel: +/-15%;</p> <p>i) Installation method and/or diameter of reel (if applicable).</p> <p>5.3. If material analyzed fails to pass any of the tests referred in Tables I, II or III, the whole qualification lot shall be rejected.</p> <p>5.4. Pre-qualification trials shall be done in case the coating system is not qualified in PETROBRAS or if any of the items listed in Clause 5.2 changes.</p> <p>5.5. Pre-production trials shall be done in case coating system is pre-qualified in PETROBRAS and production is defined to start more than 9 (nine) months after pre-qualification or production realization. These tests shall be done and results shall be obtained prior start production or application of coating system process.</p> <p>5.6. Production trials shall be done during field joint coating application process.</p> <p>5.7. During pre-qualification and pre-production phases at least 6 (six) field joints shall be produced and tested in each phase.</p> <p>5.8. PETROBRAS (or professional certified by the Company) will witness all the qualification tests mentioned in this specification. Before the beginning of the qualification, applicator shall present the procedures and ITP approved by PETROBRAS, as well as the quality certificates of the coating materials containing, at least, commercial reference, physic-chemicals characteristics and material security data sheets (MSDS).</p> <p>5.9. The qualification of the Application Procedure shall be interrupted whenever any test or inspection performed presents an unacceptable result. The failing test shall be performed again using two new samples from the same field joint. If any of these new tests fails, the whole qualification process shall be started again.</p> <p>5.10. The procedure shall be considered qualified when all tests and inspections are according to the requirements established in this specification.</p> <p>5.11. If during production any of the tests fails, two additional tests shall be performed at the same field joint. If one of them fails, the field joint shall be peeled, redone and joints immediately before and after the rejected joint shall be tested. If any fail occurs, the same procedure shall be performed until no fail is observed.</p> <p>6. MATERIALS PROPERTIES</p> <p>6.1. Materials shall meet the requirements specified in Table A.1 of ABNT NBR 15221 part 3. Prior to coating, epoxy powder shall be laboratory tested to check compliance with all requirements.</p> <p>6.2. For tests where FBE plates have to be used, they shall be prepared according to ASTM D-4703 Standard, procedure C, and conditioned according to ASTM D-618 Standard.</p> <p>6.3. A Material Qualification Dossier shall be issued, by the Applicator, containing at least the following information:</p> | | | |
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- a) Material(s) Qualification Certificate(s);
- b) Raw-material(s) supplier;
- c) Raw-material(s) specification;
- d) Name and complete identification of material, including plant of origin;
- e) Product application temperature range;
- f) Surface preparation;
- g) Surface profile;
- h) Organization that performed the material tests;
- i) Tests results.

7. COATING PROCEDURE

- 7.1. Prior to the start of production and any agreed pre-qualification or pre-productions tests, Applicator shall prepare a Coating Procedure including at least the following items:
 - a) List of applied standard and codes;
 - b) Material specification (trademarks, physical and chemicals characteristics);
 - c) Manufacturers instructions for application, including characteristics of equipment and measurement instruments that shall be used;
 - d) Range of diameters;
 - e) Wall thickness;
 - f) Procedure for field joint cleaning;
 - g) Procedure for preheating field joints, specifying temperature;
 - h) Field joint surface and plant applied coating preparation, mentioning type of preparation, equipment and applied materials;
 - i) Heating conditions of the field joint, including the method of control and the temperature measurement and record;
 - j) Procedure for application of epoxy primer;
 - k) Procedure for application of coating material;
 - l) Method of quenching, if applicable;
 - m) Procedure for protecting the coating system;
 - n) System identification;
 - o) Procedure for repair;
 - p) Inspection plan for the coating materials, coating application and field joints with the acceptance/rejection criteria for the tests included in the method of inspection;
 - q) Inspection plan for receipt of various materials;
 - r) Identification system of the field joints;
 - s) Entity responsible for the tests;
 - t) Method for determining the causes of defects with a rate of occurrence higher than acceptable levels;
 - u) Coating supplier address and telephone for technical support in Brazil;
 - v) Certifying firms or duly qualified professionals that may witness the tests.
- 7.2. The Coating Procedure shall be submitted to PETROBRAS for approval prior to the beginning of pre-qualification, pre-production and/or production works.
- 7.3. Once approved, the Coating Procedure shall not be changed by Applicator without PETROBRAS written authorization.

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8. COATING QUALIFICATION



- 8.1. Prior to start of production, Applicator shall, at his expense, carry out a coating procedure qualification trial to prove that his equipment, materials and coating procedure result in a conforming end product.
- 8.2. All the tests and inspections to qualification described in this specification will be followed by PETROBRAS during the coating application. This inspection could be done by certifying firms or duly qualified professionals indicated by PETROBRAS.
- 8.3. All people involved in the coating application process shall be trained and qualified. Only qualified operators are allowed to apply the coating on the field joints.
- 8.4. Coating materials shall be subjected to tests in accordance with requirements in Clause 6.
- 8.5. The procedure shall be qualified through the coating of at least 6 (six) field joints from which specimens shall be taken and subjected to tests described in Clause 11 in accordance to requirements for the applied coating as Clause 10.
- 8.6. The dimension and quantity of test specimens, acceptance and rejection criteria of the qualification tests shall be described in the Coating Procedure.
- 8.7. The qualification process shall be interrupted when any test or inspection realized shows unacceptable results. The coating process shall be completely redone.
- 8.8. Qualifications tests are valid to specific process conditions used on the coating application. In case of any change on the conditions as listed in Clause 5.2, all the qualification tests shall be repeated.
- 8.9. After finishing the qualification procedure, Applicator shall submit for PETROBRAS' approval a qualification dossier with the documents and/or information as defined in Clause 12.3.
- 8.10. During qualification process robot recovery system shall be submitted to trial tests according to clause 10.14.
- 8.11. During qualification data transmission system shall be submitted to trial tests according to clause 10.15.

