



شرکت ملی گاز ایران
مدیریت پژوهش و فناوری
امور تدوین استانداردها

IGS

دستورالعمل

سیستم پوششی پلی اتیلن سه لایه

3-Layer Polyethylene Coating System



تاریخ: ۱۳۹۵/۶/۱۸

شماره: ی ۰/دب/۰۱۳۶-۱۷۷۱۱



شرکت ملی گاز ایران



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باسلام،

به استحضار می‌رساند در جلسه ۱۶۹۴ مورخ ۱۳۹۵/۵/۱۷ هیأت مدیره، نامه شماره ک ۶۰۷۰۱/۰۰۰/۹ مورخ ۹۵/۰۵/۰۴ مدیر پژوهش و فناوری در مورد تصویب نهایی استانداردها به شرح زیر مطرح و مورد تصویب قرار گرفت.

۱. مشخصات فنی سیستم پوششی پلی اتیلن سه لایه IGS-C-TP-010(1)

۲. مشخصات فنی خرید دستگاه فشرده ساز لوله‌های پلی اتیلن IGS-M-PL-024(0)

۳. دستورالعمل، ارزیابی و صدور گواهینامه صلاحیت جوشکاران لوله و اتصالات پلی اتیلن به روش الکتروویژن

(حذف تبصره بند ۴-۴ بشرح پیوست) IGS-C-DN-002(2)

این مصوبه در حکم مصوبه مجمع عمومی شرکت‌های تابعه محسوب و برای کلیه شرکت‌های تابعه لازم الاجرا می‌باشد.

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FOREWORD

This standard is intended to be mainly used by NIGC and contractors, and has been prepared based on interpretation of recognized standards, technical documents, knowledge, backgrounds and experiences in natural gas industry at national and international levels. Iranian Gas Standards (IGS) are prepared, reviewed and amended by technical standard committees within NIGC Standardization division and submitted to the NIGC's "STANDARDS COUNCIL" for approval. IGS Standards are subject to revision, amendment or withdrawal, if required. Thus the latest edition of IGS shall be checked / inquired by NIGC employees and contractors.

This standard must not be modified or altered by NIGC employees or its contractors. Any deviation from normative references and / or well-known manufacturer's specifications must be reported to Standardization division. The technical standard committee welcomes comments and feedbacks about this standard, and may revise this document accordingly based on the received feedbacks.

GENERAL DEFINITIONS:

Throughout this standard the following definitions, where applicable, should be followed:

- 1- "STANDARDIZATION DIV." is organized to deal with all aspects of industry standards in NIGC. Therefore, all enquiries for clarification or amendments are requested to be directed to mentioned division.
- 2- "COMPANY": refers to National Iranian Gas Company (NIGC).
- 3- "SUPPLIER": refers to a firm who will supply the service, equipment or material to NIGC whether as the prime producer or manufacturer or a trading firm.
- 4- "SHALL": is used where a provision is mandatory.
- 5- "SHOULD": is used where a provision is advised only.
- 6- "MAY": is used where a provision is completely discretionary.

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CONTENT

1. SCOPE	2
2. REFERENCES	2
3. DEFINITIONS	6
4. SYMBOLS AND ABBREVIATED TERMS	7
5. GENERAL REQUIREMENTS	8
6. INFORMATION TO BE SUPPLIED IN THE PURCHASE ORDER	8
7. DOCUMENTS TO BE SUPPLIED BY THE APPLICATOR	9
8. COATING MATERIALS	9
9. COATING SYSTEM AND APPLICATOR QUALIFICATION	11
10. APPLICATION OF THE COATING SYSTEM	13
11. INSPECTION AND TESTING	16
12. COATING REPAIRS	17
13. MARKING	18
14. HANDLING AND STORAGE IN THE APPLICATORS FACILITIES	18
15. TEST REPORTS AND CERTIFICATE OF COMPLIANCE	19

TABLES

Table 1 – Requirements for inspection and testing of the epoxy powder (FBE) material—raw material	20
Table 2 – Requirements for inspection and testing of the epoxy powder (FBE) material – processed (as-applied)	20
Table 3 – Requirements for inspection and testing of the adhesive material (co-polymeric or grafted adhesive in pellet or powder form)	21
Table 4 – Requirements for inspection and testing of the PE top layer material	21
Table 5 – Batch certificate	22
Table 6 – Requirements for inspection of surface preparation	23
Table 7 – Requirements for inspection and testing of applied coating	24

1.SCOPE

This standard specification covers the minimum requirements for material, qualification, surface preparation, application, testing and inspection of three-layer polyethylene-based coatings to be used for external corrosion protection of underground steel pipeline systems. The coating shall be plant-applied and suitable for operating temperature from -30°C to +80°C (T_{max}).

Note1: Pipes coated in accordance with this standard are considered suitable for further protection by means of cathodic protection.

Note2: This standard withdraws and replaces IGS-E-TP-010-1, IGS-E-TP-010-2 and IGS-C-TP-010-Amnd2 standards.

2. REFERENCES

Throughout this standard specification, the following standards and codes are referred to, the edition of them, that are in effect at the time of issue of this standard specification (2015) shall, to the extent specified herein, form part of this standard specification. The applicability of changes in standards and codes that occur after the date of standards that referred shall be mutually agreed upon by the purchaser and manufacturer or supplier.

2.1 Normative references

ASTM D638(2014) "Standard test method for tensile properties of plastics"

ASTM D746 (2014) "Standard test method for brittleness temperature of plastics and elastomers by impact"

ASTM D792 (2013) "Standard test methods for density and specific gravity (relative density) of plastics by displacement"

ASTM D1238 (2013) "Standard test method for melt flow rates of thermoplastics by extrusion plastometer"

ASTM D1505 (2010) "Standard test method for density of plastics by the density-gradient technique"

ASTM D1525 (2009) "Standard test method for vicat softening temperature of plastics"

ASTM D1603 (2014) "Standard test method for carbon black content in olefin plastics"

ASTM D1693 (2015) "Standard test method for environmental stress-cracking of ethylene plastics"

ASTM D2240(2015) "Standard test method for rubber property – Durometer hardness"

ASTM D3418 (2015) "Standard test method for transition temperatures and enthalpies of fusion and crystallization of polymers by differential scanning calorimetry"

ASTM D3895 (2014) "Standard test method for oxidative-induction time of polyolefins by differential scanning calorimetry"

ASTM D4138 (2013) "Standard practice for measurement of dry film thickness of protective coating systems by destructive, cross-sectioning means"

ASTM D4940 (2015) "Standard test method for conductimetric analysis of water soluble ionic contamination of blasting abrasives"

CSA Z245.20 Series-14 (2014) "Plant-applied external coatings for steel pipe"

EN 10204 (2004) "Metallic products – Type of inspection documents"

IGS-C-PL-001(0) "Loading, Handling and Storage of Externally Coated Pipes"

IGS-M-PL-001-1(0) (2012) "SMLS/HFW Carbon Steel Pipes, Grade B, Sizes: 1/2 to 4 inch."

