



PTT Exploration and Production Public Company Limited

PTTEP Engineering General Specification
(Engineering and Development Group)

Standard

External Anticorrosion Coating for Pipelines

Document No: 10008-STD-6-COR-001-R01

October 2018

DOCUMENT REGISTER				
Document Title:		External Anticorrosion Coating for Pipelines		
Document Reference No:		10008-STD-6-COR-001-R01		
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Document Custodian Approvals Register <i>(To be signed on acceptance of Revision No.R00)</i>				
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Document Management Approvals Register <i>(To be signed before release of Revision No.R00)</i>				
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Revision History																						
Rev	Description of Revision	Date																				
Old	New Document Refer : PEGS-12059-COR-001	04-Oct-16																				
R00	Revision note : New document code and formatting <table><tr><th>Item No./Clause</th><th>Description of Change</th></tr><tr><td>All</td><td>Update document number and template align to PTTEP library standard</td></tr></table>	Item No./Clause	Description of Change	All	Update document number and template align to PTTEP library standard	8-Sep-17																
Item No./Clause	Description of Change																					
All	Update document number and template align to PTTEP library standard																					
R01	Revision note : New document code and formatting <table><tr><th>Item No./Clause</th><th>Description of Change</th></tr><tr><td>3.0</td><td>Special grade of FBE can be used up to 125°C.</td></tr><tr><td>7.3.3</td><td>Revised coat of powder epoxy of FBE to be in line with ISO 21809-1, ISO 21809-2.</td></tr><tr><td>7.4.1.2</td><td>Cut back angle to be 15 to 30° and added longer protection methods.</td></tr><tr><td>7.5.1.1</td><td>Thickness measurement to be used electromagnetic gauge and thickness of powder epoxy primer shall be between 200 and 400 microns to be in line with ISO 21809-1 and ISO 21809-2</td></tr><tr><td>8.0</td><td>Technical Requirements for Epoxy Primer for 3LPP and 3 LPE; Acceptable value of Glass transition temperature is 95°C to align with ISO 21809-1.</td></tr><tr><td>Table 12</td><td>Thermal aging and UV ageing standard to be in line with ISO 21809-1</td></tr><tr><td>PART II</td><td>Adhesives raw material products names are updated.</td></tr><tr><td>Table 17,18</td><td>Test method are updated to ISO-21809-2 and NFA49-711</td></tr><tr><td>Appendix 4</td><td>Revised Thermal ageing test for PP, PE and UV ageing test for PP, PE to be in line with ISO 21809-1.</td></tr></table>	Item No./Clause	Description of Change	3.0	Special grade of FBE can be used up to 125°C.	7.3.3	Revised coat of powder epoxy of FBE to be in line with ISO 21809-1, ISO 21809-2.	7.4.1.2	Cut back angle to be 15 to 30° and added longer protection methods.	7.5.1.1	Thickness measurement to be used electromagnetic gauge and thickness of powder epoxy primer shall be between 200 and 400 microns to be in line with ISO 21809-1 and ISO 21809-2	8.0	Technical Requirements for Epoxy Primer for 3LPP and 3 LPE; Acceptable value of Glass transition temperature is 95°C to align with ISO 21809-1.	Table 12	Thermal aging and UV ageing standard to be in line with ISO 21809-1	PART II	Adhesives raw material products names are updated.	Table 17,18	Test method are updated to ISO-21809-2 and NFA49-711	Appendix 4	Revised Thermal ageing test for PP, PE and UV ageing test for PP, PE to be in line with ISO 21809-1.	16-Oct-18
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1.0 INTRODUCTION

PEGS (PTTEP Engineering General Specification) is the PTT Exploration and Production PCL internal publishes standard. The objective of PEGS is to promote the best practices collecting from all PTTEP execution projects and to standardize those best practices to the future projects.

Every 5 years or upon request by the internal user, PEGS will be reviewed by related subject experts to reach decisions/agreements, then the document will be updated and publish to PTTEP intranet website. This is to ensure that all lesson learns from users can be applied to the future projects as the benefit to PTTEP.

2.0 PURPOSE

The purpose of the PTTEP Engineering General Specifications (PEGS) is to provide general technical guidance for the activities associated with engineering design, procurement, installation, and construction (EPIC) project process, to achieve fitness of purpose, technical integrity and optimum life cycle cost for constructing PTTEP facilities.

3.0 SCOPE

This specification covers the selection, application and inspection of anticorrosion coatings for the external protection of onshore and offshore oil, gas and water transporting lines.

The coating shall be plant applied and suitable from -20°C up to the maximum service temperature of the line. For the coating selection the following maximum temperature limits shall be considered:

1. Three-layer polypropylene coating (3LPP): 110°C. Special grade of FBE primer and PP can be used up to 125°C. For temperatures above 125°C, COMPANY approval shall be obtained.
2. Three-layer medium and high density polyethylene coating (3LPE): 80°C.
3. Fusion bonded epoxy coating (FBE): 80°C. For higher temperatures, high glass transition temperature epoxy powders are necessary.

Specific requirements and tests might be requested by COMPANY on a case by case basis for high temperatures. Qualification files specific to such product shall be submitted to COMPANY for formal approval based on the present specification. The actual pipeline maximum service temperature will be obtained from the project document. Data should be "Validated" by Asset.

The purpose of this specification is to define the following:

1. Applicator's obligations
2. Composition and characteristics of the following coatings:
 - 2.1. Epoxy primer, the adhesive and the polypropylene for 3LPP
 - 2.2. Epoxy primer, the adhesive and the polyethylene for 3LPE coating
 - 2.3. Epoxy for FBE coating
3. Application of the coating
4. Repair system
5. Characteristics of the finished coating
6. Prequalification and qualification testing
7. Inspection
8. Handling, transport and storage rules

Field joint coatings to be applied after girth welding of pipes are specified in COMPANY corrosion specification 10008-STD-6-COR-002.

Requirements from standards given in the reference listed in Section 6.2 shall be followed when they are not in conflict with those of the present document.

4.0 RESPONSIBLE ACTION PARTIES

N/A

5.0 DEFINITIONS

A number of different terms are commonly used to describe the work stages, processes, and approvals which take place during the early stages of a development. This can often be a source of confusion so the following section is intended to show the PTTEP preferred terminology as used in this document.

5.1 LANGUAGE

In this document, the words should and shall have the following meanings:

Shall	Indicates a course of action with a mandatory status. The term “shall” shall be used if a requirement is considered to be necessary to claim compliance with a PEGS document.
Should	Indicates a preferred course of action. Should is a non-mandatory word and is not forbidden, but use in the body of the text should be the exception. Where none mandatory terms are used, each paragraph within these clauses shall also have an associated commentary paragraph that provides the rationale for why the stated choices and modifications are appropriate and circumstance under which the stated choices and modifications might be different.

5.2 TERMINOLOGY

Terminology	Description
Applicator	The company in charge of the plant coating application and quality control which is eventually sub-contracted by the Contractor shall be referred to herein as the “Applicator”.
Approval	The authorization in writing given by the COMPANY to the Contractor to proceed the work without releasing in any way the Contractor from any of his obligations to conform with the technical specifications, requisitions, etc. The words “Approve”, “Approved” and “Approval” shall be construed accordingly
Company	PTT Exploration and Production Public Company Limited and affiliates.
Contract Documents	The material requisitions, material specifications, etc. issued by the COMPANY and attached to the Contract or the Purchase Order
Contractor	Per contract: Contractor – ‘The contractor who is a PARTY to this CONTRACT and where the context so requires including, SUBCONTRACTORS utilized by CONTRACTOR for the performance of the WORK’
Final coating	For the 3LPE and 3LPP coatings, the “final coating” means the final PE or PP layers respectively on top of the adhesive.
Inspector	The COMPANY’s or Contractor’s representative(s), (as applicable), or member(s) from an Inspection Agency duly appointed by the COMPANY or the Contractor (as applicable) to act as its representative(s) for the purpose of the contracts
Manufacturer	The company or its sub-contractors selected by the COMPANY or the Contractor or the Supplier (as applicable) as the Manufacturer of the said material.
Mill	The plants, mills, workshops, laboratories or other locations where the fabrication, inspection and testing of steel and pipes are to be performed complete or in part

Terminology	Description
PPS	Designates Project Particular Specification detailing the additional tests and requirements or the possible modifications to the present specification, based on the particular design conditions or the local legislation of the project.
Purchase Order	The order issued by Purchaser consisting Terms and Conditions and attachments thereto including but not limited to Data Sheets and Drawings, Specifications including referenced documentation therein, and all other documents and attachments
Purchaser	The COMPANY or the Contractor or the Supplier (as applicable) which have placed the Purchase Order to the Supplier/Vendor/Manufacturer.
Supplier/Vendor	The company designed on the Purchase Order form or Contract as being the selected supplier of the said materials.

5.3 COMMON ACRONYMS

Set out below in alphabetical order are common acronyms as found within this document:

3LPE	Three-layer polyethylene coating
3LPP	Three-layer polypropylene coating
DSC	Differential scanning calorimetry
DFT	Dry film thickness
DMTA	Dynamic mechanical thermal analysis
ESCR	Environmental stress-cracking resistance
FBE	Fusion bonded epoxy coating
GPS	Geometrical Product Specifications
MFR	Melt-mass flow rate
MFI	Melting Flow Index
MVR	Melt-volume flow rate of thermoplastics
PE	Polyethylene
PP	Polypropylene
PPT	Pre-Production Trial
PQT	Procedure for Qualification Trial
VST	Vicat softening temperature

6.0 REFERENCES

The reference documents listed below, including Industry Codes and Standards and COMPANY specifications, form an integral part of this Engineering General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published on the effective date of a contract.

The overall order of precedence of the applicable documents shall be:

1. Applicable Laws, Rules and Regulations of the country in which the system/equipment will be operated (if any);
2. Purchase Order/ Service Order/ Contract Documents (Only applicable for direct purchase by COMPANY);
3. Project Particular Specification (PPS), and relevant data sheet(s) if any;
4. COMPANY General Specification;
5. Codes and Standards in reference.

Any conflict between any of the Contract Documents, or between this specification and any other Contract Documents, shall be reported to COMPANY for decision. In such a case, and unless otherwise agreed or decided by COMPANY, it is understood that the more stringent requirement shall apply.