9. COATING APPLICATION

9.1. Surface Preparation (Internal and External)

9.1.1. Cleaning prior to welding

- 9.1.1.1. The pipe's cut back surfaces shall be free from grease, oil, grease, burrs or loose oxide layers and other foreign materials. When the surface is contaminated by oil, grease or fat, it shall be cleaned with solvent as per standard ANSI/AWWA C203 item 3.2.1.

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- 9.1.1.2. The chloride contamination of the surface shall be verify as per standard NACE No 5/SSPC-SP 12, table 2, condition SC-2 and the maximum allowable value of chloride acceptable is 2µg/cm² measured by the instrument Elcometer 130-SCM 400 or a similar device.
- 9.1.1.3. This clean environment shall be maintained by keeping the pipe's cut back covered until the welding procedure is ready to begin.
- 9.1.1.4. While the pipe is on the ready rack, the pipe's cut back surfaces to be coated shall be subject to blasted performed by turbine equipment, pressurized or similar, using steel grit until near-white metal, as per standard NACE SSPC-SP10 or, at least, one of the figures Sa 2 ½ as per standard ISO 8501-1. (See diagram 1 and 3)
- 9.1.1.5. The resulting roughness profile shall be between 60 µm and 100 µm, measured by means the method "Replica Tape" (Press-o-Film or similar) or method electronic and, in this case, considering the parameter Rz and shall have angular cut. The total roughness value shall be obtained from the average of three random measures over the pipe surface.
- 9.1.1.6. The remaining coating shall be lightly abraded for 25 mm to provide a "key" for the field joint coating overlap. (See diagram 2 and 4)
- 9.1.1.7. The blasted surface shall be cleaned with an aspirator or with a clean and dry compressed air, in order to remove all the sand, grit or dust.
- 9.1.1.8. Blasted pipes, clean and accepted for coating shall be coated within a period of four hours. Whenever the relative humidity is greater than 85%, or it is raining, this period of time shall be reduced to three hours. Whenever there is oxidation, the pipe shall be blasted again. The pipe surface shall be kept at a temperature of at least 3°C above dew point, however below 50°C.
- 9.1.1.9. The surface of the blasted pipe shall be free from powder contamination, which shall not exceed figure 3 as per standard ISO 8502-3.



9.1.2. Cleaning post welding (Internal)



- 9.1.2.1. When the completed and accepted weld (as described in the notes bellow) arrives in the coating station the remotely controlled internal combination machine (consisting of two elements the cleaner & powder coater) is positioned on the girth weld ready for the cleaning function to begin.



Note: 1) The welding operations must produce an internal weld profile that can be coated. It is mandatory that the welding procedures preclude excess penetration and weld spatter. The internal weld profile must be limited to a maximum dimension of 1.5 mm (1/16 inch) in height. CONTRACTOR shall be informed about the Welding Procedure Specification that will be used for the pipeline project.

2) When the girth weld has been completely welded and the designated welding inspector has accepted and signed for the weld, the