IGS-M-PL-001-2(0) (2013) "SMLS/HFW/SAWL/SAWH Carbon Steel Pipes, Grades B to X80, Sizes: 6 to 56 inch."

ISO 306 (2013) "Plastics – Thermoplastic materials – Determination of Vicat softening temperature (VST)"

ISO 527-1 (2012) "Plastics – Determination of tensile properties – Part 1: General principles"

ISO 527-2 (2012) "Plastics – Determination of tensile properties – Part 2: Test conditions for moulding and extrusion plastics"

ISO 527-3 (1995) "Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets"

ISO 868 (2003) "Plastics and ebonite – Determination of indentation hardness by means of a durometer (Shore hardness)"

ISO 1133-1 (2011) "Plastics – Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics– Part 1: Standard method"

ISO 1183-1 (2012) "Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pycnometer method and titration method"

ISO 1183-2 (2004) "Plastics – Methods for determining the density of non-cellular plastics – Part 2: Density gradient column method"

ISO 1183-3 (1999) "Plastics – Methods for determining the density of non-cellular plastics – Part 3: Gas pycnometer method"

ISO 2808 (2007) "Paints and Varnishes – Determination of Film Thickness"

ISO 3146 (2000) "Plastics – Determination of melting behavior (melting temperature or melting range) of semi-crystalline polymers by capillary tube and polarizing-microscope methods"

ISO 6964 (1986) "Polyolefin pipes and fittings – Determination of carbon black content by calcination and pyrolysis – Test method and basic specification"

ISO 8501-1 (2007) "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"

ISO 8502-6 (2006) "Preparation of Steel Substrates before Application of Paints and Related Products – Tests for the Assessment of Surface Cleanliness – Part 6: Extraction of Soluble Contaminants for Analysis – The Bresle Method"

ISO 8502-9 (1998) "Preparation of Steel Substrates before Application of Paints and Related Products – Tests for the Assessment of Surface Cleanliness – Part 9: Field Method for the Conductometric Determination of Water-soluble Salts"

ISO 8503-4 (2012) "Preparation of Steel Substrates before Application of Paints and Related Products – Surface Roughness Characteristics of Blast-Cleaned Steel Substrates – Part 4: Method for the Calibration of ISO Surface Profile Comparators and for the Determination of Surface Profile – Stylus Instrument Procedure"

ISO 8503-5 (2003) "Preparation of Steel Substrates before Application of Paints and Related Products – Surface Roughness Characteristics of Blast-Cleaned Steel Substrates – Part 4: Replica Tape Method for the Determination of the Surface Profile"

ISO 10474 (2013) "Steel and steel products – Inspection documents"

ISO 11124-1 (1993) "Preparation of Steel Substrates before Application of Paints and Related Products – Specifications for Metallic Blast-Cleaning Abrasives – Part 1: General Introduction and Classification"

ISO 11124-2 (1993) "Preparation of Steel Substrates before Application of Paints and Related Products – Specifications for Metallic Blast-Cleaning Abrasives – Part 2: Chilled-Iron Grit"

ISO 11124-3 (1993) "Preparation of Steel Substrates before Application of Paints and Related Products – Specifications for Metallic Blast-Cleaning Abrasives – Part 3: High-Carbon Cast-Steel Shot and Grit"

ISO 11124-4 (1993) "Preparation of Steel Substrates before Application of Paints and Related Products – Specifications for Metallic Blast-Cleaning Abrasives – Part 4: Low-Carbon Cast-Steel Shot"

ISO 11127-6 (2011) "Preparation of Steel Substrates before Application of Paints and Related Products – Test Methods for Non-metallic Blast-Cleaning Abrasives – Part 6: Determination of Water-soluble Contaminants by Conductivity Measurement"

ISO 11357-1 (2009) "Plastics – Differential scanning calorimetry (DSC) – Part 1: General principles"

ISO 11357-3 (2011) "Plastics – Differential scanning calorimetry (DSC) – Part 3: Determination of temperature and enthalpy of melting and crystallization"

ISO 11357-6 (2008) "Plastics – Differential scanning calorimetry (DSC) – Part 6: Determination of oxidation induction time"

ISO 15512 (2014) "Plastics – Determination of water content"

ISO 17855-2 (2016) "Plastics – Polyethylene (PE) moulding and extrusion materials – Part 2: Preparation of test specimens and determination of properties"

ISO 18553 (2002) / Amd 1 (2007) "Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds"

ISO21809-1 (2011) "Petroleum and natural gas industries – External coatings for buried or submerged pipelines used in pipeline transportation systems – Part 1: Polyolefin coatings (3-layer PE and 3-layer PP)"

ISO21809-2 (2014) "Petroleum and natural gas industries – External coatings for buried or submerged pipelines used in pipeline transportation systems – Part 2: Single layer fusion-bonded epoxy coatings"

ISO/TS 29001 (2010) "Petroleum, petrochemical and natural gas industries – Sector-specific quality management systems – Requirements for product and service supply organizations"

SSPC-AB 1 (2015) "Abrasive Specification No. 1 – Mineral and Slag Abrasives"

SSPC-AB 2 (2015) "Abrasive Specification No. 2 – Cleanliness of Recycled Ferrous Metallic Abrasive"

SSPC-AB 3 (2004) "Abrasive Specification No. 3 – Ferrous Metallic Abrasive"

SSPC-SP 1 (2015) "Surface Preparation Specification No. 1 –Solvent Cleaning"

2.2 Informative references

DNV-RP-F106 (2011) "Factory applied external pipeline coatings for corrosion control"

SHELL DEP 31.40.30.31-Gen. (2011) "External polyethylene and polypropylene coating for line pipe (Amendments/supplements to ISO/DIS 21809-1:2009"

TOTAL GS EP COR 220 (2009) "Three layer polyethylene external coating for pipelines"

3. DEFINITIONS

Adhesion

Bond between coating and substrate after environmental testing

Applicator

Company that undertakes the coating application

Application procedure specification (APS)

Document describing procedures, methods, equipment and tools used for coating application

Batch

Quantity of material produced in a continuous manufacturing operation using raw materials of the same source and grade

Batch certificate

Certificate of analysis issued by the manufacturer

Cutback

Length of pipe left uncoated at each end for joining purposes

Holiday

Coating discontinuity that exhibits electrical conductivity when exposed to a specific voltage

Inspection and testing plan (ITP)

Document providing an overview of the sequence of inspections and tests, including appropriate resources and procedures

Manufacturer

Company responsible for the manufacture of coating material(s)

Manufacturer's specification

Document that specifies the characteristics, test requirements and application recommendations for the coating materials

Operating temperature

Maximum and/or minimum temperature that can be endured by a pipeline (component) and/or pipeline system during operation, and that shall be within the design temperature range

Peel strength

Force required for peeling the coating from the substrate

Pipe diameter length

Any length along the pipe axis equal to the specified outside diameter of the pipe

Procedure qualification trial (PQT)

Application of a coating and subsequent inspection/testing of its properties, to confirm that the APS is adequate to produce a coating with the specified properties, carried out prior to the start of production

Purchaser

Company responsible for providing the purchase order requirements

Shift

a set of pipes coated in one production run of which the beginning and end coincide with a change in personnel. In the context of the quality control procedures of this standard, the maximum duration of a shift is 8 h.

