INTERNATIONAL STANDARD

ISO 21809-3

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Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems —

Part 3: Field joint coatings

Industries du pétrole et du gaz naturel — Revêtements externes des conduites enterrées ou immergées utilisées dans les systèmes de transport par conduites —

Partie 3: Revêtements des joints soudés sur site

Reference number
ISO 21809-3:2016(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

This second edition cancels and replaces the first edition (ISO 21809-3:2008), which has been technically revised. It also incorporates the Amendment ISO 21809-3:2008/Amd 1:2011.

ISO 21809 consists of the following parts, under the general title *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)*

— *Part 2: Single layer fusion-bonded epoxy coatings*

— *Part 3: Field joint coatings*

— *Part 4: Polyethylene coatings (2-layer PE)*

— *Part 5: External concrete coatings*

Multilayer fusion bonded epoxy coatings is to form the subject of future part 6.

Coating repairs on rehabilitation is to form the subject of future part 11.

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Introduction

Users of this part of ISO 21809 are to be aware that further or differing requirements can be needed for individual applications. This part of ISO 21809 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor is to identify any variations from this part of ISO 21809 and provide details.

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Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems —

Part 3: Field joint coatings

1 Scope

This part of ISO 21809 specifies requirements for field joint coating of seamless or welded steel pipes for buried and submerged sections of pipeline transportation systems used in the petroleum, petrochemical and natural gas industries as defined in ISO 13623. This part of ISO 21809 specifies the qualification, application and testing of the corrosion protection coatings applied to steel surfaces left bare after the joining of pipes and fittings (components) by welding.

This part of ISO 21809 defines and codifies in Table 1 the different types of field joint coatings for pipelines.

This part of ISO 21809 does not address requirements for additional mechanical protection, for thermal insulation or for joint infills of concrete weight-coated pipes.

NOTE Field joints of pipes and fittings coated in accordance with this part of ISO 21809 are considered suitable for further protection by means of cathodic protection.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 34-1, *Rubber, vulcanized or thermoplastic — Determination of tear strength — Part 1: Trouser, angle and crescent test pieces*

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 62, *Plastics — Determination of water absorption*

ISO 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 527-3, *Plastics — Determination of tensile properties — Part 3: Test conditions for films and sheets*

ISO 868, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 1431-1, *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static and dynamic strain testing*

ISO 1523, *Determination of flash point — Closed cup equilibrium method*

ISO 1817, *Rubber, vulcanized or thermoplastic — Determination of the effect of liquids*

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ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 2811-1, *Paints and varnishes — Determination of density — Part 1: Pyknometer method*

ISO 3251, *Paints, varnishes and plastics — Determination of non-volatile-matter content*

ISO 3303-1, *Rubber- or plastics-coated fabrics — Determination of bursting strength — Part 1: Steel-ball method*

ISO 3417, *Rubber — Measurement of vulcanization characteristics with the oscillating disc curemeter*

ISO 3801, *Textiles — Woven fabrics — Determination of mass per unit length and mass per unit area*

ISO 4591, *Plastics — Film and sheeting — Determination of average thickness of a sample, and average thickness and yield of a roll, by gravimetric techniques (gravimetric thickness)*

ISO 4593, *Plastics — Film and sheeting — Determination of thickness by mechanical scanning*

ISO 4624, *Paint and varnishes — Pull-off test for adhesion*

ISO 4625-1, *Binders for paints and varnishes — Determination of softening point — Part 1: Ring-and-ball method*

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 7619-1, *Rubber, vulcanized or thermoplastic — Determination of indentation hardness — Part 1: Durometer method (Shore hardness)*

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*

ISO 8501-3, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 3: Preparation grades of welds, edges and other areas with surface imperfections*.

ISO 8502-3, *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)*

ISO 8502-6, *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, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 9: Field method for conductometric determination of water-soluble salts*

ISO 8503-1, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*

ISO 8503-2, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel — Comparator procedure*

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ISO 8503-4, *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, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 5: Replica tape method for the determination of the surface profile*

ISO 8504-2, *Preparation of steel substrates before application of paints and related products — Surface preparation methods — Part 2: Abrasive blast-cleaning*

ISO 8504-3, *Preparation of steel substrates before application of paints and related products — Surface preparation methods — Part 3: Hand- and power-tool cleaning*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 11124 (all parts), *Preparation of steel substrates before application of paints and related products — Specifications for metallic blast-cleaning abrasives*

ISO 11126 (all parts), *Preparation of steel substrates before application of paints and related products — Specifications for non-metallic blast-cleaning abrasives*

ISO 11357-1, *Plastics — Differential scanning calorimetry (DSC) — Part 1: General principles*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and glass transition step height*

ISO 11357-3, *Plastics — Differential scanning calorimetry (DSC) — Part 3: Determination of temperature and enthalpy of melting and crystallization*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 21809-2, *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 80000-1:2009, *Quantities and units — Part 1: General*

EN 10204, *Metallic products — Types of inspection documents*

ASTM D70[1)], *Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)*

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*

ASTM D127, *Standard Test Method for Drop Melting Point of Petroleum Wax, Including Petrolatum*

ASTM D149, *Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies*

ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*

ASTM D695, *Standard Test Method for Compressive Properties of Rigid Plastics*

ASTM D937, *Standard Test Method for Cone Penetration of Petrolatum*

ASTM D938, *Standard Test Method for Congealing Point of Petroleum Waxes, Including Petrolatum*

ASTM D1000, *Standard Test Methods for Pressure — Sensitive Adhesive — Coated Tapes Used for Electrical and Electronic Applications*

1) American Society for Testing and Materials, 100 Harbour Drive, West Conshohocken, PA 19428-2959, USA.

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ASTM D1141, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D1321, *Standard Test Method for Needle Penetration of Petroleum Waxes*

ASTM D2084, *Standard Test Method for Rubber Property — Vulcanization Using Oscillating Disk Cure Meter*

ASTM D4285, *Standard Test Method for Indicating Oil or Water in Compressed Air*

ASTM D4541, *Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*

AWS C2.25/C2.25M[2], *Specification for Thermal Spray Feedstock Solid and Composite Wire and Ceramic Rods*

SSPC-SP1[3], *Surface preparation specification No.1 — Solvent cleaning*

SSPC CS 23.00*, Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminium, Zinc and Their Alloys and Composites for the Corrosion Protection of Steel*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
application procedure specification
APS
document describing procedures, methods, equipment and tools used for field joint coating application

3.2
applicator
company that undertakes the coating application in accordance with the provisions of this part of ISO 21809

3.3
batch
quantity of material produced in a continuous manufacturing operation using raw materials of the same source and grade

3.4
batch certificate
certificate of analysis issued by the manufacturer for a given batch

3.5
bonding agent
material applied as a film to the primed steel surface in order to ensure adhesion of the subsequent protective coating

3.6
inspection document
document issued in accordance with ISO 10474 (or EN 10204) stating compliance with the requirements given in the purchase order

3.7
coating operative
individual undertaking coating activity on the work site, including surface preparation

3.8
cutback
length of pipe left uncoated at each end for joining purposes (e.g. welding)

2) America Welding Society, 550 N.W. Le Jeune Road, Miami, Florida 33126, USA.

3) The Society for Protective Coatings, 40 24th Street, 6th Floor Pittsburgh, PA 15222-4656, USA.

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3.9
end user
company that owns and/or operates the pipeline system

3.10
field joint area
uncoated area that results when two pipe sections or a pipe section and a fitting with coating cutbacks are assembled by welding in the field

3.11
holiday
coating discontinuity that exhibits electrical conductivity when exposed to a specific voltage

3.12
inspection and testing plan
ITP
document providing an overview of the sequence of inspections and tests, including resources and procedures

3.13
inspector
end user and/or purchaser's representative responsible for one or more of the inspections specified in this part of ISO 21809

3.14
layer of tape
single wrap of tape without overlap

Note 1 to entry: Wrapping of a tape with 50 % overlap constitutes a two-layer coating.

3.15
manufacturer
company responsible for the manufacture of coating material

3.16
maximum service temperature of field joint coating
T_{max}
maximum continuous temperature that the field joint coating can resist during operation

3.17
maximum and minimum design temperature of pipeline
maximum and minimum operating temperature for which the pipeline has been designed

3.18
minimum service temperature of field joint coating
minimum temperature that the field joint coating can resist during operation and installation

3.19
overlap
length of the field joint coating over the plant-applied coating including the coating bevel

3.20
pipeline
those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances, up to and including the isolating valves

[SOURCE: ISO 13623]

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3.21
pipeline system
pipeline with compressor or pump stations, pressure control stations, flow control stations, metering, tankage, supervisory control and data acquisition system (SCADA), safety systems, corrosion protection systems, and any other equipment, facility or building used in the transportation of fluids

[SOURCE: ISO 13623]

3.22
pre-production trial
PPT
application of coating and inspection/testing of its properties immediately prior to start of production, to confirm that the APS is able to produce field joint coatings with the specified properties

3.23
primer
material applied as a film on substrate (steel and/or plant coating) to ensure adhesion of the subsequent protective coating

3.24
procedure qualification trial
PQT
application of a field joint coating and subsequent inspection/testing of its properties, to confirm that the APS is able to produce a coating with the specified properties, carried out at the premises of the applicator or any other agreed location

3.25
purchaser
company responsible for providing the product order requirements

3.26
wraparound sleeve
sleeve wrapped circumferentially around the steel pipe area being coated

4 Symbols and abbreviated terms

4.1 Symbols

c	bursting strength without heat ageing
B_{70}	bursting strength after heat ageing for 70 days
B_{100}	bursting strength after heat ageing for 100 days
C	percentage of conversion of FBE coating
ΔH	exothermic heat of reaction
ΔT_g	variation of glass transition temperature between two or more successive thermal analysis scans
E_0	elongation at break without heat ageing
E_{70}	elongation at break after heat ageing for 70 days
E_{100}	elongation at break after heat ageing for 100 days
P_0	peel strength to pipe surface without heat ageing

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P_{70} peel strength to pipe surface after heat ageing for 70 days

P_{100} peel strength to pipe surface after heat ageing for 100 days

P'_0 peel strength between layers without heat ageing

P'_{70} peel strength between layers after heat ageing for 70 days

P'_{100} peel strength between layers after heat ageing for 100 days

R_S specific electrical resistance of a coating

R_{S70} specific electrical resistance after 70 days

R_{S100} specific electrical resistance after 100 days

T_{max} maximum service temperature of field joint coating

4.2 Abbreviated terms

APS application procedure specification

DFT dry film thickness

DSC differential scanning calorimetry

EP epoxy

EPDM ethylene propylene diene monomer

FBE fusion-bonded epoxy

FJC field joint coating

HSS heat-shrink sleeve

ITP inspection and testing plan

MSDS material safety data sheet

PE polyethylene

PP polypropylene

PPT pre-production trial

PQT procedure qualification trial

PU polyurethane

PVC polyvinylchloride

TSA thermal spray aluminium

2LPE two-layer polyethylene coating

3LPE three-layer polyethylene coating

3LPP three-layer polypropylene coating

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5 General requirements

5.1 Responsibily of the end user

The end user shall be responsible for making or approving the appropriate selection of the FJC in accordance with the specified service conditions. He shall validate the information to be supplied by the purchaser as listed in Clause 6.

5.2 Rounding

Unless otherwise stated in this part of ISO 21809, to determine conformance with the specified requirements, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with ISO 80000-1:2009, Annex B, Rule A.

NOTE For the purposes of this provision, the rounding method of ASTM E29 is equivalent to ISO 80000-1:2009, Annex B, Rule A.

5.3 Compliance, testing and quality

Systems for quality and environmental management, and good laboratory practices, should be applied to assist compliance with the requirements of this part of ISO 21809.

NOTE 1 ISO/TS 29001 gives sector-specific guidance on quality management systems

NOTE 2 ISO 14001 gives guidance on the selection and use of an environmental management system.

NOTE 3 ISO/IEC 17025 gives guidance for testing laboratories.

6 Information to be supplied by the purchaser

6.1 General information

The purchase order shall include the following information:

— designation of this part of ISO 21809;

— type of field joint coating system in accordance with Table 1;

— minimum and maximum thickness of the field joint coating (if applicable);

— minimum and maximum design temperature of the pipeline;

— cutback length (or length of the field joint being coated), including tolerances;

— pipe material/grade;

— pipe nominal outer diameter and wall thickness;

— plant-applied coating system, including thickness;

— number of field joints to be coated;

— type and frequency of inspection document in accordance with ISO 10474 or EN 10204 (see 7.7).

6.2 Additional information

The purchase order shall specify which of the following provisions apply for the specific order item:

— permissible field joint coating repairs (see 9.5);

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— acceptable level of soluble salts (see 9.1.2.2);

— any special requirement with regard to FJC overall thickness and/or thickness of individual layers (see 10.5.2, 11.5.2, 12.5.2, 13.5.2, 16.5.3, 17.5.3, 18.5.2, 19.5.2);

— overlap on the parent (i.e. "plant-applied") coating or detailed drawing of the field joint coating with dimensional tolerances (see 17.5.3);

— requirements for traceability and marking;

— requirements for documentation and schedule of supply of documentation (see 7.7);

— qualification of the applicator's personnel who apply and/or inspect the coating (see 7.5);

— purchaser's approval of the application procedure specification (APS) (see 7.1);

— use of specific proprietary coating materials (see 7.2);

— procedure qualification trial (PQT) (see 7.3);

— pre-production trial (PPT) (see 7.4);

— subsequent coating (or infill) being applied;

— temperature range during installation;

— method of installation of the pipeline;

— time constraints for application and number and dimensions of working stations, if relevant;

— specific testing conditions and minimum requirements when applicable (e.g. cathodic disbondment or flexibility) (see.17.5.8, 17.5.10, etc.).

7 Application procedures and qualification

7.1 Application procedure specification (APS)

The applicator shall prepare an APS to be approved by the end user and/or purchaser prior to the start of production and prior to any agreed PQT and/or PPT (see 7.3 and 7.4). The responsibilities shall be clearly defined between all parties. Once approved, the APS shall not be changed without prior written authorization of the parties.

The APS shall include the following:

— identification of the coating;

— manufacturer's instructions for application, including the acceptable temperature range during installation;

— preparation of steel surface and plant-applied coating, including inspection (see 9.1);

— data sheets defining coating and abrasive blasting material properties, including all health and safety data (see 7.2 and 9.1.2.2);

— maximum service temperature, T_{max}, of field joint coating;

— receipt, handling and storage of coating and abrasive blasting materials (see 7.2 and 9.1.2.2);

— coating application procedure, tools and equipment;

— overlap (with tolerances) of FJC over plant coating (a drawing should be considered for certain types of FJC);

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— time required for coating application;

— inspection and testing of applied FJC;

— repair and testing of defective FJC;

— stripping of defective FJC;

— marking, traceability and documentation.

The APS shall cover all items associated with quality control as defined in this part of ISO 21809 and any agreed options for the specific FJC.

All coating work, testing and inspection shall be carried out according to the APS.

7.2 Coating materials

The applicator shall provide the data sheets specified in Clauses 10 to 20 for each coating material from the manufacturer.

In addition to the coating-material data sheets, the applicator shall provide the following information from the manufacturer:

— batch certificates certifying that the coating materials delivered meet the coating characteristics as set forth in the coating data sheets;

— any agreed optional requirements, if applied according to the manufacturer's instructions;

— packaging, transport and storage requirements of coating materials;

— range of application conditions including minimum and maximum application temperatures (for materials and substrate) and relative humidity;

— material safety data sheet (MSDS).

Marking on each shipment of coating materials shall contain the following information:

— manufacturer's name;

— name and complete identification of material, including plant of origin;

— reference to applicable coating-material standards, if any;

— production batch number;

— mass/size;

— date of production;

— expiry date.

7.3 Procedure qualification trial (PQT)

If specified by the purchaser or otherwise required by this part of ISO 21809, the APS shall be qualified by a PQT. Test methods and frequencies for PQT are specified in Annex A. Acceptance criteria are given in the relevant clauses referred to in Annex A.

The applicator may request the manufacturer(s) to assist during the PQT to ensure the correct use of the coating material(s) and to train applicator personnel.

PQT may be carried out independently of any project. In this case, representative pipes having the diameter, thickness and plant-coating as agreed upon between manufacturer, applicator, end user and purchaser, if any, shall be used.

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For a PQT related to a specific project, tests shall be carried out on test zones distributed along a pipe coated with the actual plant-applied coating. The length of the test zones shall be equivalent to the field joint coating length. The test points shall be defined in the PQT programme.

If not present, a circumferential cap weld shall be added at the centre of each of the test zones to simulate the field weld.

If heating of the area to be coated is specified in the APS, it shall be demonstrated that there is no visual detrimental effect such as blistering or disbondment of the plant-applied coating.

All tools and equipment (e.g. for induction heating, abrasive blasting, coating application and inspection) being used for PQT shall be of the same type as those being used for the actual field joint coating.

Unless otherwise specified, at least three test zones shall be coated.

Coating repairs and stripping of defective FJC shall be included in PQT if they are allowed.

The time for coating application during PQT shall be consistent with the estimated field joint coating time in the field. Any significant differences in the PQT environment compared to actual production conditions should be considered, e.g. number of work stations, lifting equipment.

For pipelines that experience deformations above 0,3 % during handling or installation (e.g. reeling), the PQT shall include relevant tests carried out after pipe deformation. The test temperature shall be at least 5 °C below minimum deformation temperature.

The applicator shall submit a complete report of the qualification test results to the purchaser for approval.

7.4 Pre-production trial (PPT)

If specified by the purchaser or otherwise required by this part of ISO 21809, a PPT shall be performed on site to verify the following:

— surface condition and adhesion of the plant-applied coating on steel in the vicinity of the cut-backs;

— field joint coating materials;

— application procedure;

— equipment being used for surface preparation and coating application;

— heating equipment (when used);

— application of the coating system;

— qualification of the coating operatives and purchaser's inspectors that will actually be used in the field;

— properties of the applied FJC.

The above shall comply with the requirements of this part of ISO 21809 and the results of any previous PQT.

Test methods and frequencies for PPT are specified in Annex A. Acceptance criteria are given in the relevant clauses to which reference is made in Annex A.

The PPT shall be carried out in presence of the end user and/or purchaser (or their representative) at the start of operations when equipment and personnel are mobilized on site. The PPT shall be performed on the first joints to be coated or, if agreed, on a dummy pipe.

The applicator shall submit a complete report of the tests containing the values and other results obtained in the PPT.

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7.5 Qualification of coating and inspection personnel

The coating operatives shall be qualified to undertake the coating application procedure and repair work. The qualification may be obtained by demonstration during PQT, during PPT, through a certification organization or as agreed with the end user.

The applicator shall request the manufacturer of the coating material(s) and equipment to provide technical assistance to the coating operatives if necessary.

Inspectors and applicator personnel carrying out the coating inspection shall be trained and qualified. Proof of successful qualification shall be documented.

7.6 Production testing and inspection

The applicator shall perform inspection and testing during production in accordance with an ITP to verify the surface preparation, coating application and the specified properties of the applied FJC.

The ITP shall be prepared by the applicator and shall be approved by the purchaser prior to the start of the coating work and prior to the start of any PQT and/or PPT. The ITP shall identify all inspection activities and tests, their frequency and the relevant inspection authorities.

Test methods and frequencies are specified in Annex A. Acceptance criteria are given in the relevant clauses to which reference is made in Annex A.

7.7 Inspection documents and traceability

The inspection documents shall be in accordance with ISO 10474 or EN 10204. The type of certificate of compliance shall be defined in the purchase order.

FJC reports shall identify each field joint by a unique number for identification purposes and shall record the material batch number for traceability. Test results shall be linked to the field joint number or repair on which they were performed. Records shall be maintained on a shift and daily basis and shall be available for inspection by the purchaser and/or end user.

The inspection documents signed by the applicator (and the inspector, if applicable) shall be transmitted to the purchaser at a frequency defined in the purchase order. Cumulative production records shall be maintained daily.

8 Classification of field joint coatings

The FJC types covered by this part of ISO 21809 are classified in Table 1.

Table 1 — FJC types

Clause	Code	Type of field joint coating
10	10	Hot-applied bituminous tape coatings
11	11A	Petrolatum tape coatings
	11B	Wax-based tape coatings
12	12	Cold-applied polymeric tape coatings
13	13A	Non-crystalline low-viscosity polyolefin based coatings with polymeric tape outer wrap
	13B	Non-crystalline low-viscosity polyolefin based coatings with heat shrinkable material outer wrap

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Table 1 *(continued)*

Clause	Code	Type of field joint coating
14	14A	Coatings based on heat-shrinkable materials, polyethylene-base, applied without primer
	14B	Coatings based on heat-shrinkable materials, polyethylene-based, applied over a liquid epoxy, fusion-bonded epoxy, or other compatible primer layer
	14C	Coatings based on heat-shrinkable materials, polyolefin-based, with reinforced backing (hybrid), applied over a liquid epoxy, fusion-bonded epoxy, or other compatible primer layer
	14D	Coatings based on heat-shrinkable materials, polypropylene-based, applied over a liquid epoxy, fusion-bonded epoxy, or other compatible primer layer
15	15	Hot-applied microcrystalline wax coatings
16	16A	Elastomeric coatings, polychloroprene-based
	16B	Elastomeric coatings, EPDM-based
17	17A	Single-layer fusion-bonded epoxy powder coatings
	17B	Two-layer fusion-bonded epoxy powder coatings
18	18A	Liquid applied epoxy based coatings
	18B	Liquid applied polyurethane based coatings
	18C	Fibre-reinforced epoxy based coatings
	18D	Fibre-reinforced vinylester based coatings
	18E	Cast solid polyurethane based coatings
19	19A	Coatings based on flame-sprayed polypropylene powder applied over an epoxy layer
	19B	Coatings based on polypropylene tapes/sheets hot-applied over an epoxy layer
	19C	Coatings based on injection-moulded polypropylene over an epoxy layer
	19D	Coatings based on flame-sprayed polyethylene powder applied over an epoxy layer
	19E	Coatings based on polyethylene tapes/sheets hot-applied over an epoxy layer
20	20	Thermal spray aluminium (TSA) coatings

The FJC shall be compatible with the plant-applied coating and ensure continuity of corrosion protection.

The weld geometry and structure shall be taken into consideration during the selection of the FJC system.

The maximum service temperature, T_{max}, of the FJC shall be equal to or greater than the maximum design temperature of the pipeline.

The FJC shall be compatible with the minimum operating temperature of the pipeline and the minimum ambient temperature during transportation and handling during the construction of the pipeline.