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| <p>CONTRACTOR field coating operators can begin the internal cleaning and coating sequence.</p> <p>9.1.2.2. The cleaning cycle for internal surface shall be carried out by locating the machine with the use of at least three cameras that shall supply a “real time” image for the inspection operator crew.</p> <p>9.1.2.3. The cameras shall, before the cleaning sequence begins, check for:</p> <ul style="list-style-type: none"> i. Foreign objects along the pipe; ii. Girth weld area for it’s number assignment; iii. Anomalies; iv. Lining up with the field joint area; v. Position of the vacuum unit; vi. The beginning of the cleaning and vacuuming cycle; vii. The cleaning quality and the contamination of the weld area as required in this Technical Specification; viii. The repositioning of the machine for the FBE coating to be applied. <p>9.1.2.4. The cleaning cycle for external surface shall be carried by a visual inspection and the item 9.1.2.3 shall be achieved.</p> <p>9.1.3. External Surface Cleaning and Preparation</p> <p>9.1.3.1. Prior to coating application, the surface shall be dry and free of any contamination (such as detritus, dust, non adhering particles, grease, oil, soluble, etc.) detrimental to surface preparation or to adhesion of the coating on the steel. Oils, grease and wax shall be removed by solvent cleaning in accordance with SSPC SP1.</p> <p>9.1.3.2. Steel defects and irregularities (e.g. arc strikes, scratches, weld spatter, slag and burrs) shall be brought to the attention of PETROBRAS’ representative disposition.</p> <p>9.1.3.3. The coating around the field joint shall be clean, free from oil or grease and dry. The plant applied coating shall be beveled and roughened, by means of flap disc, for the minimum length according to the specified overlap on plant coating. The plant applied coating shall not be removed or contaminated by abrasive dust.</p> <p>9.1.3.4. Contamination by chlorides shall be verified according NACE Nº 5/SSPC-SP 12, Table 2, condition SC-2. Maximum acceptable value is 2 µg/cm², measured by ELCOMETER 130-SCM 400 or similar equipment. If chlorides contamination is found, suitable chemical pre-treatment or high pressure demineralised water shall be used to eliminate it prior to blasting.</p> <p>9.1.4. External Blasting</p> | | | |
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| <p>9.1.4.1. Field Joint blasting shall be done through blasting machine. Manual blasting is not allowed.</p> <p>9.1.4.2. Compressed air for blast cleaning shall be free of oil, condensed moisture or any other contaminants and shall conform to the requirements of ASTM D-4285.</p> <p>9.1.4.3. Prior to blast cleaning, the field joint shall be preheated using a propane torch to remove all moisture. Steel surface shall be kept at least 5°C above the dew point and below 85°C.</p> <p>9.1.4.4. Surfaces of the field joint shall be blast-cleaned by means of air operated machine shown to near white metal as per SSPC-SP 10 Standard. A finishing comparable to the one shown on pictures Sa 2 ½ of Standard SIS-055900 is the least expected. During blast cleaning the coated end area shall be protected using rubber strips rolled around the pipe.</p> <p>9.1.4.5. After blasting, external field joint surface shall be cleaned. The blast cleaned surface profile shall be measured using the replica tape method. Roughness profile shall be between 60 and 100µm. Residual dust contamination after blasting shall be determined by adhesive tape method (ISO 8502-3) and shall not be greater than 2. All slivers, scabs and gouges shall be brought to the attention of PETROBRAS' representative for disposition. Each ground area shall not exceed 150cm² and the total ground area shall exceed 0.5% at the pipe total area. Acid wash may be used to remove any remaining contamination on external field joint surface.</p> <p>9.1.4.6. Field joints subjected to blasting and accepted for coating shall be coated within a period of two hours. Whenever it is raining or the relative humidity of the air is greater than 85%, the maximum waiting period shall be reduced to 60 minutes, so as to avoid surface oxidation. Whenever oxidation or another type of contamination occurs, the field joint shall be cleaned and blasted again according to cleaning procedure and the coating shall be applied prior to any surface contamination.</p> <p>9.2. Pipe Heating</p> <p>9.2.1. Field joint heating shall be done through induction oven with the relevant open coil.</p> <p>9.2.2. The field joint surface temperature shall be continuously monitored by a temperature sensitive crayon or contact thermometer connected to a graphic recorder.</p> <p>9.2.3. External surface Temperature shall also be controlled by temperature sensitive crayon at a maximum interval of 60 minutes.</p> <p>9.2.4. Field joint heating temperature shall be kept within the epoxy Applicator recommendations. The temperature shall not exceed 220°C.</p> <p>9.2.5. Heating time and temperature shall not result in oxidation of the surface of the steel detrimental to the quality of the coating or damage the plant applied coating on a field joint.</p> | | | |
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| <p>9.2.6. Field joints that were not coated within the qualified temperature range shall be re-coated.</p> <p>9.3. Internal mono Layer FBE Application</p> <p>9.3.1. Epoxy powder shall be stored in accordance with manufacturer's recommendation. Ambient conditions (at least temperature and relative humidity of the air) in the storage room shall be monitored and registered all the time.</p> <p>9.3.2. Over the entire surface, the epoxy powder shall be applied by spray guns connected to a compressed air system. The supplied air shall be free of water, oil or any other contamination. The equipment shall have silica-gel and carbon activated separators, in order to remove water and oil, or any other system that guarantee the air purity.</p> <p>9.3.3. The total thickness shall be 450 –50/+150 µm.</p> <p>9.3.4. FBE shall be applied within 120 days from manufacturing date. If this time is exceeded, the FBE shall be tested according with table A.1 of ABNT NBR 15221 Part 3</p> <p>9.4. External Dual Layer FBE Application</p> <p>9.4.1. Epoxy powder shall be stored in accordance with manufacturer's recommendation. Ambient conditions (at least temperature and relative humidity of the air) in the storage room shall be monitored and registered all the time.</p> <p>9.4.2. Epoxy powder shall be applied by a fluid air unit depositing fluidized powder on heated steel surface. Compressed air for epoxy powder application shall be free of oil, condensed moisture or any other contaminants and shall conform to the requirements of ASTM D-4285. The equipment shall be provided at least with separating filters containing silica gel and active carbon for removal of water and oil, respectively, or other else drying device to provide the quality of the air.</p> <p>9.4.3. Application process shall be performed using a high vacuum powder extraction system in order to avoid pollution by FBE powder.</p> <p>9.4.4. The FBE Dual Layer powder shall be applied to the steel substrate and any exposed FBE overlap area using coating frame or manual application spray head in the minimum number of passes to achieve specified coating thickness.</p> <p>9.4.5. Minimum number of passes shall be determined during the set up of the FBE application machine for each layer, during pre-production Tests.</p> <p>9.4.6. Recycling of the processed FBE powder is not allowed.</p> <p>9.4.7. Thickness of each FBE Layer shall be in conformance with Table I.</p> <p>9.4.8. All FBE Layers shall be applied within 120 days from manufacturing date. If this time is exceeded, the FBE shall be tested according with table A.1 of ABNT NBR 15221 Part 3.</p> | | | |
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10. COATING PROPERTIES

10.1. Coating as applied shall follow the requirements of Table I and Clause 10.

10.2. Appearance and Constitution of the Coating

10.2.1. Appearance of the coating shall be uniform, smooth, with homogeneous color. Defects in detrimental to quality of the coating, especially grooves, cracks or flaws should not be observed.

10.2.2. Coating shall be homogeneous in weight and, in particular, free of blistering and lamination.

10.2.3. Appearance and constitution of the coating shall be checked visually on all joints.

10.3. Applied Coating Properties



10.3.1. FBE mono-layer and Dual Coat material properties shall comply with requirements of Table I. Tests shall be performed on applied mono-layer over steel blasted and on overlap zone of girth welds.