Total coating thickness

Sum of all three layers

4. SYMBOLS AND ABBREVIATED TERMS**4.1 Symbols**

T_g glass transition temperature, expressed in degrees Celsius

ΔT_g difference in the glass transition temperature between two successive thermal analysis scans, expressed in degrees Celsius

4.2 Abbreviations

APS application procedure specification

DSC differential scanning calorimetry

ESCR environmental stress cracking resistance

FBE fusion-bonded epoxy

HDPE high-density polyethylene

IR infrared

ITP inspection and testing plan

MFR melt flow rate

MS manufacturer specification

OIT oxidation induction time

PE polyethylene

UV ultraviolet

3LPE three-layer polyethylene coating

5. GENERAL REQUIREMENTS

5.1 H.S.E.

Application of coatings can include the use of hazardous materials, operations and equipment. This standard does not purport to address all the potential safety concerns associated with their use. It is the responsibility of the applicator to establish appropriate safety and health requirements and determine any regulatory requirements or limitations prior to use.

Health, Safety and Environment concerns shall be identified and included in the detailed coating procedure and pre-job discussions. All surface preparation and coating application systems shall undergo a complete safety inspection and checkout prior to use.

Adequate exhaust/ventilation equipment shall be used, as required, for removal of any air contaminated products to achieve acceptable air quality standards and to protect personnel.

The safe practices recommended in industry standards shall be followed. Waste material shall be handled and disposed of properly. Protective equipment requirements in the Manufacturer's Material Safety Data Sheet(s) shall be followed.

Coating work pieces shall be electrically grounded (earthed) as required to eliminate static charges associated with surface preparation and coating operations.

5.2 Company access

The purchaser's representative, including independent inspectors or consultants as may be engaged by the purchaser, shall be permitted access to the coating application site at any time to conduct performance analyses, including quality control tests of the materials being used.

The purchaser's representative has the right to request quality control tests at any time in addition to those completed at pre-determined intervals.

5.3 Compliance with standard

The applicator shall be responsible for complying with all the applicable requirements of this standard. The purchaser shall be allowed to make any investigations necessary to ensure compliance by the applicator and to reject any material and/or coating that does not comply.

5.4 Quality assurance system

The applicator and the coating manufacturer shall implement a quality management system in accordance with ISO/TS 29001.

6. INFORMATION TO BE SUPPLIED IN THE PURCHASE ORDER

The purchase order shall include the following information:

- number of this standard and year of publication;

- pipe quantity, outside diameter, minimum wall thickness, minimum, maximum and nominal length, grade of steel;
- bare pipe standard (IGS-M-PL-001-1&2) otherwise to be approved by the purchaser;
- design temperature range;
- coating thickness;
- Type of certificate of compliance.

7. DOCUMENTS TO BE SUPPLIED BY THE APPLICATOR

Before the start of coating production, the following documents shall be submitted to the purchaser for approval:

- certificates and inspection documents of incoming bare pipes;
- checking bare pipe traceability based on pipe number;
- incoming bare pipes inspection;
- surface preparation procedures;
- surface pretreatment procedures;
- marking detail of coated pipes;
- storage and handling procedures;
- certificates and inspection documents of incoming coating materials;
- checking incoming coating materials traceability based on batch number;
- incoming coating materials inspection;
- application procedure specifications (APS);
- methods, frequency and acceptance criteria for inspection and testing;
- inspection and testing plan and/or daily log;
- Quality Control Plan (QCP) consisting of Manufacturing Plan (MP) and Inspection and Test Plan (ITP);
- coating system qualification information;
- applicator's qualification information;
- coating application procedures;
 - procedure qualification trial (PQT);
- documentation and schedule for supply of documentation;
- handling and storage procedures for coated pipes;
- protection against adverse ambient conditions during storage;
- marking pattern details for coated pipes;
- Pipe end protection.

The applicator shall confirm that the coating system is suitable for use under the requirements of this standard specification.

8. COATING MATERIALS

8.1 General

The coating system shall consist of three layers: epoxy powder (FBE), adhesive and PE top layer.

8.2 Batch certificate

8.2.1 The applicator shall provide batch certificates supplied by the manufacturer for each batch of materials including epoxy powder (FBE), adhesive and PE top layer. The batch

Certificates shall contain the information given in Table 5. The batch certificates shall state test methods and acceptance criteria.

The applicator shall identify the materials traceability and shall confirm that the certificates relate to the specified materials.

Upon receiving the manufacturer's test report, the applicator shall verify that the materials meet the requirements of this standard specification.

8.2.2 The manufacturer's specification for epoxy powder (FBE) material shall include the following:

- trade name;
- generic type (Infra-red spectrogram);
- maximum thickness, expressed in micrometers (see Annex A of ISO 21809-1);
- maximum and minimum storage temperatures, expressed in degrees Celsius;
- Storage maximum moisture content and ventilation requirements;
- shelf-life at storage temperature, expressed in months;
- color;
- Technical properties, in accordance with Table 1 and 2.
-

8.2.3 The manufacturer's specification for adhesive and PE top layer materials shall include the following:

- trade name;
- description, type and grade of adhesive and PE top layer;
- maximum and minimum storage temperatures, expressed in degrees Celsius;
- Storage maximum moisture content and ventilation requirements;
- shelf-life at storage temperature, expressed in months;
- Technical properties, in accordance with Tables 3 and 4.

8.3 Qualification of the coating materials

8.3.1 General requirements

The manufacturer shall qualify each type of coating materials including epoxy powder (FBE), adhesive and PE top layer in compliance with the requirements of this standard specification. The qualification shall be repeated in case of changes in the material composition, changes in the production process which influence the material processing behavior and change in production facility.

The manufacturer shall carry out and report the material qualification tests in accordance with the requirements of this clause and subclasses which follow and Tables 1, 2, 3 and 4. The test report shall contain the results of the qualification tests and the data required in Table 5.

8.3.2 Epoxy powder (FBE) material

As a quality control routine test for raw material, the applicator shall take samples from each batch of epoxy powder (FBE) material and perform the qualification tests as specified

in Tables 1 and 2. The qualification tests shall be performed at the presence of purchaser's inspector.