9 General requirements for surface preparation, coating application, testing and repair

9.1 Surface preparation

9.1.1 General

Surface preparation shall be carried out in accordance with the APS and as detailed below.

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9.1.2 Preparation of the steel substrate

9.1.2.1 General

Prior to the coating application, the surface shall be dry and free of any contamination (such as detritus, dust, non-adhering particles, grease, oil, soluble salts) detrimental to surface preparation or to adhesion of the coating on the steel.

Oil, grease and wax shall be removed by solvent cleaning in accordance with SSPC-SP1.

All visible surface imperfections of substrate caused by the girth welding operation, such as welding slag and spatter, sharp edges or burrs that could damage the coating, detected before or during surface preparation shall be removed by an approved grinding method or filing techniques according to the following grades:

— P3 of standard ISO 8501-3 for components and fittings to be used in submerged conditions (permanent or intermittent);

— P2 of standard ISO 8501-3 for components and fittings to be used in buried conditions.

Grinding of steel defects shall not reduce the wall thickness below the specified minimum wall thickness of the pipe.

Areas of rust or scaling shall be removed by spot abrasive blast-cleaning or wire brushing as specified in the APS.

9.1.2.2 Abrasive blast-cleaning

Abrasives used in the preparation of field joints shall comply with ISO 11124 or ISO 11126.

Compressed air for blast-cleaning shall be free of oil, condensed moisture and any other contaminants, and shall conform to the requirements of ASTM D4285.

Reclaimed abrasive blast materials shall not be used unless automatic reclaiming equipment is used. Blasting equipment that includes devices to recycle abrasives shall have equipment that ensures removal of dust, fines, corrosion products and other contaminants.

The cleanliness shall be checked in accordance with the requirements of ISO 8501-1. Acceptance criteria are given for each system in Clauses 10 to 20.

NOTE

— Sa 3 is approximately equivalent to NACE No.1/SSPC-SP5 (White metal blast cleaning).

— Sa 21/2 is approximately equivalent to NACE No.2/SSPC-SP10 (Near-white metal blast cleaning).

— Sa 2 is approximately equivalent to NACE No.3/SSPC-SP6 (Commercial blast cleaning).

The profile/roughness shall be checked in accordance with the requirements of ISO 8503-5. Acceptance criteria are given for each system in Clauses 10 to 20. Other methods (see ISO 8503-1, ISO 8503-2, ISO 8503-3 and ISO 8503-4) may be used if correlated with ISO 8503-5. The profile shall be of an angular and dense nature.

In areas where the roughness of the profile does not meet these requirements, the surface shall be reblasted.

The level of soluble salts measured in accordance with the requirements of ISO 8502-6 or ISO 8502-9 shall be ≤20 mg/m^2 for coating types 14B, 14C, 14D, 16, 17, 18, 19 and 20. It is not necessary to measure the level of soluble salts on the steel surface for the other coating types.

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Testing of the soluble-salt level during production may be reduced or omitted by agreement between applicator and end user or purchaser, if the PPT has demonstrated that the application procedure ensures a salt level below these requirements.

9.1.2.3 Wire-brush cleaning

If wire-brush cleaning is permissible (see 9.1.1), it shall be performed in accordance with ISO 8504-3. The surface preparation shall be in accordance with ISO 8501-1 grade St 3 using a power tool.

Manual wire-brush cleaning shall be allowed only if the manufacturer of the FJC requires a degree of cleanliness of ISO 8501-1 grade St 2 and if defined in the APS.

NOTE

— St 2 is approximately equivalent to SSPC-SP2 (Hand tool cleaning).

— St 3 is approximately equivalent to SSPC-SP3 (Power tool cleaning) or SSPC-SP11 (Power tool cleaning down to bare metal).

9.1.2.4 Final check and preparation of the steel surface

Dust contamination shall be measured in accordance with ISO 8502-3. Acceptance criteria are given for each FJC type in Clauses 10 to 20.

Chemical treatment of the steel may be used by agreement between the applicator and the purchaser and/or end user, subject to the manufacturer's recommendation.

9.1.3 Preparation of the adjacent plant-applied coating

The plant-coated area adjacent to the cutback shall be prepared to ensure the adhesion of the field joint coating in accordance with Clauses 10 to 20 for each of the different FJC types.

9.2 Application of the coating

The temperature of the substrate shall be at least 3 °C above the dew point.

The coating shall be applied by qualified personnel and in accordance with the APS. The coating shall be applied symmetrically and with approximately equal overlaps onto the plant-applied coating on either side.

Following surface preparation, the surface being coated shall not be exposed for a length of time that can result in flash rust detrimental to the quality of the coating.

At the time of application of the coating, the temperature of the substrate shall be within the temperature range specified in the APS. The temperature of the field joint shall be monitored to ensure that the application conditions are fully satisfied and are uniform across the steel substrate and the plant-applied coating. The methods of monitoring and recording shall be defined in the APS.

During adverse weather conditions, cleaning and coating operations shall be stopped unless protective enclosures are installed that maintain the field joint area in a clean and dry condition as specified in the APS throughout the surface preparation and coating application and curing.

9.3 Visual inspection of the applied coating

The applied coating shall be free of anomalies, contain no surface defects detrimental to the quality of the coating (grit, foreign particles, fish eyes, blisters, etc.) and have approximately equal overlaps onto the plant coating on either side.

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9.4 Testing of the field joint coating

Inspection and testing shall be carried out during production in accordance with the agreed ITP. Test procedures and acceptance criteria are defined in Clauses 10 to 20 for different FJC types. Testing frequencies are given in Annex A.

Damaged areas created by testing shall be repaired in accordance with 9.5.

9.5 Repairs

The acceptable size and frequency of field joint coating repairs and the repair procedures shall be subject to agreement between the purchaser and the applicator.

FJC materials and repair procedures shall be included in the APS.

9.6 Verification, handling and storage of coating materials

The applicator shall ensure that the materials used for surface preparation and the coating(s) comply with the material specification and that the manufacturer's handling and storage instructions are followed.

10 Hot-applied bituminous tape coatings

10.1 Coating identification

Hot-applied bituminous tape coatings (FJC Type 10) shall be identified in the APS in accordance with Table 2 and shall meet the requirements of Table 3.

Data sheets for the coating materials shall be in accordance with Table 4 (primer) and Table 5 (tape).

Application instructions shall be provided by the manufacturer in accordance with Table 6.

10.2 Description of the coatings

Bituminous tape coatings consist of a single layer or multiple layers of fusible bituminous tape, hot-applied, with or without a primer. Maximum service temperature is 30 °C.

10.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS. The edges of the plant coating shall be bevelled and the plant coating shall be roughened for the minimum length according to the overlap on the plant coating (10.4.4).

The area being coated shall be cleaned by mechanical rotary wire brush to a minimum of grade St 3 as defined in ISO 8501-1. Alternatively, surface preparation can be achieved by abrasive blast-cleaning to a minimum grade of Sa 2 as defined in ISO 8501-1.

Dust contamination shall be grade 3 or better, measured in accordance with ISO 8502-3.

10.4 Coating application

10.4.1 General

Application of the coating shall be carried out in accordance with the APS.

10.4.2 Application of the primer

If applicable, application of the primer shall be carried out in accordance with the APS.

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10.4.3 Application of the bituminous tapes

Application shall be carried out in accordance with the APS. As a general guideline, the following procedure shall be followed.

— Clean the area being coated with the approved cleaning method.

— Pre-heat it to a temperature recommended by the manufacturer.

— Verify the temperature of the substrate using a temperature-measuring device (e.g. hand-held thermocouple).

— Apply a thin coat of compatible primer; allow the primer to dry.

— Cut a sufficient length of bituminous tape (circumference plus 50 mm for overlap).

— If necessary, pre-heat again the surface being coated.

— Heat the bituminous side of the tape until the bitumen becomes liquid and put it with this side down on the surface being coated.

— Heat additionally the outer side and smooth the overlap.

— Install the required number of pre-cut sheets side by side, with the prescribed overlap, including the required overlap on the plant-applied coating

— If it is necessary to install a second layer of bituminous tape, heat the surface of the first layer and smooth it until the anti-adhesive coat is incorporated.

— Install the second layer of bituminous tape.

10.4.4 Overlap

The minimum tape overlap shall be in accordance with Table 7, or the manufacturer's required overlap (Table 6) if greater.

The overlap of tape on plant-applied coating shall be in accordance with the manufacturer's application instructions (Table 6) and shall be at least 50 mm.

The width of the tape used depends on the diameter of the pipes. For all types of manual application, an appropriate width shall be chosen to avoid wrinkling of the tape, which can occur if the tape is too wide.

10.5 Testing of the applied coatings

10.5.1 General

The tests in 10.5.2 to 10.5.10 shall be carried out for production quality control, and for PQT and PPT if required.

10.5.2 Thickness

The nominal thickness is the calculated sum of the thickness of all the layers of the coating before application. The minimum thickness of the coating on the body of the joint shall be not less than 90 % of the nominal value or as otherwise agreed to by the purchaser.

Unless otherwise agreed with the purchaser, the minimum thickness on the weld cap shall be not less than 0,6 mm.

NOTE The coating thickness on the weld cap is normally less than on the body because some of the polymeric adhesive flows from the weld cap to the body, both during and after the application. This is necessary to prevent voids in the coating and is not detrimental to the corrosion protection.

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The coating thickness shall be measured using the method given in Annex B.

10.5.3 Holiday detection

The entire surface of the coated joint shall be checked for holidays or other discontinuities according to the method defined in Annex C at a voltage of 5 kV/mm + 5 kV to a maximum of 25 kV. The voltage shall never exceed the acceptable voltage for the plant-applied coating.

Holidays shall be repaired in accordance with the APS.

10.5.4 Impact resistance

The impact resistance shall be measured using the method given in Annex D and shall meet the requirements of Table 3.

10.5.5 Indentation resistance

The indentation resistance shall be measured using the method given in Annex E and shall meet the requirements of Table 3.

10.5.6 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured using the method given in Annex F and shall meet the requirements of Table 3.

10.5.7 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 3.

10.5.8 Peel strength to pipe surface and plant coating

The minimum waiting period between application of the coating and the peel strength test shall be 24 h, unless specified otherwise by the manufacturer.

The peel strength shall be measured using the methods given in Annex H and shall meet the requirements of Table 3. The method given in H.1 should preferably be used for PQT. The method given in H.2 can be used for PPT and production testing, as well as for PQT in agreement with purchaser.

Failure shall not occur at the interface between steel and adhesive, except for a peeling strength 50 % higher than the values listed in Table 3.

10.5.9 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I.

The peel strength after the hot-water immersion test shall be measured using the method given in H.1 and shall meet the requirements of Table 3.

10.5.10 Lap shear strength

The lap shear strength resistance shall be measured using the method given in Annex J and shall meet the requirements of Table 3.

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Table 2 — Coating identification

Property
Coating trade name
FJC Type and code as per Table 1
Maximum and minimum service temperature
Primer trade name
Number of layers[a]
Trade names of all layers
Nominal thickness of the coating system
Compatible plant coatings[b]

[a] Excluding primer.

[b] State all types of plant coatings that have been tested successfully with the coating.

Table 3 — Requirements for Type 10 — Hot-applied bituminous tape

Property	Test temperature °C	Unit	Requirements	Test method
Thickness	—	mm	≥0,9 × nominal value	Annex B
Holiday detection at 5 kV/mm + 5 kV, max. 25 kV	—	—	no holiday	Annex C
Impact resistance	23	J/mm	≥2	Annex D
Indentation resistance, pressure		N/mm^2	1,0	Annex E
— Residual thickness	23	mm	≥0,6	
Specific electrical insulation resistance				
— R_{S100}	23	$\Omega \cdot m^2$	$\geq 10^6$	Annex F
— R_{S100}/R_{S70}		—	≥0,8[a]	
Cathodic disbondment resistance, 28 days	23	mm	≤20	Annex G
Peel strength				
— to steel surface[b]	23	N/mm	≥0,4	Annex H
— to plant coating	23	N/mm	≥0,2	
— plant coating after 28-day hot-water immersion test at 30 °C	23	N/mm	≥0,1	Annex I
— steel surface after 28-day hot-water immersion test at 30 °C	23	N/mm	≥0,2	
Lap shear strength	23	N/mm^2	≥0,05	Annex J

[a] This requirement is only applicable if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.

[b] If the result is less than 0,4 N/mm, residual thickness of bituminous compound on the pipe surface or plant coating shall be ≥0,25 mm.

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Table 4 — Data sheet — Primer

Property	Unit	Test method
Primer trade name	—	—
Generic type	—	—
Solid content	%	ISO 3251
Type of solvent	—	—
Flash point	°C	ISO 1523
Density	g/cm^3	ISO 2811-1
Coverage area	m^2/l	—
Dry film thickness	µm	ISO 2808
Storage conditions		
— temperature, minimum	°C	—
— temperature, maximum	°C	—
Shelf life at storage temperature	month	—

Table 5 — Data sheet[a] — Tape

Property	Unit	Test method
Trade name	—	—
Description of coating material	—	—
Colour	—	—
Minimum total thickness	mm	ISO 4591 and ISO 4593
or		
Surface density[b]	g/m^2	ISO 3801
Polymeric film/reinforcement		
— generic type of polymeric film	—	—
— generic type of reinforcement material	—	—
— nominal thickness, or	mm	ISO 4591 and ISO 4593
— surface density	g/m^2	ISO 3801
Adhesive		
— generic type	—	—
— nominal thickness or	mm	ISO 4591 and ISO 4593
— surface density	g/m^2	ISO 3801
— softening point ring and ball[c]	°C	ISO 4625-1
Mechanical properties		
— tape strength	N/mm	ISO 527-3
— modulus at 10 % elongation[c]	N/mm	
— elongation at break[c]	%	
Storage conditions		
— temperature, minimum	°C	—
— temperature, maximum	°C	—

[a] Data according to this data sheet shall be supplied for each coating component.

[b] Also called "mass per unit area," a deprecated designation.

[c] If applicable.

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Table 5 *(continued)*

Property	Unit	Test method
Shelf life at storage temperature	month	—
[a] Data according to this data sheet shall be supplied for each coating component.		
[b] Also called "mass per unit area," a deprecated designation.		
[c] If applicable.		

Table 6 — Application instructions

Property	Unit
Ambient conditions	
— minimum temperature	°C
— maximum temperature	°C
— relative humidity	%
Surface preparation — steel surface	
— cleanliness (ISO 8501-1)	—
— profile in case of abrasive blast-cleaning (ISO 8503-2)	—
— Surface preparation — plant coating	—
Application of primer	
— method	—
— minimum surface temperature	°C
— maximum surface temperature	°C
— pot life	h
— minimum overcoating time	h or min
— maximum overcoating time	days or h
— curing temperature	°C
Application of tape	
— method	—
— minimum material temperature	°C
— minimum overlap of tape	% or mm
General	
— minimum overlap on plant coating[a]	mm
— specific application instructions	—
— holiday detection voltage	kV
— repair procedure	—
[a] It is necessary that this be given for each compatible plant coating.	

Table 7 — Overlap of tape

Tape width	Overlap
<50 mm	≥50 %
≥50 mm	≥25 mm

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11 Petrolatum and wax-based tape coatings

11.1 Coating identification

Petrolatum and wax-based tape coatings (FJC Types 11A and 11B) shall be identified in the APS in accordance with Table 2 and shall meet the requirements of Table 8 for petrolatum tape coatings (Type 11A) or Table 9 for wax tape coatings (Type 11B).

Data sheets for the coating materials shall be in accordance with Table 4 (primer) and Table 5 (tape).

Application instructions shall be provided by the manufacturer in accordance with Table 6.

11.2 Description of the coatings

11.2.1 Petrolatum tapes (Type 11A)

Petrolatum tape coatings consist of a single layer or multiple layers of petrolatum tapes, with or without a primer.

The use of any outerwrap is possible if agreed by the manufacturer and the end user.

Maximum service temperature is 30 °C.

A T_{max} higher than 30 °C can be agreed between the end user and the manufacturer.

11.2.2 Wax-based tapes (Type 11B)

Wax-based tape coatings consist of a primer and a single layer or multiple layers of wax-based tapes.

The use of any outerwrap is possible if agreed by the manufacturer and the end user.

Maximum service temperature is 30 °C.

A T_{max} higher than 30 °C can be agreed between the end user and the manufacturer.

11.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS. The edges of the plant coating shall be bevelled and the plant coating shall be roughened for the minimum length according to the overlap on the plant coating (11.4.4).

The area being coated shall be cleaned according to ISO 8501-1, grade St 2, by hand-tool cleaning as described in ISO 8504-3.

Alternatively, surface preparation can be achieved by abrasive blast-cleaning to a minimum grade of Sa 1 as defined in ISO 8501-1.

Dust contamination shall be grade 3 or better, measured in accordance with ISO 8502-3.

11.4 Coating application

11.4.1 General

Application of the coating shall be carried out in accordance with the APS.

11.4.2 Application of the primer

If applicable, application of the primer shall be carried out in accordance with the APS.

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11.4.3 Application of petrolatum or wax-based tapes

Application shall be carried out in accordance with the APS. As a general guideline, the following application procedure shall be followed.

— Wipe the surface to remove visible moisture.

— Prepare the surface.

— Apply a thin coat of compatible primer (if any) by brush, by hand or using other applicable tools.

— Spirally wrap the area being coated with tapes of recommended width, employing the correct overlap and ensuring the complete coverage and adherence of the coating to the pipe surface.

— Apply any outerwrap if applicable.

11.4.4 Overlap

The minimum tape overlap shall be in accordance with Table 7, or the manufacturer's required overlap (Table 6) if greater.

The overlap of tapes on plant-applied coating shall be in accordance with the manufacturer's application instructions (Table 6) and shall be at least 50 mm.

The width of the tape used depends on the diameter of the pipes. For all types of manual application, an appropriate width shall be chosen to avoid wrinkling of the tape, which can occur if the tape is too wide.

11.5 Testing of the applied coatings

11.5.1 General

The tests in 11.5.2 to 11.5.10 shall be carried out for production quality control, and for PQT and PPT if required.

11.5.2 Thickness

The nominal thickness is the calculated sum of the thickness of all the layers of the coating before application. The minimum thickness of the coating on the body of the joint shall be not less than 90 % of the nominal value or as otherwise agreed to by the purchaser.

Unless otherwise agreed with the purchaser, the minimum thickness on the weld cap shall be not less than 0,6 mm.

NOTE The coating thickness on the weld cap is normally less than on the body because some of the polymeric adhesive flows from the weld cap to the body, both during and after the application. This is necessary to prevent voids in the coating and is not detrimental to the corrosion protection.

The coating thickness shall be measured using the method given in Annex B.

11.5.3 Holiday detection

The entire surface of the coated joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm to a maximum of 25 kV according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS.

11.5.4 Impact resistance

The impact resistance shall be measured using the method given in Annex D and shall meet the requirements of Table 8 or 9.

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11.5.5 Indentation resistance

The indentation resistance shall be measured using the method given in Annex E and shall meet the requirements of Table 8 or 9.

11.5.6 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured using the method given in Annex F and shall meet the requirements of Table 8 or 9.

11.5.7 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 8 or 9.

11.5.8 Peel strength to pipe surface and plant coating

The minimum waiting period between application of the coating and the peel strength test shall be 1 h, unless specified otherwise by the manufacturer.

Petrolatum and wax-based tapes shall leave a film of compound, visible without magnification, on the entire surface of the substrate when the coating is peeled off.

11.5.9 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I.

Petrolatum and wax-based tapes shall leave a film of compound on the substrate when peeled off after the hot-water immersion test.

11.5.10 Drip resistance

No dripping of the compound shall occur when the tape is tested in accordance with Annex K for types 11A and 11B as listed in Table 8 or 9.

Table 8 — Requirements for Type 11A — Petrolatum tape

Property	Test temperature °C	Unit	Requirements	Test method
Thickness	—	mm	≥0,9 × nominal value	Annex B
Holiday detection at 5 kV/mm max. 25 kV	—	—	no holiday	Annex C
Impact resistance	23	J/mm	≥0,8	Annex D
Indentation resistance, test pressure — Residual thickness	 23	N/mm^2 mm	0,1 ≥0,6	Annex E
Specific electrical insulation resistance — R_{S100} — R_{S100}/R_{S70}	23	$\Omega \cdot m^2$ —	$\geq 10^6$ ≥0,8[a]	Annex F
Cathodic disbondment resistance at 28 days	23	mm	≤ 20	Annex G

[a] This requirement is only applicable if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.

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Table 8 *(continued)*

Property	Test temperature °C	Unit	Requirements	Test method
Peel strength to pipe surface and plant coating	23	—	leave a film of compound on the substrate	—
Peel strength to steel and plant coating before and after 28-day hot-water immersion test at 30 °C	23	—	leave a film of compound on the substrate	Annex I
Drip resistance	45	—	no dripping of compound	Annex K

[a] This requirement is only applicable if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.

Table 9 — Requirements for Type 11B — Wax-based tape and primer

Property		Test temperature °C	Units	Requirements	Test method
Primer					
Congeal point		—	°C	>55	ASTM D938
Flash point		—	°C	≥65	ASTM D92
Density		25	g/cm^3	<1	ASTM D70
Cone penetration		25	mm	7,5 to 25	ASTM D937
Dielectric strength		—	V/µm	≥4	ASTM D149
Tape					
Congeal point of saturant		—	°C	>65	ASTM D938
Flash point of saturant		—	°C	≥60	ASTM D92
Thickness		—	mm	>1,75	ASTM D1000
Dielectric strength		—	V/µm	>6,6	ASTM D149
Drip resistance		45	—	No dripping of compound	Annex K
Complete coating					
Holiday detection at 5 kV/mm, max. 25 kV		—	—	no holiday	Annex C
Impact resistance		23	J/mm	≥0,8	Annex D
Indentation resistance, test pressure		23	N/mm^2	0,1	Annex E
— Residual thickness			mm	≥0,6	
Specific electrical insulation resistance	R_{S100}	—	Ω·m^2	≥10^6	Annex F
	R_{S100}/R_{S70}		—	≥0,8[a]	
Cathodic disbondment resistance at 28 days		23	mm	<12	Annex G
Peel strength to pipe surface and plant coating		23	—	Leave a film of compound on the substrate	11.5.8
Peel strength to steel and plant coating before and after 28-day hot-water immersion test at 30 °C		23	—	Leave a film of compound on the substrate	Annex I and 11.5.8

[a] This requirement is only applicable if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.