10.3.2. Coating Applicator shall confirm that requirements of Table I will be adhered to for all materials within his scope of supply prior to the award of any contract.

10.3.3. Coating Applicator shall perform testing on production materials to prove such compliance as required in this document.

Table I– Applied FBE mono-layer and FBE Dual Coat Properties



| REQUIREMENTS | UNIT | VALUES | TEST METHOD |
|---|--------|-------------|--------------------|
| External Epoxy Base coat Layer Thickness | µm | 550(-0+100) | Clause 10.4 |
| External Epoxy Top coat Layer Thickness | µm | 550(-0+100) | Clause 10.4 |
| Internal Epoxy Layer Thickness | µm | 450(-0+100) | Clause 10.4 |
| Holiday Detection | - | No Holiday | Clause 10.5 |
| Water Absorption | % mass | 30 max | NFA 49-706 Annex D |
| Adhesion “Pull-Off” of external epoxy powder Base coat at (23 ± 2) °C | MPa | 17.2 min | ASTM D-4541 |
| Adhesion “Pull-Off” of external epoxy powder Top coat at (23 ± 2) °C | MPa | 17.2 min | ASTM D-4541 |
| Adhesion “Pull-Off” of internal epoxy powder coat at (23 ± 2) °C | MPa | 17.2 min | ASTM D-4541 |



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| DSC (External FBE Base coat Cure Analysis) ($\Delta Tg = Tg4 - Tg3$) | °C | ΔTg between -2 and +3 | CAN/CSA Z245.20 Item 12.7 |
| DSC (External FBE Top coat Cure Analysis) ($\Delta Tg = Tg4 - Tg3$) | °C | ΔTg between -2 and +3 | CAN/CSA Z245.20 Item 12.7 |
| DSC (Internal FBE Cure Analysis) ($\Delta Tg = Tg4 - Tg3$) | °C | ΔTg between -2 and +3 | CAN/CSA Z245.20 Item 12.7 |
| Adhesion after water immersion 24h @ 75 °C | mm | 3 max | CAN/CSA Z245.20 Item 12.14 |
| Internal and External Interface Porosity | Rating scale figure | 1 to 3 | CAN/CSA Z245.20 Item 12.10 |
| Internal and External Cross Section porosity | Rating scale figure | 1 to 3 | CAN/CSA Z245.20 Item 12.10 |
| Hot Water Soak | - | Rating 3 | ISO 21809-3 |
| External Impact Strength at (20 ± 2) °C | J/mm | 5 min | DIN 30670 |
| External Impact Strength at (0 ± 2) °C | J/mm | 5 min | DIN 30670 |
| Internal and External Cathodic Disbondment at (20 ± 2) °C at 28 days | mm | 5 max | CAN/CSA Z245.20 Item 12.8 |
| Internal and External Cathodic Disbondment at (65 ± 2) °C at 2 days | mm | 5 max | CAN/CSA Z245.20 Item 12.8 |
| Internal and External Cathodic Disbondment at (70 ± 2) °C at 28 days | mm | 7 max | CAN/CSA Z245.20 Item 12.8 |
| Internal and External Flexibility 3.0%/PD min. at (0 ± 2) °C | - | No cracks | CAN/CSA Z245.20 Item 12.11 |
| Internal and External Hardness Shore D | - | 80 min | ASTM D-2240 |
| External Shear Scratch Resistance | - | By Agreement | Clause 10.11 |
| Full Scale Bending | - | No cracks | Clause 10.12 |
| Full Scale Stinger Roller | - | No cracks | Clause 10.13 |

10.4. Coating Thickness

10.4.1. Thickness at any point of the coating, including over a weld seam, if applicable, shall not be less than the total coating thickness value defined in the design specifications. Tolerance is defined in table I.

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| <p>10.4.2. Monitoring of thickness shall be carried out according to an electromagnetic equipment or US equipment (with 5µm of precision) on at least 4 sections of the coated pipe. At least the 12, 3, 6 and 9 hours position shall be measured at each section. One of these 4 positions shall be on the longitudinal weld seam, if applicable. All the 12 points per section shall be registered.</p> <p>10.4.3. Measure equipment shall be calibrated at least once per 8 hours of work.</p> <p>10.4.4. Thickness measurements shall be performed in accordance to Table I.</p> <p>10.5. Holiday Detection</p> <p>10.5.1. Coating must be free of porosity detectable by the test carried out at entire coating surface. The test shall be conducted after final layer application.</p> <p>10.5.2. External applied voltage is limited to the maximum value between 3,0 e 3,5 kV.</p> <p>10.5.3. Internal applied voltage is limited to the maximum value of 2,0 kV.</p> <p>10.5.4. Contact electrode shall be made of conducted rubber or by several rectangular wires. Rate of inspection shall not exceed 18m/min.</p> <p>10.5.5. Coating shall be free of any kind of defect. Defects detected shall be repaired in accordance to Clause 13.</p> <p>10.6. Cathodic Disbondment</p> <p>10.6.1. Cathodic Disbondment on external and internal applied FBE is evaluated from the difference of initial radius and radius of the damaged edge on which the coating is detached from the metal surface. The test shall be performed in accordance to CAN/CSA Z245.20, Item 12.8:</p> <ol style="list-style-type: none"> 48 hours at (65 ± 2) °C at -3.5V; 28 days at (20 ± 2) °C at -1.5V; 28 days at (70 ± 2) °C at -1.5V. <p>10.6.2. Average disbondment shall be determined by six measurements. Acceptance criteria are defined in Table I.</p> <p>10.7. Adhesion Pull-Off</p> <p>10.7.1. The adhesion of the FBE coating shall be tested by the pull-off method in accordance to ASTM 4541 Standard. The adhesion test shall be performed at ambient temperature.</p> <p>10.7.2. Acceptance criteria is defined in Table I. Cohesive failure caused by voids in the coating leaving a honeycomb structure on the steel surface constitutes a fail condition. During Qualification phase applicator shall perform 4 adhesion tests on each side of 3 coated pipes. At least the 12, 3, 6 and 9 hours position shall be measured at each coated pipe length and at 12 hour shall be on the seam weld, if applicable. Total of 24 tests.</p> <p>10.7.3. During Production phase applicator shall perform 4 adhesion tests on each side of a selected pipe for each 500 pipes produced. At least the 12, 3, 6 and 9 hours position shall be measured at each coated pipe length and at 12 hour shall be on the seam weld,</p> | | | |
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if applicable. The specimen shall be obtained at one of the pipe end and shall be realized before the cut back preparation described in clause 9.7.1