Exceptions to, or deviations from this specification are not permitted unless previously accepted in writing by COMPANY. For this purpose, requests for substitutions or changes of any kind shall be completed with all pertinent information required for COMPANY assessment. COMPANY's approval, nevertheless, will not, in any way, relieve the responsibility of the Contractor to meet the requirements of the industry Codes and Standards referred to and amended herein, in the event of conflict.

6.1 PTTEP INTERNAL REFERENCES

Internal documents applicable to this document are indicated in the table below.

Document Number	Document Title
10008-STD-6-COR-002	Field Joint Coating for Pipelines
10008-STD-6-GEN-005	Quality Requirements for Contractor/Vendor
10008-STD-6-INT-001	Inspection and Testing Requirements

6.2 INTERNATIONAL STANDARDS

International standards applicable to this document are indicated in the table below i.e. ISO, IEC or ITU.

Document Number	Document Title
ISO 1133	Plastics - Determination of the Melt-Mass Flow Rate (MFR) and Melt-Volume Flow Rate (MVR) of Thermoplastics
ISO 11357-1 & 3	Plastics - Differential Scanning Calorimetry (DSC) - Part 1 & 3
ISO 1183	Plastics - Methods for Determining the Density of Non-Cellular Plastics
ISO179-2	Plastics -- Determination of Charpy impact properties -- Part 2: Instrumented impact test
ISO 2808	Paints and Varnishes - Determination of Film Thickness
ISO 2811-1	Paints and Varnishes - Determination of Density - Part 1: Pycnometer Method
ISO 306	Plastics - Thermoplastic Materials - Determination of Vicat Softening Temperature
ISO 4287	Geometrical Product Specifications (GPS) - Surface Texture: Profile Method - Terms, Definitions and Surface Texture Parameters
ISO 4892-2	Plastics -- Methods of exposure to laboratory light sources -- Part 2: Xenon-arc lamps
ISO 527 – Part 1 & 2	Plastics - Determination of Tensile Properties
ISO 8130-6	Coating Powders - Part 6 - Determination of Gel Time of Thermosetting Coating Powders at a Given Temperature
ISO 8501-1	Preparation of Steel Substrates Before Application of Paints and Related Products. Visual Assessment of Surface Cleanliness. Part 1: Rust Grades and Preparation Grades of Uncoated Steel Substrates and of Steel Substrates After Overall Removal of Previous Coatings.

Document Number	Document Title
ISO 8502	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) Part 4: Surface Roughness Characteristics of Blast Cleaned Steel Substrates. Method for the Calibration of ISO Surface Profile Comparators and for the Determination of Surface Profile. Stylus Instrument Procedure. Part 6: Extraction of Soluble Contaminants for Analysis - the Bresle Method. Part 9: Field Method for Conductimetric Determination of Water-Soluble Salts.
ISO 868	Plastics and Ebonite - Determination of Indentation Hardness by Means of a Durometer (Shore Hardness)
ISO 21809-1	External coatings for buried or submerged pipelines used in pipeline transportation systems - Polyolefin coatings (3-layer PE and 3-layer PP)
ISO 8503-4	Method for the calibration of ISO surface profile comparators and for the determination of surface profile - Stylus instrument procedure

6.3 CODE AND OTHER STANDARDS

Codes, standards and regional legislation applicable to this document are indicated in the table below.

Document Number	Document Title
ASTM D 1693	Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D 4940	Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives
ASTM D 570	Standard Test Method for Water Absorption of Plastics
ISO-21809-1	Petroleum and natural gas industries – External Coating for buried or submerged pipelines used in pipeline transportation systems – Part 1: Polyolefin coatings (3 Layer PE and 3 Layer PP)
ISO 21809-2	Petroleum and natural gas industries – External Coating for buried or submerged pipelines used in pipeline transportation systems – Part 2: Fusion-bonded epoxy coatings
CAN/CSA Z245-20	External Fusion Bond Epoxy Coating for Steel Pipes
NACE SP 0274	High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation
NFA49-711	External Coating with Three Layers Polypropylene Coating

7.0 REQUIREMENTS FOR EXTERNAL ANTICORROSION COATING FOR PIPELINES

7.1 OBLIGATIONS OF APPLICATORS AND MANUFACTURERS

7.1.1 QUALIFICATION OF APPLICATOR'S PLANT

Independently from specific projects, COMPANY audits coating plants for qualification.

After attribution of the contract, an audit shall be carried out, if it has not already been done previously for another project, by COMPANY representative(s) for the qualification of the proposed application plant.

Audit shall be organized jointly by the Contractor and the Applicator and carried out as per COMPANY approved procedure.

7.1.2 SELECTION OF COATING PRODUCTS

COMPANY provides a list of acceptable products (Part II of Appendix 1 and Appendix 2).

Applicator shall consider them in their proposal. Whenever new raw materials are proposed (i.e. not listed in Appendix 1) a full application process shall be witnessed by COMPANY and coating properties measured at least two months before coating application. All data and measurements shall meet the requirements of this specification. If the proposed product fails, one of the approved products listed in Appendix 1 shall be used.

7.1.3 COMPANY REQUIREMENTS REGARDING COATING PRODUCTS

1. Applicator shall, in his tender, submit the data sheets of its selected products including the repair products for approval. Applicator shall obtain from the Manufacturers of the products test certificates, properties requirements and conformity certificates as detailed in the present document. A copy of these documents shall be submitted to COMPANY.
2. All proposed products shall meet COMPANY requirements.
3. Required characteristics shall be valued / tested according to the specified methods.
4. Once approved these products shall not be changed by the Applicator until end of coating application and final acceptance stage.

The Manufacturer shall deliver the products (especially epoxy powder) in waterproof plastic bags to prevent water contamination and absorption of humidity during storage and transportation.

Approval of the products by the COMPANY shall not, under any circumstances, be considered as a guarantee from the COMPANY with respect to coating materials and repair products but simply as an authorization for use.

7.1.4 QUALIFICATION OF THE PROPOSED COATING SYSTEM

A PQT, witnessed by COMPANY representative, shall be organized:

1. To qualify the selected products
2. To confirm Applicator capability to apply the coating with the required quality considering the special parameters of the current project (pipe diameter, pipe thickness, etc.)

To ensure that a suitable solution can be implemented in case test results fail to meet the requirements of this specification, PQT shall be organized at least two months before the coating application.

PQT shall consist of the following steps:

1. Raw materials
 - 1.1. Conformity certificates and tests results (see Section 7.2) shall be submitted to COMPANY for approval prior to the start of qualification process of the coating.
 - 1.2. Certificate of analysis (see Section 7.2) for each batch of product used for qualification process shall be submitted to COMPANY
 - 1.3. For PP and PE only: Tests results (from an independent laboratory with accreditation to ISO/IEC 17025) for thermal and UV ageing resistance as per Appendix 4 shall be submitted to COMPANY for approval. The tests results shall be from coated pipe samples. Tests results shall not be older than three years.
 - 1.4. For PE only: Tests results (from an independent laboratory) for ESCR resistance as per ASTM D1693, Condition B shall be submitted to COMPANY for approval. Test result shall not be older than three years.
 - 1.5. For FBE only, tests results (Appendix 3, Table 17) on laboratory coated sample plates.
2. Coating process: Witnessed by COMPANY representative and in accordance with Section 7.4. Coating process parameters shall be carefully recorded as they have to be strictly applied during the production process.
3. Coating properties: Witnessed by COMPANY representative and in accordance with Section 7.5

A summary of Qualification tests as well as acceptance criteria and frequency of the test are given in Appendix 1 through Appendix 3 for each coating. Contractor and Applicator shall submit a complete joint report of the PQT test results to the COMPANY for approval. Once approved, the coating system will be considered as qualified on the corresponding coating line. Any change in the constituents of the system or in the application of a qualified system shall lead to a new qualification process.

PQT is to be carried out for each project except when qualification test results for previous COMPANY project not older than three years, are available and:

1. Pipe diameters and thicknesses are the same as previous qualification and
2. Same coating products are used.

Production tests cannot replace the PQT.

Qualification test results are no longer valid if the owner of the plant is changed. If there is a change of ownership during the project phase, new PQT have to be implemented.

During the qualification tests, all requirements of section 7.6.1.1, 7.6.1.2 and related appendixes 1, 2 and 3 shall be met. The frequency of each test during PQT and startup of the pipe coating are given in Part IV of appendixes 1, 2 and Part III of appendix 3.

7.2 COATING SYSTEM AND CHARACTERISTICS OF RAW MATERIALS AND REPAIR PRODUCTS

7.2.1 CONTENT OF CONFORMITY CERTIFICATE

The conformity certificate is a document issued by the raw material Manufacturer (specific to each raw material). It is a list of physical or chemical characteristics controlled for every production batches. For each of these characteristics, a conformity range is reported by the Manufacturer. The conformity certificate shall also include the following information:

1. Name of Manufacturer
2. Name of product
3. Manufacturing plant
4. Date of issue
5. Production batch number
6. Name, function and signature of the person issuing the document

Conformity certificate shall be considered valid for one year, provided there is no change of any kind for the product for that period.

7.2.2 CONTENT OF CERTIFICATE OF ANALYSIS

The certificate of analysis is issued by raw material Manufacturer with every batch of product. It reports all characteristics controlled on the corresponding batch. The content of certificate of analysis shall be equivalent to the conformity certificate, except that measured values shall be reported instead of conformity range or Manufacturer specification.

7.2.3 MARKING AND IDENTIFICATION

Raw materials shall be clearly identified with the following markings (whatever the packaging of the product):

1. Name of Manufacturer
2. Production plant
3. Name of product
4. Batch number
5. Date of manufacture
6. Shelf-life (mainly for epoxy powder)

7.2.4 INSPECTION OF RAW MATERIALS

Raw material inspection shall be performed upon delivery of the coating materials and repair product by the Applicator's Quality Control Department in the presence of the Inspector. It shall include the following operations:

1. Inspection of packaging and marking to be sure that all required information is provided.
2. Inspection of storage facilities to be sure that they are in accordance with the Manufacturer's instructions.
3. Inspection of the raw materials deliveries for conformity with the requirements.
4. Verification of the various application parameters of all products to ensure that the procured products can be applied as required by the Applicator.