The epoxy powder (FBE) material shall be considered qualified if the results of all tests comply with the requirements of Tables 1 and 2.

Qualification shall be repeated in case of change in manufacturer or grade of material.

Using an approved method, an Infra-red spectrogram, preferably made by using a standard KBr (Potassium Bromide) disc, shall be obtained from the manufacturer. This shall subsequently be used for comparison with another type of spectrogram.

8.3.3 Adhesive material

As a quality control routine test for raw material, the applicator shall take samples from each batch of adhesive material and perform the qualification tests as specified in Table 3. The qualification tests shall be performed at the presence of purchaser's inspector.

The adhesive material shall be considered qualified if the results of all tests comply with the requirements of Table 3.

Qualification shall be repeated in case of change in manufacturer or grade of material.

8.3.4 PE top layer material

As a quality control routine test for raw material, the applicator shall take samples from each batch of PE top layer material and perform the qualification tests as specified in Table 4. The qualification tests shall be performed at the presence of purchaser's inspector.

The PE top layer material shall be considered qualified if the results of all tests comply with the requirements of Table 4.

Qualification shall be repeated in case of change in manufacturer or grade of material.

Note 1: The use of carbon black suitable for plastics is recommended. Carbon blacks produced as industrial or rubber grade are not recommended.

Note 2: The use of waxes is not allowed.

Note 3: The use of master batch is not allowed to be used by the applicator. Applicator shall use black compounded PE for extrusion.

8.4 Storage and handling of coating materials

Storage and handling of coating materials shall be in accordance with the manufacturer's specification.

9. COATING SYSTEM AND APPLICATOR QUALIFICATION

9.1 Coating system qualification

9.1.1 General

The coating system shall be qualified as follows:

Before bulk production of the 3LPE coating starts, 20 pipes shall be coated by the applicator in accordance with the requirements of this standard specification at the presence of purchaser's inspector. 3 of the 20 coated pipes shall be selected by the inspector and the tests specified in Table 7 shall be performed on each pipe. The test specimens needed as per table 7 shall be marked at one end and just before the cut back area of each pipe. The specimens shall then be cut and sent to an independent test laboratory or if approved by the purchaser to the applicator's test laboratory.

Coating system shall be considered qualified if the results of all test specimens comply with the requirements of Table 7.

Qualification shall be carried out separately for each coating line. The applicator shall carry out and report the coating qualification in accordance with the requirements of this standard specification. The test report shall contain the results of the qualification tests and data as required in Table 7. The applicator shall exclusively use the coating materials qualified in accordance with the requirements of Clause 8.3.

Qualification shall be repeated in case of modifications to the coating line, coating materials or application procedures.

9.1.2 Application procedure specifications (APS)

The APS shall cover all items associated with quality control as defined in this standard specification. Prior to the start of coating production and any specified PQT, the applicator shall prepare an APS, including:

- incoming inspection of bare pipes and coating material;
- data sheets for coating materials, including any materials used for coating repairs;
- data sheets for abrasive blast cleaning materials;
- certification, receipt, handling and storage of materials for coating and abrasive blast cleaning;
- cleaning procedure for all application equipment;
- preparation of the steel surface including monitoring of environmental parameters, methods and tools for inspection, grinding of pipe surface defects and testing of surface preparation;
- coating application, including tools/equipment for control of process parameters essential for the quality of the coating;
- lay-out sketch or flow diagram for the coating plant;
- methods and tools/equipment for inspection and testing of the applied coating;
- repair of pipes with defective coating (specified in Clause 12) and any associated inspection and testing;
- stripping of defective coating;
- preparation of coating cutback areas;
- marking and traceability;
- handling and storage of pipes;
- any special conditions for dispatch of coated pipes, including protection of pipe ends;
- Documentation.

9.1.3 Procedure qualification trial (PQT)

The application procedure specifications (APS) shall be qualified by a PQT in accordance with the requirements of Annex L of ISO 21809-1

The APS shall be available to the purchaser on request at any time during production.

For new applicators, the APS shall be qualified prior to the start of production.

9.1.4 Quality Control Plan (QCP)

The applicator shall prepare a Quality Control Plan (QCP) including application procedure specifications (APS), consisting of Manufacturing Plan (MP) and Inspection and Test Plan (ITP) and a daily log to record quality control data in accordance with Annex L of ISO 21809-1.

9.2 Applicator qualification

9.2.1 General

For new applicators, before coating production commences, the applicator shall be qualified for the application of the coating system. The qualification shall be carried out according to the following procedures:

9.2.2 Coating plant

To demonstrate that the available equipment is capable of applying the specified coating according to this standard, the applicator shall submit full details of the coating plant, including:

- layout diagram of the coating plant and plant flow scheme;
- general description of the equipment available to carry out the coating process;
- details of process control and inspection equipment required for the coating process such as temperature control, thickness control, holiday testers, laboratory equipment, etc.;
- details on the line pipe marking, handling, storage and transport equipment and procedures;
- applicator's QCP including application procedure specifications(APS).

9.2.3 Qualification

After approval of the coating plant (9.2.2) and before the coating production starts, the applicator shall be qualified with the requirements of this standard specification. The experienced applicators shall demonstrate by means of submitting documents to the purchaser of prior projects that he has successfully applied the similar coating systems on pipes of the similar material, and that the coating system qualification was approved and the quality control test results have complied with the requirements of Tables 6 and 7.

10. APPLICATION OF THE COATING SYSTEM

10.1 Surface preparation

10.1.1 Initial preparation

All dirt, deleterious matter and contaminants, such as oil, grease, etc. shall be removed from the pipe prior to coating. If a chemical cleaner is used, subsequent washing with

potable water will be necessary. The pipe shall be cleaned in accordance with the requirements of SSPC-SP1.

All pipes shall be pre-washed with potable water.

The steel defects and irregularities (e.g. laminations, slivers, scratches) shall be removed in accordance with the APS.

All pipes shall be dry prior to entering the abrasive blast cleaning unit(s).

The pre-heating temperature shall be 40 °C to 70 °C.

10.1.2 Abrasive blast cleaning

The abrasives used in the coating plant shall be in accordance with the requirements of ISO 11124 (all parts).

Note: If the pipe being coated is of a high-strength grade, e.g. X80 or higher, harder abrasives may be needed to provide the required cleanliness and surface profile.

The abrasives (including recycled materials) shall be maintained clean, dry and free from contaminants in accordance with SSPC-AB 1, SSPC-AB 2 and SSPC-AB 3 or ASTM D4940 so as not to contaminate the substrate.

The cleanliness achieved at entry to the coating line shall be in accordance with the requirements of ISO 8501-1, grade Sa 2½.