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12 Cold-applied polymeric tape coatings

12.1 Coating identification

Cold-applied polymeric tape coatings (FJC Type 12) shall be identified in the APS in accordance with Table 2 and shall meet the requirements of Table 10. Data sheets for the coating materials shall be in accordance with Table 4 (primer) and Table 5 (tape).

Application instructions shall be provided by the manufacturer in accordance with Table 6.

12.2 Description of the coatings

Cold-applied polymeric tape coatings consist of several layers of one or more polymeric tapes, with or without a primer.

This coating type can be further subdivided into the following:

— **12-1:** with a T_{max} not greater than 50 °C;

— **12-2**: with a T_{max} not greater than 80 °C;

— **12-3**: with a T_{max} not greater than 120 °C.

The T_{max} shall be stated in brackets, e.g. FJC Type 12-1(30) or FJC Type 12-1(50).

A T_{max} higher than 120 °C can be agreed as long as the requirements of Table 10 are met.

12.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS. The edges of the plant coating shall be bevelled and the plant coating shall be roughened for the minimum length according to the overlap on the plant coating (12.4.4).

The area being coated shall be cleaned by abrasive blast-cleaning as described in ISO 8504-2 to a minimum grade Sa 2 according to ISO 8501-1. The profile/roughness shall be in accordance with the manufacturer's application instructions.

For FJC Type 12-1, surface preparation can be achieved by power tool cleaning as described in ISO 8504-3 to a minimum of grade St 3 according to ISO 8501-1, by agreement of the end user.

Dust contamination shall be grade 3 or better, measured in accordance with ISO 8502-3.

12.4 Coating application

12.4.1 General

Application of the coating shall be carried out in accordance with the APS.

12.4.2 Application of the primer

If applicable, application of the primer shall be carried out in accordance with the APS.

12.4.3 Application of polymeric tapes

Application shall be carried out in accordance with the APS. As a general guide, the following application procedure shall be followed.

— Prepare the surface according to the approved method.

— Apply a thin coat of compatible primer (if any); allow the primer to dry.

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— Spirally wrap the area being coated with tapes of an adequate width, employing the right overlap and using sufficient tension to ensure a complete conformability of the coating. Any tenting effect shall be prevented. A manual application tool should be used to achieve these goals.

A single piece of wrapping wide enough to cover the required area may be used in certain circumstances (in particular, for offshore installation on a conventional barge).

12.4.4 Overlap

The minimum tape overlaps shall be in accordance with Table 7, or the manufacturer's required overlap (Table 6) if greater.

The overlap of tape on plant-applied coating shall be in accordance with the manufacturer's application instructions (Table 6) and shall be at least 50 mm.

The width of the tape used depends on the diameter of the pipe. For all types of manual application, an appropriate width shall be chosen to avoid wrinkling of the tape, which can occur if the tape is too wide.

12.5 Testing of the applied coatings

12.5.1 General

The tests in 12.5.2 to 12.5.11 shall be carried out for production quality control, and for PQT and PPT if required.

12.5.2 Thickness

The nominal thickness is the calculated sum of the thickness of all the layers of the coating before application. The minimum thickness of the coating on the body of the joint shall be not less than 90 % of the nominal value or as otherwise agreed to by the purchaser.

Unless otherwise agreed with the purchaser, the minimum thickness on the weld cap shall be not less than 0,6 mm.

NOTE The coating thickness on the weld cap is normally less than on the body because some of the polymeric adhesive flows from the weld cap to the body, both during and after the application. This is necessary to prevent voids in the coating and is not detrimental to the corrosion protection.

The coating thickness shall be measured using the method given in Annex B.

12.5.3 Holiday detection

The entire surface of the coated joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm + 5 kV at a maximum of 25 kV according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS.

12.5.4 Impact resistance

The impact resistance shall be measured using the method given in Annex D and shall meet the requirements of Table 10.

12.5.5 Indentation resistance

The indentation resistance shall be measured using the method given in Annex E and shall meet the requirements of Table 10.

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12.5.6 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 10. A test duration of 48 h instead of 28 days can be used for PPT provided that the test temperature is increased to 65 °C and a comparison of results is performed during PQT.

The maximum cathodic disbondment after 28 days at maximum service temperature shall be agreed between the end user and the applicator.

12.5.7 Peel strength between tape layers of polymeric tapes

The peel strength between tape layers shall be measured using the method given in Annex L and shall meet the requirements of Table 10.

12.5.8 Peel strength to pipe surface and plant coating

Unless specified otherwise by the manufacturer, the minimum waiting period between application of the coating and the peel strength test shall be 120 h. This waiting period may be reduced to 24 h. However, if this test fails, it shall be carried out again after a waiting period of 120 h.

The peel strength shall be measured using the methods given in Annex H and shall meet the requirements of Table 10. The method given in H.1 shall be used for PQT. The method given in H.2 can be used for PPT and production testing.

Failure shall not occur at the interface between steel and adhesive, nor between adhesive and polyolefin backing, except for coatings with a peeling strength 50 % higher than the values listed in Table 10.

12.5.9 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I.

The peel strength after the hot-water immersion test shall be measured using the method given in H.1 and shall meet the requirements of Table 10.

12.5.10 Lap shear strength

The lap shear strength resistance of polymeric tapes shall be measured using the method given in Annex J and shall meet the requirements of Table 10.

12.5.11 Thermal ageing resistance

The thermal ageing resistance shall be measured using the method given in Annex M and shall meet the requirements of Table 10.

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Table 10 — Requirements for Type 12 — Polymeric tapes

Property	Test temp.	Unit	Requirements for Type 12–1 (T_{max} ≤ 50 °C)	Requirements for Type 12–2 (T_{max} ≤ 80 °C)	Requirements for Type 12–3 (T_{max} ≤ 120 °C)	Test method
Thickness	—	mm	≥0,9 × nominal value			Annex B
Holiday detection at 5 kV/mm + 5 kV, max. 25 kV	—	—	no holiday			Annex C
Impact resistance	23 °C	J/mm	≥4			Annex D
Indentation resistance, pressure	23 °C and	N/mm^2	10,0	1,0	1,0	Annex E
— Residual thickness	T_{max}	mm	≥0,6	≥0,6	≥0,6	
Cathodic disbondment resistance at 28 days	23 °C	Mm	≤15	≤15	≤15	Annex G
	T_{max}	mm	a	a	a	
Peel strength between tape layers						Annex L
— inner/inner	23 °C	N/mm	≥1,50	≥1,50	≥2,00	
— outer/inner	23 °C	N/mm	≥1,50	≥1,50	≥1,50	
— inner/inner, outer/inner	T_{max}	N/mm	≥0,20	b	b	
— outer/outer	23 °C	N/mm	≥0,20	≥0,20	≥0,80	
— outer/outer	T_{max}	N/mm	≥0,20	b	b	
Peel strength						
— to steel surface	23 °C	N/mm	≥1,00	≥1,00	≥1,00	Annex H
— to steel surface	T_{max}	N/mm	≥0,10	b	b	
— to plant coating	23 °C	N/mm	≥0,40	≥0,40	≥0,40	
— to plant coating	T_{max}	N/mm	≥0,04	b	b	
— to plant coating after 28-day hot-water immersion test at 50 °C	23 °C	N/mm	≥0,4	≥0,40	≥0,40	Annex I
— to steel surface after 28-day hot-water immersion test at 50 °C or 80 °C	23 °C	N/mm	≥0,40	≥0,40	≥0,40	Annex I
Lap shear strength	23 °C	N/mm^2	≥0,050	≥0,050	≥0,100	Annex J
	T_{max}	N/mm^2	≥0,050	≥0,020	b	
Thermal ageing resistance	—					Annex M
Ratio of		—	$1,25 \geq E_{100}/E_0 \geq 0,75$		a	
— elongation at break		—	$E_{100}/E_{70} \geq 0,8$			
— peel strength between tape layers		— —	$P'_{100}/P'_0 \geq 0,75$ $P'_{100}/P'_{70} \geq 0,8$			
— peel strength to pipe surface		— —	$P_{100}/P_0 \geq 0,75$ $P_{100}/P_{70} \geq 0,8$			

a By agreement after qualification.

b The test is considered passed when the tape leaves a film of adhesive on the substrate.

13 Non-crystalline low-viscosity polyolefin based coatings

13.1 Coating identification

Non-crystalline low-viscosity polyolefin based coatings (FJC Types 13A and 13B) shall be identified in the APS in accordance with Table 11 and shall meet the requirements of Table 12.

Data sheets for the non-crystalline low-viscosity polyolefin based compound used as the base of the coatings shall be in accordance with Table 13.

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Application instructions shall be provided by the manufacturer in accordance with Table 14.

13.2 Description of the coatings

Non-crystalline low-viscosity polyolefin based coatings consist of the following:

— a non-crystalline (fully amorphous) low-viscosity (non-crosslinked) non-reactive polyolefin (e.g. polyisobutylene, other polybutenes, or atactic polypropylene) based compound layer with a direct bond to the substrate, which can be reinforced by fabrics and/or be covered by a backing film;

— a polymeric outer wrap tape or sheet (FJC type 13A), or a heat shrinkable outer wrap material (FJC type 13B), or any other agreed material.

The purposes of the compound are to prevent corrosion of the steel surface and to prevent voids and repair small coating defects of the complete FJC.

The purposes of the outer wrap are to provide additional circumferential compression, accelerate the bond, support self-healing and provide additional mechanical protection for the coating system.

Additional mechanical protection can be used over the FJC to improve mechanical properties, that may be needed during transportation (e.g. when it travels over rollers on a lay-barge) and operation.

The non-crystalline low-viscosity polyolefin based compound is available in the following forms:

— tapes;

— wraparound sheets;

— pre-formed shapes;

— mouldable compounds;

— pourable liquids.

Non-crystalline low-viscosity polyolefin based coatings can be divided into the following:

— **13A-1** and **13B-1** with a T_{max} not greater than 50 °C;

— **13A-2** and **13B-2** with a T_{max} not greater than 70 °C;

— **13A-3** and **13B-3** with a T_{max} not greater than 95 °C.

The T_{max} shall be stated in brackets.

A T_{max} higher than 95 °C can be agreed as long as the requirements of Table 12 are met.

NOTE High temperature classes can require either more time or a higher substrate temperature to achieve the prescribed levels of bonding (cohesive separation mode and full coverage).

The T_{max} shall be defined in the APS in accordance with Table 11.

13.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS. The edges of the plant coating shall be bevelled and the plant coating shall be cleaned over the minimum length specified for the overlap on the plant coating (see 13.4.2).

Surface preparation shall be carried out by means of wire-brush cleaning in accordance with 9.1.2.1 and 9.1.2.3 to a minimum degree of cleanliness of ISO 8501-1 grade St 2.

Alternative surface preparation methods can be used by agreement.

Dust contamination shall be grade 3 or better measured in accordance with ISO 8502-3.

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13.4 Application of the coatings

13.4.1 General

Application of the coatings shall be carried out in accordance with the APS.

The non-crystalline low-viscosity polyolefin based compound shall be applied without tension and/or moulded in place assuring coverage and adhesion on any compatible substrate.

The outer wrap shall be applied with tension to provide circumferential compression in accordance with the manufacturer's recommendations.

The minimum application temperature shall be at least 20 °C above the glass transition temperature of the non-crystalline low-viscosity polyolefin(s).

13.4.2 Overlap

The minimum overlap of the compound onto the plant-applied coating shall be in accordance with the manufacturer's application instructions (see Table 14).

A double thickness of the compound shall be applied in an area extending 25 mm either side of the weld cap.

The outer wrap shall cover the non-crystalline low-viscosity polyolefin compound layer, except that a minimum of 3 mm of compound shall be visible on both sides of the outer wrap. Alternatively, the outer wrap shall overlap the plant-applied coating by at least 50 mm on both sides excluding bevels.

The overlap of the spirally wrapped outer wrap tape shall be 50 %, or in accordance with the manufacturer's instructions.

13.5 Testing of the applied coating

13.5.1 General

If required, the tests in 13.5.2 to 13.5.14, summarized in Table 12, shall be carried out for PQT, PPT and production testing.

The tests shall be carried out on pipes coated with the complete coating. Cut samples or flat surfaces are not allowed unless otherwise specified.

13.5.2 Thickness

The minimum thicknesses of the compound and of the complete coating on the body of the field joint shall be as specified in the APS.

Unless otherwise agreed with the end user and the manufacturer, the minimum thickness of the complete coating on the weld cap shall be not less than 0,6 mm and there shall be no holidays (13.5.3).

NOTE The coating thickness on the weld cap is normally less than on the body because some of the coating material flows from the weld cap to the body, both during and after application. This is necessary to prevent voids in the coating and is not detrimental to the corrosion protection.

The coating thickness shall be measured using the method given in Annex B.

13.5.3 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm + 5 kV at a maximum of 25 kV, in accordance with the method defined in Annex C. This test shall be carried out after application of the compound and may be repeated after completion of the coating where so required by the end user.

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Holidays shall be repaired in accordance with the APS.

13.5.4 Impact resistance

The impact resistance shall be measured on the complete coating, using the method given in Annex D, and shall meet the requirements of Table 12.

13.5.5 Indentation resistance

The indentation resistance shall be measured on the complete coating at 23 °C and at maximum service temperature, using the method given in Annex E, and shall meet the requirements of Table 12.

13.5.6 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured on the compound layer, using the method given in Annex F, and shall meet the requirements of Table 12.

13.5.7 Cathodic disbondment resistance

The cathodic disbondment resistance shall be measured on the complete coating over a period of 28 days at 23 °C and at maximum service temperature (limited to 95 °C maximum), using the method given in Annex G for small-diameter pipe. The 6 mm hole through the coating shall be obtained by using a 6 mm hollow hammer punch, followed by surface cleaning to bare steel.

A test duration of 48 h at 65 °C instead of 28 days at 23 °C can be used for PPT or production testing provided that comparison of results is performed during PQT.

The cathodic resistance shall meet the requirements in Table 12 and at the end of the test the thickness of the compound at the artificial defect shall be as a minimum the specified thickness in the APS as per 13.5.2 and there shall be no holidays (self healing) as per 13.5.3.

13.5.8 Peel strength between layers of outer wrap

The peel strength between the outer wrap layers (FJC Types 13A and 13B) shall be measured at 23 °C and at maximum service temperature, using the method given in Annex L, and shall meet the requirements of Table 12.

13.5.9 Adhesion to pipe surface and plant coating

The adhesion test shall be carried out after application of the outer wrap and after cooling where heat has been applied.

The adhesion to steel and plant coating of compound containing reinforcement shall be tested at 23 °C and at maximum service temperature, using the methods given in Annex H, and the results concerning the force required for peeling recorded. The separation mode and substrate coverage shall meet the requirements given in Table 12. A cohesive separation mode is required (the reinforcement is pulled out of the compound). The compound shall leave a film of corrosion protective coating material on the substrate with a minimum coverage area of 95 %. The method given in H.1 shall be used for PQT. The method given in H.2 can be used for PPT and production testing.

The adhesion to steel and plant coating of compound containing no reinforcement shall be measured as follows. Adhesion testing shall be carried out at the 6 o'clock and 12 o'clock positions of the FJC or coated pipe sample by using a utility knife to attempt to lift the coating material from the steel surface. The coating material shall leave a film of corrosion protective coating material on the substrate. There shall be no evidence of adhesive failure.

When applicable adhesion to the plant coating of the outer wrap polymeric tape (FJC Type 13A) or of the outer wrap shrinkable material (FJC Type 13B) shall be measured using the peel strength method given in Annex H and shall meet the requirements given in Table 12.

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13.5.10 Thermal ageing resistance

A thermal ageing test of the complete system shall be carried out in accordance with M.3 for 100 days at T_{max} + 20 °C. After this test, the adhesion of the compound to the pipe surface and the plant coating shall be measured as specified in 13.5.9 and shall meet the requirements of Table 12.

The thermal ageing test for the outer wrap tape and outer wrap heat shrinkable material shall be carried out in accordance with Annex M for 100 days at T_{max} + 20 °C using the method given in M.1 adapted for the measurement of the elastic modulus instead of elongation at break (ISO 527-1), M.2 (peel strength between layers) and M.3 (peel strength to pipe surface, when applicable) and shall meet the requirements of Table 12.

13.5.11 Resistance to lap shear

The lap shear strength of the compound shall be measured at 23 °C and at maximum service temperature, using the method given in J.2, and shall meet the requirements of Table 12. A cohesive peel mode is required. The compound shall leave a film of corrosion protective coating material on the substrate. There shall be no evidence of adhesive failure.

13.5.12 Hot-water immersion test

A hot-water immersion test of the complete coating system shall be carried out in accordance with Annex I for 100 days at T_{max} + 20 °C, limited as specified in Annex I. After the immersion test, the adhesion of the compound to the pipe surface and the plant coating shall be measured as specified in 13.5.9 and shall meet the requirements of Table 12.

A hot-water immersion test of the outer wrap shall be carried out in accordance with Annex I for 100 days at T_{max}, limited as specified in Annex I. The adhesion of the outer wrap to the plant coating (if applicable) shall be measured using the method given in Annex H and shall meet the requirements of Table 12.

13.5.13 Glass transition and crystallization temperatures

The glass transition temperature and crystallization temperature of the non-crystalline polyolefin shall be determined by differential thermal analysis of a sample of the material in accordance with ISO 11357-1, ISO 11357-2 and ISO 11357-3 and shall meet the requirements of Table 12.

13.5.14 Drip resistance

No dripping of the compound shall be allowed, as specified in Table 12, when performing the test in accordance with Annex K with a modified test temperature of T_{max} + 20 °C, with a minimum test temperature of 80 °C for 13A-1 and 13 B-1.

Table 11 — Coating identification

Property
Coating trade name
Type of FJC
Maximum and minimum service temperature
Form of non-crystalline low-viscosity polyolefin compound
Types, number and thicknesses of layers
Trade names of all layers
Nominal thickness of complete coating
Compatible plant coatings[a]
[a] State all types of plant coating that have been tested sucessfully with the coating.

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Table 12 — Requirements for non-crystalline low-viscosity polyolefin based coatings (Types 13A and 13B)

Property		Test temp.	Units	Requirements		Test method
Non-crystalline low-viscosity polyolefin compound						
Minimum thickness		23 °C	mm	≥specified minimum value		Annex B
Glass transition temperature		—	°C	at least 20 °C below minimum application temperature		ISO 11357-2
Crystallization temperature		—	°C	No evidence of crystallization		ISO 11357-3
Holiday detection at 5 kV/mm + 5 kV, max. 25 kV		—	—	No holiday		Annex C
Drip resistance		T_{max} + 20 °C (minimum 80 °C)	—	No dripping of compound		Annex K
Adhesion test of reinforced compound with respect to steel and to plant coating before and after thermal ageing and before and after hot-water immersion, both for 100 days at T_{max} + 20 °C		23 °C	N/mm	≥0,04	Cohesive separation mode Coverage ≥ 95 %	Annex H (and M.3 and Annex I)
		T_{max}		≥0,02		
Adhesion test of compound without reinforcement with respect to steel and to plant coating before and after thermal ageing and before and after hot-water immersion, both for 100 days at T_{max} + 20 °C)		23 °C	—	The coating shall leave a film of compound on the substrate.		13.5.9 (and M.3 and Annex I)
		T_{max}				
Lap shear resistance		23 °C	N/mm²	≥0,004	Cohesive separation mode Coverage ≥95 %	Annex J
		T_{max}		≥0,002		
Specific electrical insulation resistance	R_{S100}	23 °C	Ω·m²	≥10⁸		Annex F
	R_{S100}/R_{S70}		—	≥0,8[a]		
[a] This requirement shall be fulfilled only if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.						
Complete coating						
Impact resistance		23 °C	J	≥15		Annex D
Indentation resistance	FJC Type	23 °C and T_{max}	N/mm²	13A	13B	Annex E
	Test pressure			1,0	10,0	
	Residual thickness		mm	≥0,6		
Cathodic disbondment resistance at 28 days		23 °C and T_{max}	mm	0 mm, no holiday		Annex G (and Annex C and 13.5.7)
Type 13A (Outer wrap — Polymeric tape)						
Peel strength of outer wrap layer to outer wrap layer		23 °C	N/mm	≥0,20		Annex L
		T_{max}		≥0,02		
Peel strength to plant coating (if applicable, see 13.4.2)		23 °C	N/mm	≥1,0		Annex H
		T_{max}		≥0,1		

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Table 12 *(continued)*

Property	Test temp.	Units	Requirements	Test method
Peel strength (P'_{100}/P'_0) outer layer to outer layer after hot water immersion for 100 days at T_{max}, max. 95 °C.	23 °C	—	≥0,75	Annex L (and Annex I)
Peel strength (P_{100}/P_0) to plant coating (if applicable, see 13.4.2) after hot water immersion for 100 days at T_{max}, max. 95 °C.	23 °C	—	≥0,75	Annex H (and Annex I)
Elastic modulus (E_{100}/E_0) after thermal ageing for 100 days at T_{max} + 20 °C	23 °C	—	≥0,75	M.1 and ISO 527-2
Peel strength (P'_{100}/P'_0) outer wrap layer to outer wrap layer after thermal ageing for 100 days at T_{max} + 20 °C	23 °C	—	≥0,50	M.2
Peel strength to plant coating (if applicable, see 13.4.2) after thermal ageing (P_{100}/P_0) for 100 days at T_{max} + 20 °C	23 °C	—	≥0,75	M.3
Type 13B (Outer wrap — Heat-shrinkable material)				
Peel strength outer layer to outer layer	23 °C	N/mm	≥1,0	Annex L
	T_{max}		≥0,1	
Peel strength to plant coating (if applicable, see 13.4.2)	23 °C	N/mm	≥1,0	Annex H
	T_{max}		≥0,1	
Peel strength (P'_{100}/P'_0) outer layer to outer layer after hot water immersion for 100 days at T_{max}, max. 95 °C	23 °C	—	≥0,75	Annex L (and Annex I)
Peel strength to plant coating coating (if applicable, see 13.4.2) after hot water immersion (P_{100}/P_0) for 100 days at T_{max}, max. 95 °C	23 °C	—	≥0,75	Annex H (and Annex I)
Elastic modulus (E_{100}/E_0) after thermal ageing for 100 days at T_{max} + 20 °C	23 °C	—	≥0,50	M.1 and ISO 527-2
Peel strength (P'_{100}/P'_0) outer layer to outer layer after thermal ageing for 100 days at T_{max} + 20 °C	23 °C	—	≥ 0,75	M.2
Peel strength (P_{100}/P_0) to plant coating (P''_{100}/P''_0) (if applicable, see 13.4.2) after thermal ageing for 100 days at T_{max} + 20 °C	23 °C	—	≥0,75	M.3

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Table 13 — Data sheets of non-crystalline low-viscosity polyolefin compound

Property	Units	Test method
Trade name	—	—
Prefabricated compound[a] — generic type of non-crystalline low-viscosity polyolefin — generic type of reinforcement material	—	—
Colour	—	—
Nominal thickness of prefabricated compound	mm	ISO 4591/ ISO 4593
Density	g/cm^3	—
Maximum and minimum service temperature	°C	—
Storage conditions — temperature range (minimum/maximum)	°C	—
Shelf life at storage temperature	month	—
Data according to this data sheet shall be supplied for each coating component. [a] If applicable.		