10.8. Foaming

10.8.1. FBE voids/foaming levels shall be compared against the visual standards in CAN/CSA Z245.20. Maximum level of foaming shall be level/rating 2.

10.9. Flexibility

10.9.1. Bending test shall be performed according to CAN/CSA Z245.20, Item 12.11.

10.9.2. Acceptance criterion is defined in Table I. Test to be performed at (0 ± 2) °C.

10.9.3. After bending, samples shall be verified using Holiday Detection.

10.10. Impact Strength

10.10.1. The Impact Strength Test shall be performed according to the method defined in DIN 30670, at (23 ± 2) °C and at (70 ± 2) °C.

10.10.2. Acceptance criterion is defined in Table I.

10.10.3. During qualification procedure at least 10 (ten) points at each field joint shall be tested. **Three impacts shall be developed on a grown grade of energy with the main objective to determine the impact coating strength.**



10.11. Shear Scratch Resistance Test

10.11.1. The shear scratch resistance test sometimes referred to as the “gouge test” is designed to simulate a coated pipe being dragged across a sharp gouging force such as a rock protruding into the drill bore hole. For this test the loads shall be defined by agreement in order to have a properly designed Horizontal Directional Drilling (HDD) where loads are properly designed.

10.11.2. The test shall be performed using a test panel to be fixed to a rolling cart that is pulled at a controlled rate by a tensile test machine under a weighted point. The gouged area shall be checked for depth of penetration. The gouged area shall also be checked for holidays using a holiday tester set at 5 volts per micron of coating thickness. The test is repeated with additional weight until the weighted point has penetrated the full thickness of the coating or the gouged area jeps. The weight causing holiday(s) shall be recorded. In addition, X-Y plots shall be generated for weight vs. depth of penetration. These plots should be used to give a feel for how the coating resists the gouge force and correlations to de HDD design shall be done.

10.12. Full Scale Bending

10.12.1. This test simulates the cycle of bending and straightening to which a pipe would be subjected during installation when using Reel-Lay Method.

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10.12.2. For Pre-Qualification, Full Scale Bending Test shall be performed with a radius of curvature equal to 7.5m.

10.12.3. For Pre-Production, Full Scale Bending Test shall be performed with a radius of curvature equal to the reel radius of the laying vessel.

10.12.4. The loading procedure consists of the following steps:

- a) Pipe is placed in the test arrangement in the initially unstressed position;
- b) Bending moment is applied to bend the pipe around the bending former;
- c) An axial force shall be applied to pipe during 5 minutes. The force value shall be informed by PETROBRAS prior to test performance;
- d) Axial force is removed and the pipe is kept under bending moment for 24 hours;
- e) All loads are removed and the pipe is allowed to take up its residual deflect shape;
- f) Test pipe is then bent in the reverse direction around the straightening former;
- g) All loads are removed from the pipe;
- h) The bending/straightening cycle shall be repeated on a total of five (5) times.

10.12.5. At the end of the test, a visual inspection of the coated pipe shall be performed. The coating shall be free from detection of cracks, disbonding between layers or any type of coating collapse indication. The acceptance criteria shall also be no delamination or cracking of the coated pipe and no disbondment between the field joint, if applicable and parent coating. Field joint area shall also be cut in sections in order to expose the intersection field joint/factory coating in the area submitted to the major tension.

10.12.6. After the Full Scale Bending Test, the following tests shall be performed in the tested coated pipe:

- a) Holiday Detection as per Clause 10.5;
- b) Cathodic Disbondment as per Clause 10.6;
- c) Adhesion Pull-Off as per Clause 10.7;
- d) Hot Water Soak 28 days according to ISO 21809-3.



10.13. Full Scale Stinger Roller

10.13.1. This test simulates the coated pipeline moving through the rollers of the laying vessel ramp or stinger. An evaluation of the effect of the local loads applied on the coating material by the rollers of the laying vessel (straightener or stinger) shall be done in accordance with this clause.

10.13.2. The pipe sample shall be placed in a ramp roller load testing bench and supported by two fixed rollers placed at each extremity of the bench. Then, a third roller positioned in the middle of the pipe begins to apply the load on the coated pipe. The load shall be gradually increased until reaching the specified contact load between the pipe and the roller, in accordance with the project. All loads shall be recorded.