Non-conformity with any of the specified requirements shall cause the immediate rejection of the delivery. Inspector may take samples of the raw coating materials or repair product for testing in laboratories selected by COMPANY in order to check the quality of the products. These tests will be at COMPANY cost if their results are satisfactory but they will be back charged to the Contractor / Applicator if the coating material and/or repair product are not in accordance with this specification requirements. In order to cater to any dispute arising at a later stage, three of 50 gram-sample of each raw coating material shall be taken from each production batch. One shall be kept by the Applicator, one shall be transmitted to the COMPANY and one shall be kept as a check sample in the Applicator's laboratory for six months, away from humidity at a temperature below and close to 20°C.

7.2.5 NOTIFICATION PRIOR TO STARTING COATING WORK

Contractor shall notify the COMPANY, at least 10 working days before production dates of the coating process to allow for mobilization of the Inspector.

The Inspector shall have free access to the workshops, storage yards and laboratory of the Applicator who shall also provide him with all the facilities necessary for the proper execution of his work (i.e. office, telephone and fax, handling equipment, measuring instruments with calibration certificates, etc.).

Upon arrival at the coating plant, the Inspector shall receive from the main Contractor the documents supplied by the Manufacturer.

7.3 COATING SYSTEMS

7.3.1 THREE-LAYER POLYPROPYLENE COATING (3LPP)

3LPP shall consist of:

1. One layer of FBE primer,
2. One layer of adhesive coat,
3. Extruded polypropylene final coat

7.3.2 THREE-LAYER POLYETHYLENE COATING (3LPE)

3LPE shall consist of:

1. One layer of epoxy primer,
2. One layer of adhesive coat,
3. Extruded polyethylene final coat

7.3.3 FUSION BONDED EPOXY COATING (FBE)

The FBE external coating system shall consist of one coat of powder epoxy of 400 to 550 microns DFT. Coating shall be applied in one coat.

7.3.4 CHARACTERISTICS OF THE COATING AND REPAIR PRODUCTS

7.3.4.1 COATING PRODUCTS

The characteristics of all raw materials (type and nature), the technical requirements and the content of the conformity certificates are given in the Part I of Appendix 1, Appendix 2 and Appendix 3 for 3LPP, 3LPB and FBE coating respectively.

7.3.4.2 REPAIR PRODUCTS

The repair products shall be:

1. Suitable for the corrosion protection of the pipeline for the pipeline design conditions,
2. Compatible with the applied pipe coating

7.3.5 FINISHING COATING FOR CONCRETE WEIGHT COATING

Surface treatment to increase surface roughness of coating shall be either granule or powder application before cooling of the applied coating. This surface processing shall not affect the minimum thickness specified for the pipe coating.

7.4 APPLICATION OF THE COATING AND REPAIR PRODUCTS

7.4.1 GENERAL REQUIREMENTS

7.4.1.1 REQUIREMENTS ON COATING THICKNESS

Coating thickness is dependent on pipe laying method, service constraints and pipe weight. "Normal thickness" is used for buried conditions with low mechanical aggressiveness or on lines with additional anti-rock protection. "Reinforced thickness" is used for mechanically aggressive ground (rock or clay), for submerged pipelines, with or without concrete, and in depths not greater than 200-300 meters. In the depths beyond 300 meters, the value may be modified by a job specification or by long duration documented tests. Higher thickness may be acceptable as per particular specification. The minimum required thickness is given in Table 7 in Appendix 1 and Table 14 in Appendix 2 for PP and PE coatings respectively.

For longitudinal or spiral welded pipes, coating thickness shall be measured on the pipe body as well as on the weld. The minimum total thickness may be reduced by a maximum of 10 % of the minimum thickness on the seam weld for SAW pipes.

7.4.1.2 REQUIREMENTS ON CUT-BACKS

As a minimum, a 150 mm + 20/-0 mm cut-back shall be provided at each pipe end unless otherwise specified. In case concrete weight coating is applied on top of the final coating, the cut-back maybe longer in order to accommodate the rollers of the concrete coating machine. In any case, the cut-back length shall be determined by the pipe laying Contractor in relation with the coating Applicator(s) to take into account the coating yard requirements and the welding process heat input effect on the coating.

The coating shall be cut just after cooling and removed manually or mechanically with power brushes. The stripped steel ends shall be brushed clean. For the 3LPE and 3LPP coatings, the FBE primer shall be visible for a few millimeters at cut back to avoid any disbonding during storage.

The ends of the final coating shall be beveled in order to ensure a satisfactory bonding of field joint material on site. The bevel angle shall be approximately 15 to 30°.

The cut-backs shall be protected by peeling varnish in order to avoid rusting of the bare metal during storage/transportation. For longer term protection, two full wraps of End Seal Tape may be applied to cover all parts of the exposed steel, and at least 75 mm over the coating/ steel transition area.

7.4.2 SURFACE PREPARATION

Inspection shall be performed during surface preparation for checking of the following parameters:

1. Contamination by oil, grease and loose deposits
2. Climatic conditions (air and steel temperatures, dew point) and preheating pipe temperature prior to abrasive blasting
3. Degree of surface cleanliness after abrasive blasting
4. Dust level of the prepared surface
5. Roughness (Ry5) of the prepared surface
6. Characteristics and cleanliness of the abrasive

7.4.2.1 CONTAMINATION

Before abrasive blasting all pipes surfaces (100 %) shall be:

1. Inspected for oil, grease and loose deposit contaminations and cleaned to remove any visible trace of oil or grease using an appropriate non-oily and non-toxic product.
2. Washed with high pressure water or hot water to reduce the chloride contamination below 2 micrograms per square cm (ISO 8502-6 and ISO 8502-9). Only Bresle Method is acceptable to determine concentration of soluble salts on metal surfaces before coating application.

7.4.2.2 CLIMATIC CONDITIONS AND PREHEATING PIPE TEMPERATURE PRIOR TO ABRASIVE BLASTING

Air temperature, metal temperature and air dew point shall be measured every four hours. Depending on the dew point, pipe shall be preheated to be at least 10°C above the air dew point in order to reach at least 3°C above the dew point prior to the application of the first coating (generally pre-heating temperature is about 40°C to 70°C). The heating can be

provided during hot water washing (see above paragraph). Pre-heating temperature of the pipes shall be checked by IR camera on a continuous process.

7.4.2.3 CLEANLINESS OF THE ABRASIVE

At start of production, cleanliness and salt contamination of abrasives shall be checked as per ASTM D4940. Conductivity shall be lower than 1000 micro Siemens/cm with no oil visible after 30 minute.

7.4.2.4 SURFACE CLEANLINESS AFTER ABRASIVE BLASTING

The pipe surface shall be blast cleaned using automatic blasting machine(s). Surface cleanliness shall be Sa 3 as per ISO 8501-1. All pipe surfaces (100 % of the prepared surface of each pipe) shall be inspected.

7.4.2.5 DUST LEVEL OF GRIT BLASTED SURFACE

Immediately after abrasive blasting, all dust and traces of abrasives shall be removed from the pipe surface by brushing and vacuum cleaning. Then the dust level shall be measured according to ISO 8502-3. Maximum acceptable level shall be 2. Each of the first 10 pipes at the beginning of the production and then 4 pipes per shift shall be checked.

7.4.2.6 AVERAGE ROUGHNESS OF GRIT BLASTED SURFACE

The grit shall be selected so that the average roughness Ry5 (as per ISO 4287) obtained ranges from 60 to 100 microns. Surface profile roughness shall be measured with electronic apparatus in accordance with ISO 8503-4. The use of replica tape to assess the roughness is not allowed.

Each cleaned pipe shall be inspected for surface defects. Any defect shall be removed.

Each of the first 10 pipes at the beginning of the production and then 4 pipes per shift shall be checked for roughness.

7.4.2.7 PIPE TEMPERATURE PRIOR TO COATING APPLICATION

Cleaned pipes shall be coated before degradation of the prepared surface. They shall not be left in a moist and/or salt contaminated atmosphere. The metal temperature shall always be 3°C above the ambient dew point temperature. Any pipe which has not been coated before degradation of its surface preparation shall be completely re-blasted before coating. Pipe temperature shall be monitored with optical pyrometer (Infrared camera) and temperature recorder upstream of the powder spray cabinet control is continuously recorded over total pipe length. Temperature shall be in accordance with the powder Manufacturer requirements.

Notes:

1. No silica, grit is allowed.
2. No chemical treatment of the pipe surface (e.g. using chromates) is allowed to improve

adhesion. Required adhesion shall be obtained only by using suitable powder epoxy and surface preparation process.

7.5 APPLICATION OF THE COATING

The pipes shall be coated on a continuous coating line without any risk of deterioration to the pipe (external pipe wall, bevels, and coating) during the various heating, powder spraying, curing and quenching operations. The coating process parameters recorded during the PQT shall be strictly applied. The use of recycled FBE powder, adhesive powder, PE and PP is not permitted.

7.5.1 APPLICATION OF 3LPP AND 3LPE COATINGS

7.5.1.1 POWDER EPOXY PRIMER APPLICATION

The pipes shall be heated by induction. The temperature of the pipe and the intercoat time (time between primer and adhesive applications) shall be set in accordance with the gel time of the epoxy primer specified by the epoxy Manufacturer.

The powder epoxy primer shall be sprayed using electrostatic spray guns. The thickness of the coat shall be between 200 and 400 microns (as per ISO 2808, By Electromagnetic Gauge) except if Manufacturer requires thicker coating depending on the service conditions. The proposed value shall be documented by the Applicator.

The use of recycled FBE powder is not permitted for the FBE primer.

During application the following parameters shall be measured and recorded:

1. Epoxy layer thickness: one per shift.
2. Epoxy curing (see Appendix 4): one per shift. Delta Tg (in absolute value) shall be lower than 3°C.

7.5.1.2 ADHESIVE APPLICATION

The adhesive shall be applied in a time frame (after epoxy application) compatible with the gel time of the epoxy primer. Extrusion parameters shall be set following adhesive Manufacturer recommendations to meet the COMPANY requirements. The adhesive thickness shall be 200 microns as a minimum. Spray application of the adhesive is acceptable.

During application the following parameters shall be recorded:

1. Intercoat time shall be measured twice per shift and recorded.
2. Adhesive layer thickness shall be measured one per shift.

7.5.1.3 FINAL COATING APPLICATION

The top coat shall be applied by extrusion exclusively. At that stage, no addition of any kind to the pipe coating is allowed. No air entrapment, micro voids and/or micro bubbles are allowed within the layer thickness of the final coat. A cut through the thickness of the final coat shall be performed to visually inspect the homogeneity of the layer. Frequency of the test and acceptance criteria is specified in section 7.6.1.