The height of the surface profile attained shall be within 60 µm and 100 µm, as measured in accordance with the requirements of ISO 8503-4 (Stylus method) or ISO 8503-5 (Replica tape method). The Stylus method shall be used for verification. The Replica tape method may be used when a correlation is established with the Stylus (Profilometer) method with a cut-off length of 2.5 mm.

If grinding is required after blast cleaning, the maximum allowable area of grinding shall be 10 cm² per meter of pipe length or 0.5 % of the pipe surface area whichever is lower. If the grinding area required exceeds these limits, the pipe shall be reblasted.

During blast-cleaning the pipe surface temperature shall be simultaneously higher than 5 °C and more than 3 °C above the ambient dew point. The relative humidity shall not exceed 85%.

Line speed and blasting parameters shall not cause any over blasting of the pipe surface and result in microscopic steel laminations that may disbond from the pipe surface.

No repairs to the pipe shall be made without a procedure agreed by the purchaser.

After any grinding or mechanical repairs, the remaining wall thickness shall be checked and compared with the minimum requirements of the line pipe specification (IGS-M-PL-001-1&2). Pipes not meeting the minimum wall thickness shall be rejected.

10.1.3 Chemical pre-treatment

The phosphoric acid wash shall be used as a surface treatment after all surface preparation operations and just prior to heating for coating application.

The phosphoric acid treatment shall be applied at an acid concentration of 10 % by volume +/- 3%. The concentration shall be measured using a titration method recommended by the manufacturer.

Pipe temperature shall be uniformly at 45°C to 65°C for treatment within the maximum elapsed time after blast cleaning.

The phosphoric acid solution shall be uniformly applied to the pipe surface with a low pressure (0.5 – 2.0 bar) spray application and shall remain on the surface in accordance with the manufacturer's recommendations.

Pipe surfaces shall remain wet at all times during the phosphoric acid treatment. Any treated pipe shall be reblasted if the acid solution is allowed to dry anywhere on the surface of that pipe.

A uniform PH of 1 or less shall be maintained over the entire surface of treated area.

The acid washed pipe surface shall remain wetted for 10 to 30 seconds. After the dwell time, the pipe surface shall be thoroughly rinsed with high pressure clean water before it starts to dry out.

High-pressure rinse water used shall be at 700 – 1000 psi (50 – 70 bar) to remove any treatment residue. The water used shall meet the following requirements:

Chlorides shall not exceed 10 ppm, sulfates shall not exceed 40 ppm, and nitrates shall not exceed 10 ppm. The total of these salts shall not exceed 60 ppm. The water shall not be reused.

The minimum pH of the wet surface after rinsing shall be 6.0, as determined by touching pH paper directly to the pipe surface. The pH paper shall have a measurement increment of 0.5 pH units or less.

The appearance of the pipe surface after drying shall be substantially the same as it was immediately after blast cleaning. Occasional watermarks are permitted.

The maximum allowable residual soluble salts (chloride contamination) level on the surface shall be 20 mg/m² in accordance with ISO 8502-6 or ISO 8502-9 or ISO 11127-6 or SCM400 methods.

10.2 Coating application

10.2.1 General

The coating shall be applied in accordance with the APS. During the application of the coating components, the preheating temperature of the pipe shall be monitored and recorded using contact thermometers.

Optical pyrometers and temperature-measuring crayons may be used when a correlation is established with the contact thermometer.

The maximum elapsed time between surface preparation and start of the coating application shall be no longer than 4 hours for relative humidity up to 70% and no longer than 2 hours for relative humidity between 70% and 85%.

During coating, the bevelled ends of the pipes and the pipe bore shall be protected against mechanical damage and against contamination with coating material.

10.2.2 Epoxy application

The pipes shall exclusively be heated by induction coil (electrical). The pipe temperature prior to and during epoxy application shall be monitored based on manufacturer's recommendations and in accordance with the APS.

The powder epoxy shall be sprayed using electrostatic spray guns.

The thickness of the epoxy layer after curing and the degree of cure shall be in accordance with Table 7.

10.2.3 Adhesive application

Adhesive application shall be monitored based on manufacturer's recommendations and in accordance with the APS. The elapsed time between epoxy application and adhesive application and the adhesive application parameters shall be in accordance with the APS.

10.2.4 PE top layer application

PE top layer application shall be monitored based on manufacturer's recommendations and in accordance with the APS. The PE application parameters shall be in accordance with the APS.

The applied coating shall be cooled to a temperature that prevents handling damage during finishing and final inspection.

The total coating thickness shall be in accordance with Table 7.

10.3 Cutback

The coating at the pipe ends shall be removed to expose a length of bare metal in accordance with Table 7.

The coating shall be bevelled to an angle not exceeding 30° measured in the direction of the pipe axis.

The cutback length shall be measured from the root face of the pipe to the beginning of the coating bevel.

11. INSPECTION AND TESTING

11.1 General

Inspection and testing of raw coating materials shall be carried out in accordance with the APS, and ITP and meet the requirements of Tables 1 to 4.

Inspection and testing of applied coating shall be carried out in accordance with the APS, and ITP and meet the requirements of Tables 6 and 7.

11.2 Retesting

Pipes that fail to meet the requirements of Table 6 shall not be coated until the cause has been identified and corrected. Pipes that have been coated since the last acceptable test shall be accepted if they meet the requirements of Table 7.

Pipes that fail to meet the requirements of Table 7 shall be retested for the parameter(s) found to be out of this standard specification. If the retest also fails to meet the requirements in Table 7, two pipes in the coating sequence prior to the pipe that failed and two pipes in the sequence after that pipe shall be retested.

If the results of all retested pipes are satisfactory, the coating shall be considered acceptable on all pipes except the pipe that failed. If any of the retested pipes also fail, the total production back to the last test passed shall be rejected.

12. COATING REPAIRS

12.1 General

If the 3LPE coating of pipe is damaged during production, handling, loading and unloading at the coating plant, the damage to the coating shall be repaired according to this standard specification.

12.2 Coating repair material

Since the repair materials are required to be approved by purchaser, a copy of technical specification and data sheets together with inspection certifications for the repair materials including PE melt stick, filler mastic, repair patch and heat shrinkable sleeve shall be submitted to purchaser for review and approval.

12.3 Qualification of repair procedure

The repair procedure shall be qualified at the presence of purchaser's inspector. In this case a line pipe with damaged coating shall be repaired in accordance with the instructions recommended by the repair material manufacturer. The repaired area shall then be inspected for minimum thickness, adhesion and holiday detection and if satisfactory results achieved, the repair procedure will be considered acceptable. The inspection findings shall then be recorded and signed by both parties and kept as a proof of repair procedure qualification.