Table 14 — Application instructions

Property	Units
Ambient conditions	
— minimum temperature	°C
— maximum temperature	°C
— maximum relative humidity	%
Surface preparation of steel surface	
— surface cleanliness (ISO 8501-1)	—
Surface preparation of plant coating	—
Application of coating	
— method of application	—
— surface temperature/dewpoint	°C
— material temperature	°C
General	
— minimum thickness	mm
— overlap on plant coating (minimum and maximum)[a]	mm
— specific application instructions	—
— repair procedures	—
[a] To be given for each compatible plant coating.	

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14 Coatings based on heat-shrinkable materials

14.1 Coating identification

Coatings based on heat-shrinkable materials (FJC Types 14A, 14B, 14C and 14D) shall be identified in the APS as per Table 15 and shall meet the requirements of Table 16 or 17 (depending on coating type).

Data sheets for the coating materials shall be in accordance with Table 18 (liquid primer), ISO 21809-2 (epoxy powder) or Table 19 (shrinkable materials).

Application instructions shall be provided by the manufacturer in accordance with Table 20.

NOTE Heat-shrinkable coatings for use in horizontal directional drilling and slick bore applications can be subject to additional requirements.

14.2 Description of the coatings

14.2.1 General

Heat-shrinkable materials consist of an external backing made of extruded and cross-linked polyolefin and an internal adhesive made of thermoplastic material. The shrinkage of the backing instils a level of circumferential compression in the coating that supplements the bonding of the sleeve to the pipe surface. Some versions include an epoxy layer applied to the steel.

Heat-shrinkable materials are available in the following forms:

— tubular sleeve;

— wrap-around sleeve;

— pre-formed material (assembly for complex configuration parts);

— tapes.

14.2.2 Type 14A

Type 14A coatings are cross-linked, heat-shrinkable materials based on polyethylene, applied without primer, which can be further subdivided into the following:

— **14A-1**: mastic adhesive, with a T_{max} not greater than 50 °C;

— **14A-2**: mastic adhesive, with a T_{max} not greater than 80 °C;

— **14A-3**: hot-melt adhesive, with a T_{max} not greater than 120 °C.

The T_{max} shall be stated in brackets.

A T_{max} higher than 120 °C can be agreed as long as the requirements of Table 16 are met.

Polypropylene can be used instead of polyethylene if approved by the end user. In this case, the requirements given in Tables 16 should be adapted by agreement.

14.2.3 Types 14B, 14C and 14D

Types 14B, 14C and 14D are cross-linked, heat-shrinkable materials coatings applied with a liquid epoxy, FBE or any other compatible primer which can be further subdivided into the following:

— 14B-1: cross-linked heat-shrinkable polyethylene-based material, with a T_{max} not greater than 60 °C;

— 14B-2: cross-linked heat-shrinkable polyethylene-based material, with a T_{max} not greater than 80 °C;

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— 14C: cross-linked heat-shrinkable polyolefin-based material with reinforced backing (hybrid), with a T_{max} not greater than 110 °C;

— 14D-1: cross-linked heat-shrinkable polypropylene-based material, with a T_{max} not greater than 110 °C;

— 14D-2: cross-linked heat-shrinkable polypropylene-based material meeting the requirements of Clause 19 for polypropylene systems types 19-A, 19-B and 19-C, with a T_{max} not greater than 110 °C.

The test temperature shall be stated in brackets, e.g. Type 14C (60).

A T_{max} higher than 110°C can be agreed as long as the requirements of Table 17 are met.

The minimum thickness of primer shall be specified in order to fulfil the requirements of Table 17. The recommended minimum thickness is 200 µm for FBE and 150 µm for liquid epoxy, measured in accordance with Annex B.

14.3 Surface preparation

Surface preparation shall be carried out according to the APS. The edges of the plant coating shall be bevelled and the plant coating shall be roughened for the minimum length according to the overlap on plant coating (see 14.4.4).

The area being coated shall be cleaned by abrasive blast-cleaning as described in ISO 8504-2 to a minimum grade Sa 21/2 according to ISO 8501-1. The profile/roughness shall be in accordance with the manufacturer's application instructions.

Provided that the maximum design temperature does not exceed 50 °C, for FJC Type 14A-1 and Type 14A-2, surface preparation can be achieved by power tool cleaning as described in ISO 8504-3 to a minimum of grade St 3 according to ISO 8501-1, by agreement of the end user.

Dust contamination shall be grade 2 or better, measured in accordance with ISO 8502-3. Grade 3 may be accepted for Type 14A-1 and Type 14A-2 provided that the maximum design temperature does not exceed 50 °C.

14.4 Application of the coatings

14.4.1 General

Application of the coating shall be carried out in accordance with the APS.

14.4.2 Application of the primer

Application of the primer, if any, shall be carried out in accordance with the APS.

14.4.3 Application of heat-shrinkable materials

Application of the material shall be carried out in accordance with the APS. As a general guideline, the following procedure shall be followed.

— If using a tubular sleeve, position the sleeve beside the weld before welding.

— After welding, clean the area with the approved cleaning method.

— Pre-heat the area to be coated as per manufacturer recommendations. Where possible and/or practical, induction heating should be used. This is to ensure a uniform and consistent pre-heat level, especially for pipe diameters larger than 600 mm (24").

— Position the sleeve so as to provide the correct overlap on the plant coating when shrinking is completed.

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— Heat the sleeve to the specified surface temperature with a gas torch or other heat source (e.g. infrared heater).

The heat shall be applied progressively and regularly to ensure a uniform heat pattern as specified in the APS in accordance with the manufacturer's instructions, and demonstrated by the applicator in the PPT, if performed.

NOTE Two operators are usually necessary for pipe diameters larger than 300 mm (12").

Temperature shall be checked by a temperature-measuring device (e.g. hand-held thermocouple), at a minimum of one location on each side of the pipe, immediately prior to application of the sleeve.

The heating time and the temperature shall not result in visible oxidation of the surface of the steel and of the coating, detrimental to the quality of the coating of the joint or damage the plant-applied coating.

In addition, for Types 14B, 14C and 14D when using FBE, the heating time and the temperature shall not adversely affect the mechanical properties of the pipe steel (see NOTE and CAUTION in 17.4.3).

If a delay results in the surface cooling to below the temperature range specified by the powder manufacturer, the pipe shall be re-heated, and, if required, the abrasive blasting shall be repeated to meet specification requirements.

14.4.4 Overlap

The overlap of shrinkable materials on the plant-applied coating shall be in accordance with the manufacturer's application instructions (Table 20). For all materials, this overlap shall be at least 50 mm after shrinking.

14.5 Testing of the applied coatings

14.5.1 General

The tests in 14.5.2 to 14.5.12 shall be carried out for production quality control, and for PQT and PPT if required.

14.5.2 Thickness

The manufacturer shall provide the as-supplied product thickness that achieves the specified minimum thickness required by the purchaser or end user for the applied coating system.

The coating thickness shall be measured using the method given in Annex B.

The thickness of the coating on the body of the joint shall not be less than the minimum thickness specified in the APS or as otherwise agreed to by the purchaser.

The minimum thickness of the coating measured on top of the weld cap shall not be less than 75 % of the specified minimum thickness.

NOTE The thickness on the weld cap is normally less than the thickness on the body because some of the polymeric adhesive flows from the weld cap to the body both during and after the application.

14.5.3 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm + 5 kV at a maximum of 25 kV, according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS.

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14.5.4 Peel strength

The minimum waiting period between application of the coating and the peel-strength test shall be 24 h, unless specified otherwise.

The peel strength shall be measured using the methods given in Annex H and shall meet the requirements of Table 16 or Table 17 as applicable. The method given in H.1 should preferably be used for PQT. The method given in H.2 can be used for PPT and production testing, as well as for PQT in agreement with purchaser.

Peel mode separation shall occur cohesively within the adhesive layer for all types of coatings.

14.5.5 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 16 or Table 17. A test duration of 48 h instead of 28 days can be used for PPT provided that the test temperature is increased to 65 °C and that a comparison of results is performed during PQT.

The cathodic disbondment after 28 days at the maximum service temperature (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 16 or 17.

14.5.6 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 100 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I. The peel strength shall be measured using method given in H.1 and shall meet the requirements in Tables 16 and 17.

14.5.7 Impact resistance

The impact resistance shall be measured using the method given in Annex D and shall meet the requirements of Table 16 or 17.

14.5.8 Indentation resistance

The indentation resistance shall be measured using the method given in Annex E and shall meet the requirements of Table 16 or 17.

14.5.9 Lap shear strength

The lap shear strength resistance shall be measured using the method given in Annex J and shall meet the requirements of Table 16 or 17.

14.5.10 Thermal ageing resistance and thermal stability

Except for Type 14D-2, the thermal ageing resistance shall be measured using the method given in Annex M and shall meet the requirements of Table 16 or 17.

For Type 14D-1, the thermal stability shall be tested at 130 °C for 50 weeks on the installed system using the method given in Annex N and shall meet the requirements of Table 17.

14.5.11 Bursting strength

For Types 14C, the bursting strength of the backing shall be tested in accordance with Annex O and shall meet the requirements of Table 17.

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14.5.12 Oxidation induction time

For Type 14D-2 and 14D-3, the oxidation induction time shall be tested on backing in accordance with ISO 11357-6 and shall meet the requirements of Table 17.

Table 15 — Coating identification

Property
Coating trade name
Basic type of coating material
Form of shrinkable material
Minimum thickness of the applied coating system
Compatible plant coatings[a]
Primer trade name
Nominal thickness of primer

[a] State all types of plant coatings that have been tested successfully with the coating.

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Table 16 — Requirements for type 14A joint coatings — PE backed, without primer

Property	Test temp.	Unit	Type 14A-1 (T_{max} ≤ 50 °C)	Type 14A-2 (T_{max} ≤ 80 °C)	Type 14A-3 (T_{max} ≤ 120 °C)	Test method
Thickness	—	mm	≥specified minimum value			Annex B
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday			Annex C
Impact resistance (holiday detection at 5 kV/mm + 5 kV)	23 °C	J/mm	≥5	≥5	≥7	Annex D
Indentation resistance: Pressure and residual thickness	23 °C	N/mm^2	1,0	1,0	10,0	Annex E
		mm	≥0,60	≥0,60	≥1,0	
	T_{max}	N/mm^2	1,0	1,0	1,0	
		mm	≥0,60	≥0,60	≥1,0	
Cathodic disbondment at 28 days	23 °C	mm	≤10	≤10	≤15	Annex G
	T_{max}	mm	≤15	≤20	≤20[a]	—
Peel strength to pipe surface and plant applied coating	23 °C	N/mm	≥0,70	≥1,0	≥3,0	Annex H
	T_{max}	N/mm	≥0,10	≥0,10	≥0,20	Annex H
Peel strength to pipe surface and plant applied coating after 100-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	P_{100}/P_0	≥0,75	≥0,75	≥0,75	Annex I and Annex H
Lap shear strength at 10 mm/min	23 °C	N/mm^2	≥0,05	≥0,10	≥5,0	Annex J
	T_{max}	N/mm^2	≥0,01	≥0,01	≥0,10	
Thermal ageing resistance (aged at T_{max} + 20 °C)	23 °C	—				Annex M
Elongation at break						
E_{100}/E_0			≥0,75	≥0,75	≥0,75	
E_{100}/E_{70}			≥0,80	≥0,80	≥0,80	
Peel strength to pipe surface						
P_{100}/P_0	23 °C	—	≥0,75	≥0,75	≥0,75	
P_{100}/P_{70}			≥0,80	≥0,80	≥0,80	

[a] Test carried out at 95 °C.

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Table 17 — Requirements for type 14B, 14C and 14D joint coatings — PE-backed, hybrid or PP-backed, applied onto a primer (3-Layer Systems)

Property	Test temp.	Unit	Type 14B-1 polyethylene (T_{max} ≤ 60 °C)	Type 14B-2 polyethylene (T_{max} ≤ 80 °C)	Type 14C hybrid (T_{max} ≤ 110 °C)	Type 14D-1 polypropylene (T_{max} ≤ 110 °C)	Type 14D-2 polypropylene (T_{max} ≤ 110 °C)	Test method
Thickness – Sleeve Layers	—	—	≥specified minimum value					Annex B
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday					Annex C
Impact resistance (holiday detection at 5 kV/mm + 5 kV)	23 °C	J/mm	≥5	≥7	≥7	≥10	≥10	Annex D
Indentation resistance:								
Pressure	T_{max}	N/mm²	10,0	10,0	10,0	10,0	10,0	Annex E
Residual thickness		mm	≥0,6	≥0,6	≥0,6	≥0,6	—	
Amount of penetration		mm	—	—	—	—	≤0,9	
Cathodic disbondment at 28 days	23 °C	mm	≤5,0	≤5,0	≤5,0	≤5,0	≤5,0	Annex G
	T_{max} limited to 95 °C	mm	≤10	≤10	≤10	≤10	≤10	
Peel strength at 10 mm/min to pipe surface and to polyolefin plant coating	23 °C	N/mm	≥4,0	≥5,0	≥4,0	≥4,0	≥15,0	H.1
	T_{max}	N/mm	≥0,20	≥0,30	≥0,20	≥2,0	≥4,0	
Peel strength at 10 mm/min to pipe surface and to polyolefin plant coating after 100-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	P_{100}/P_0	≥0,75	≥0,75	≥0,75	≥0,75	≥0,75	Annex I and Annex H
Lap shear strength at 10 mm/min	23 °C	N/mm²	≥1,0	≥3,0	≥6,0	≥5,0	≥9,0	Annex J
	T_{max}	N/mm²	≥0,07	≥0,20	≥0,6	≥1,0	≥1,0	
Thermal ageing resistance (aged at T_{max} + 20 °C)								Annex M
— Elongation at break E_{100}/E_{70})	23 °C	—	≥0,75	≥0,75	N. A.	≥0,75	N. A.	Annex M
— Peel strength to pipe surface (P_{100}/P_{70})		—	≥0,75	≥0,75	≥0,75	≥0,75	N. A.	
Bursting strengt hof reinforced backing (B_{100}/B_{70})	23 °C	—	—	—	≥0,75	—	—	Annex O
Bursting strength of reinforced backing	23 °C	N	—	—	2 000	—	—	
Oxidation induction time on the backing at 220 °C (intercept in the tangent method)	—	min	—	—	—	≥15	≥15	ISO 11357–6
Thermal stability at 130 °C for 50 weeks, installed system	130 °C	visual	—	—	—	No cracks	—	Annex N

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Table 18 — Data sheet — Liquid primer

Property	Unit	Test method
Trade name	—	—
Generic type	—	—
Solid content	100 %	—
Density (base and hardener)	g/cm^3	ISO 2811-1
Mix ratio	—	—
Storage temperature, max.	°C	—
Shelf life at storage temperature	month	—
Recommended dry film thickness	mm	—
Pot life at 23 °C	—	—
Flash point (base and hardener)	—	—

Table 19 — Data sheet — Shrinkable materials

Property	Unit	Test method
Trade name	—	—
Description of coating material	—	—
Colour	—	—
Shrinkable material type	—	—
Nominal thickness (as supplied)	mm	ISO 4591 and ISO 4593
Adhesive type	—	—
Storage temperature, min., max.	°C	—
Shelf life at storage temperature	month	—

Table 20 — Application instructions

Property	Unit
Ambient conditions (minimum temperature, maximum temperature, relative humidity, dew point)	—
Surface preparation of steel surface	—
Cleanliness (ISO 8501-1)	—
Profile (ISO 8503-2)	—
Pre-heat temperature range	°C
Surface preparation of plant coating	—
Application of primer	—
Mixing ratio	—
Pot life	—
Cure temperature profile (temperature vs. time)	—
Application of heat-shrinkable material	—
Surface pre-heat temperature	—
Method of pre-heat	—
Shrink procedure	—
Overlap on plant coating (minimum)	—
Repair procedures	—

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15 Hot-applied microcrystalline wax coatings

15.1 Coating identification

Coatings made from hot-applied microcrystalline wax (FJC Type 15) shall be identified in the APS as per Table 21 and shall meet the requirements of Table 22.

Data sheets for the coating materials shall be in accordance with Table 23.

Application instructions shall be provided by the manufacturer, in accordance with Table 23.

15.2 Description of the coating

The coating consists of the following:

— a microcrystalline wax applied directly to the surface;

— an outer wrap;

— a final layer of hot-applied wax.

Maximum service temperature is 50 °C.

15.3 Surface preparation

Surface preparation shall be carried out by wire-brush cleaning according to the provisions of 9.1.2.3 to a minimum cleanliness of ISO 8501-1:2007, grade St 2.

The plant-applied coating shall be bevelled and roughened for the minimum length according to the overlap on plant coating (15.4.2). The plant-applied coating shall not be removed.

Dust contamination shall be grade 3 or better, measured in accordance with ISO 8502-3.

The adjoining plant-applied coating shall be cleaned and abraded to expose a fresh surface of plant-applied coating for a minimum distance of 50 mm each side of the joint.

15.4 Application of the coating

15.4.1 General

The coating is applied using an outer wrap system in either a spiral wrap or wraparound application.

Pipe surface temperature shall be greater than 3 °C above the dew point temperature prior to coating. If pre-heating is used to eliminate surface moisture, the heating time and the temperature shall not damage the plant-applied coating.

15.4.2 Application of the microcrystalline wax

The wax shall be applied in accordance with the APS and the manufacturer's instructions.

The wax shall be heated in accordance with the APS and flood coated onto the pipe surface.

The overlap on the plant-applied coating, excluding bevels, shall be not less than 50 mm, unless otherwise specified in the APS.

At the beginning of each shift, adhesion shall be checked in accordance with 15.5.4. If the adhesion level is not acceptable, the application temperature shall be raised by 15 °C and adhesion shall be retested. If adhesion is acceptable, then all coating shall be applied at the increased temperature.

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15.4.3 Application of the outer wrap

At any interval after application of the first layer of wax, the outer wrap shall be applied in either a spiral or a wraparound application, as specified by the purchaser.

15.4.4 Application of wax top coat

A final flood coat of wax may be applied over the outer wrap.

15.5 Testing of the applied coatings

15.5.1 General

The tests in 15.5.2 to 15.5.5 shall be carried out for production quality control, and for PQT and PPT if required, after cooling of the material.

15.5.2 Thickness

The minimum thickness of the primary wax layer shall be 0,5 mm and the minimum thickness of the outer wrap shall be 0,3 mm. This is applicable on the weld cap as well as on the body of the pipe.

No minimum thickness is specified for the final layer of hot-applied wax which shall be visually uniform.

The thickness shall be measured using the method given in Annex B.

15.5.3 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities, after the outer wrap is applied, at a voltage of 5 kV/mm at a maximum of 25 kV, in accordance with the method defined in Annex C.

Holidays shall be repaired in accordance with the APS. The number of allowable repairs shall be agreed as defined in 6.2.

15.5.4 Adhesion

Adhesion testing shall be carried out at the 6 o'clock and 12 o'clock positions of the FJC by using a utility knife to attempt to lift the coating from the steel surface. Test temperature shall be equal to the maximum service temperature.

The coating shall leave a film of wax on the substrate. There shall be no evidence of adhesive failure.

Adhesion to the plant coating shall be verified in the same manner.

15.5.5 Hardness

Coating hardness shall be measured by needle penetration in accordance with ASTM D1321 and shall meet the requirements of Table 22.

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Table 21 — Coating identification

Property	Unit
Date of issue	—
Name of manufacturer	—
Commercial name of the material	—
Type of material	—
Application methods and conditions (ambient conditions)	—
Maximum service temperature	°C
Minimum thickness	mm
Outer wrap composition and thickness	—

Table 22 — Requirements for hot-applied wax for T_{max} of 50 °C

Property	Unit	Requirements	Test method
Microcrystalline wax			
Density at 25 °C	g/cm^3	< 1	ASTM D70
Needle penetration at 25 °C	dmm[a]	25 to 50	ASTM D1321
Melting point	°C	>70	ASTM D127
Flash point	°C	≥260	ASTM D92
Dielectric strength	V/µm	≥4	ASTM D149
Cathodic disbondment at 25 °C, 28 days	mm	≤19	Annex G
Outer wrap — Wax-laminated plastic film on spun-bonded plastic mat			
Plastic film thickness	µm	15 to 25	ASTM D1000
Wax melt point	°C	71 to 99	ASTM D127
Average thickness	µm	305	ASTM D1000
Dielectric strength	V/µm	≥14	ASTM D149
Outer wrap — Wax-saturated spun-bonded plastic mat			
Wax melt point	°C	71 to 99	ASTM D127
Total thickness	µm	250 to 635	ASTM D1000
Dielectric strength	V/µm	≥14	ASTM D149
[a] Decimillimetre (equal to 0,1 mm).			

Table 23 — Data sheet and application instructions for hot-applied wax

Property	Unit
Storage conditions	—
Application methods and conditions (ambient conditions)	—
Minimum and maximum temperature of the steel during application	°C
Maximum service temperature	°C
Minimum thickness	mm
Outer wrap composition and thickness	—

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16 Elastomeric coatings

16.1 Coating identification

Elastomeric coatings using polychloroprene or EPDM (FJC Types 16A and 16B) shall be identified in the APS as per Table 24 and shall meet the requirements of Table 25.

Elastomeric FJC shall be applied only with plant-applied coating of the same elastomer.

Data sheets for the coating materials shall be in accordance with Table 26 (polychloroprene) or Table 27 (EPDM).

Application instructions shall be provided by the manufacturer in accordance with Table 28.

16.2 Description of the coatings

The coating consists of a thick elastomer applied to a steel surface treated with a primer and a bonding agent. The elastomer may be:

— polychloroprene (type 16A), a solid synthetic rubber;

— EPDM (Type 16B), a synthetic ethylene-propylene-diene rubber with a higher temperature resistance.

There are two methods to apply the field joint elastomer coatings:

— with the use of a vulcanized split wraparound rubber sleeve;

— with the use of an unvulcanized rubber that is cured *in situ*.