The extrusion temperature, at the die, shall be in compliance with the coating Manufacturer's recommendations. The coating shall be smoothed by pressure rollers (for side extrusion).

The extrusion temperature shall be measured once per shift.

7.5.1.4 SURFACE PREPARATION FOR CONCRETE WEIGHT COATING (FRICTION COAT)

As specified in Section 7.3.5, if a concrete weight coating is required, the surface of the final coat shall be processed to improve the friction coefficient between the concrete and the pipe coating surface. Granules or powder of coating shall be sprayed on the hot extruded pipe coating surface (before quenching). The granules, not being totally melted, will provide a rough surface. Requirement for such a friction coat shall be specified in the project specification. Applicator shall select the application procedure that approved by COMPANY.

7.5.1.5 COOLING

When wrapping of the final coat (and also friction coat if relevant) is completed, the pipe shall be sprayed with water in order obtain a pipe temperature of 60°C maximum to ensure safe handling by personnel and no marking on the pipe during handling.

7.5.1.6 APPLICATION OF REPAIR PRODUCTS

All defects detected by holiday detection (see Section 7.6.1.1.2) and damaged coating areas less than 50 cm² resulting from destructive testing or mechanical accidents shall be repaired at the Applicator's expense as follows:

1. If any individual damaged area is greater than 50 cm², the pipe will be completely recoated.
2. Maximum of three repairs per pipe joint is allowed, but total repaired areas shall not exceed 150 cm².
3. Damaged areas due to testing, peel test and adhesion test, shall be repaired at Applicator's expenses. However, the limitation of 50 cm² or maximum 150 cm² damaged areas for maximum of three repairs per pipe joint from item 1 and 2 above shall be exclusive from test areas.

The following procedures should be applied for the repairs:

1. Repair methods and its qualification tests shall be submitted by the Contractor to the COMPANY for approval before production begins. Test requirements and criteria shall follow part IV of appendix 1 and 2 including adhesion test, impact test, hardness

test and cathodic disbonding test as a minimum.

2. Any part of the coating which is not bonded satisfactorily in the faulty area shall be removed. If the bare metal is exposed, it shall be carefully cleaned by brushing. The edges of the coating shall be beveled. The area shall be made free of dust and degreased with appropriate products.
3. Repaired area shall be 100 % checked with a holiday detector set to 10 kV per mm of coating thickness.

7.5.2 APPLICATION OF FUSION BONDED EPOXY (FBE) COATING

7.5.2.1 APPLICATION OF FBE

Application and curing temperature of the external pipe surface shall be as selected by the Applicator within the Manufacturer recommendation range and shall not exceed 275°C.

Recycled powder of FBE is permitted only when collected and processed through a closed system, which controls the ratio of recycled to virgin powder. Sieving equipment of 350 microns or finer and a magnetic particle separator shall be used. The ratio of recycled powder to virgin powder shall not exceed 20 %.

The applied coating thickness shall be a minimum thickness of 400 to 550 microns for non-concrete coated pipelines. If concrete coating is to apply, thicker FBE shall be used with COMPANY's approval and qualification.

The pipe shall cool in a manner as to avoid damage to the newly applied coating. After completing cure in accordance with the powder Manufacturer recommendations, the pipe may be quenched with running water or forced air cooling to facilitate coating handling, inspection and repair. The time to quench shall be monitored to ensure compliance with the Manufacturer recommendation's minimum curing requirements. For safety reasons, temperature after cooling shall not exceed 60°C.

7.5.2.2 APPLICATION OF REPAIR PRODUCTS

a) Repair product qualification

Repair products shall be submitted to COMPANY for approval prior to use. Technical Data Sheet, Safety Data Sheet, Certificate of analysis, Certificate of conformity of each product shall be provided.

As a minimum, tests mentioned in Appendix 3 Table 18 shall be performed on representative sample plates of the repair process either in the coating plant and/or in the field (both processes shall be tested if considered not equivalent). It shall incorporate at least one interface with the parent coating to assess compatibility.

b) Repair procedure

It shall be proposed jointly by the Applicator and Manufacturer and submitted to COMPANY for approval. Preferred choice is two-part liquid epoxy material.

7.6 CHARACTERISTICS OF APPLIED COATING

Applied coating shall be inspected, tested and its characteristics shall be measured to ensure that the final coating quality is as per COMPANY requirements. Required inspection and testing are summarized below and COMPANY requirement is mentioned for each type of inspection and/or testing.

Coating inspection shall be carried out by the Applicator's Quality Control Department in the presence of the Inspector from the beginning of the work and throughout production. The Inspector may take samples of coated pipe(s) for testing in laboratories selected by the COMPANY in order to check the quality of the coating.

7.6.1 INSPECTION OF COATED PIPES

7.6.1.1 GENERAL CHARACTERISTICS OF THE APPLIED COATINGS (VALID FOR 3LPP, 3LPE AND FBE)

Inspection shall be performed after coating application on each dry coated pipe cooled down to ambient temperature. Destructive tests are performed either on pipe extremities or on pipe samples.

7.6.1.1.1 VISUAL ASPECT, HOMOGENEOUS COLOR

After application of each coat, the coating shall be of a uniform color and aspect, and free of any surface defect detrimental to its quality. It shall not show any crack, blister, lamination, wrinkle or disbonding, pin holes and irregularities.

7.6.1.1.2 ELECTRICAL POROSITY

Maximum temperature for pipe inspection is set at 60°C.

Adjustable DC holiday detector with voltage indicator shall be used. The voltage to be applied is 10 kV/mm of coating thickness with a maximum voltage of 25 KV on 3LPP, 3LPE coatings. For FBE, the test voltage shall be set to 5 kV/mm. The annular electrode shall cover 100 % of pipe surface circumference and it shall be operated over the dry surface of coating. Control shall be conducted during the automatic process in accordance with NACE RP 0274. Contact of the electrode has to be ensured with the coating and pipe. The travel speed shall be below or equal to 0.2 to 0.3 meter per second.

The finished coating shall be free of porosity. All pipes shall be 100% inspected for holiday detection. The holiday detector shall be calibrated once per shift.

7.6.1.1.3 PRESENCE OF VOIDS AND MICRO-BUBBLES

Within the thickness of the layer, there shall be no micro-voids and/or micro-bubbles. The inspection is visual. One test shall be carried out every 30 pipes on a coated pipe sample. If the test does not satisfy the requirements, 2 other tests shall be made on pipes coated since the last check, and none of them shall be failed.

7.6.1.1.4 CUT BACK LENGTH

The cut back length shall be measured with a ruler or a specific gauge on each pipe and at each pipe extremity.

7.6.1.1.5 RESIDUAL MAGNETIC INTENSITY

The residual magnetic intensity shall be below 2.5 milliTesla (or 25 gauss), measured on the cutbacks at each coated line pipe end. 100% of coated pipes shall be tested.

7.6.1.2 SPECIFIC CHARACTERISTICS OF COATINGS

Specific characteristics of the 3LPP, 3LPE and FBE coatings are given in Part II through Part IV of Appendix 1, Appendix 2 and Appendix 3, respectively.

7.6.2 ACCEPTANCE CERTIFICATES

The Contractor and the Applicator shall sign jointly with the Inspector for the coated pipes acceptance certificate including the results of all tests and inspections as set forth in this specification. The acceptance certificate of coated pipes shall certify that all tests and inspections have been performed by the Applicator under the responsibility of the Contractor for all COMPANY ordered pipes and have been witnessed by the Inspector. One copy of the acceptance certificates shall be transmitted to COMPANY and one copy to the Inspector.

7.6.3 REPORTING

The coating Applicator shall deliver, at the end of the coating application, a report containing all the coating material certificates, inspection results including pipe reference number, the list of all rejected coated pipes reference numbers, the reason for rejection and what corrective action, if any, has been taken to fix the problem.

7.7 HANDLING, TRANSPORT AND STORAGE RULES

The Applicator shall be responsible for any damage occurring to the pipes from unloading at reception of the pipes to the loading of the coated pipes for shipment. The Applicator shall consequently inspect the bare pipes upon delivery to check that they have not suffered previous damage, take all necessary precautionary measures to prevent any deterioration of the pipe coating and the pipe bevels during handling, transfer to storage yard, storage, and loading of pipes for shipment.

Existing pipe joint marking shall be preserved or reinstated.

All repairs and inspection shall be at the Applicator's expense.

If coated pipes are to be stored for more than 6 months, they shall be protected against ultraviolet rays.

If the bare pipes have been delivered to the Applicator with end caps, these end caps (or new ones) should be fitted again on the pipe ends after coating if required in the Contract.

Temporary protection with varnish shall be applied on the cut-backs except if otherwise stated.

8.0 APPENDICES

Appendix 1. 3LPP COATING

PART I: CHARACTERISTICS OF THE RAW MATERIALS

Epoxy Primer

It shall be 100 % solid powder form. It shall meet the technical requirements specified in Table 1 below. The content of the conformity certificate shall be as mentioned in Table 2 below.

Adhesive

The COMPANY requirements are given in Table 3 below. The content of the conformity certificate shall be as mentioned in Table 4.

Polypropylene

Blends of different PP type or grade shall not be allowed. Additives (TiO₂, anti-oxidants, etc) shall be incorporated by means of a master-batch. PP raw material Manufacturer shall be the only one authorized to perform this step. No addition of any kind shall be allowed at the coating plant during extrusion.

Technical requirements are specified in Table 5 below. The content of the conformity certificate shall be as mentioned in Table 6 below.