10.13.3. Expected load value will be informed by PETROBRAS prior to testing.

10.13.4. At the end of the test a visual inspection of the coated pipe shall be performed. The coating shall be free from detection of cracks, disbonding or any type of coating collapse indication, deformation or crush. In the event that any kind of coating collapse occurs, the applied load and the coating / straightener or stinger roller contact surface shall be registered and the pipe is refused.

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10.13.5. After the Full Scale Stinger Roller Test, the following tests shall be performed:

- a) Holiday Detection as per Clause 10.5;
- b) Cathodic Disbondment as per Clause 10.6;
- c) Adhesion Pull-Off as per Clause 10.7;

10.14. Robot Recovery Procedure

10.14.1. Before the beginning of this qualification, the applicator shall present the robot Recovery Procedure approved by PETROBRAS. Then, at least 3 pipes of 12 meters length shall be taken and welded. According to the robot Recuperation Procedure Application, the painting robot shall be rescued by the recovery robot. The pipeline shall be inclined with 1.25 times the maximum allowed angle. The recovery robot shall recover the paint robot in the other end of the pipeline.

10.15. Data Transmission System

10.15.1. The data transmission system shall be tested through internal line up clamp in a pipeline. This pipeline shall be done with at least five pipes with 12 meters length. The antennas shall be positioned in one end of the pipe and the robot in the other. One internal girth weld coating shall be done.

10.16. Hot Water Soak

10.16.1. A coated sample of 200 x 100 mm machined from a ring of the coated pipe shall be immersed in tap water at 95°C for 28 days. The bare edges of the sample shall be coated to prevent ingress of moisture beneath the coating.



10.16.2. After each 7 days exposure the coated sample shall be removed from the water bath and allowed to cool to ambient temperature. The coating shall then be examined visually and the adhesion shall be tested. The coating shall show no evidence of blistering or disbonding and shall show no failure of adhesion when tested.



11. FREQUENCY OF TEST

- 11.1. Table II lists the frequency of tests to be performed during pre-qualification, pre-production and production phases applicable in accordance with the status of the coatings.
- 11.2. Destructive tests might be performed on a spare pipe since this pipe has the same diameter and wall thickness of production pipes.

Table II – Frequency of Tests

| PROPERTIES | PRE-QUALIFICATION | PRE-PRODUCTION | PRODUCTION |
|---|-------------------|----------------|------------|
| Surface Preparation and Heating Requirements | | | |
| Visual inspection of bare pipes | All pipes | All pipes | All pipes |

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| Chloride Contamination | All pipes | All pipes | once per shift | |
| Conductivity evaluation of abrasive material | All pipes | All pipes | once per shift | |
| Abrasive Blast cleaning | All pipes | All pipes | 4 times per shift | |
| Dust level on the blast cleaned surface | All pipes | All pipes | 4 times per shift | |
| Roughness Profile | All pipes | All pipes | 4 times per shift | |
| Pipe Heating | All pipes | All pipes | 4 times per shift | |
| Ambient Condition | All pipes | All pipes | 4 times per shift | |
| FBE mono-layer and Dual Coat Requirements | | | | |
| Internal and External FBE Thickness | 1 test on 1 pipe | 1 test on 1 pipe | Once per shift | |
| DSC (FBE External Base coat and Top Coat Cure Analysis) ($\Delta T_g = T_{g4} - T_{g3}$) | 1 test on 1 pipe | 1 test on 1 pipe | - | |
| DSC (FBE Internal Cure Analysis) ($\Delta T_g = T_{g4} - T_{g3}$) | 1 test on 1 pipe | 1 test on 1 pipe | - | |
| External Adhesion Pull-Off at $(23 \pm 2) ^\circ\text{C}$ | 5 tests on 1 pipe | 3 tests on 1 pipe | 3 tests on 1 pipe per shift | |
| Flexibility at 3.0°PD at $(0 \pm 2) ^\circ\text{C}$ | 5 tests on 1 pipe | 3 tests on 1 pipe | - | |
| Internal and External Foaming | 2 tests on 1 pipe | - | - | |
| Internal and External Interface Porosity | 2 tests on 1 pipe | - | - | |
| Internal and External Cross-Section Porosity | 2 tests on 1 pipe | - | - | |
| External Total Thickness | Every pipe | Each pipe | 1 test per 5 pipes | |
| Internal and External Holiday Detection | Every pipe | Every pipe | All pipes | |
| Internal and External Cathodic Disbondment at $(20 \pm 2) ^\circ\text{C}$ at 28 days | 2 tests on each pipe | 2 tests on 3 pipes | - | |
| Internal and External Cathodic Disbondment at $(65 \pm 2) ^\circ\text{C}$ at 48 hours | 2 tests on each pipe | 2 tests on 3 pipes | - | |
| Internal and External Cathodic Disbondment at $(70 \pm 2) ^\circ\text{C}$ at 28 days | 2 tests on each pipe | 2 tests on 3 pipes | - | |
| External Impact Strength at $(23 \pm 2) ^\circ\text{C}$ | 1 test on 2 pipes | 1 test on 2 pipes | 1 test on first pipe of shift | |
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| External Impact Strength at (70 ± 2) °C | 1 test on 2 pipes | 1 test on 2 pipes | 1 test on each 500 pipes |
| Internal and External Hardness Shore D | 2 tests on 2 pipes | 2 tests on 2 pipes | 1 test on each 500 pipes |
| External Shear Scratch Resistance | 1 test on 1 pipe | 1 test on 1 pipe | - |
| Full Scale Bending | 1 test on 1 pipe | 1 test on 1 pipe | - |
| Full Scale Stinger Roller | 1 test on 1 pipe | - | - |

12. QUALIFICATION TEST REPORTS

- 12.1. The laboratory tests, simulated service tests and full scale tests reports related to different project phases (pre-qualification, pre-production, production) shall be organized in a complete report and presented to PETROBRAS analysis and approval before any other phase of the project starts.
- 12.2. All test data shall be presented to PETROBRAS. These tests data shall be recorded and stored during all test time including the initial of the test (non-stabilized period) and the test period.
- 12.3. Reports shall be presented in a digital file and in paper format containing at least information described in clause 8.9.