12.4 Acceptable number of repairs in a line pipe

The maximum acceptable number of damage in any coated line pipe, may be three points, provided that the total damaged areas do not exceed 200 cm², however the total number of pipes with coating repairs, shall not exceed 2% of total number of coated pipes in any individual order.

12.5 Unrepairable damage

The following damages are not allowed to be repaired: (In such cases the pipe coating shall be fully stripped and the pipe recleaned and recoated.)

- If the damage to the pipe coating, is reached to the FBE layer.
- No repair will be allowed on coating edges at either sides of pipe coating.
- If the maximum surface of 3 repaired areas in any line pipe, exceed 200 cm².

12.6 Repairable damage

Repair Procedure

The damages which are allowed to be repaired are limited to the following:

- **Minor damages:** If the damaged depth is less than 1.5 mm and the related area is less than 5 cm², the damage may be repaired by PE melt stick.
- **Intermediate damages:** If the damaged depth is less than the thickness of PE and adhesive layers and the maximum area of the damages does not exceed 50 cm², with the biggest dimension of 10 cm, the damage shall be repaired by filler mastic and repair patch.

- **Major damages:** If the damage depth is less than the thickness of PE and adhesive layers and the maximum area of the damage does not exceed 100 cm² with the biggest dimension of 30 cm, the damage shall be repaired by filler mastic together with a wraparound heat shrinkable sleeve.

Note: Any repair activities shall be performed fully in accordance with the instructions recommended by the repair material manufacturer.

12.7 Repair quality control

All repaired areas shall be subjected to visual inspection and holiday detection test. In case of any failure, the repaired portion shall be removed, recleaned and repaired again. Repair material shall be suitable for maximum operating temperature and also other physical properties to be matchable with 3LPE coating.

13. MARKING

13.1 General

Coated pipes shall be marked in accordance with the requirements of 13.2 and with any additional markings specified in the purchase order. Additional markings, as desired by the applicator, shall be by agreement.

13.2 Required markings

Marking shall be carried out using a method such as stencil painting or printing to ensure legible and indelible identification.

The pattern of coated pipe marking shall be prepared by the applicator and approved by the purchaser.

The markings shall include as a minimum:

- Pipe number
- applicator's name or code;
- IGS standard designation and year of publication (IGS-C-TP-010(1): 2016);
- date of coating production;
- specified total coating thickness;

Note: Marking shall be carried out at one end of pipe coating.

14. HANDLING AND STORAGE IN THE APPLICATORS FACILITIES

14.1 Handling

Coated pipes shall be handled in a manner to avoid damage to the pipe, pipe ends and pipe coating. The applicator shall submit details of the handling procedures; such procedures shall include loading requirements where the applicator is responsible for loading.

Pipe coating that is damaged during processing shall be repaired and subsequently inspected in accordance with the requirements of Clause 12 of this standard specification. Bevel protectors and/or end caps as installed by the pipe manufacturer shall be re-installed after coating and before handling of the pipes.

Pipes shall only be lifted by means of slings, lifting hooks or vacuum lifters, fitted with suitable spreader bars. Hooks shall be padded with soft material to prevent damage to the bevelled ends. Wire ropes and chains shall never be used to lift the coated pipes.

Lifting trucks or front-end loaders shall have soft padded forks or grips to prevent damage to pipes or pipe coating.

Coated pipes shall not be rolled or dragged over the ground.

Pipes shall not be lifted in bundles without prior approval by the purchaser.

When more than one pipe is lifted, separate slings or hooks shall be used for each pipe and coated pipes shall be provided with soft padding between the pipes.

Note: In addition to the above, handling of coated pipe shall be in accordance with the requirements of IGS-C-PL-001(0).

14.2 Storage

The applicator shall specify in the APS details of the facilities and the methods being used for yard storage.

Pipes shall be stored in designated areas. Pipes shall not be stored with other consignments or pipes for other contracts.

Pipes shall be stacked only to such a height that no damage is caused to the pipes or their coatings due to the weight of other pipes.

Pipe supports shall be spaced so that no bending of pipes occur.

Pipe supports shall be made of soft padded wooden bolsters or sand rows, free of stones, covered with plastic sheets. The pipe surface shall not be in contact with the soil.

Piles of pipe shall be secured by wooden wedges or ground pins, provided with adequate padding to prevent coating damage, and of sufficient size to prevent collapse of the piles.

Coated pipes shall be stacked using soft separators such as rubber pads or tyre tread.

When stored outdoors, pipes shall be placed at a small angle to allow drainage of any rainwater from the inside of the pipes.

Note: In addition to the above, storage of coated pipe shall be in accordance with the requirements of IGS-C-PL-001(0).

15. TEST REPORTS AND CERTIFICATE OF COMPLIANCE

Unless otherwise specified in the purchase order, an Inspection Certificate of type 3.1 in accordance with ISO 10474 (or type 3.1 in accordance with EN 10204) shall be issued by the applicator, which provides the results from the inspection and testing of the coating materials and coated pipes in accordance with the requirements of this standard specification.

The applicator shall keep accurate records of all relevant data of the coating process.

This documentation shall, as a minimum, consist of:

- copies of the coating system information;
- copies of qualification information;
- copies of, or reference to, all procedures for coating of the pipes;
- pipe numbers as given by the pipe manufacturer (e.g. by copies of the pipe mill data sheets);
- serial numbers as given by the coating applicator (if applicable) correlated with the manufacturer's pipe numbers;
- the order of coating, the day and shift of coating of each pipe;

- the batch numbers of the coating materials, the day and time of loading of each batch;
- serial numbers of rejected pipes and the reason for rejection;
- records of any repairs;
- the results of all quality control testing;
- records of temperatures during the coating process for each pipe, with the processing time of every tenth pipe marked on the temperature chart with the pipe number;
- names and signatures of the responsible persons for the coating process and quality control;
- an overall compliance certificate for the total order.

This documentation shall be submitted to the purchaser after completion of the coating work, together with the testing and inspection instruments' calibration certificates.

Table 1 – Requirements for inspection and testing of the epoxy powder (FBE) material – raw material

Item	Properties	Unit	Requirements	Test method	Frequency qualification	Frequency production
1	Moisture content	% mass	≤ 0.5	ISO 21809-1 (Annex K)	Once at start up	Once per FBE batch ^b
2	Minimum glass transition temperature (T_{g2}) (DSC analysis ^a)	°C	≥ 95 and within manufacturer's specification	ISO 21809-1 (Annex D)	Once at start up	Once per FBE batch ^b
3	Gel time at 205 °C ± 3 °C	s	Within 20 % of the nominal value specified by the manufacturer	ISO 21809-1 (Annex J)	Once at start up	Once per FBE batch ^b
4	Density	g/cm ³	Within ±0.05 of the manufacturer's specified nominal value	ISO 21809-1 (Annex N)	Once at start up	Once per FBE batch ^b
5	Particle size	%	3.0% maximum powder retained on 150 µm mesh and 0.2% maximum powder retained on 250 µm mesh	ISO 21809-2 (Clause A.6)	Once at start up	Once per FBE batch ^b

^a Curing condition (procedure as per manufacturer's specification).
^b The qualification test results can be accepted as production for the same batch.