Table 1 - Technical Requirements for Epoxy Primer for 3LPP

Characteristics	Methods	Units	Acceptable values
Moisture content	20 g Temperature: 105°C Time: 30	%	0.5 Maximum
Glass transition temperature	Differential Scanning Calorimeter (DSC)	°C	At least 5°C above maximum pipeline service temperature with a minimum of 95°C
Bend test	CAN/CSA Z245-20, Clause 12.11. 2.5° at minimum temperature		No holiday
Water absorption test	ASTM D 570 (on a free film of 500 ± 50µm thickness)	% wt	Less than 15% after 28 days exposure at 80°C

Table 2 - Content of the Conformity Certificate for FBE Primer for 3LPP

Characteristics	Methods	Units	Conformity range
Gel time	ISO 8130-6	Seconds	Manufacturer specification
Density	ISO 2811-1	g/ml	Manufacturer specification
Glass transition Temperature - First heating - Second heating		°C °C	Manufacturer specification and as per Table 1
Enthalpy		J/g	Manufacturer specification
IR Spectra			Manufacturer specification
Particle size analysis	Manufacturer		Manufacturer specification
Moisture content	Manufacturer		Manufacturer specification and as per table 1

Table 3 - Technical Requirements for Adhesive for 3LPP

Characteristics	Standards	Units	Acceptable values
Elongation at break	ISO 527-1 and -2	%	> 400
VICAT Softening point (9.8 N)	ISO 306	°C	> 120
Melting point	ISO 11357-1 and -3	°C	> 140

In addition:

1. A full DSC spectra shall be provided once for each adhesive, from -40°C up to 200°C, heating rate 20°C/min, cooling rate 10°C/min (first and second heating)
2. DMTA spectra shall be provided once at a frequency of one Hertz from - 40°C up to 160°C.

Table 4 - Content of the Conformity Certificate for 3LPP Adhesive

Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16 kg; 230°C)	ISO 1133	g/10min	Manufacturer specification
Density	ISO 1183		Manufacturer specification
Reactive site content	Manufacturer		Manufacturer specification
In addition, for powder adhesive: Particle size analysis	Manufacturer		Manufacturer specification

Table 5 - Technical Requirements for PP

Characteristics	Standards	Units	Acceptable values
VICAT Softening point (9.8 N)	ISO 306	°C	>140
Melting point	ISO 11357-1 and -3	°C	> 160
Elongation at break at 23°C	ISO 527	%	> 400
Thermal ageing*	ISO 21809-1**		≤ 0.35
UV ageing*	ISO 21809-1**		≤ 0.35
Charpy notched test at -20°C	ISO 179-2	KJ/ m ²	> 4

Notes:

* Certificate from independent laboratory shall not exceed three years from issue date.

** In accordance to ISO 21809-1 with the acceptance criteria of change in MFR maximum 35%.

Table 6 - Content of the Conformity Certificate for PP

Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16 kg; 230°C)	ISO 1133	g/10 min	Manufacturer specification
Additives content	Manufacturer		Manufacturer specification

PART II: TYPICAL RAW MATERIALS PRODUCTS

Typical raw materials to be considered for qualification:

Epoxy primers

1. Eurokote 71441 BS Coating
2. Eurokote 714 31PP ES Coating
3. Scotchkote 226N 3M, 626-130, 626-140, 6233P
4. Basepox 50-7 179 BASF Coatings

Adhesives

1. Orevac PP-C Arkema
2. Hifax EP2015/60 Bianco Basell
3. BBI27E Borealis

Polypropylene

1. Moplen Coat EP/60 Bianco Basell
2. BB 108 E-1199 Borealis

This list is for information only. This shall not be considered as an exemption of qualification process. Other products can be proposed.

PART III: SPECIFIC CHARACTERISTICS OF THE APPLIED 3LPP COATING

Thickness of the Applied Coating

The coating thickness shall be measured using a coating thickness gauge that has been calibrated at least once every working shift (to a maximum of 12 hours) against a thickness standard that is within 10 % of the nominal coating thickness specified.

The minimum thickness on the pipes shall be as mentioned in Table 7 below.

Table 7 - Minimum Thickness for the Applied Coating

Pipe weight,W (kg/m)	Minimum thickness (mm)	
	Normal	Reinforced
W<15	1.3	2.1
15<W<50	1.5	2.4
50<W<130	1.8	2.8
130<W<300	2.2	3.2
300 <W	2.5	3.8

The thickness on each pipe shall be measured at least at :-

1. Both ends, about 10 to 20 cm from the cut backs at four quadrants.
2. About the middle of the pipe at four quadrants

Each value shall be an average value of three readings within a square of approximately 10 cm x 10 cm. If any of the values are less than minimum required thickness, the coating thickness of the affected pipe shall be measured along the pipe length at intervals not exceeding 1 meter. None of the individual values shall be less than the minimum required thickness. Failing to meet these requirements, pipes shall be stripped and re-coated.

Impact Resistance

Test shall be performed according to ISO 21809-1.

Impact resistance at 23°C +/- 2°C shall be equal or higher than 10 Joules/mm. Actual thickness shall be measured to evaluate the impact energy. The coating shall be examined with a holiday detector, over the points of impact, at a voltage of 10 kV per mm of coating thickness (maximum 25 kV). Pipe shall be repaired after impact tests. Impact tests on pipe extremities before cut back preparation are acceptable. Each reading shall consist of 5 impacts minimum.

The frequency of the test is one per shift.

Shore D Hardness

Test shall be performed at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and according to ISO 868. Average measured hardness shall be equal to or higher than 60.

Frequency of the test is one per shift.

Resistance to Peeling

Test shall be performed in accordance with ISO 21809-1.

1. At $23 \pm 2^{\circ}\text{C}$, the peeling strength shall be equal to or higher than 1000 N/ 50 mm
2. At $110 \pm 2^{\circ}\text{C}$, the peeling strength shall be equal to or higher than 200 N/ 50 mm

If the maximum operating temperature is higher than 110 deg C, testing at maximum operating temperature is acceptable with the same acceptance criteria. In addition to ISO 21809-1 requirements, at least one peeling test shall be carried out in a circumferential direction at both 23°C and 110°C (or maximum operating temperature if it is lower or higher than 110°C) on each pipe subject to testing. The acceptance criteria are the same as for the tests in the direction of pipe axis.

Frequency is as follow:

1. Two pipes at the start-up of each shift then one test every 60 pipes on the cut back.
2. If one test does not satisfy the requirements, tests shall be performed on 10 pipes coated since the last check, and none of them shall be failed.

Elongation at Break

Test shall be performed in accordance with ISO 527-1 and -2.

At $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for PP top coat, elongation shall be higher than 400 %.

Frequency is two pipes at the start-up of the pipe coating and then one test every 60 pipes.

Indentation Test

The test shall be performed in accordance with ISO 21809-1.

Penetration shall be less than:

1. 0.10 mm at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (duration: 2 hours)
2. 0.40 mm at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (duration: 4 hours)

Frequency is one sample per shift, but 3 tests minimum on the same sample. If one fails, 5 new samples shall be tested, none of them shall fail.

Flexibility Test

Test shall be performed in accordance with ISO 21809-1.

Test temperature is ambient temperature. No holiday shall be detected.

The frequency is one test every 60 pipes.

Cathodic Disbonding

Test shall be performed in accordance with ISO 21809-1. Equipment shall be as per ISO 21809-1 Appendix H. The pH of the water shall be monitored during the test and it shall remain between pH 6 and pH 8. If not, it shall be adjusted by adding diluted NaOH or HCl depending on the pH of the solution.

After:

1. 28 days* at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$, the increase of the radius shall be less than 5 mm
2. 48 hours at $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$ the increase of the radius shall be less than 3 mm
3. 28 days at maximum operating temperature*, the increase of the radius shall be less than 15 mm

* During production, only 48-hour tests shall be carried out. Tests at 28 days (both at 23°C and at maximum operating temperature) are mandatory during qualification process described in Section 7.1.4. Test results shall be known before start of production.

During the evaluation of the coating disbonding, coating around the hole shall be removed until sound coating is reached.

The frequency is one test every 2 shifts at $65 \pm 2^{\circ}\text{C}$ during 48 hours.

Adhesion along the Seam Weld for the Longitudinally Welded Pipes.

Coating shall be cut at least two locations on the seam weld along at least 15 cm (or the cut back length) to check the adhesion of the coating to the pipe. The inspection is visual. The acceptance criteria are the absence of void between coating and pipe.

Frequency is as follows:

1. Two pipes at the start-up of each shift then one test every 60 pipes on the cut back.
2. If one test does not satisfy the requirements, tests shall be performed on 5 pipes coated since the last check, and none of them shall be failed.

PART IV: QUALIFICATION AND PRODUCTION START UP TEST REQUIREMENTS

For qualification and production test, at least 5 pipes shall be used.

Test/Checks	PQT	PPT	Fabrication
1) Pre-heating	5 pipes minimum	5 pipes minimum	IR camera monitoring -All
2) Surface preparation			
Abrasive Cleanliness	At start	At start	At start
Degree of surface cleanliness	5 pipes minimum	5 pipes minimum	All
Salt contamination	5 pipes minimum	5 pipes minimum	Once per shift (at start)
Dust level	5 pipes minimum	5 pipes minimum	4 per shift
Roughness	5 pipes minimum	5 pipes minimum	Every 10 pipes, both ends
Steel temperature	1 pipe	1 pipe	4 per shift
Pipe travel speed (Record during PQT, During production, within 5% of recorded PQT value)	Once	Once	Twice per shift
3) Coating application			
Pipe temperature after induction heating	5 pipes minimum	5 pipes minimum	All
Intercoat time	5 pipes minimum	5 pipes minimum	Twice per shift
Extrusion temperature	5 pipes minimum	5 pipes minimum	Once per shift
Cooling	5 pipes minimum	5 pipes minimum	All
4) Raw materials			
Conformity certificate test results • Epoxy primer • Adhesive Polypropylene	Each raw material	Each raw material	N/A
UV and thermal resistance	For PP coating only (Not older than 3 years)	N/A	N/A
Certificate of analysis	Every batch	Every batch	Every batch
5) Coating			

Test/Checks	PQT	PPT	Fabrication
FBE thickness	2 pipes	2 pipes	One at start of each shift
Epoxy curing	1 pipe	1 pipe	One at start of each shift
Adhesive thickness	2 pipes	2 pipes	One at start of each shift
Final coating thickness	5 pipes minimum	5 pipes minimum	Every 5 pipes
Visual inspection	5 pipes minimum	5 pipes minimum	All
Holiday detection	5 pipes minimum	5 pipes minimum	All
Cut backs	5 pipes minimum at both ends	5 pipes minimum at both ends	All at both ends
Impact resistance	2 pipes /at two locations each	2 pipes /at two locations each	One at start of each shift
Shore D hardness	2 pipes / at three locations each	2 pipes /at three locations each	One at start of each shift
Peeling force	2 pipes (both ends and middle) at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 2 pipes (both ends and middle) at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (or at max. operating temperature, whichever is higher)*	2 pipes (both ends and middle) at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 2 pipes (both ends and middle) at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (or at max. operating temperature, whichever is higher)*	Both ends at start of shift and Both ends at start of shift
Indentation	2 pipes at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 2 pipes at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (or at max. operating temperature, whichever is higher)**	2 pipes at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 2 pipes at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (or at max. operating temperature, whichever is higher)**	Once per shift
Flexibility	1 pipe	N/A	N/A
Cathodic disbonding	1 pipe at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 28 days 1 pipe at $110^{\circ}\text{C} \pm 2^{\circ}\text{C}$ or at maximum Operating temperature, whichever is higher, and 28 days 1 pipe at $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 48 hours***	N/ A N/ A 2 pipes at $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and 48 hours***	N/A N/A Once every two shift

Test/Checks	PQT	PPT	Fabrication
Residual magnetic intensity	5 pipes minimum at both ends	5 pipes minimum at both ends	All at both ends

* On each pipe, test shall be performed at three locations in pipe axis direction and one test shall be carried out in circumferential directions. Acceptance criteria remain the same in both directions.