16.3 Surface preparation

Surface preparation shall be carried out by abrasive blasting in accordance with the provisions of 9.1.2.1 and 9.1.2.2 to a minimum cleanliness of Sa 21/2. The surface profile attained shall be between 50 µm and 100 µm as measured in accordance with the requirements of ISO 8503-5.

The plant-applied coating shall be bevelled and roughened for the minimum length according to the overlap on the plant coating. The plant-applied coating shall not be removed or contaminated by abrasive dust.

Dust contamination shall be grade 2 or better measured in accordance with ISO 8502-3.

16.4 Application of the coatings

16.4.1 General

The coating shall be applied in accordance with the APS.

Application of the primer, bonding agent, epoxy adhesive and elastomer shall take place when the relative humidity is less than 85 % and when the steel temperature is 3 °C above dew point.

16.4.2 *In situ* vulcanization method

The primer, bonding agent and elastomer shall be applied immediately after blasting and before any visible rusting or surface contamination occurs. The bonding agent shall also be applied over cured rubber to enhance bonding.

The unvulcanized rubber shall be applied to obtain the same thickness as the original plant-applied coating and make the FJC flush.

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Polyamide tape shall be tightly wound around the joint with a minimum of 50 % overlap and shall terminate at a minimum of 150 mm over the plant coating.

A portable steam autoclave shall be used to cure the rubber. After curing is complete, the polyamide tape shall be completely removed. Alternatively, electrical heating tapes may be used to wrap around the surface, fully covering the field joint area.

16.4.3 Ambient-cure adhesive method

If required due to a short application window (e.g. offshore), a wraparound cured rubber sleeve may be applied with the existing elastomer coating and secured with an ambient curing epoxy adhesive.

The plant-applied coating should be bevelled at a 45° bevel with a tapering tail to ease alignment of the overwrap sleeve. After the wraparound sleeve is applied to the bare steel, it shall be secured and held firmly in place by filament tape. The tape shall be applied first around the middle of the sleeve. The sleeve shall be twisted a quarter turn to spread the adhesive uniformly and be brought back to its original position.

A shrink sleeve may be used over the newly bonded FJC to provide mechanical protection when it travels over the stinger rollers on a lay-barge.

16.5 Testing of the applied coatings

16.5.1 General

The tests in 16.5.2 to 16.5.16 shall be carried out for production quality control, and for PQT and PPT if required.

16.5.2 Visual appearance

The cured elastomer shall be smooth and free of anomalies, e.g. blistering, delamination, porosity.

16.5.3 Coating thickness

The minimum thickness of the complete FJC shall be equal to the thickness of the plant-applied coating unless otherwise agreed.

The thickness shall be measured using the method given in Annex B.

16.5.4 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 6 kV/mm at a maximum of 25 kV, according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS. The number of allowable repairs shall be agreed as defined in 6.2.

16.5.5 Hardness

Hardness Shore A shall be measured at at least five locations, in accordance with ISO 7619-1, and shall meet the requirements of Table 25.

16.5.6 Adhesion

The peel strength shall be measured using the methods given in Annex H and shall meet the requirements of Table 25. The method given in H.1 should preferably be used for PQT. The method given in H.2 can be used for PPT and production testing, as well as for PQT in agreement with the purchaser.

The presence of bare metal (adhesion failure between metal and primer) shall be considered as a failure.

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16.5.7 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I. The adhesion to pipe surface and plant coating shall be measured in accordance with D.2 and shall meet the requirements of Table 25.

16.5.8 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 36. A test duration of 48 h instead of 28 days can be used for PPT provided that the test temperature is increased to 65 °C and a comparison of results is performed during PQT.

The cathodic disbondment after 28 days at the maximum service temperature, (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 25.

16.5.9 Density

Density of the cured elastomer shall be measured in accordance with ISO 2781, method A. The value shall be within ±2 % of the manufacturer's stated value.

16.5.10 Rheometer curve — Oscillating disc

A rheometer curve shall be established for uncured elastomer in accordance with ISO 3417 and used to define the acceptance limits of the following parameters:

— minimum torque, expressed in decinewton-metres;

— time, expressed in minutes to a 1 dN·m rise above minimum torque;

— time, expressed in minutes to 90 % of the torque increase;

— maximum torque at which the curve plateaus, expressed in decinewton-metres.

Once a standard curve with the above parameters has been established by the manufacturer and approved by the applicator, all subsequent curves shall fall within these limits.

16.5.11 Tensile strength

The tensile strength of the cured elastomer shall be measured using the method in accordance with ISO 37 and shall meet the requirements of Table 26 or 27.

16.5.12 Elongation at break

The elongation at break of the cured elastomer shall be measured using the method in accordance with ISO 37 and shall meet the requirements of Table 26 or 27.

16.5.13 Tear strength

The tear strength of the cured elastomer shall be measured using the method in accordance with ISO 34-1 and shall meet the requirements of Table 26 or 27.

16.5.14 Electrical volume resistivity

The electrical volume resistivity shall be given by the manufacturer for information.

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The volume resistivity is affected by the composition of the elastomeric material. The use of carbon black filler reduces this characteristic.

NOTE The design of the cathodic protection system can be affected by the composition of the elastomeric material.

16.5.15 Ozone resistance

The ozone resistance shall be measured using the method in accordance with ISO 1431-1, procedure A, with an ozone concentration of 0,5 µl/l for 72 h at 40 °C. The elastomer shall show no cracks or other detrimental effects when held at a fixed 20 % strain.

16.5.16 Resistance to seawater

The seawater resistance shall be measured using the method in accordance with ISO 1817 with substitute seawater, in accordance with ASTM D1141.

Testing shall be performed for 28 days at 85 °C.

The volume change after this period shall be a maximum of 5 %.

The maximum change in tensile strength shall not exceed 20 % of that of an unexposed sample as determined in accordance with 16.5.11.

The change in Shore A hardness shall be in the range of 0 to +5.

The test shall show no evidence of cracking or splitting.

Table 24 — Coating identification

Property
Date of issue
Name of manufacturer
Commercial name of the material
Basic type of coating material
Application methods and conditions (ambient conditions)
Maximum service temperature
Name of and thickness of primer
Name of and thickness of bonding agent
Nominal thickness of coating system

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Table 25 — Requirements for elastomer FJC

Property	Test temperature	Unit	Requirements	Test method
Visual appearance of coating	—	—	16.5.2	Visual
Coating thickness	—	—	Same as main pipe coating	ISO 2178
Holiday detection at 6 kV/mm at a maximum of 25 kV[a]	—	—	No holiday	Annex C
Hardness	—	Shore A	60 to 70	ISO 7619-1
Adhesion (peel strength)	23 °C	N/mm	Cohesive and >12	Annex H
Adhesion to pipe surface and plant coating after 28-days hot-water immersion test at T_{max} limited as per Annex I	23 °C	N/mm	Cohesive and >10	Annex I and Annex H
Cathodic disbondment at 28 days	23 °C	mm	≤ 7	Annex G
	T_{max} limited to 95 °C	mm	≤ 10	Annex G

[a] Holiday detection test may not be relevant for low resistivity elastomeric coatings.

Table 26 — Data sheet for polychloroprene

Property	Unit	Requirements	Test method
Hardness, Shore A	—	60 to 70	ISO 7619-1
Density	g/cm^3	Stated value ±2 %	ISO 2781
Rheometer curve	—	Standard curve	ASTM D2084
Tensile strength	N/mm^2	>14	ISO 37
Elongation at break	%	>350	ISO 37
Tear strength	N/mm	>40	ISO 34-1
Ozone resistance	—	No cracking or other detrimental effects	ISO 1431-1
Resistance to seawater	—	Tensile strength ±20 % of unexposed value, maximum volume change of 5 %	ISO 1817

Table 27 — Data sheet for EPDM

Property	Unit	Requirements	Test method
Hardness, Shore A	—	70	ISO 7619-1
Density	g/cm^3	Stated value ±2 %	ISO 2781
Rheometer curve	—	Standard curve	ASTM D2084
Tensile strength	N/mm^2	>16	ISO 37
Elongation at break	%	>350	ISO 37
Tear strength	N/mm	>40	ISO 34-1
Ozone resistance	—	No cracking or other detrimental effects	ISO 1431-1
Resistance to seawater	—	Tensile strength ±20 % of unexposed value maximum volume change of 5 %	ISO 1817

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Table 28 — Application instructions

Property	Unit	Primer	Bonding agent	Elastomer
Ambient conditions	—	×	×	×
Minimum temperature	°C	×	—	×
Maximum temperature	°C	×	—	×
Relative humidity	%	×	—	×
Surface preparation	—	×	—	—
Metal surface	—	×	—	—
Cleanliness (ISO 8501-1)	—	×	—	—
Profile (ISO 8503-2, ISO 8503-4 or ISO 8503-5)	µm	×	—	—
Application of the materials	—	×	×	×
Surface pre-heat temperature range	°C	×	—	—
Mixing ratio (if any)	—	×	—	—
Pot life (if any)	min	×	—	—
Curing temperature	—	×	—	—
Minimum overlap on plant coating	mm	—	—	×
Holiday inspection voltage	kV	—	—	×
Repair procedures	—	×	—	×

17 Fusion-bonded epoxy (FBE) powder coatings

17.1 Coating identification

The epoxy powder for a single-layer coating (FJC Type 17A) and for the base layer of a two-layer coating (FJC Type 17B) shall meet the qualification requirements defined in ISO 21809-2.

Data sheets and application instructions for the coating materials shall be in accordance with ISO 21809-2.

17.2 Description of the coatings

The coating consists of one (type 17A) or two (type 17B) layers of FBE powder applied to the pipe and cured.

Maximum service temperature shall be established by agreement between end user and applicator.

For type 17B, application conditions, tests and acceptable results shall be established by agreement between end user or purchaser and applicator.

17.3 Surface preparation

Surface preparation shall be carried out by abrasive blasting according to the provisions of 9.1.2.1 and 9.1.2.2 to a minimum cleanliness of Sa 21/2. The surface profile attained shall be between 50 µm and 100 µm as measured in accordance with ISO 8503-5.

The plant-applied coating shall be roughened for a minimum length of 50 mm each side of the joint. The plant-applied coating shall not be removed.

Dust contamination shall be grade 2 or better measured in accordance with ISO 8502-3.

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17.4 Application of the coatings

17.4.1 General

Application of the coating shall be carried out in accordance with the APS.

17.4.2 Transport and storage of epoxy powder

Powder shall be transported and stored in a sealed container that prevents the ingress of water.

Temperature shall be controlled to meet the manufacturer's requirements and conformance shall be demonstrated by temperature-indication tags or other logging devices. If necessary, refrigeration shall be provided to maintain the required temperature.

17.4.3 Heating

The field joint area shall be uniformly pre-heated, using an induction-heating coil, to a temperature as recommended by the powder manufacturer and in accordance with the APS. If a PQT is performed, the required heat profile shall be verified.

The temperature of the field joint shall be monitored using temperature-indicating crayons or another temperature-measuring device (e.g. hand-held, direct-reading thermocouple or contact thermometer) to ensure that the application conditions are fully satisfied and that the temperature is uniform across the steel substrate and the plant-applied coating. The methods of monitoring and recording shall be specified in the APS.

The amount of crayon used shall be the minimum required for accurate measurement. Any residue shall be removed by wire brushing.

The heating time and the temperature shall not

— result in oxidation of the surface of the steel detrimental to the quality of the FJC,

— damage the plant-applied coating, and

— adversely affect the mechanical properties of the pipe steel.

NOTE For conventional steel grades, a maximum temperature of 275 °C is generally accepted.

CAUTION — For pipe grades over X80, the maximum heating temperature shall be given by the pipe manufacturer.

If a delay results in the surface cooling to below the temperature range specified by the powder manufacturer, the pipe shall be re-heated, and, if required, the abrasive blasting shall be repeated to meet specification requirements.

17.4.4 Application of epoxy powder

The FBE shall be applied immediately after the substrate has attained the correct temperature, as specified in the APS.

The FBE overlap onto the plant-applied coating shall be a minimum of 25 mm.

The FBE powder shall be uniformly applied, by means of a semi-automatic powder ring or carriage that is fitted to and rotates around the pipe to cover the blast-cleaned and pre-heated surface, to provide the specified minimum dry film thickness (DFT). Alternative methods may be used with the approval of the end user.

The coating shall be cured in accordance with the APS.

The cured, field-applied FBE shall not be over-coated with another layer of FBE.

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17.5 Testing of the applied coatings

17.5.1 General

The tests in 17.5.2 to 17.5.10 shall be carried out for production quality control, and for PQT and PPT if required, after the FBE has cured and the joint has cooled down to ambient temperature. For production testing, higher test temperatures may be agreed upon.

17.5.2 Visual appearance

The FJC shall be smooth and free of anomalies, e.g. blisters and sags.

17.5.3 Thickness

The thickness shall be measured using the method given in Annex B.

For type 17A coatings, the thickness shall be 300 µm minimum unless otherwise agreed between the end user and/or purchaser and the applicator.

The maximum thickness of the FJC and the thickness at the overlap between the plant and field joint coating shall be agreed between the end user and/or purchaser and the applicator.

NOTE The specified maximum total thickness of epoxy on the pipe body, weld bead and overlap is especially important in case of bending or reeling/unreeling (e.g. offshore reel barge laying procedure) to prevent any risk of cracking.

For type 17B coatings, the minimum thickness shall be equal to the plant-applied coating thickness.

17.5.4 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS. The number of allowable repairs shall be agreed as defined in 6.2.

17.5.5 Adhesion

The adhesion of the FBE to the steel surface shall be tested in accordance with the method described in Annex Q. The maximum rating shall be 2.

It shall be demonstrated that there is no visual appearance of delamination between the plant and field applied coatings at the overlaps.

17.5.6 Degree of cure

The degree of cure of the epoxy powder shall be determined by differential thermal analysis of a sample of the epoxy layer taken from the FJC, according to the method defined in P.4.

The acceptance criterion shall be the value of ΔT_g given by the manufacturer.

17.5.7 Impact resistance

The impact resistance shall be measured using the method given in Annex D except that the diameter of the hemispherical head is 15,8 mm. The result shall exceed 1,5 J.

17.5.8 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

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The average radius of disbondment shall not exceed the following:

— 8 mm after a period of 28 days at a potential of –1,5 V and 23 °C ± 2 °C;

— 8 mm after a period of 24 h at a potential of –3,5 V and 65 °C ± 2 °C;

— 18 mm after a period of 28 days at a potential of –1,5 V and 65 °C ± 2 °C.

Other testing regimes may be used when agreed between the end user and/or purchaser and the applicator.

17.5.9 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I. Acceptable results shall be a rating 3 or better when assessed using Annex Q.

17.5.10 Flexibility

If required by specific installation methods (e.g. offshore reel barge), flexibility of the coating shall be verified using a method agreed between end user or purchaser and applicator. The bending strain and the test temperature shall be in accordance with the installation conditions.

No visible cracks shall be present after testing.

18 Liquid-applied coatings

18.1 Coating identification

Liquid-applied coatings (FJC Types 18A, 18B, 18C, 18D and 18E) shall be identified in the APS in accordance with Table 29 and shall meet the requirements of Table 30 or 31.

Maximum service temperature shall be established by agreement between end user and manufacturer.

Data sheets for the coating materials shall be in accordance with Table 32.

Application instructions shall be provided by the manufacturer in accordance with Table 33.

18.2 Description of the coatings

18.2.1 Liquid epoxy — 18A

The coating consists of an epoxy based resin applied by spray, roller, brush or trowel.

18.2.2 Liquid polyurethane — 18B

The coating consists of a polyurethane based resin applied by spray, roller, brush or trowel.

18.2.3 Fibre reinforced epoxy — 18C

The coating consists of an epoxy resin applied by spray, roller, brush or trowel and reinforced by glass flakes, glass fibres or glass mat.

18.2.4 Fibre reinforced vinyl ester — 18D

The coating consists of a vinyl ester resin applied by spray, roller, brush or trowel and reinforced by glass flakes, glass fibres or glass mat.

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18.2.5 Cast polyurethane — 18E

The coating consists of a solid polyurethane resin applied by casting.

18.3 Surface preparation

Surface preparation shall be carried out by abrasive blasting according to the provisions of 9.1.2.1 and 9.1.2.2 to a minimum cleanliness of Sa 21/2. The surface profile attained shall be between 50 µm and 100 µm as measured in accordance with the requirements of ISO 8503-5.

The plant-applied coating shall be bevelled and roughened for the minimum length according to the overlap on the plant coating (18.4.3). The plant-applied coating shall not be removed or contaminated by abrasive dust.

Dust contamination shall be grade 2 or better measured in accordance with ISO 8502-3.

If liquid coatings are used in conjunction with a polyolefin plant-applied coating, the plant-applied coating surface may be subject to additional treatments (e.g. flame treatment, chemical treatment) according to the FJC manufacturer's instructions. Such treatments shall be included in the APS and qualified by a PQT.

18.4 Application of the coatings

18.4.1 General

Application of the coating shall be carried out in accordance with the APS.

The manufacturer's instructions, including pot life, thinners, spray guns, tips, nozzles and painter safety, shall be followed.

When fibre reinforcement is used, it shall be prevented that fibres are in direct contact with the steel.

18.4.2 Heating

If applicable, heating using an induction coil or any other agreed method shall be carried out in accordance with the APS.

The temperature of the field joint shall be monitored using temperature-indicating crayons or another temperature-measuring device (e.g. hand-held, direct-reading thermocouple or contact thermometer) to ensure that the application conditions are fully satisfied and that the temperature is uniform across the steel substrate and the plant-applied coating. The methods of monitoring and recording shall be specified in the APS.

The amount of crayon used shall be the minimum required for accurate measurement. Any residue shall be removed by wire brushing.

The heating time and the temperature shall not

— result in oxidation of the surface of the steel detrimental to the quality of the FJC, and

— damage the plant-applied coating.

18.4.3 Liquid coatings application

Coating, including primer if required, shall be applied in accordance with the APS.

The wet-film thickness shall be checked using a wet-film thickness gauge. Insufficient film thickness, bare areas and pinholes shall be corrected within the over-coating time and in accordance with the APS.

The overlap with the plant-applied coating shall be not less than 50 mm, unless otherwise specified.

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18.5 Testing of the applied coatings

18.5.1 General

The tests in 18.5.2 to 18.5.14 shall be carried out for production quality control, and for PQT and PPT if required.

18.5.2 Thickness

The minimum thickness of the coating on the body of the pipe and on the weld cap shall be defined by agreement between the end user and/or purchaser and the applicator and shall not be less than the manufacturer's recommendation.

The dry-film thickness shall be measured using the method given in Annex B.

18.5.3 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm at a maximum of 25 kV, according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS. The number of allowable repairs shall be agreed as defined in 6.2.

18.5.4 Adhesion

The adhesion to the steel surface and to the plant-applied coating shall be tested in accordance with ISO 4624 (pull-off test).

Adhesion shall meet the requirements of Table 30 or 31. These figures are applicable when using a hand driven mechanical device. A proper correlation with the corresponding figures obtained with an automatic device should be established and documented, preferentially during the PQT.

18.5.5 Impact resistance

The impact resistance shall be measured for types 18A, 18B, 18C and 18D using the method given in Annex D and shall meet the requirements of Table 30.

NOTE This test is not applicable for type 18E.

18.5.6 Hardness

Hardness Shore A or Shore D shall be checked using a suitable hardness gauge in accordance with ISO 868. The applicator shall include in the ITP the manufacturer's data that specify the acceptable value obtained.

18.5.7 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 30 or 31. A test duration of 48 h instead of 28 days can be used for PPT, provided that the test temperature is increased to 65 °C and a comparison of results is performed during PQT.

The cathodic disbondment after 28 days at maximum service temperature (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 30 or 31.

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18.5.8 Hot-water immersion test

A hot water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I.

The adhesion to the steel surface and to plant-applied coating shall be tested in accordance with ISO 4624 (pull-off test) and shall meet the requirements of Table 30 or 31.

18.5.9 Flexibility

If required by specific installation methods (e.g. offshore reel barge), flexibility of the coating shall be verified using a method agreed between end user or purchaser. The bending strain and the test temperature shall be in accordance with the installation conditions.

No visible cracks shall be present after testing.

18.5.10 Indentation resistance

The indentation resistance shall be measured for types 18A, 18B, 18C and 18D using the method given in Annex E and shall meet the requirements of Table 30.

NOTE This test is not applicable for type 18E.

18.5.11 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured for types 18A, 18B, 18C and 18D using the method given in Annex F and shall meet the requirements of Table 30.

NOTE This test is not applicable for type 18E.

18.5.12 Compressive strength

For type 18E, the compressive strength shall be measured in accordance with ASTM D695 and shall meet the requirements of Table 31.

18.5.13 Electrical volume resistivity

For type 18E, the electrical volume resistivity shall be measured in accordance with ASTM D257 and shall meet the requirements of Table 31.

18.5.14 Water absorption

For type 18E, the water absorption shall be measured in accordance with ISO 62 and shall meet the requirements of Table 31.

Table 29 — Coating identification

Property
Coating trade name
Basic type of coating material
Minimum thickness of the applied coating system
Compatible plant coatings[a]
Maximum service temperature
[a] State all types of plant coating that have been tested successfully with the coating.

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Table 30 — Requirements for types 18A, 18B, 18C and 18D liquid coatings

Property	Test temp.	Unit	Type 18A	Type 18B	Type 18C	Type 18D	Test method
			Liquid epoxy	Liquid PU	Reinforced epoxy	Reinforced vinyl ester	
Minimum thickness	—	µm	by agreement				Annex B
Visual inspection	—	—	Continuous and uniform film free of sags runs and colour striations (when applicable)		—	—	—
Holiday detection at 5 kV/mm at a maximum of 25 kV	—	—	no holiday				Annex C
Impact resistance (holiday detection at 5 kV/mm)	23 °C –5 °C	J/mm	≥3 ≥1,5	≥5 ≥2,0	≥5 ≥1,5	≥5 ≥1,5	Annex D
Indentation resistance at 10 N/mm²	*T*max	% DFT	≤ 30	≤30	≤10	≤10	Annex E
Cathodic disbondment at 28 days	23 °C T_{max} limited to 95 °C	mm	≤8 ≤15	≤10 ≤20	≤8 ≤15	≤8 ≤15	Annex G
Hardness (Shore A or D)	23 °C	—	as per manufacturer specification				ISO 868
Adhesion to pipe surface	23 °C	MPa	≥10,0[a]	≥10,0[a]	≥7	≥7	ISO 4624
Adhesion to FBE, liquid applied epoxy or PU plant coatings	23 °C	MPa	≥10,0[a]	≥10,0[a]	≥10,0[a]	≥10,0[a]	ISO 4624
Adhesion to polyolefin plant coatings	23 °C	MPa	≥3,5	≥3,5	≥2,0	≥2,0	ISO 4624
Adhesion to pipe surface after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	MPa	≥7,0	≥7,0	≥7,0	≥7,0	Annex I plus ISO 4624
Adhesion to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	MPa	≥2,0	≥2,0	≥2,0	≥2,0	Annex I plus ISO 4624
Specific electrical insulation resistance (R_{S100})	23 °C	Ω·m²	≥10⁶	≥10⁶	≥10⁶	≥10⁶	Annex F
R_{S100}/R_{S70}	—	—	≥0,80[b]	≥0,80[b]	≥0,80[b]	≥0,80[b]	—

[a] Figures applicable for PQT and PPT. For production testing, results of 70 % of these figures may be accepted by agreement due to a possible lack of curing of the glue during the allowable duration of testing, provided that the failure occurs within the glue.