13. REPAIR

- 13.1. After producing, all the coated pipes shall be inspected in accordance to Clause 10.5.
- 13.2. If any defect or damage is found, it should be marked with paint, crayon or similar to facilitate the location of areas to be repaired.
- 13.3. There are two types of defects liable to be repaired as described in 13.4 and 13.5.
- 13.4. The Type I defect - Pinhole detected by coating discontinuity test. No more than 3 repairs per coated pipe are acceptable.
- 13.5. The Type II defect – defect except pinhole, with an area smaller than 20cm² and having the higher dimension no longer than 30cm. No more than 1 type II is acceptable. Pipes having a defect with area higher than 20cm² shall be rejected.
- 13.6. Surface preparation shall be in accordance with clause 11.2 of ABNT NBR 15221-3.
- 13.7. Repair application shall be performed according to clause 11.3 of ABNT NBR 15221-3.
- 13.8. All repair materials shall be fully compatible with the FBE Dual Coat. The repair system shall be field proven and suitable for subsea conditions at the design life, maximum and minimum design temperature.

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13.9. The repairs shall be executed according to a qualified Repair Application Procedure. The requirements for Repair Application Procedure and its qualification shall follow the requirements below.

13.10. Repair Application Procedure

13.10.1. The repair application procedure shall be submitted for PETROBRAS approval inserted in Coating application procedure.

13.10.2. The Repair Application Procedure shall contain all the steps to the coating repair execution, including the parameters to be controlled to guarantee the fitness of the product to its purpose. The Repair Application Procedure shall be presented in step-by-step format, with photographic / illustrative pictures for each step.

13.10.3. The Repair Application Procedure shall be the official inspection document to be used in the production and construction line (onshore and offshore).

13.10.4. Applicator shall be responsible to keep the repair applicators and equipment following strictly the Repair Application Procedure.

13.10.5. Applicator shall submit for PETROBRAS approval any kind of practice executed that do not belong to the Repair Application Procedure qualified.

13.10.6. Applicator shall only execute the repairs with operators qualified by PETROBRAS. CONTRACTOR shall be responsible to evaluate the number of operators to be qualified. The number of operators shall be presented to PETROBRAS together with Repair Application Procedure emission.

13.10.7. Coating manufacturer shall not accept or apply raw materials without Quality Certificates and with the Pot Life or Validity exceeded.

13.11. Qualification Tests

13.11.1. For each specific project, PETROBRAS may request tests to evaluate the suitability of the FBE repair material for the application. These tests may evaluate:



- a) Raw material of Repair Coating
- b) The Coating Repair itself and the adhesion with Parent Coating
- c) Coating Manufacturer Equipment Tests
- d) Operators that will apply the repairs

13.11.2. The qualification tests shall be executed in order to verify if the raw material of repair and repair applied itself is suitable to the intended application

13.11.3. All the qualification tests requested by PETROBRAS shall be executed in presence of PETROBRAS official representative or certifying authority (only if permitted by PETROBRAS). Tests executed outside this condition will not be considered valid.

13.11.4. For applied repair qualification, the repair to be tested shall be based on the maximum damage dimensions permitted by repair method.

13.11.5. All operators to apply FBE Dual Coat repairs shall be qualified for each project. Each operator shall apply three repairs for testing. The “holiday detector” test, “visual

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inspection” and “flexibility” test shall be executed according to Application and repair procedure. All the three samples shall be approved in tests for operator qualification.

14. RECEIVING, STORAGE AND TRANSPORTATION OF COATING MATERIAL AND COATED CUT BACK TRACEABILITY

14.1. Coating Materials

14.1.1. Coating material shall be inspected at the time they are received, including their package and conditioning, which shall be in compliance with the purchase documents and design specifications and regular conditions of application. The material technical characteristics shall meet all the requirements of clause 6.

14.1.2. Inspection when materials are received shall include at least:

- a) The checking of the Quality Certificates, which shall certify compliance with the requirements of clause 6;
- b) The checking of the expiration date and packages integrity;

14.2. Storage

14.2.1. The epoxy powder shall be stored in their closed package, at least 10 cm distant from the floor. The room temperature shall be not higher than 27°C and the air relative humidity shall be less or equal to 70%. The conditions shall be controlled, monitored and recorded.

14.2.2. In case of different storage characteristics as described the coating material shall be revalidated. Gel time, glass transition temperature and moisture content test shall be done and the results shall comply with according with table A.1 of ABNT NBR 15221 Part 3

14.2.3. All the materials shall be stored strategically so that the ones to be utilized first are the ones marked with the soonest expiring dates.

14.3. Transportation



14.3.1. The coating Material shall be transported in a way to avoid damages.

14.3.2. Packages with the coating material shall not be left under the weather.

14.4. Receiving of coated pipes

14.4.1. Received inspection shall include at least checking the bevels status, as well as whether there is out-of-roundness and dents

14.4.2. Pipe handling shall be done as to avoid bevels and coating damages.

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14.5. Storage of coated pipes

14.5.1. Storage shall be done so as to avoid any kind of damage or wear that may endanger the performance of the coating.