** One sample is taken from each pipe but three tests shall be carried out on each sample.

*** Three samples shall be tested per pipe.

Appendix 2. 3LPE COATING

PART I: CHARACTERISTICS OF THE RAW MATERIALS

Epoxy Primer

It shall be 100 % solid powder form. The use of liquid epoxy is not allowed. It shall meet the technical requirements specified in Table 8 below. The content of the conformity certificate shall be as mentioned in Table 9 below.

Adhesive

The adhesive shall be based on linear-type PE (i.e. low pressure manufacturing process) with grafted reactive sites. Both extruded and powdered adhesive applications are allowed. The COMPANY requirements for the 3LPE adhesive shall be as mentioned in Table 10 below. The content of the conformity certificate is given in Table 11.

Polyethylene

PE shall be based on a butane, hexane or octane comonomer type PE. Blends of different PE type or grade shall not be allowed. Additives (Carbon black, antioxidants, etc) shall be incorporated by means of a master batch. PE raw material Manufacturer shall be the only one authorized to perform this step. No additive of any kind shall be allowed at the coating plant during extrusion.

Technical requirements are specified in Table 12 below. The content of the conformity certificate shall be as mentioned in Table 13 below.

Table 8 - Technical Requirements for Epoxy Primer for 3LPE

Characteristics	Methods	Units	Acceptable values
Moisture content	20 g Temperature: 105°C Time: 30 mm	%	0.5 (Maximum)
Glass transition temperature	Differential Scanning Calorimeter (DSC)	°C	At least 5°C above maximum pipeline design temperature with a minimum of 95°C
Bend test	CAN/CSA Z245-20, Clause 12.11. 2.5° at minimum temperature		No holiday
Water absorption test	ASTM D 570 (on a free film of 500 ± 50µm thickness)	%wt	Less than 15% after 28 days exposure at 80°C

Table 9 - Content of the Conformity Certificate for FBE Primer for 3LPE

Characteristics	Methods	Units	Conformity range
Gel time	ISO 8130-6	Seconds	Manufacturer specification
Density	ISO 2811-1	g/ml	Manufacturer specification
Glass transition temperature • First heating • Second heating		°C °C	Manufacturer specification and as per Table 8
Enthalpy		J/g	Manufacturer specification
IR Spectra			Manufacturer specification
Particle size analysis	Manufacturer		Manufacturer specification
Moisture content	Manufacturer		Manufacturer specification and as per table 8

Table 10 - Technical Requirements for Adhesive for 3LPE

Characteristics	Standards	Units	Acceptable values
Elongation at break	ISO 527-1 and -2	%	> 500
VICAT Softening point (9.8 N)	ISO 306	°C	> 90
Melting point	ISO 11357-1 and -3	°C	> 120

In addition:

1. A full DSC spectra shall be provided once for each adhesive, from – 40°C up to 200°C, heating rate 20°C/min, cooling rate 10°C/min (first and second heating)
2. DMTA spectra shall be provided once at a frequency of one Hertz from – 40°C up to 140°C.

Table 11 - Content of the Conformity Certificate for 3LPE Adhesive

Characteristics	Methods	Units	Conformity Range
Melt Flow Index (2.16kg; 190°C)	ISO 1133	g/10min	Manufacturer specification
Density	ISO 1183		Manufacturer specification
Reactive site content	Manufacturer		Manufacturer specification
In addition, for powder adhesive: Particle size analysis	Manufacturer		Manufacturer specification

Table 12 - Technical Requirements for PE

Characteristics	Standards	Units	Acceptable Values
VICAT Softening point (9.8 N)	ISO 306	°C	>110
Density with carbon black	ISO 1183		> 0.940
Carbon black content	ISO 6964	%	>2
Carbon black particle size		nm	<25 or (type P)
Melting point	ISO 11357-1 and -3	°C	> 120
Thermal ageing*	ISO 21809-1**		≤ 0.35
UV ageing*	ISO 21809-1**		≤ 0.35
Stress Cracking resistance	ASTM D 1693, Cond B (10 % Igepal)	F20	> 1000 hrs.

Note: *Certificate from independent laboratory shall not exceed three years from issue date.

** In accordance to ISO 21809-1 with the acceptance criteria of change in MFR maximum 35%.

Table 13 - Content of the Conformity Certificate for PE

Characteristics	Methods	Units	Conformity range
Melt Flow Index (2.16kg; 190°C)	ISO 1133	g/10min	Manufacturer specification
Density	ISO 1183		Manufacturer specification and as per Table 12
Carbon black content	ISO 6964		Manufacturer specification and as per Table 12

PART II: TYPICAL RAW MATERIALS PRODUCTS

Typical raw materials to be considered for qualification:

Epoxy primers

1. Eurokote 71441 BS Coating
2. Scotchlcote 226N 3M
3. Basepox 50-7 179 BASF Coatings

Adhesives

1. Orevac 18350 Arkema
2. ME 0420, ME 0433 Borealis
3. Fusabond EM 158 D Dupont

Polyethylene

1. Lacqtene 2006PBK35 Total Petrochemicals
2. HE 3450 Borealis
3. Lupolen 3652D-SW00413 Basell

This list is for information only. This shall not be considered as an exemption of qualification process. Other products can be proposed.

PART III: SPECIFIC CHARACTERISTICS OF THE APPLIED 3LPE COATING

Thickness of the Applied Coating

The coating thickness shall be measured using a coating thickness gauge that has been calibrated at least once every working shift (to a maximum of 12 hours) against a thickness standard that is within 10 % of the nominal coating thickness specified.

The minimum thickness on the pipes shall be as mentioned in Table 14 below.

Table 14 - Minimum Thickness for the Applied Coating

Pipe weight, W (kg/m)	Minimum thickness (mm)	
	Normal	Reinforced
W<15	1.3	2.3
15<W<50	1.5	2.7
50<W<130	1.8	3.1
130<W<300	2.2	3.5
300 < W	2.5	4.2

The thickness shall be measured on each pipe at least at

1. Both ends about 10 to 20 cm from the cut backs at four quadrants.
2. About the middle of the pipe at four quadrants

Each value shall be an average value of three readings within a square of approximately 10cm x 10cm. If any of the values are less than minimum required thickness, the coating thickness of the affected pipe shall be measured along the pipe length at intervals not exceeding 1 meter. None of the individual values shall be less than minimum required thickness. Failing to meet the requirements, pipes shall be stripped and re coated.

Impact Resistance

Test shall be performed according to ISO 21809-1.

Impact resistance at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ shall be equal or higher than 7 Joules/mm. Actual thickness shall be measured to evaluate the impact energy. The coating shall be examined with a holiday detector, over the points of impact, at a voltage of 10 kV per mm of coating thickness (maximum 25 kV). Pipe shall be repaired for impact after tests. Impact tests on pipe extremities before cut back preparation are acceptable. Each reading shall consist of 5 impacts minimum.

The frequency of the test is one per shift.

Shore D hardness

Test shall be performed at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and in accordance with ISO 868.

Average measured hardness shall be equal or higher than Shore D 50.

Frequency of the test is one per shift.

Resistance to Peeling

Test shall be performed in accordance with ISO 21809-1.

1. At $23 \pm 2^{\circ}\text{C}$, the peeling strength shall be equal or higher than 1000 N/ 50 mm
2. At $80 \pm 2^{\circ}\text{C}$, the peeling strength shall be equal or higher than 200 N/ 50 mm

In addition to ISO 21809-1 requirements, at least one peeling test shall be carried out in circumferential direction at both 23°C and 80°C on each pipe subject to testing. The acceptance criteria are the same as for the tests in the direction of pipe axis.

Frequency is as follows:

1. Two pipes at the start of each shift then one test every 60 pipes at cut back areas.
2. If one test does not satisfy the requirements, tests shall be performed on 10 pipes coated since the last check, and none of them shall be failed.

Elongation at break

Test shall be performed in accordance with ISO 527-1 and -2.

At $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for PE top coat shall be higher than 500 %.

Frequency is two pipes at the startup of the pipe coating and then one test every 60 pipes.

Indentation test

The test shall be performed in accordance with ISO 21809-1.

Penetration shall be less than:

1. 0.20 mm at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (duration: 2 hours)
2. 0.50 mm at $80^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (duration: 4 hours)

Frequency is one sample per shift, but 3 tests minimum on each sample. If one fails, 5 new samples shall be tested, none of them shall fail.

Flexibility test

Test shall be performed in accordance with ISO 21809-1. Test temperature is ambient temperature. No holiday shall be detected after the test. The frequency is one test every 60 pipes.

Cathodic disbonding

Test shall be performed in accordance with ISO 21809-1 or NFA49-711. Equipment shall be as per ISO 21809-1 Appendix H. The pH of the water shall be monitored during the test and it shall remain between pH 6 and pH 8. If not, it shall be adjusted by adding diluted NaOH or HCl depending on the pH of the solution.

After:

1. 28 days* at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$, the increase of the radius shall be less than 5 mm
2. 48 hr at $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$, the increase of the radius shall be less than 3 mm
3. 28 days at $80^{\circ}\text{C} \pm 2^{\circ}\text{C}$, the increase of the radius shall be less than 15 mm

* During production, only 48-hour tests shall be carried out. Tests at 28 days (at 23°C and 80°C) are mandatory during qualification process. Test results shall be known before start of production.

During the evaluation of the coating disbonding, coating around the hole shall be removed until sound coating is reached. The frequency is one test every 2 shifts at $65 \pm 2^{\circ}\text{C}$ during 48 hours.