[b] It is necessary that this requirement ($R_{S100}/R_{S70} \geq 0,8$) be fulfilled only if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days.

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Table 31 — Requirements for solid cast polyurethane — 18E

Property	Test temp.	Unit	Type 4E Solid cast polyurethane	Test method
Minimum thickness	—	—	By agreement	Annex B
Holiday detection at 5 kV/mm at a maximum of 25 kV	—	—	No holiday	Annex C
Compressive strength	23 °C	MPa	≥30	ASTM D695
Cathodic disbondment at 28 days	23 °C T_{max} limited to 95 °C	mm —	≤10 ≤20	Annex G —
Hardness (Shore A or D)	23 °C	—	As per manufacturer specification	ISO 868
Adhesion to pipe surface	23 °C	MPa	≥10	ISO 4624
Adhesion to plant coating	23 °C	MPa	≥3,5	ISO 4624
Adhesion to pipe surface after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	MPa	≥7	Annex I plus ISO 4624
Adhesion to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	MPa	≥2,0	Annex I plus ISO 4624
Electrical volume resistivity	23 °C	Ω·cm	$\geq 10^{12}$	ASTM D257
Water absorption at 7 days	23 °C	mass %	≤0,1	ISO 62

Table 32 — Data sheet

Property	Unit	Test method
Trade name	—	—
Description of coating material	—	—
Solid content	%	—
Density	g/cm^3	ISO 2811-1
Mix ratio	—	—
Colour	—	—
Minimum thickness	mm	ISO 4591 and ISO 4593
Maximum application temperature	°C	—
Minimum application temperature	°C	—
Maximum service temperature	°C	—
Minimum design temperature	°C	—
Maximum storage temperature	°C	—
Minimum storage temperature	°C	—
Shelf life at storage temperature	month	—

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Table 33 — Application instructions

Property	Unit
Ambient conditions (dew point)	—
Surface preparation of steel surface	—
Cleanliness (ISO 8501-1)	—
Profile (ISO 8503-2)	—
Surface preparation of plant coating	—
Pre-heat temperature range	—
Application of liquid coatings	—
Mixing ratio	—
Pot life	—
Cure temperature profile (temp. vs. time)	—
Overlap on plant coating (minimum)	—
Repair procedures	—

19 Hot-applied polyolefin-based coatings

19.1 Coating identification

Coatings made from polypropylene (PP) or polyethylene (PE) and with an innermost layer of epoxy resin (FJC Types 19A, 19B, 19C, 19D and 19E) shall be identified in the APS in accordance with Table 34 and shall meet the requirements of Table 35 or 36.

Data sheets for the coating materials shall be in accordance with Table 37 (epoxy material), Table 38 (modified PP or PE powder) and Table 39 (PP or PE top coat material).

Application instructions shall be provided by the manufacturer in accordance with Table 40.

19.2 Description of the coatings

19.2.1 Flame-sprayed polypropylene — Type 19A

The coating consists of the following:

— an epoxy resin layer, applied in the form of powder by flocking or by electrostatic spray, or applied in liquid form by spraying or by manual application;

— a layer of chemically modified PP powder applied by spraying or flocking;

— a top layer of chemically modified PP powder applied by flame spraying.

Two-layer coatings (with chemically modified PP incorporated in the PP powder) can be used with the agreement of all parties provided that the requirements of Table 35 are met.

Flocking operation can be done with the same equipment as used for flame spraying.

Maximum service temperature is 110 °C or as agreed between the applicator and the end user.

19.2.2 Hot-applied polypropylene tapes/sheets — Type 19B

The coating consists of the following three layers:

— an epoxy resin layer, applied in the form of powder by flocking or by electrostatic spray, or applied in liquid form by spraying or by manual application;

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— a layer of chemically modified PP applied by spraying, extruding or wrapping;

— a top layer of hot-applied PP tape or sheet wrapped in a spiral or wraparound method.

Two-layer coatings (with chemically modified PP incorporated in the PP tape or sheet) can be used with the agreement of all parties provided that the requirements of Table 35 are met.

Maximum service temperature is 110 °C or as agreed between the applicator and the end user.

19.2.3 Injection-moulded polypropylene — Type 19C

The coating consists of the following three layers:

— an epoxy resin layer, applied in the form of powder by flocking or by electrostatic spray, or applied in liquid form by spraying or by manual application;

— a layer of chemically modified PP powder applied by spraying or flocking;

— a top layer of PP applied by injection into a mould.

Maximum service temperature is 110 °C or as agreed between the applicator and the end user.

19.2.4 Flame-sprayed polyethylene — Type 19D

The coating consists of the following:

— an epoxy resin layer, applied in the form of powder by flocking or by electrostatic spray, or applied in liquid form by spraying or by manual application;

— a layer of chemically modified PE powder applied by spraying or flocking;

— a top layer of chemically modified PE powder, applied by flame spraying.

Flocking operation can be done with the same equipment as used for flame spraying.

Two-layer coatings (with chemically modified PE incorporated in the PE powder) can be used with the agreement of all parties provided that the requirements of Table 36 are met.

Maximum service temperature is 70 °C or as agreed between the applicator and the end user.

19.2.5 Hot-applied polyethylene tapes/sheets — Type 19E

The coating consists of the following three layers:

— an epoxy resin layer, applied in the form of powder by flocking or by electrostatic spray, or applied in liquid form by spraying or by manual application;

— a layer of chemically modified PE applied by spraying, extruding or wrapping;

— a top layer of hot-applied PE tape or sheet wrapped in a spiral or wraparound method.

Two-layer coatings (with chemically modified PE incorporated in the PE tape or sheet) can be used with the agreement of all parties provided that the requirements of Table 36 are met.

Maximum service temperature is 80 °C or as agreed between the applicator and the end user.

19.2.6 Thickness of the epoxy primer

The minimum thickness of the primer shall be specified in order to fulfil the requirements of Tables 35 and 36. The recommended minimum thickness is 200 µm measured in accordance with Annex B.

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19.3 Surface preparation

Surface preparation shall be carried out by abrasive blasting according to the provisions of 9.1.2.1 and 9.1.2.2 to a minimum cleanliness of Sa 21/2. The surface profile attained shall be between 50 µm and 100 µm as measured in accordance with the requirements of ISO 8503-5.

The plant-applied coating shall be bevelled and roughened for the minimum length according to the overlap on the plant coating (19.4.4). The plant-applied coating shall not be removed or contaminated by abrasive dust.

Dust contamination shall be grade 2 or better measured in accordance with ISO 8502-3.

19.4 Application of the coating

19.4.1 General

Application of the coating shall be carried out in accordance with the APS.

Precautions for transportation and storage of epoxy powder in accordance with 17.4.2 apply.

19.4.2 Heating

The field joint area shall be uniformly pre-heated, using an induction-heating coil, to a temperature as recommended by the powder manufacturer and in accordance with the APS.

The temperature of the field joint shall be monitored using temperature-indicating crayons or another temperature measuring device (e.g. hand-held, direct-reading thermocouple or contact thermometer) to ensure that the application conditions are fully satisfied and the temperature is uniform across the steel substrate and the plant-applied coating. The methods of monitoring and recording shall be specified in the APS.

The amount of crayon used shall be the minimum required for accurate measurement. Any residue shall be removed by wire brushing.

The heating time and the temperature shall not

— result in oxidation of the surface of the steel detrimental to the quality of the FJC,

— damage the plant-applied coating, and

— adversely affect the mechanical properties of the pipe steel.

NOTE For conventional steel grades, a maximum temperature of 275 °C is generally accepted.

CAUTION — For pipe grades over X80, the maximum heating temperature shall be given by the pipe manufacturer.

If a delay results in a surface cooling to below the temperature range specified by the powder manufacturer, the pipe shall be re-heated, and, if required, the abrasive blasting shall be repeated to meet specification requirements.

19.4.3 Application of the epoxy layer

The epoxy layer shall be applied on the steel surface manually or automatically by spraying of the liquid or the powder, in accordance with the APS.

The overlap with the plant-applied coating shall be as specified in the APS.

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19.4.4 Application of the chemically modified PP or PE

If applied as a powder directly after or together with the epoxy in one continuous process, the chemically modified PP or PE shall not overlap the plant-applied coating.

In all other cases, the overlap on the plant-applied coating, excluding bevels, shall not be less than 10 mm unless otherwise specified.

The chemically modified PP or PE shall be applied within the epoxy gel time.

19.4.5 Application of the polyolefin top coat

19.4.5.1 General

The plant-applied coating in the overlap area shall be heated to the temperature specified in the APS and shall be monitored during coating application.

The overlap on the plant-applied coating, excluding bevels, shall not be less than 50 mm, unless otherwise specified.

19.4.5.2 Types 19A and 19D

The chemically modified PP or PE powder shall be applied by flame spray to obtain the specified coating thickness.

The applicator shall control the application parameters to ensure that the oxidation requirements in 19.5.11 are met.

19.4.5.3 Types 19B and 19E

The PP or PE shall be applied by wrapping a pre-heated tape or sheet in a spiral or wraparound method by means of an automatic or semi-automatic machine to obtain the specified coating thickness.

A heating system shall be used to ensure adhesion on the plant-applied coating and between the tape overlapping. The overlap between successive layers shall be specified in the APS.

The tape shall be wrapped with sufficient tension to avoid any wrinkling or air entrapment.

The tape may also be heated during application.

19.4.5.4 Type 19C

The top coat shall be applied by injection of molten PP to obtain the specified coating thickness.

A heating system shall be used to ensure adhesion on the plant-applied coating. Surface conditions and plant-applied coating surface temperature shall be in accordance with the APS.

Tolerances on circumference/ovality at pipe ends shall be in accordance with the applicable linepipe specification.

19.5 Testing of the applied coatings

19.5.1 General

The tests in 19.5.2 to 19.5.12 shall be carried out for production quality control, and for PQT and PPT if required.

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19.5.2 Thickness

The minimum thickness of the epoxy layer shall be defined by agreement between the end user or purchaser and the applicator.

The minimum thickness of the complete FJC on the body of the pipe shall be equal to the thickness of the plant-applied coating unless otherwise agreed. The same minimum thickness shall also apply to areas with seam welds. .

A maximum thickness should be specified to ensure safe passage of the coated field joints through tensioner equipment onboard the pipelay vessel.

The thickness shall be measured using the method given in Annex B.

19.5.3 Holiday detection

The entire surface of the coated field joint shall be checked for holidays or other discontinuities at a voltage of 10 kV/mm at a maximum of 25 kV, according to the method defined in Annex C.

Holidays shall be repaired in accordance with the APS. The number of allowable repairs shall be agreed as defined in 6.2.

19.5.4 Peel strength

The peel strength shall be measured using methods given in Annex H and shall meet the requirements of Table 35 or Table 36. The method given in H.1 should preferably be used for PQT. The method given in H.2 can be used for PPT and production testing, as well as for PQT in agreement with purchaser.

If the thickness of the field joint coating is greater than 3 mm, the thickness may be reduced before testing.

Disbondment between epoxy and steel shall be considered a failure of the test whatever the measured value of peel strength.

19.5.5 Adhesion to plant coating

Adhesion of the FJC to the plant coating shall be checked using a method agreed between end user and/or purchaser and applicator. It may be carried out during a peeling test on the overlap.

Delamination between coatings shall be considered a failure of the test.

19.5.6 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I with a duration of 28 days, the test temperature being the maximum service temperature of the joint coating, limited as specified in Annex I.

The adhesion to pipe surface and plant coating shall be measured in accordance with Annex H and shall meet the requirements of Table 35 or 36.

19.5.7 Degree of cure

The degree of cure of the epoxy powder shall be determined by differential thermal analysis of a sample of epoxy layer taken from the FJC, according to the method defined in P.4.

The acceptance criterion shall be the value of ΔT_g given by the manufacturer.

19.5.8 Cathodic disbondment

The cathodic disbondment shall be measured using the method given in Annex G.

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The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 35 or 36. A test duration of 48 h instead of 28 days can be used for PPT if the test temperature is increased to 65 °C and provided that comparison of results is performed during PQT.

The cathodic disbondment after 28 days at the maximum service temperature (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 35 or 36.

19.5.9 Impact resistance

The impact resistance shall be measured using the method given in Annex D and shall meet the requirements of Table 35 or 36.

19.5.10 Indentation resistance

The indentation resistance shall be measured using the method given in Annex E and shall meet the requirements of Table 35 or 36.

19.5.11 Oxidation induction time

The oxidation induction time shall be measured in accordance with ISO 11357-6 at a temperature of 220 °C. The minimum acceptable value of the intercept in the tangent method shall be 15 min.

19.5.12 Flexibility

If required by specific installation methods (e.g. offshore reel barge), flexibility of the coating shall be verified using a method agreed between end user or purchaser. The bending strain and the test temperature shall be in accordance with the installation conditions.

No visible cracks shall be present after testing.

Table 34 — Coating identification

Property
Basic type of coating material
Minimum thickness of coating system
Compatible plant coatings

Table 35 — Requirements for types 19A, 19B and 19C — PP

Property	Test temperature	Unit	Requirements	Test method
Total coating thickness	—	mm	By agreement	Annex B
Epoxy layer thickness	—	mm	By agreement	Annex B
Holiday detection at 10 kV/mm, max. 25 kV	—	—	No holiday	Annex C
Peel strength	23 °C	N/mm	≥15	Annex H
	T_{max}	N/mm	≥4	Annex H
Adhesion to pipe surface and plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	P_{28}/P_0	≥0,75	Annex I plus Annex H
Degree of cure	—	°C	ΔT_g given by the manufacturer	Annex P
Cathodic disbondment at 28 days	23 °C	mm	≤7	Annex G
	T_{max} limited to 95°C	mm	≤15	Annex G

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Table 35 *(continued)*

Property	Test temperature	Unit	Requirements	Test method
Impact resistance[a]	23 °C	J/mm	$7 \times \alpha \times \beta$ [b] for 19A $10 \times \alpha \times \beta$ [b] for 19B and 19C	Annex D
Indentation resistance at a pressure of 10 N/mm^2	T_{max} [c]	mm	≤0,9	Annex E
Flexibility	d	—	d	d
Oxidation induction time at 220 °C (intercept in the tangent method)[e]	—	min	≥15	ISO 11357-6

[a] The maximum impact energy used for testing shall be 21 J for type 19A and 25 J for types 19B and 19C.

[b] α = 0,7 for coating thickness less than or equal to 2 mm;

α = 1 for coating thickness greater than 2 mm;

β = 0,7 for pipe with nominal diameter less than 65 mm;

β = 0,85 for pipe with nominal diameter from 65 mm to less than 200 mm;

β = 1,0 for pipe with nominal diameter from 200 mm.

[c] For types 19A and 19B the test is carried out at 90 °C

[d] By agreement, if applicable.

[e] May be omitted for types 19B and 19C if agreed between end user or purchaser and applicator.

Table 36 — Requirements for types 19D (flame-sprayed PE) and 19E (PE tapes)

Property	Test temperature	Unit	Value	Test method
Total coating thickness	—	mm	By agreement	Annex B
Epoxy layer thickness	—	mm	By agreement	Annex B
Holiday detection at 10 kV/mm, max. 25 kV	—	—	No holiday	Annex C
Peel strength	23 °C	N/mm	>15	Annex H
	*T*max	N/mm	>4,0	Annex H
Adhesion to pipe surface and plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	—	>10 N/mm	Annex I plus Annex H
Degree of cure	—	°C	ΔT_g given by the manufacturer	Annex P
Cathodic disbondment at 28 days	23 °C	mm	≤7	Annex G
	*T*max	mm	≤10	Annex G
Impact resistance[a]	23 °C	J/mm	$5 \times \alpha \times \beta$	Annex D
Indentation resistance at a pressure of 10 N/mm^2	*T*max	mm	≤1,0	Annex E
Flexibility	b	—	b	b
Oxidation induction time at 220 °C (intercept in the tangent method)[c]	—	min	≥ 15	ISO 11357-6

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Table 36 *(continued)*

Property	Test temperature	Unit	Value	Test method
[a] α = 0,7 for coating thickness less than or equal to 2 mm; α = 1 for coating thickness greater than 2 mm; β = 0,7 for pipe with nominal diameter less than 65 mm; β = 0,85 for pipe with nominal diameter from 65 mm to less than 200 mm; β = 1,0 for pipe with nominal diameter from 200 mm. [b] By agreement, if applicable. [c] May be omitted for types 19E if agreed between end user or purchaser and applicator.				

Table 37 — Data sheet — Epoxy material

Property	Unit	Test method
Trade name	—	—
Generic type (powder or liquid)	—	—
Solid content	%	—
Density	g/cm^3	ISO 2811-1
Mix ratio (if any)	—	—
Storage conditions max	°C	—
Shelf life at storage temperature	month	—

Table 38 — Data sheet — Modified PP or PE powder

Property	Unit	Test method
Trade name	—	—
Description of the powder	—	—
Colour	—	—
Type	—	—
Storage conditions	—	—
Shelf life	month	—

Table 39 — Data sheet — PP or PE top coat material

Property	Unit	Test method
Trade name	—	—
Description of the top coat material	—	—
Colour	—	—
Storage conditions	—	—
Shelf life	month	—

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Table 40 — Application instructions

Property	Unit	Epoxy	PE or PP
Ambient conditions	—	×	×
Minimum temperature	°C	×	×
Maximum temperature	°C	×	×
Relative humidity	%	×	×
Surface preparation	—	×	—
Metal surface	—	×	—
Cleanliness (ISO 8501-1)	—	×	—
Profile (ISO 8503-2, ISO 8503-4 or ISO 8503-5)	µm	×	—
Application of the epoxy primer	—	×	—
Method of application	—	×	×
Surface pre-heat temperature range	°C	×	—
Mixing ratio (if any)	—	×	—
Pot life (if any)	min	×	—
Curing temperature	—	×	—
Application of the modified PP or PE powder	—	—	×
Method of pre-heat of PE or PP materials	—	—	×
Application of the PP or PE materials	—	—	×
Minimum overlap on plant coating	mm	—	×
Holiday inspection voltage	kV	—	×
Repair procedures	—	×	×

20 Thermal spray aluminium (TSA) coatings

20.1 Coating identification

TSA field joint coatings (FJC Type 20) shall be applied only in conjunction with TSA plant-applied coating and shall meet the requirements of Table 41.

Data sheets for the coating materials shall be in accordance with Table 42.

The chemical composition for 1100 or 1350 aluminium wire for thermal spray shall conform to the requirements of AWS C2.25/C2.25M. Mill certificates showing the chemical composition of each lot of wire shall be provided by the manufacturer.

20.2 Description of the coating

The coating consists of the following:

— thermal spray coating of aluminium;

— a top coat of a liquid sealer that penetrates into the interconnected pores of the TSA.

NOTE The sealer is intended to fill the porosity of the TSA and not to build film thickness.

20.3 Qualification

The APS and the coating personnel shall be qualified by a PQT and PPT in accordance with 7.3, 7.4 and 7.5.

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20.4 Surface preparation

Surface preparation shall be carried out by abrasive blasting according to the provisions of 9.1.2.1 and 9.1.2.2 to a minimum cleanliness of Sa 3. The surface profile attained shall be between 60 µm and 125 µm as measured in accordance with the requirements of ISO 8503-5.

Surface preparation shall continue onto the plant-applied coating to ensure adhesion. Feathering shall be used to provide for a smooth transition between coatings, as required. The edges of the plant-applied coating shall be angle-blasted to provide a 50 mm to 75 mm feathered overlap.

Dust contamination shall be grade 2 or better measured in accordance with ISO 8502-3.

The level of soluble salts, measured in accordance with ISO 8502-6 and ISO 8502-9, shall be less than 20 mg/m^2.

20.5 Application of the coating

20.5.1 General

Thermal spray coatings and sealers shall be applied when the surface temperature is at least 3 °C above the dew point.

If pre-heating is used to eliminate surface moisture, maximum surface temperature shall not exceed 65 °C.

20.5.2 Aluminium

Thermal spray equipment shall be set up, calibrated and operated according to the manufacturer's instructions and the APS.

The area being coated shall be heated to approximately 40 °C to 65 °C.

The specified coating thickness shall be applied in several crossing passes. Spray parameters and thickness of each crossing pass shall be set for spraying the specified thermal spray material.

For manual spraying, right-angle crossing passes shall be used to minimize thin spots in the coating.

For semi-automatic spraying with clamp-shell-type equipment, overlapping shall be programmed to eliminate thin spots and stay within the coating thickness specification.

20.5.3 Sealer

Handling, mixing, storage and application of sealer materials and solvents shall be in accordance with the manufacturer's recommendations and the APS.

The sealer may be thinned with thinners and sprayed in two or three coats. Sealer materials and thinners shall be made and supplied by the same manufacturer.

Spray equipment used to apply liquid sealers shall be equipped with dual air pressure regulation controls and pressure gauges for independent control of pot and gun pressures. Spray gun tips shall be in accordance with the manufacturer's recommendations for application of thin and low-viscosity sealers.

20.6 Testing of the applied coating

20.6.1 General

The tests in 20.6.2 to 20.6.7 shall be carried out for PQT, PPT and production quality control. Companion coupons necessary for performing tests described in 20.6.3 and 20.6.5 shall be prepared during application according to the APS.

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20.6.2 Visual inspection

The deposited TSA shall be examined with 10× or higher magnification and shall be uniform, without blisters, cracks, loose particles or exposed steel.