Table 2 – Requirements for inspection and testing of the epoxy powder (FBE) material – processed (as-applied)^a

Item	Properties	Unit	Requirements	Test method	Frequency qualification	Frequency production
1	3.0°ppd flexibility, at -30 °C	--	No cracking	ISO 21809-2 (Clause A.13)	Once at start up	N/A
2	Average radius of cathodic disbondment, max (at 65±3 °C / 28 d / -1.5 V)	mm	15	ISO 21809-2 (Clause A.9)	Once at start up	N/A
3	Hot-water adhesion, max 24 h at 75±3 °C	--	Rating 2	ISO 21809-2 (Clause A.16)	Once at start up	N/A

^a Test specimens shall be mild steel and shall have dimensions in accordance with the applicable test method. The substrate shall be abrasively blast cleaned with steel grit, in accordance with ISO 11124-3, to provide a cleanliness in accordance with the requirements of ISO 8501-1, grade Sa 2½. The surface shall have a peak-to-trough height of between 60 µm and 100 µm as measured in accordance with ISO 8503-4 (Stylus method), or ISO 8503-5 (Replica tape method). The thickness of the coating on the completed test specimen shall be 350 µm to 500 µm. This should be measured by a calibrated coating thickness gauge verified to ± 5 % of full scale range.

**Table 3 – Requirements for inspection and testing of the adhesive material
(co-polymeric or grafted adhesive in pellet or powder form)**

Item	Properties	Unit	Requirements	Test method	Frequency qualification	Frequency production
1	Density	g/cm ³	Within 1 % of the manufacturer's specified nominal value	ISO 1183 (all parts) or ASTM D792 or ASTM D1505	Once at start up	Once per adhesive batch ^b
2	MFR (190 °C / 2.16 kg)	g/10min	Within 20 % of the manufacturer's specified nominal value provided the adhesive is recommended for pipe coating by the manufacturer	ISO 1133-1 or ASTM D1238	Once at start up	Once per adhesive batch ^b
3	Melting temperature	°C	≥ 120	ISO 3146 or ISO 11357-1 and -3 or ASTM D3418	Once at start up	Once per adhesive batch ^b
4	Vicat softening temperature A/50 (9.8 N)	°C	≥ 95	ISO 306 or ASTM D1525	Once at start up	Once per adhesive batch ^b
5	Brittleness temperature	°C	≤ -50	ASTM D746	Once at start up	N/A
6	Water content	%	≤ 0.1	ISO 15512	Once at start up	N/A
7	Elongation at break at 23±2 °C ^a	%	≥ 600	ISO 527-1 and -2 or ISO 527-1 and -3 or ASTM D638	Once at start up	Once per adhesive batch ^b
8	Tensile yield strength at 23±2 °C ^a	MPa	≥ 8	ISO 527-1 and -2 or ISO 527-1 and -3 or ASTM D638	Once at start up	Once per adhesive batch ^b

^a 2 mm-thick compression-moulded sheet, test specimen type according to ISO 527-3, strained at 50 mm/min.

^b The qualification test results can be accepted as production for the same batch.

Table 4 – Requirements for inspection and testing of the PE top layer material

Item	Properties	Unit	Requirements	Test method	Frequency qualification	Frequency production
1	Density	g/cm ³	≥0.940 (Base resin) or ≥0.945 (Compound)	ISO 1183 (all parts) or ASTM D792 or ASTM D1505	Once at start up	Once per PE batch ^b
2	MFR (190 °C / 2.16 kg)	g/10min	0.3-0.8 and within 20 % of the manufacturer's specified nominal value	ISO 1133-1 or ASTM D1238	Once at start up	Once per PE batch ^b
3	Melting temperature	°C	≥ 125	ISO 3146 or ISO 11357-1 and -3 or ASTM D3418	Once at start up	Once per PE batch ^b
4	Vicat softening temperature A/50 (9.8 N)	°C	≥ 115	ISO 306 or ASTM D1525	Once at start up	Once per PE batch ^b
5	Brittleness temperature	°C	≤ -70	ASTM D746	Once at start up	N/A
6	Water content	%	≤ 0.05	ISO 15512	Once at start up	N/A
7	Elongation at break at 23±2 °C ^a	%	≥ 600	ISO 527-1 and -2 or ISO 527-1 and -3 or ASTM D638	Once at start up	Once per PE batch ^b
8	Tensile yield strength at 23±2 °C ^a	MPa	≥ 15	ISO 527-1 and -2 or ISO 527-1 and -3 or ASTM D638	Once at start up	Once per PE batch ^b
9	Carbon black content	%	2-2.5	ISO 6964 or ASTM D1603	Once at start up	Once per PE batch ^b
10	Carbon black dispersion	Grade	≤ 3	ISO 18553	Once at start up	Once per PE batch ^b
11	Hardness Shore D	--	≥ 55	ISO 868 or ASTM D2240	Once at start up	Once per PE batch ^b
12	ESCR (50 °C, F ₀ , Cond. A: 10 % Igepal CO-630)	hour	≥1000	ASTM D1693	Once at start up	Once per PE batch ^b
13	OIT	min	≥ 30 at 210 °C or ≥ 10 at 220 °C	ISO 11357-1 and -6 or ASTM D3895	Once at start up	Once per PE batch ^b
14	Thermal ageing	%	ΔMFR ≤ 35	ISO 21809-1 (Annex G)	Once at start up	N/A
15	UV resistance	%	ΔMFR ≤ 35	ISO 21809-1 (Annex G)	Certificate shall be supplied by the manufacturer	N/A

^a Preparation of the test specimen in accordance with ISO 17855-2 (2 mm thickness), strained at 50 mm/min.

^b The qualification test results can be accepted as production for the same batch.

Table 5 – Batch certificate

Content	Coating material		
	FBE	Adhesive	PE top coat
Identification of the manufacturer	x	x	x
Product identification	x	x	x
Batch identification	x	x	x
Date and place of manufacturing	x	x	x
Density	x	x	x
MFR		x	x
Gel time	x		
Particle size	x ^a		
Moisture/water content	x	x ^a	x ^a
Carbon black content			x
Pigment dispersion			x
Thermal characteristic	x		
Reactive site content		X ^{a,b}	
Infra-red scan in the form of a graph	x ^a		
^a If applicable. ^b Direct and indirect methods can be proposed by the manufacturer.			