Adhesion along the seam weld for the longitudinally welded pipes

Coating shall be cut at least two locations on the seam weld along at least 15 cm (or the cut back length) to check the adhesion of the coating to the pipe. The inspection is visual. The acceptance criteria are the absence of void between coating and pipe.

Frequency is as follows:

1. Two pipes at the startup of each shift then one test every 60 pipes on the cut back.

2. If one test does not satisfy the requirements, tests shall be performed on 5 pipes coated since the last check, and none of them shall be failed.

PART IV: QUALIFICATION AND PRODUCTION START UP TEST REQUIREMENTS.

For the qualification and production tests at least 5 pipes shall be used.

Test / Checks	PQT	PPT	Fabrication
1) Preheating	5 pipes minimum	5 pipes minimum	IR camera monitoring -All
2) Surface preparation			
Abrasive Cleanliness	At start	At start	At start
Degree of surface cleanliness	5 pipes minimum	5 pipes minimum	All
Salt contamination	5 pipes minimum	5 pipes minimum	Once per shift (at start)
Dust level	5 pipes minimum	5 pipes minimum	4 per shift
Roughness	5 pipes minimum	5 pipes minimum	Every 10 pipes, both ends
Steel temperature	1 pipe	1 pipe	4 per shift
Pipe travel speed (Record during PQT, During production, within 5% of recorded PQT value)	Once	Once	Twice per shift
3) Coating application			
Pipe temperature after induction heating	5 pipes minimum	5 pipes minimum	All
Intercoat time	5 pipes minimum	5 pipes minimum	Twice per shift
Extrusion temperature	5 pipes minimum	5 pipes minimum	Once per shift
Cooling	5 pipes minimum	5 pipes minimum	All
4) Raw materials			
Conformity certificate Test results - Epoxy primer - Adhesive - Polypropylene	Each raw material	Each raw material	N/A
UV and thermal resistance	For PE coating only	N/A	N/A
Certificate of analysis	Every batch	Every batch	Every batch

Test / Checks	PQT	PPT	Fabrication
5) Coating			
FBE thickness	2 pipes	2 pipes	One at start of each shift
Epoxy curing	1 pipe	1 pipe	One at start of each shift
Adhesive thickness	2 pipes	2 pipes	One at start of each shift
Final coating thickness	5 pipes minimum	5 pipes minimum	Every 5 pipes
Visual inspection	5 pipes minimum	5 pipes minimum	All
Holiday detection	5 pipes minimum	5 pipes minimum	All
Cut backs	5 pipes minimum at both ends	5 pipes minimum at both ends	All at both ends
Impact resistance	2 pipes / at two locations each	2 pipes /at two locations each	One at start of each shift
Shore D hardness	2 pipes / at three locations each	2 pipes /at three locations each	One at start of each shift
Peeling force	2 pipes both ends and middle) at 23°C ± 2°C and 2 pipes both ends and middle) at 80°C ± 2°C (or at max. operating	2 pipes (both ends and middle) at 23°C ± 2°C and 2 pipes (both ends and middle) at 80°C ± 2°C (or at max. operating temperature)*	Both ends at start of shift Both ends at start of shift
Indentation	1 pipe at 23°C ± 2°C and 1 pipe at 80°C ± 2°C (or at max. operating temperature)**	2 pipes at 23°C ± 2°C and 2 pipes at 80°C ± 2°C (or at max. operating temperature)**	Once per shift Once per shift
Flexibility	1 pipe	N/A	N/A
Cathodic disbonding	1 pipes at 23°C ± 2°C and 28 days, 1 pipes at 80°C ± 2°C and 28 days. (or at maximum operating temperature, whichever is higher, and 28 days) 1 pipe at 65°C	N/A N/A 2 pipes at 65°C and 48 hours***	N/A N/A Once every two shift

Test / Checks	PQT	PPT	Fabrication
Residual magnetic intensity	10 pipes at both ends	5 pipes minimum at both ends	All at both ends

* On each pipe, test shall be performed at three locations in pipe axis direction and one test shall be carried out in circumferential directions. Acceptance criteria remain the same in both directions.

** One sample is taken from each pipe but three tests shall be carried out on each sample.

*** Three samples shall be tested per pipe.

Appendix 3. FBE COATING

PART I: CHARACTERISTICS OF THE RAW MATERIALS

The epoxy powder shall be 100 % solid powder form.

The epoxy powder shall meet the technical requirements specified in Table 15.

The content of the conformity certificate for the epoxy product shall be as mentioned in Table 16.

The FBE product shall be qualified by the Manufacturer through testing of laboratory coated samples for each of the applicable tests of Table 17 below. Qualification is valid for three years. It can be re qualified by COMPANY after this period by a statement from Manufacturer that product formulation and manufacturing plant are identical to previous qualification.

For the qualification, laboratory coated samples shall be prepared as follows:

1. Steel plates shall be mild steel 6 mm thick 100 x 100 mm (unless otherwise agreed or requested by tests).
2. Salt contamination shall be checked prior to abrasive cleaning and shall be lower or equal to 2 micrograms/square centimeter as per ISO 8502-6 and ISO 8503-9.
3. Cleanliness after blast cleaning shall be Sa3 as per ISO 8501-1.
4. Surface roughness shall be such as: 60 microns <Ry5 <90 microns. It shall be measured as per ISO 8503-4 (stylus method). The use of replica tape is not allowed.
5. Cured film thickness of the applied coating shall be 450 ± 50 microns.
6. The applied epoxy powder shall fulfill the requirements of Table 15.
7. Before performing any tests, it shall be clearly demonstrated that the samples of epoxy powder are fully cured as checked by DSC.

Table 15 - Technical Requirements for Epoxy

Characteristics	Methods	Units	Acceptable values
Moisture content	20 g Temperature: 105°C Time: 30 mm	%	0.5 (maximum)
Glass transition temperature	Differential Scanning Calorimeter (DSC)	°C	At least 5°C above maximum pipeline design temperature with a minimum of 95°C
Bend test	CAN/CSA Z245-20, Clause 12.11. 2.5° at minimum temperature		No holiday
Water absorption test	ASTM D 570 (on a free film of 500± 50µm thickness)	%wt	Less than 15%after 28 days exposure at 80°C

* This requirement is for service temperature up to 80°C. For higher service temperature, high glass transition temperature materials are requested. They shall be submitted for COMPANY approval on a case by case basis.

Table 16 - Content of the Conformity Certificate for FBE

Characteristics	Methods	Units	Conformity range
Gel time	ISO 8130-6	Seconds	Manufacturer specification
Cure time	Manufacturer	Seconds	Manufacturer specification
Density	ISO 2811-1	g/ml	Manufacturer specification
Glass transition Temperature		°C	Manufacturer specification and as per Table 15
• First heating		°C	
• Second heating		J/g	Manufacturer specification
Enthalpy			
IR Spectra			Manufacturer specification
Particle size analysis	Manufacturer		Manufacturer specification
Moisture content	Manufacturer		Manufacturer specification and as per table 15

Table 17 - Technical Requirements of Laboratory Coated Test Samples

Properties	Requirement	Number of test specimens	Test method
Thermal characteristics (curing and Tg) DSC	As per Table 15. ΔTg lower than 3°. No residual enthalpy	1	DSC (see appendix 4)
Water permeability	For information, but mandatory for qualification	1 (free film) Manufacturer	As per Manufacturer. Film thickness to be noted.
Water absorption Value after three month at 23°C.	For information, but mandatory for qualification	1 (free film)	As per Manufacturer. Film thickness to be noted
Cathodic disbonding 48hrs, 65°C ± 2°C	3 mm max radius	3	ISO 21809-2 or NFA49 711
Cathodic disbonding 28 days, 23°C ± 2°C	5 mm max radius	3	ISO 21809-2 or NFA49 711
Cathodic disbonding 28 days, 80°C ± 2°C	10 mm max radius	3	ISO 21809-2 or NFA49 711
28 days hot water soak test, 65°C ± 2°C	Rating of 1-2	3	Appendix 4
Cross-section porosity	Rating 1-2	1	CAN/CSA Z245.20-06 Chap 12.10
Interface porosity	Rating 1-3	1	CAN/CSA Z245.20- 06 Chap 12.10

Properties	Requirement	Number of test specimens	Test method
Flexibility	2.5° at - 20°C	3	CAN/CSA Z245.20-06 Chap 12.11
Impact	1.5 J at -30°C	3	CAN/CSA Z245.20- 06 Chap 12.12
Strain polarization	No cracking or disbonding	3	CAN/CSA Z245.20-06 Chap 12.13

Table 18 - Repair Product Characteristics

Test	Test method	Requirement
Adhesion	Appendix 3 - Part II-2	1-2 (to steel and parent coating)
Hot water soak test, 28 days at 65°C ± 2°C	Appendix 4 - Paragraph 2	Rating 1-2
Cathodic disbonding test 28 days at 23°C ± 2°C	ISO 21809-2 or NFA49 711	5 mm max

PART II: SPECIFIC CHARACTERISTICS OF THE APPLIED FBE COATING

Thickness of the Applied Coating

The coating thickness shall be measured using a coating thickness gauge that has been calibrated at least once every working shift (to a maximum of 12 hours) against a thickness standard that is within 10 % of the nominal coating thickness specified.

The thickness shall be measured on each pipe at least at

- Both ends about 10 to 20 cm from the cut backs at four quadrants
- About the middle of the pipe at four quadrants

Each value shall be an average value of three readings within a square of approximately 10cm x 10cm. If any of the values are less than minimum required thickness, the coating thickness of the affected pipe shall be measured along the pipe length at intervals not exceeding 1 meter. None of the individual values shall be less than minimum required thickness. Failing to meet this requirements, pipes shall be stripped and re coated.

The coating thickness shall be 400 to 550 microns.

Adhesion Test

The following procedure shall be implemented:

Inscribe a V-cut with two 20 mm lines intersecting approximately 5 mm from their ends at 30° to 45°.

Insert blade of the knife at the point of the V-cut to the surface. Then with an upward flicking action, attempt to dislodge the coating within the V. If little or no coating is removed, repeat

this action within the V at least 4 times to confirm the integrity of the coating. Examine the appearance of the disbonded surface and compare with the following descriptive rating below:

1. Rating 1: No coating removed
2. Rating 2: Coating removed in small chips with difficulties
3. Rating 3: Coating removed in chips, slightly larger in area to tip of knife inserted under the coating. Some of the coating remains adherent to the surface of the steel within the V-cut
4. Rating 4: Coating removed with no chipping of the coating and minimal resistance
5. Rating 5: No coating remains adherent to the steel within the V-cut

The adhesion rating shall be 1-2.