20.6.3 TSA porosity

The porosity shall be measured on companion coupons by metallographic examination and shall not exceed 10 % by volume unless otherwise specified.

20.6.4 Coating thickness

The coating thickness shall be measured in accordance with ISO 2178 before the application of sealer and shall meet the requirements of Table 41.

Thickness measurements shall be conducted along a straight line. The average value of five readings taken in a line at 25 mm intervals shall be determined.

If the TSA thickness is less than the specified minimum requirement, the applicator shall apply additional TSA. If the TSA thickness is greater than the specified maximum value without exceeding 500 µm, the purchaser may accept the coating subject to an acceptable adhesion test.

20.6.5 Bend test

Three steel companion coupons shall be used to monitor the adhesion of the TSA. The bend test shall be conducted using a 180° bend of a 3 mm thick and 50 mm wide steel coupon on a 25 mm diameter steel mandrel in accordance with SSPC CS 23.00.

There shall be no lifting from the substrate when a knife blade is used.

20.6.6 Pull-off adhesion test

Pull-off adhesion strength to substrate shall be measured on unsealed TSA in accordance with ISO 4624 for labarotory testing and ASTM D4541 for field testing, and shall meet the requirements of Table 41.

20.6.7 Sealer penetration

Sealer shall be inspected at 30× power magnification and shall exhibit no voids or missed areas in coverage.

Table 41 — Requirements for TSA coatings

Property	Test method	Requirements
TSA finish	Visual inspection	Uniform, no bare spots, no blister
Porosity	Metallographic examination	Maximum 10 % or by agreement between the purchaser and the applicator
Thickness	ISO 2178	200 µm to 375 µm
Sealer penetration	Metallographic examination	Penetrate through interconnected pores
Bend test	SSPC CS 23.00, except: 25 mm diameter mandrel and 3 mm thick coupon	No peeling off
Adhesion	Pull-off lab method (ISO 4624)	≥14 MPa
	Pull-off field method (ASTM D4541)	≥7 MPa

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Table 42 — Data sheet — TSA

Property	Unit	Test method
Name of wire manufacturer	—	—
Wire size	mm	—
Chemical composition of wire	—	—
Minimum thickness	mm	ISO 2178
Name of sealer manufacturer	—	—
Sealer product name	—	—

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Annex A
(normative)

Test programmes for procedure qualification trials (PQT), pre-production trials (PPT) or production testing

A.1 General

This Annex gives the testing frequencies for PQT, PPT and production testing, as defined in 7.3, 7.4 and 7.6.

Alternative test regimes and frequencies can be used by agreement.

Requirements for PQT and PPT shall be defined in the purchase order.

A.2 Inspections, tests and frequencies

The inspections that shall be carried out during PQT, PPT and production testing are summarized in Table A.1 (depending on the FJC). The list of verifications and test methods together with their frequencies are given in Table A.1.

Some of the requirements for production testing may not be achievable on site, e.g. offshore. The production test programme may therefore be adapted to suit the site conditions based on comparative testing during PQT or PPT.

Any test required that is not mentioned in Table A.1 shall be documented by the manufacturers. This covers long-term tests related to the material itself, such as specific electrical insulation resistance, thermal ageing, or thermal stability.

A shift is defined as the time period when a crew of workers is at work.

A.3 Retest

If one of the tests fails, the test shall be repeated. No further failure is allowed.

Table A.1 — Frequency of testing and inspection for specific FJC types

Property	FJC types	Reference subclause[a]	Method of testing	Frequency		
				PQT	PPT	Production
Surface condition of the area to be coated before preparation	All	9.1.2.1	Visual	3 joints	3 joints	Each joint
Visual inspection of the cleaned surface	All	9.1.2.2 or 9.1.2.3	ISO 8501-1	3 joints	3 joints	Each joint
Roughness of the abrasive blast cleaned surface	All	9.1.2.2	ISO 8503-1	3 joints	3 joints	3 times per shift

[a] Not restricted to the specified subclause.

[b] Testing of the soluble salt level during production may be reduced or omitted, by agreement between applicator and end user or purchaser, if a PPT has demonstrated that the application procedure ensures a salt level below these requirements.

[c] ISO 4624 may be used.

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Table A.1 *(continued)*

Property	FJC types	Reference subclause[a]	Method of testing	Frequency		
				PQT	PPT	Production
Level of soluble salts on the abrasive blast cleaned surface	14B, 14C, 14D, 16, 17, 18, 19 and 20	9.1.2.2	ISO 8502-6 and ISO 8502-9	3 joints	3 joints	3 times per shift[b]
Dust contamination	All	9.1.2.1	ISO 8502-3	3 joints	3 joints	3 times per shift
Examination of the adjacent dulled plant-applied coating	All except 20	9.1.3	Visual	3 joints	3 joints	Each joint
Temperature of the surface to be coated	All	9.2	—	3 joints	3 joints	Each joint
Application criteria	All	—	—	3 joints	3 joints	Continuously
Degree of cure of epoxy	14B, 14C, 14D, 17A, 17B, 19	—	Annex P	3 joints	3 joints	—
Oxidation induction time (intercept in the tangent method)	19	19.5.11	ISO 11357-6	3 joints	3 joints	By agreement
Visual inspection of the coating	All	9.3	—	3 joints	3 joints	Each joint
Inspection of thickness	All	—	Annex B	3 joints	3 joints	By agreement
Holiday detection test	All except 20	—	Annex C	3 joints	3 joints	Each joint
Impact resistance test	All except 20	—	Annex D	3 joints	3 joints	—
Indentation resistance test	All except 20	—	Annex E	3 joints	—	—
Shore hardness	18	18.5.6	ISO 868	3 joints	3 joints	—
Peel strength between layers at ambient temperature	12	12.5.7	Annex L	3 joints	3 joints	—
Peel strength between layers at maximum service temperature	12	12.5.7	Annex L	3 joints	By agreement	—
Peel strength on steel surface and plant coating at ambient temperature	10, 12, 14A, 14B, 14C, 14D	10.5.8, 12.5.8 14.5.4	Annex H	3 joints	3 joints	Once per shift
Peel strength on steel surface and plant coating at T_{max}	12, 14A, 14B, 14C, 14D	12.5.8 14.5.4	Annex H	3 joints	—	—
Peel strength on steel surface and plant coating at ambient temperature	11A, 11B	11.5.8	—	3 joints	3 joints	Once per shift
Adhesion to steel surface at ambient temperature	17	17.5.5	Annex Q	3 joints	3 joints	Once per shift

[a] Not restricted to the specified subclause.

[b] Testing of the soluble salt level during production may be reduced or omitted, by agreement between applicator and end user or purchaser, if a PPT has demonstrated that the application procedure ensures a salt level below these requirements.

[c] ISO 4624 may be used.

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Table A.1 *(continued)*

Property	FJC types	Reference subclause[a]	Method of testing	Frequency		
				PQT	PPT	Production
Adhesion to steel surface and plant coating at ambient temperature	18A, 18B, 18C, 18D	18.5.4	ISO 4624	3 joints	3 joints	Once per shift
Adhesion to steel surface and plant coating at ambient temperature	18E	18.5.4	ISO 4624	3 joints	—	—
Adhesion to plant coating at ambient temperature	17	17.5.5	—	3 joints[c]	3 joints[c]	Once per shift
Peel strength on steel surface at ambient temperature and T_{max}	19	19.5.4 19.5.5	Annex H	3 joints	3 joints	—
Peel strength on plant coating at ambient temperature and T_{max}	7	19.5.4 19.5.5	—	3 joints	3 joints	—
Adhesion to steel surface at ambient temperature	20	20.6.6	ISO 4624	3 joints	—	—
Adhesion to steel surface at ambient temperature	20	20.6.6	ASTM D4541	—	3 joints	Once per shift
Adhesion to steel surface and plant coating at 50 °C	15	15.5.4	—	3 joints	3 joints	—
Peel strength on steel surface and plant coating at ambient temperature	16	16.5.6	Annex H	3 joints	3 joints	Once per shift
Hot-water immersion test	All except 15 and 20	—	Annex I	By agreement	By agreement	—
Peel strength on pipe surface and plant coating at ambient temperature after hot-water immersion	10, 12, 14A, 14B, 14C, 14D	10.5.9 12.5.9 14.5.6	Annex H	3 joints	By agreement	—
Peel strength on pipe surface and plant coating at ambient temperature after hot-water immersion	11A, 11B	11.5.9	—	3 joints	3 joints	—
Adhesion on steel surface at ambient temperature after hot-water immersion	17	17.5.9	Annex Q	3 joints	By agreement	—

[a] Not restricted to the specified subclause.

[b] Testing of the soluble salt level during production may be reduced or omitted, by agreement between applicator and end user or purchaser, if a PPT has demonstrated that the application procedure ensures a salt level below these requirements.

[c] ISO 4624 may be used.

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Table A.1 *(continued)*

Property	FJC types	Reference subclause[a]	Method of testing	Frequency		
				PQT	PPT	Production
Adhesion on steel surface and plant coating at ambient temperature after hot-water immersion	18	18.5.8	ISO 4624	3 joints	By agreement	—
Adhesion on steel surface and plant coating at ambient temperature after hot-water immersion	19	19.5.6	Annex H	3 joints	By agreement	—
Adhesion on steel surface and plant coating at ambient temperature after hot-water immersion	16	16.5.7	Annex H	3 joints	By agreement	—
Lap shear strength at ambient temperature	10, 12, 14A, 14B, 14C, 14D	10.5.10, 12.5.10 14.5.9	Annex J	3 joints	By agreement	—
Lap shear strength at maximum service temperature	12, 14A, 14B, 14C, 14D	12.5.10 14.5.9	Annex J	3 joints	By agreement	—
Cathodic disbondment test at ambient temperature	All except 15 and 20	—	Annex G	3 joints	3 joints	—
Cathodic disbondment at maximum service temperature	All except 10, 11A, 11B, 15 and 20	—	Annex G	3 joints	By agreement	—
TSA porosity	20	—	Metallographic examination	3 joints	3 joints	—
Thickness	18	—	ISO 2178	3 joints	3 joints	Each joint
Sealer penetration	20	—	Metallographic examination	3 joints	3 joints	—
Bend test with 25 mm diameter mandrel and 3 mm thick coupon	20	—	SSPC CS 23.00	3 joints	3 joints	Once per shift
Peel strength between outer wrap tape layers at ambient and maximum service temperatures	13A-a	18.5.8	Annex L	3 joints	By agreement	—
Peel strength of outer wrap with respect to plant coating (when relevant) at ambient and maximum service temperatures	13A	13.5.9	Annex H	3 joints	By agreement	—

[a] Not restricted to the specified subclause.

[b] Testing of the soluble salt level during production may be reduced or omitted, by agreement between applicator and end user or purchaser, if a PPT has demonstrated that the application procedure ensures a salt level below these requirements.

[c] ISO 4624 may be used.

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Table A.1 *(continued)*

Property	FJC types	Reference subclause[a]	Method of testing	Frequency		
				PQT	PPT	Production
Adhesion of compound tape to steel surface and plant coating at ambient temperature	13A, 13B	13.5.9	Annex H or 13.5.9	3 joints	3 joints	Once per shift
Adhesion of compound tape to steel surface and plant coating at maximum service temperature	13A, 13B	13.5.9	Annex H or 13.5.9	3 joints	By agreement	—
Adhesion of compound tape to steel surface and plant coating at ambient and maximum service temperatures after hot-water immersion test	13A, 13B	13.5.12	Annex H or 13.5.9	3 joints	By agreement	—
Lap shear test of compound tape at ambient temperature	13A, 13B	13.5.11	Annex J	3 joints	By agreement	—
Lap shear test of compound tape at maximum temperature	13A, 13B	13.5.11	Annex J	3 joints	By agreement	—
Drip resistance of the compound tape	11A, 11B, 13A, 13B	11.5.10 13.5.14	Annex K	3 joints	By agreement	—
Glass transition temperature of compound tape	13A, 13B	13.5.13	Annex P	3 joints	—	—
Bursting strength	14C	14.5.11	Annex O	3 joints	—	—

[a] Not restricted to the specified subclause.

[b] Testing of the soluble salt level during production may be reduced or omitted, by agreement between applicator and end user or purchaser, if a PPT has demonstrated that the application procedure ensures a salt level below these requirements.

[c] ISO 4624 may be used.

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Annex B
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Inspection of thickness

B.1 General

The inspection consists of measuring the thickness of the FJC.

B.2 Equipment

The equipment consists of a magnetic, electromagnetic or ultrasonic measuring instrument, with ±10 % reading accuracy, calibrated for the range of coating thickness being measured.

B.3 Procedure

At the start of each shift, the instrument readings shall be checked using calibrated plates and shims of the same thickness and temperature range as the FJC and, if necessary, be adjusted.

On each FJC being inspected, a total of eight measurements shall be carried out on the body of the pipe.

The measurements shall be taken at points distributed along four equally spaced longitudinal lines along the pipe length with two circumferential lines, one on each side of the weld bead.

In addition, four additional measurements shall be carried out on a circumferential line on top of the weld bead.

For measuring a thickness of less than 1 mm, the surface profile of the joint shall be taken into account for calibration.

B.4 Results

The minimum value, and maximum value where required, for the body and for the weld bead shall be recorded.

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Annex C
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Holiday detection test

C.1 General

The test consists of detecting any porosity of the FJC using a scanning electrode energized by a high arc voltage.

Defects shall be detected by a spark occurring between the steel and the electrode at the defect, accompanied by a sound and/or light signal.

C.2 Equipment

The equipment consists of an adjustable, high-voltage holiday detector with ±10 % reading accuracy, equipped with a sound and/or light signal. The detector uses DC and may produce either a continuous or pulsed voltage. The type of holiday detector, voltage settings and operator competence shall be specified in the APS.

A scanning electrode is used, in the form of a metal brush, coiled spring with continuous spirals or conductive rubber conforming to the shape of the joints.

Conductors connect the joint to an earth electrode.

C.3 Procedure

The test shall be performed only on a coating that is free from surface moisture. Temperature range requirements can be specified by the APS.

The instrument (holiday detector) and earth shall be connected to the coated pipe. The scanning electrode shall be passed over the surface of the coating being inspected with a continuous, relative movement not exceeding 300 mm/s.

Excessive voltages, slow survey speeds or multiple passes can damage the coating. The voltage should only be applied when the electrode is moving.

The electrode shall not be damaged and shall be in constant touch with the coating.

At the time of the test, the voltage shall be set at a value depending on the material and the nominal thickness of the coating. This value is given in the present standard for each type of FJC.

At the start of each shift, the instrument shall be verified by a certified voltmeter and adjusted if necessary.

C.4 Results

The report should state the test voltage and nominal coating thickness in mm.

The number of holidays shall be recorded. All holidays shall be marked.

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Annex D
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Impact test

D.1 General

The test consists of verifying the strength of the FJC by the impact of a punch of defined shape falling directly onto the coating from a fixed height and at a fixed temperature. The test shall be carried out on pipes or cut samples. This test shall not be carried out on pipes with a diameter of less than 50 mm.

D.2 Equipment

The equipment consists of the following:

— Drop weight testing machine, consisting of the following:

  — straight guide made of steel, aluminium or plastic, rigid and non-deformable, with an inside diameter between 40 mm and 60 mm, length at least 1,30 m and incorporating a smooth and even inside surface;

  — support and levelling device (for example, two spirit levels for the horizontal plane and a plumb-line for the vertical plane);

  — graduated rod, to determine the drop height to an accuracy of 5 mm;

  — hard steel punch, with a hemispherical head, free from notches, porosity or other surface irregularities and with a diameter of 25 mm (A small metal rod with a diameter of 6 mm shall be fixed perpendicular to the flat face of the head and in its centre; this rod shall be long enough to hold the additional weights required for the tests. The punch shall be equipped with a system for raising it to the required height; the mass of this assembly shall be 1 kg ± 0,005 kg.);

  — number of weights, formed of metal discs (preferably made of stainless steel) with an outside diameter of approximately 24 mm and incorporating a central hole of diameter 6,5 mm. The mass of each disc shall have an accuracy of ±5 g.

— Holiday detection equipment.

Other guides may be used by agreement.

D.3 Procedure

The test shall be carried out at a temperature of 23 °C ± 3 °C. If the test is performed outside this temperature range, the method described shall be adapted, by agreement.

The coated component shall be placed on a rigid, stable, horizontal support, and the component interior shall be supported to reduce its elastic response.

Before carrying out an impact test, the holiday detection test shall be undertaken (see Annex C) to identify defective points and to avoid impact testing at these locations. If the number of faults found is too high, another coated test piece shall be taken.

For each point of impact, the drop weight testing machine shall be placed perpendicular to the coating surface. The loaded punch shall fall freely without friction or resistance.

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The drop height is 1 m. Ten impacts shall be carried out with the required energy. The points of impact shall be at least 50 mm to the side of the weld bead and/or the pipe end and there shall be at least 50 mm between the axes of the impacts.

The holiday detection test shall then be undertaken immediately after each impact (see Annex C).

The hard steel punch shall be checked every 30 impacts. If damaged, it shall be replaced.

D.4 Results

The impact energy, the actual coating thickness, and holiday detection results shall be recorded.

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Annex E
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Indentation test

E.1 General

The test consists of measuring the indentation of a punch into the FJC under fixed conditions of temperature and load.

E.2 Equipment

The equipment consists of the following:

— chamber or bath, thermostatically controlled to ±2 °C;

— penetrometer, comprised of the following:

  — a cylindrical indenter on the top of which is mounted a weight; the assembly, indenter plus weight, shall produce a pressure in accordance with Table E.1;

  — dial gauge or any other measurement system, accurate to ±0,01 mm.

Table E.1 — Pressure, indenter diameter and mass of assembly

Pressure	Indenter diameter	Mass of the assembly
N/mm2	mm	kg
0,10	11,2 ± 0,05	1,0
1,00	5,65 ± 0,05	2,5
10,0	1,80 ± 0,05	2,5

E.3 Procedure

The test shall be performed three times on one coating sample and shall be completed on the installed coating system, as applied on the steel plate or pipe sample. The dimensions of the sample shall be agreed.

The test sample, held within the penetrometer assembly, shall be placed in the thermostatically controlled chamber and set to the test temperature (±2 °C). The test sample shall be kept in the chamber for 1 h.

The following readings shall be made.

— t_0 is the reading on the dial gauge placed on an uncovered part of the steel plate or pipe.

— t_1 is the reading on the dial gauge with the indenter without the mass positioned centrally over the sample.

— t_2 is the reading of the dial gauge after the mass has been applied, giving the total desired pressure on the indenter for a minimum duration of 24 h.

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E.4 Results

The quantities t_3, the coating thickness; t_4, the residual thickness of the coating; and t_5, the indentation into the coating, can be calculated on the basis of the measurements described in E.3 using Formulae (E.1) to (E.3), respectively:

$$t_3 = t_1 - t_0 \quad \text{(E.1)}$$

$$t_4 = t_2 - t_0 \quad \text{(E.2)}$$

$$t_5 = t_1 - t_2 \quad \text{(E.3)}$$

The arithmetic mean of the three individual determinations of each of the thicknesses t_3, t_4 and t_5 shall be calculated and recorded.

Depending on the type of FJC tested, either indentation depth or residual thickness shall be used as the acceptable value, as specified in Clauses 10 to 20.

The pressure used for the test shall be reported.

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Annex F
(normative)

Specific electrical insulation resistance

F.1 General

The test consists of measuring the specific electrical insulation resistance (electrical resistance of the coating in relation to the surface area of the coated pipe) by exposure to a sodium chloride solution over a period of 100 days.

F.2 Equipment

The equipment consists of the following:

— supply, direct current (d.c.), with a voltage of ≥50 V;

— voltmeter, with an accuracy of 0,1 V, and ammeter, with an accuracy of 5 %, or DC-ohmmeter, with equivalent accuracy;

— counter electrode (copper), inert, with an area of at least 10 cm^2 and conducting leads for connecting the pipe and electrode to the power supply.

F.3 Preparation of the test samples

Three 0,5 m lengths of pipe of at least 50 mm diameter prepared in accordance with ISO 8501-1, grade Sa 21/2, shall be coated in accordance with the manufacturer's instructions. Testing shall commence after a period defined by the manufacturer. The coated area shall be at least 0,03 m^2.

Prepare a 0,1 mol/l sodium chloride (NaCl) solution.

The immersion of the pipe shall be carried out in one of the two following ways.

— The coated sample shall be placed horizontally in a plastic container through appropriate holes in the opposite faces of the side walls. The entry of the pipe shall be sealed with a suitable non-conductive sealant.

— The coated sample shall be sealed at one end with a suitable non-conductive sealant, ensuring that the metal pipe is prevented from contacting the sodium chloride (NaCl) solution. The sample shall be supported vertically in the plastic container.

Fill the container with the sodium chloride (NaCl) solution.

F.4 Procedure

Immerse at least 10 cm^2 of the counter electrode into the solution.

The test shall be carried out at 23 °C ± 2 °C.

For each measurement, connect the positive pole of the d.c. supply to the end of the pipe that is not immersed and the negative pole to the counter electrode.

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Apply the voltage during measurements only. Measure the resistance using an ohmmeter or record voltage (U) and current (I) after 1 min. The first measurement shall be taken after three days. Then, continue to monitor the measurement at weekly intervals for a total of 100 days.

If the resistance of any one sample falls below the specified value, the test shall be repeated with three new samples.

The measured value of the resistance or current is that due only to the current passing through the submersed coating. If this requirement is not met, it is advised to check for possible current leakage.

F.5 Results

Calculate the specific electrical resistance, R_S, expressed in ohm square metres, using Formula (F.1):

$$R_S = U \times A/I = R_1 \times A \quad \text{(F.1)}$$

where

R_1 is the measured electrical resistance of the submerged sample, expressed in ohms;

U is the voltage between counter electrode and pipe, expressed in volts;

A is the submerged surface area of coating, expressed in square metres;

I is the measured current, expressed in amperes.

Plot a graph of specific electrical resistance against time. Between the 70th day (R_{S70}) and the 100th day (R_{S100}), a linear, straight regression line shall be calculated from the measured values. Using the regression line, calculate the ratio of the specific electrical resistance, R_{S100}/R_{S70}.

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Annex G
(normative)

Cathodic disbondment test

G.1 General

The test consists of assessing the resistance to disbondment of damage to the FJC when exposed to cathodic polarization.

The test shall be performed on a test sample previously subjected to holiday detection (see Annex C), and in which an artificial defect of a defined size has been created.