14.5.2. Pipes having a diameter/thickness relation above 120, wooden crosspieces with rubber protection shall be installed at their ends to avoid out-of roundness.

15. FIELD JOINTS IDENTIFICATION

15.1. The identification on internal and external coated field joints shall be made on a position previously agreed upon between the purchaser and the coating applicator. The identification shall contain the following information:

- a) Logo or name of the applicator;
- b) Coating type;
- c) Coating application date;
- d) Traceability code.

Note: All original identifications made by the manufacturer of the internal coated pipe shall be kept or remade, in case of damage in the process course of the field joint coating.

16. APPENDIX – DIAGRAMS

INTERNAL COATING

DIAGRAM 1

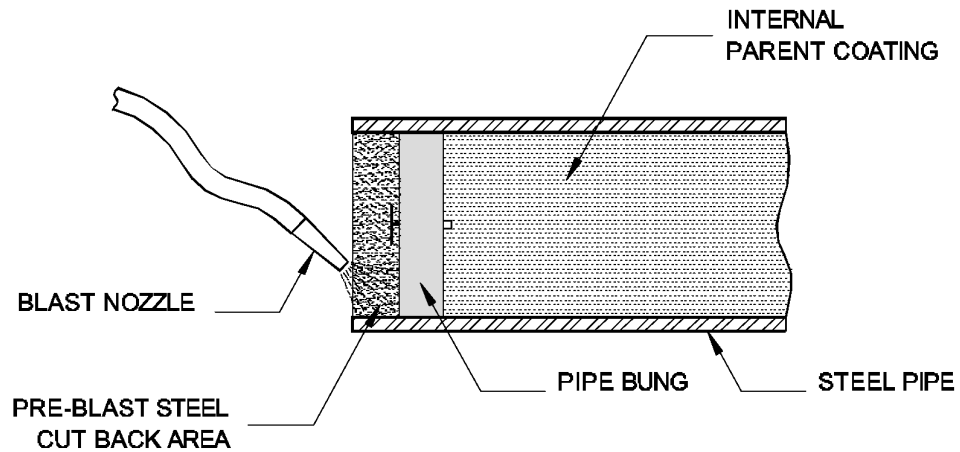
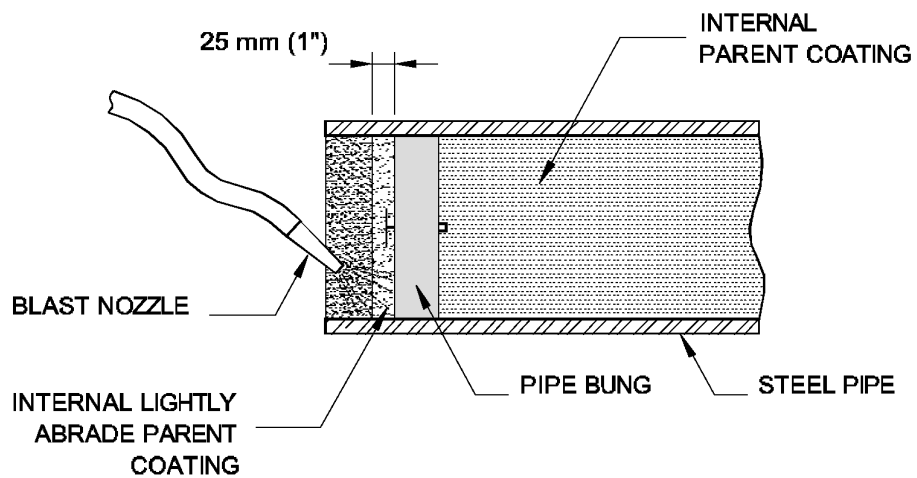


DIAGRAM 2



EXTERNAL COATING

DIAGRAM 3

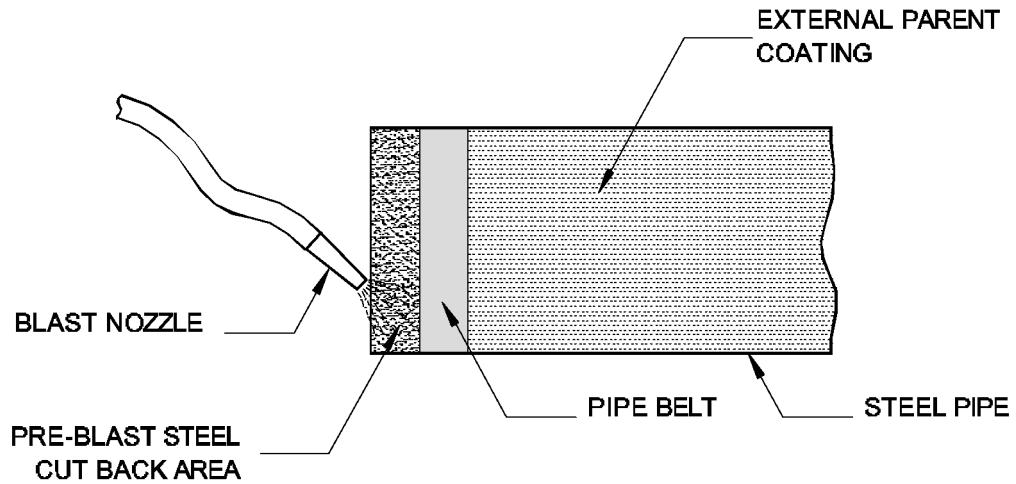


DIAGRAM 4