Impact Test

Test shall be performed in accordance with CAN/CSA Z245.20-06 Chap 12.12 at -30°C.

Actual thickness shall be measured to evaluate the impact energy. The coating shall be examined with a holiday detector, over the points of impact, at a voltage of 5 kV per mm of coating thickness. Each reading shall consist of 5 impacts minimum.

The frequency of the test is one per shift.

Energy shall be 1.5 J minimum.

Bend Test

Test shall be performed in accordance with CAN/CSA Z245.20-06 Chap 12.11.

The flexibility shall be measured at 2.5° bending at the test temperature of -20°C. No holiday shall be detected.

The frequency is one test every 60 pipes.

Cathodic Disbonding

Test shall be performed in accordance with ISO 21809-2 or NFA49-711. The increase of the radius shall be less than

1. 3 mm after 48 hours at $65 \pm 2^\circ\text{C}$ (qualification and production test)
2. 5 mm after 28 days at $23^\circ\text{C} \pm 2^\circ\text{C}$ (qualification test and in case of conflict on 48 hours test)
3. 10 mm after 28 days at $80^\circ\text{C} \pm 2^\circ\text{C}$ (qualification test and in case of conflict on 48 hours test)

Frequency is one test every 2 shifts at $65 \pm 2^\circ\text{C}$ during 48 hours.

During production, only 48-hour tests shall be carried out. Tests at 28 days (at 23°C and 80°C) are mandatory during qualification process. Test results shall be known before start of production.

28 days Hot Water Soak Test at 65°C

The rating shall be 1-2 (Appendix 4 Paragraph 2)

Cross Section Porosity

Test shall be performed in accordance with CAN/CSA Z245.20-06 Chap 12.10. The rating shall be 1-2.

PART III QUALIFICATION AND PRODUCTION START UP TEST REQUIREMENTS

For the qualification and production tests at least 5 pipes shall be used

Test /Checks	PQT	PPT	Fabrication
1) Preheating	5 pipes minimum	5 pipes minimum	IR camera monitoring -All
2)Surface preparation			
Abrasive cleanliness	At start	At start	At start
Degree of surface cleanliness	5 pipes minimum	5 pipes minimum	All
Salt contamination	5 pipes minimum	5 pipes minimum	Once per shift (at start)
Dust level	5 pipes minimum	5 pipes minimum	4 per shift
Roughness	5 pipes minimum	5 pipes minimum	Every 10 pipes, both ends
Steel temperature	1 pipe	1 pipe minimum	4 per shift
Pipe travel speed	Once	Once	Twice per shift
3) Coating application			
Pipe temperature after induction heating	5 pipes minimum	5 pipes minimum	All
Cooling	5 pipes minimum	5 pipes minimum	All
4) Raw materials			
Conformity certificate	Each raw material	Each raw material	N/A
Test results	Each raw material	Each raw material	N/A
Laboratory coated samples	Each raw material	N/A	N/A

Test /Checks	PQT	PPT	Fabrication
Certificate of analysis	Every batch	Every batch	Every batch
5) Coating			
Visual inspection	5 pipes minimum	5 pipes minimum	All
FBE thickness	5 pipes minimum	5 pipes minimum	All
Thermal characteristics	5 pipes minimum	5 pipes minimum	Once per shift
Holiday detection	5 pipes minimum	5 pipes minimum	All
Cut backs	5 pipes at both ends	5 pipes at both ends minimum	All at both ends
Impact resistance	2 pipes at two locations each	2 pipes /at two locations each	One at start of each shift
Adhesion	5 pipes minimum	2 pipes /at three locations each	One at start of each shift
Flexibility	2 pipes minimum	2 pipes (both ends and middle) at 23°C $\pm$ 2°C and 2 pipes (both ends and middle) at 110°C $\pm$ 2°C (or at max. operating temperature)*	Both ends at start of shift Both ends at start of shift
Cathodic disbonding	1 pipes at 23°C $\pm$ 2°C and 28 days, 1 pipes at 80°C $\pm$ 2°C and 28 days. (or at maximum operating temperature, whichever is higher, and 28 days) 1 pipe at 65°C $\pm$ 2°C and 48 hours***	N/A N/A 2 pipes at 65°C and 48 hours***	N/A N/A Once two shift
Residual magnetic intensity	10 pipes at both ends	5 pipes (All) at both ends	All at both ends

*On each pipe, test shall be performed at three locations in both pipe axis and circumferential directions

** One sample is taken from each pipe but three tests shall be carried out on each sample.

*** Three samples shall be tested per pipe.

Appendix 4. SPECIFIC TESTS

Curing of epoxy layer

1. Take a sample of epoxy from a coated pipe at cut back (where top coat was applied with no adhesive) by scratching with any tool.
2. Weigh about 10-15 mg out, and put it in DSC pan
3. After calibration of DSC, run a first scan at 20°C/min up to 280°C (or any other max temperature as advised by Manufacturer)
4. Cool down to ambient at 40°C/min. Wait at ambient for the temperature in the cell to stabilize (i.e. 2-3 minutes)
5. Run a second scan at 20°C/min up to $T_g + 20^\circ\text{C}$
6. Calculate the Delta T_g in absolute value between first and second run
7. The T_g is understood here as the inflection point in the DSC curve.

Should a pre-heating of the sample before the first scan be proposed for homogenising, it shall demonstrate **Absolutely No Curing** Occurs.

Hot water soak test (For FBE only)

1. Fresh tap water heated up to $65^\circ\text{C} \pm 3^\circ\text{C}$.
2. Place the specimen in water bath for 28 days (qualification testing only), fully immersed. For quality control, the immersion time shall be revised to 48 hours and tests carried out at the frequency of once per 400 pipes.
3. While the specimen is still warm, use the utility knife to scribe approximately 30 mm x 15 mm rectangle through the coating to the substrate, then air cool the test specimen to $20^\circ\text{C} \pm 3^\circ\text{C}$.
4. Within one hour removal from heat, insert the tip of the knife under the coating at a corner of the scribed rectangle. Use a levering action to remove the coating. Continue inserting the tip of the knife and levering it under the coating until either all of the coating in the rectangle is removed or the coating demonstrates a definite resistance to the levering action.
5. Rate the adhesion as follows:
 - 5.1. Rating 1: Cannot be removed
 - 5.2. Rating 2: less than 50 % is removed
 - 5.3. Rating 3: More than 50 % is removed, but coating shows a definite resistance to levering action
 - 5.4. Rating 4: Coating is easily removed in strips or large chips
 - 5.5. Rating 5: Coating is removed as a single piece

6. For 3LPE and 3LPP coating, hot water soak test shall only be carried out for FBE layer during qualification test. Such test is not required during coating production.

UV ageing test for PP and PE

The test shall consist of subjecting PE/PP material test samples to the continuous irradiation of a xenon lamp under given temperature and humidity conditions.

Evaluation shall be performed by assessing the change in the material through the variation in its melt flow rate (MFR) or alternatively by assessing the variation in the elongation at break.

Equipment

- Irradiation chamber, equipped with a xenon lamp (see ISO 4892-2).
- Melt flow tester (see ISO 1133).
- Tensile testing equipment to perform tests in accordance with ISO 527-1 and ISO 527-2

Sampling

The test shall be carried out on samples of PE/PP in accordance with ISO 1872-2 for PE and ISO 527-2 for PP.

Procedure

1. The size of the sample shall be large enough to make ten test specimens of type 1B, 5A or 5B. (Referred to Figures 1 and A.2 in ISO 527-2).
2. The test sample(s) shall be exposed under the following conditions:
 - artificial weathering (see ISO 4892-2:2013, Table 3, Method A);
 - black standard temperature ($65\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$);
 - relative humidity ($65\% \pm 5\%$);
 - spray cycle: 18 min $\pm$ 0.5 min spray, 102 min $\pm$ 0.5 min dry;
 - total radiant energy: 7 GJ/m² for PE and 5GJ/m² for PP materials.
 - continuous exposure.

Three melt-flow-rate measurements shall be undertaken on the test sample in accordance with ISO 1133. The melt-flow-rate MFR 1, for the exposed samples shall be calculated as the arithmetic mean of the three results. MFR 0 for an unexposed test sample of identical shape shall be calculated in accordance with ISO 1133.

Results and test report

The results shall be expressed as the percentage variation of the melt flow rate, ΔMFR , after exposure using Equation (Eq.1).

$$\Delta MFR = \frac{MFR_1 - MFR_0}{MFR_0} \times 100 \quad (\text{Eq.1})$$

where

MFR_0 is the melt flow rate measured before exposure;

MFR_1 is the melt flow rate measured after exposure.

The test reports shall include at least the following:

- identification of the number and type of test specimens;
- procedure used;
- instruments used;
- reference to test method in ISO 21809;
- date of test;
- test results.

Thermal ageing test for PP or PE

The test shall consist of subjecting PP/PE material test samples to the effect of dry heat from a thermostatically controlled oven. The evaluation shall assess the change in the material by the variation in its melt-flow rate.

Equipment:

- Oven, thermostatically controlled, with air circulation maintaining a test temperature within $\pm 3^\circ\text{C}$
- Melt-flow tester (see ISO 1133)

Sampling

The test shall be carried out on samples of PE/PP in accordance with ISO 1872-2 for PE and ISO 527-2 for PP.

Procedure

Temperature of test: $150^\circ\text{C} (\pm 3^\circ\text{C})$ for PP and $100^\circ\text{C} (\pm 3^\circ\text{C})$ for PE

Duration of test shall be referred to Table G.1, ISO 21809-1: 2011.

Test method: ISO 21809-1 Annex G

Three melt-flow-rate measurements shall be undertaken on the test sample in accordance with ISO 1133. The melt-flow-rate MFR_1 , for the exposed samples shall be calculated as the

arithmetic mean of the three results. MFR 0 for an unexposed test sample of identical shape shall be calculated in accordance with ISO 1133.

Results and test report

The results shall be expressed as the percentage variation of the melt flow rate, ΔMFR , after exposure using Equation (Eq.1).

The test reports shall include at least the following:

- identification of the number and type of test specimens;
- procedure used;
- instruments used;
- reference to test method in ISO 21809;
- date of test;
- test results.

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