Table 6 – Requirements for inspection of surface preparation

Item	Properties	Unit	Requirements	Test method	Frequency qualification	frequency production
1	Relative humidity	%	≤ 85	Calculation and direct measurement	Once at start up	Every 4 h
2	Pipe temperature before blasting	°C	higher than 5 °C and more than 3 °C above the dew point	Thermocouple	Once at start up	Every 4 h
3	Size, shape and properties of abrasive	--	Compliance to APS	Visual and certification ISO 11124 (all parts)	Once at start up	1 / shift
4	Water-soluble contamination of abrasives	μS/cm	Conductivity max. 60	ASTM D4940	Once at start up	1 / shift
5	Surface roughness of blasted surface (R_z/R_{y5})	μm	60 to 100	ISO 8503-4 or	5 pipes at start up	1 pipe / shift
				ISO 8503-5 ^a	5 pipes at start up	Every 1 h
6	Visual inspection of blasted surface	--	Grade Sa 2½	ISO 8501-1	Each pipe	Each pipe
7	Soluble salt after blasting	mg/m ²	Salt content (as NaCl) max. 20 ^b	ISO 8502-6 or ISO 8502-9 or ISO 11127-6 or SCM400	5 pipes at start up	Every 4 h
8	Chemical pre-treatment,			Clause 10.1.3	5 pipes at start up	2 / shift
	• Phosphoric acid concentration	% by volume	10 ± 3			
	• Phosphoric acid pressure spray application	bar	0.5 to 2.0			
	• Pipe temperature for treatment	°C	45 to 65			
	• Pipe surface pH over the entire surface of treated area	--	≤ 1			
	• Dwell time	second	10 to 30			
	• Rinse water pressure	psi (bar)	700 to 1000 (50 to 70)			
	• Rinse water chlorides	ppm	≤ 10			
	• Rinse water sulfates	ppm	≤ 40			
	• Rinse water nitrates	ppm	≤ 10			
• Rinse water total dissolved salts (TDS)	ppm	≤ 60				
• Pipe wet surface pH after rinsing	--	≥ 6				
9	Visual inspection of pipe prior to introduction to coating line	--	No rust	Visual	Each pipe	Each pipe
10	Temperature of extruded adhesive and PE	°C	Compliance to APS	Thermometer	Once at start up	Every 1 h
11	Preheating temperature before coating	°C	Compliance to APS	Contact thermometer or Optical pyrometer or Temperature-measuring crayon ^c	Each pipe	Each pipe

^a The Replica tape method may be used when a correlation is established with the Stylus (Profilometer) method with a cut-off length of 2.5 mm.

^b If the soluble salt content (as NaCl) to be measured after blasting is more than 20 mg/m², pre-washing and abrasive blast cleaning shall be re-done in accordance with Clause 10.1.1 and Clause 10.1.2.

^c Optical pyrometer and temperature-measuring crayons may be used when a correlation is established with the contact thermometer.

Table 7 – Requirements for inspection and testing of applied coating

Item	Properties	Unit	Requirements	Test method	Frequency qualification	Frequency production
1	FBE layer thickness ^a	µm	200 to 300	ISO 2808 or ASTM D4138	1 pipe at start up	1 pipe / shift
2	Adhesive layer thickness ^a	µm	150 to 250	ISO 2808 or ASTM D4138	1 pipe at start up	1 pipe / shift
3	Minimum total thickness of coating ^b , Pipe diameter, mm (in): • DN < 250 (10) • 250 (10) ≤ DN < 500 (20) • 500 (20) ≤ DN < 900 (36) • DN ≥ 900 (36)	mm	2.0 2.5 3.0 3.5	ISO 21809-1 (Annex A)	3 pipes at start up	4 pipes / shift
4	Appearance of coating	--	Uniform colour, free of defects and discontinuities, delaminations, separations	Visual	Each pipe	Each pipe
5	Continuity / Holiday detection (maximum speed: 0.3 m/s)	--	No holidays	ISO 21809-1 (Annex B)	Each pipe	Each pipe
6	Impact resistance, min	at 23±2 °C	7	ISO 21809-1 (Annex E)	3 pipes at start up and 1 pipe / 50 km	Once per PE batch
		at -30±3 °C	3	CSA Z245.20 Series-14 (Clause 12.12)	3 pipes at start up and 1 pipe / 50 km	N/A
7	Indentation, max	at 23±2 °C	0.2	ISO 21809-1 (Annex F)	3 pipes at start up and 1 pipe / 50 km	Once per PE batch
		at 80±3 °C	0.4		3 pipes at start up and 1 pipe / 50 km	Once per PE batch
8	Elongation at break at 23±2 °C, min	%	400	ISO 527-1 and -3	3 pipes at start up and 1 pipe / 50 km	Once per PE batch
9	Peel strength (Adhesion)	at 23±2 °C	Peeled surface shall be cohesive. No bare steel after peeling.	ISO 21809-1 (Annex C)	3 pipes at start up and 1 pipe / 50 km	3 pipes / shift
		at 80±3 °C				
10	Degree of cure of FBE (first layer), ΔTg	°C	-2 ≤ ΔTg ≤ +3	ISO 21809-1 (Annex D)	1 pipe at start up and 1 pipe / 50 km	1 pipe / shift
11	Product stability during application of the PE top layer process (In process degradation of PE)	%	ΔMFR ≤ 20 for PE (virgin compounded granulate before application / coating after application of the same batch)	ISO 1133-1 or ASTM D1238	1 pipe at start up and 1 pipe / 50 km	Once per PE batch
12	Average radius of cathodic disbondment, max	at 65±3 °C / 24 h / -3.5 V	5	ISO 21809-1 (Annex H)	3 pipes at start up and 1 pipe / 50 km	One of 300 pipes ^c
		at 23±2 °C / 28 d / -1.5 V	5		3 pipes at start up and 1 pipe / 50 km	N/A
		at 80±3 °C / 28 d / -1.5 V	12		3 pipes at start up and 1 pipe / 50 km	N/A
13	Flexibility	--	No cracking at an angle of 2.5° per pipe diameter length	ISO 21809-1 (Annex I)	1 pipe at start up and 1 pipe / 50 km	N/A
14	Hot water immersion test	mm	Average ≤2 and maximum ≤3	ISO 21809-1 (Annex M)	3 pipes at start up and 1 pipe / 50 km	One of 300 pipes ^c
15	Cutback, Pipe diameter, mm (in): • DN < 500 (20) • DN ≥ 500 (20)	mm	100 ± 10 150 ± 20	Measuring	Each pipe	Each pipe
16	Coating repairs	--	No holidays	Visual/Clause 12	Once for validation	Each defect

^a It is measured on part-coated pipes over the length of pipe partially coated at start-up.

^b The total thickness may be reduced by a maximum of 10 % on the weld seam for SAW welded pipes.

^c These tests can be performed on dummy pipes; e.g. end of lead pipes used for start up after interrupted coating application.