G.2 Equipment

G.2.1 Electrical source, consisting of a controlled voltage d.c. power unit (potentiostat) capable of supplying 20 mA to each test area simultaneously

Except when otherwise specified, a cathodic polarization potential (E) equivalent to -1 260 mV vs. standard hydrogen electrode shall be maintained. E equals to -1 500 mV when a saturated calomel reference electrode is used. The potentials are defined as follows:

— "E" is the potential of the "working electrode" with regard to the "reference electrode".

— "V" is the difference of potential between the "working electrode" and the "auxiliary electrode".

G.2.2 Electrolytic cell, having a typical test-cell configuration as shown in Figure G.1 for large-diameter components and as in Figures G.2 and G.3 for small-diameter components

The electrolytic cell shall comprise of the following:

— a rigid plastic pipe with an internal diameter of minimum 50 mm. The height shall be such that the total volume of the electrolyte is equal to or greater than 150 cm^3 with a minimum height of the electrolyte of 70 mm;

— a rigid plastic cover in which holes shall be drilled to allow the passage of the electrodes and any other measuring instruments deemed necessary, and to allow the escape of hydrogen.

G.2.3 Electrodes.

G.2.3.1 Reference electrode, capable of giving a suitable potential (see G.2.1) and suitable for the test temperature required, placed in an electrode holder situated in a glass pipe with a porous end diaphragm

The end of this assembly shall be placed approximately 10 mm from the surface of the coating and approximately 20 mm from the coating defect.

G.2.3.2 Auxiliary electrode (anode), consisting of an inert material, e.g. platinum wire, 0,8 mm to 1,0 mm in diameter

It shall be immersed in the electrolyte to within approximately 10 mm over the coating defect.

The ratio of the surface area of the auxiliary electrode (anode) to that of the working electrode (cathode) shall be greater than 1.

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G.2.3.3 Working electrode (cathode), represented by the artificial defect, 6 mm in diameter, with a maximum depth of 0,5 mm in the steel substrate (see Figure G.4)

G.2.4 Electrolyte, consisting of a 3 % solution of NaCl in distilled or deionized water

The solution shall be made from technical grade sodium chloride. The pH at 23 °C ± 2 °C during the test shall be in the range of 6 to 9.

The height of the electrolyte in the cell shall be at least 70 mm.

G.2.5 Heating equipment, suitable to establish and to maintain the test temperature of the sample

If not heated in an oven, the temperature shall be checked on the artificial defect by an appropriate means, e.g. a temperature sensor.

G.3 Sampling

The test shall be performed on a large-diameter coated component (field joint coated pipe) according to Figure G.1 or on a small-diameter coated component (field joint coated pipe) according to Figures G.2 or G.3.

The test can be performed on a cold cut sample from a coated component (pipe) which shall have a minimum size of 80 mm × 80 mm and upon agreement by end user and/or purchaser and manufacturer.

Unless otherwise specified by end user and/or purchaser, tests samples shall not be taken from the weld area.

For each sample, the thickness of the area of the coating subject to the test shall be measured and recorded.

The integrity of the coating on all test samples shall be checked by holiday detection (see Annex C).

A 6 mm diameter hole through the coating shall be obtained by drilling, a hammer hole puncher, or any other method, in the centre of the test sample. In case of drilling (see Figure G.4), the depth of the hole in the steel substrate shall not exceed 0,5 mm. At the initiation of the test, the total surface area subject to the test shall be free from residual coating and swarf or grinding of drilling.

The test area shall be degreased using a suitable solvent and then rinsed with potable water and subsequently dried.

G.4 Procedure

The plastic pipe forming the electrolytic cell shall be sealed using a suitable sealant, e.g. a chemically inert adhesive. The artificial defect shall be in the centre of the cell.

The cell shall be filled with the NaCl electrolyte (G.2.4). The test temperature shall be controlled within ±2 °C.

A negative cathodic potential shall be applied between the reference and working electrodes (see Figures G.1, G.2 and G.3), with an accuracy of ±10 mV. If a saturated calomel electrode is used, the potential shall be -1 500 mV.

The test shall be performed for the test period required. The level of the electrolyte shall be readjusted with distilled or deionized water, if necessary.

G.5 Investigation procedure

After the test, the cell with the electrolyte shall be removed. The test sample shall be rinsed with water and dried.

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After drying, the area of the coating subjected to the test shall be examined in accordance with the following method.

— Inspect and assess each coating immediately after the test period.

— Make about 12 radial incisions, using a sharp knife, through the coating to the substrate, extending outwards from the holiday for a distance of at least 40 mm. Make these incisions at an angle of approximately 30° from each other.

— Insert the knife point into the centre portion of the holiday down to the metal substrate. Using a gentle levering action, peel away slowly a radial section of coating continuing until firm adhesion is encountered. For FJC Types 10, 11, 13, 14A, 14B, 14C, 14D and 15, loss of adhesion being not always obvious, careful examination of the substrate for signs of continuous residual coatings can indicate that disbondment has not occurred at these locations. In this case, the relevant disbondment is the area where the coating system is not adhering to the steel anymore.

— Repeat with each radial segment.

For FJC Type 14B, 14C, 14D, 18B and 18E with a thickness higher than 1,2 mm, the coating can be removed completely by using a chisel and hammer or stripping of the coating, after the coating has been heated above the softening point. In this case, the area where the metal is dark is considered as the area of disbondment.

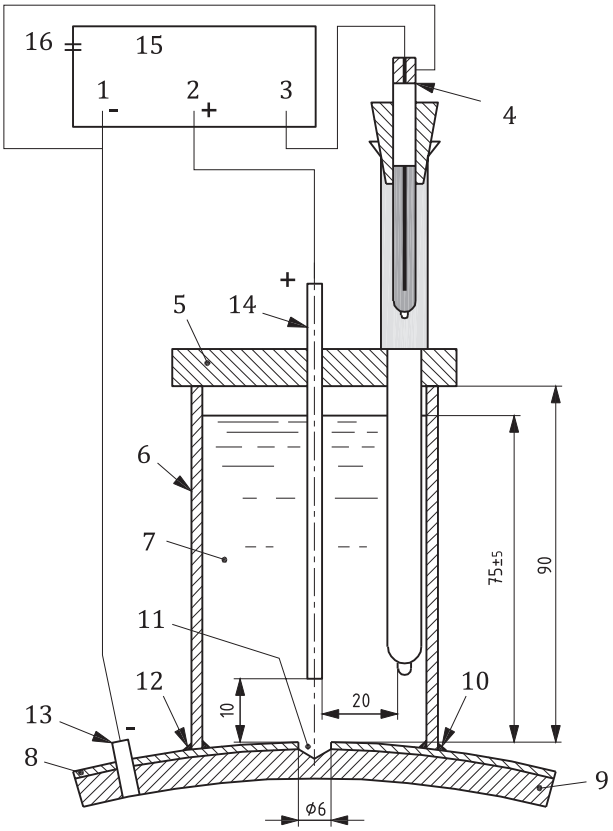
G.6 Results

The result of the cathodic disbondment test shall be defined as the arithmetic mean value of the 12 single values.

The mean value shall be recorded.

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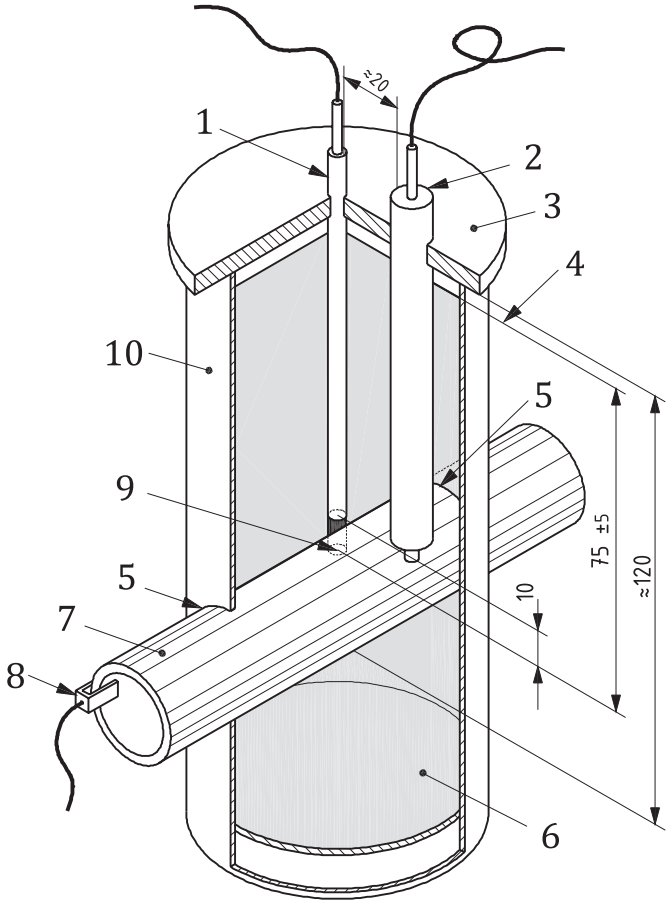
Key

1	connection to working electrode	9	steel test piece
2	connection to auxilliary electrode (anode)	10	sealing material
3	connection to reference electrode	11	artificial defect, Ø 3 mm to 6 mm if coating thickness is less than 1 mm; Ø 6 mm in other cases
4	reference electrode	12	sealing material
5	plastic cover	13	working electrode (cathode)
6	plastic pipe, minimum internal Ø 50 mm	14	platinum electrode, Ø 0,8 mm to 1,0 mm (anode)
7	electrolyte ≥150 ml	15	potentiostat
8	Coating	16	220 V power supply

Figure G.1 — Electrolytic cell for large-diameter pipe

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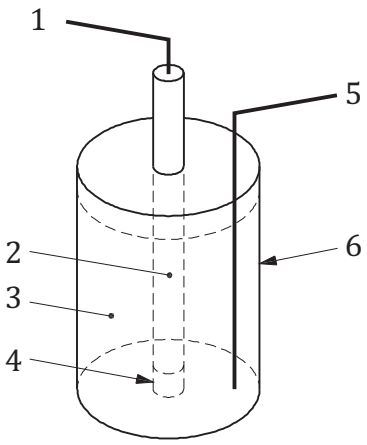
Key

1	auxilliary electrode, e.g. platinum wire Ø 0,8 mm to 1,0 mm (anode)	6	electrolyte
2	reference electrode	7	coated pipe
3	plastic cover	8	working electrode (cathode)
4	electrolyte level	9	artificial defect, Ø 3 mm to 6 mm if coating thickness is less than 1 mm; Ø 6 mm in other cases
5	sealing material	10	plastic pipe, minimum internal Ø 50 mm

Figure G.2 — Electrolytic cell for small-diameter pipe — Example 1

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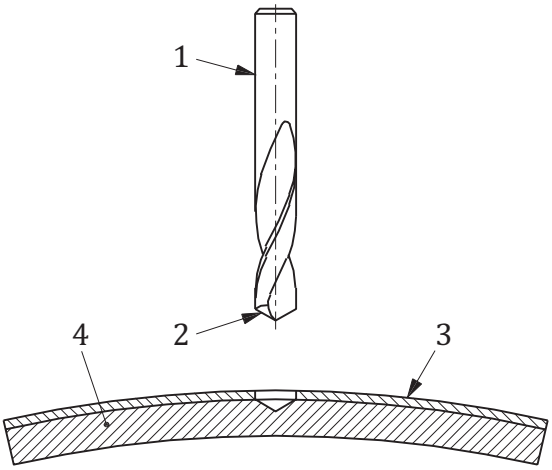
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Key

1 to negative lead (−)
2 holiday
3 electrolyte
4 end cap
5 to positive lead (+)
6 beaker

Figure G.3 — Electrolytic cell for small-diameter pipe — Example 2



Key

1 fluted and mill face mill Ø 3 mm to 6 mm if coating thickness is less than 1 mm; Ø 6 mm in other cases
2 conic end
3 coating
4 steel

Figure G.4 — Drilling of artificial defect

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Annex H
(normative)

Peel strength test

H.1 Measurement of the peel strength with a tensile testing machine

H.1.1 General

The test consists of measuring the force required for peeling the FJC from the metal substrate of the joint at a constant rate of pull. When specified in Clauses 10 to 20, the same method shall be used to measure the force required for peeling the FJC from the plant coating at overlap.

H.1.2 Equipment

The equipment consists of the following:

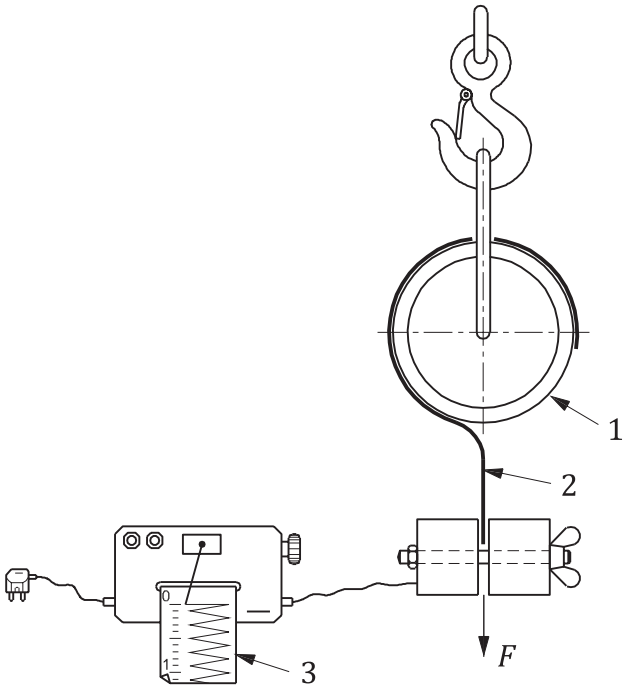
— a tensile testing machine, capable of recording the peel force with ± 5 % reading accuracy, that operates at a rate of pull of 10 mm/min ± 1 mm/min, as shown in Figure H.1 for small diameters or as in Figure H.2 for large diameters;

— a cutting tool, e.g. knife;

— an equipment, as suggested in Figures H.1 or H.2.

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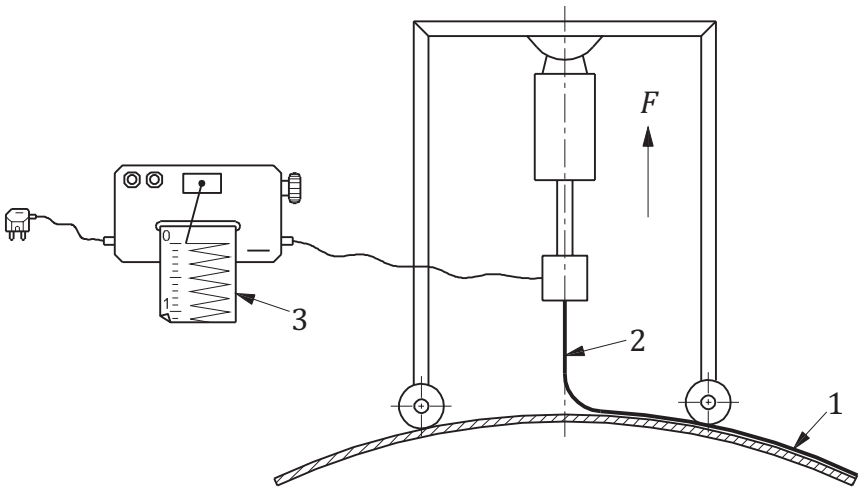
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Key

1 pipe ring
2 coating strip
3 registration unit
F peel force

Figure H.1 — Peel-strength test equipment for a small-diameter joint



Key

1 coated pipe surface
2 coating strip
3 registration unit
F peel force

Figure H.2 — Peel-strength test equipment for a large-diameter joint

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H.1.3 Procedure

H.1.3.1 General

The peeling test for ambient temperature shall be performed at the temperature specified in the tables in Clauses 10 to 20.

The peeling test for maximum service temperature shall be carried out if the maximum service temperature is greater than 30 °C.

A peeling test for other temperatures may be performed if agreed between the applicator and the end user.

All test temperatures shall be controlled within ±3 °C.

The temperature shall be measured by means of an adapted probe on the external surface of the joint at the root of the peeled strip.

The coating shall be peeled off with a peeling rate of 10 mm/min perpendicular to the surface of the pipe.

H.1.3.2 Small-diameter pipes

A pipe ring 200 mm in length shall be cut from the pipe. A sample coating strip shall be cut in the circumferential direction of the pipe ring measuring a minimum of 160 mm long and 20 mm to 50 mm wide.

The pipe ring shall be free to rotate about its axis, as shown in Figure H.1. The cut end of the coating strip shall be secured to one of the gripping jaws of the testing machine and peeled perpendicular to the pipe axis.

H.1.3.3 Large-diameter pipes

The pipe shall be supported during the test to prevent movement.

A sample coating strip shall be cut in the circumferential direction of the pipe, measuring a minimum of 160 mm long and 20 mm to 50 mm wide. The cut end of the coating strip shall be secured to one of the gripping jaws of the testing machine and peeled perpendicular to the pipe axis.

H.1.4 Results

The peel-force data for 140 mm of peeling shall be divided into seven intervals of 20 mm and the first and last intervals discarded. The peel strength shall be calculated from the remaining data.

The average peel strength shall be the arithmetic mean over the 100 mm length. If this value is not automatically determined, the arithmetic mean may be estimated from the 20 mm bands across the 100 mm length.

The average peel strength shall meet the requirements as specified in the tables in Clauses 10 to 20 and no single recorded peeling value shall be more than 30 % below the specified value.

The test should be regarded as passed even if the forces measured are below the peel strength requirement when the test stripe is elongated provided that there is no delamination between FJC and steel nor delamination between layers of the FJC.

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H.2 Measurement of the peel strength with a spring balance or a digital load cell

H.2.1 General

The method consists of using a spring balance or digital load cell to determine whether the force required for peeling the field joint coating from the metal substrate is greater than the minimum specified value. When specified in Clauses 10 to 20, the same method shall be used to measure the force required for peeling the FJC from the plant coating at overlap. The test may be carried out axially or circumferentially as agreed between all parties.

H.2.2 Equipment

The equipment shall consist of the following:

— a spring balance or digital load cell, with a clamp, accurate to ±10 %, as shown in Figure H.3;

— a cutting tool, e.g. knife;

— a measuring tape.

H.2.3 Procedure

The test shall be performed at a temperature of 23 °C ± 5 °C. If provision has been made to perform this test outside this temperature range, the method described shall be adapted, after agreement between the applicator and purchaser, if necessary.

The temperature shall be measured by means of an adapted probe, on the external surface of the steel at the root of the peeled strip (evaluation on 100 mm).

The direction of peeling, either circumferential or axial, shall be by agreement between the applicator, contractor and purchaser.

According to the agreed direction of peel, the test specimen shall be prepared by making two parallel cuts measuring a minimum of 160 mm long and 20 mm to 50 mm apart through the coating to the steel substrate. At one end of the cuts, the coating strip shall be carefully released from the pipe surface without causing damage to the material or the cut edges. Sufficient warming to allow the coating to become pliable may be necessary to release and bend the coating back through 90 degrees. The released end of the coating shall be secured in the clamp of the spring balance or digital load cell.

Marking in visible contrasting colour should be made on to the coating along the specimen, every 10 mm, in order to help in evaluating the pulling speed.

The test shall be carried out using either of the following methods. The method to be adopted shall be agreed between all parties as being appropriate for the type of coating under test.

H.2.3.1 Controlled rate of peel — Force to be recorded

It shall first be established whether peeling will occur at the required minimum force or at the force reasonably expected for the material. If peeling does occur, the force needed to initiate peeling and the first 20 mm of peeling shall be disregarded.

The coating shall be peeled off with a peeling rate of 10 mm/min perpendicular to the surface of the pipe. The peel force shall be recorded at least every 6 seconds over a distance of 100 mm. During the peeling, care shall be taken to adjust the applied force so as to maintain the rate of peel to as close as reasonably practicable to 10 mm/min by use of a stopwatch and the markings made on the pipe surface.

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H.2.3.2 Controlled application of force — Rate of peel to be recorded

It shall first be established whether peeling will occur at the required minimum force or at a force reasonably expected for the material, once the initial peak value has been overcome. If peeling does occur, the first 20 mm of peeling shall be disregarded.

Throughout the test, care shall be taken to maintain the force at approximately 0 % to 10 % greater than the minimum specified value. The rate of peeling shall be recorded by timing the progress of peeling over 10 sequential 10 mm distances by means of a stopwatch and measuring tape.

H.2.4 Results

H.2.4.1 Controlled rate of peel

The peel strength, expressed in Newtons per millimetre, shall be the arithmetic mean of the values recorded over the 100 mm length.

No peeling at the required minimum force, or a peel strength that equals or exceeds the required minimum force shall be deemed as acceptable.

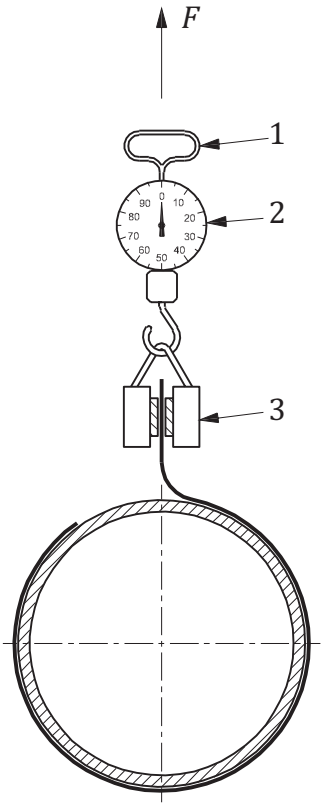
H.2.4.2 Controlled application of force

The rate of peel, expressed in mm/min, shall be calculated as the arithmetic mean over the 10 recorded rate of peel values. If no peeling occurs, the rate of peel shall be recorded as 0 mm/min.

A rate of peel that is equal to or less than 10 mm/min shall be deemed as acceptable.

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Key

1 handle
2 spring balance
3 clamp
F peel force

Figure H.3 — Peel-strength test equipment with a spring balance or digital load cell

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Annex I
(normative)

Hot water immersion test

I.1 General

This test shall be carried out to assess the comparative resistance of FJC applied to a bare steel substrate and the plant-applied coating to loss of adhesion due to water immersion.

Unless otherwise specified, the test temperature shall be the maximum service temperature of the FJC, with the following limitations.

— If the maximum service temperature of the FJC being tested exceeds 95 °C, the test temperature shall be limited to 95 °C.

— The test temperature shall not be greater than the maximum service temperature of the plant coating.

I.2 Equipment

The equipment consists of the following:

— oven, controllable to within ±3 °C;

— holiday detector;

— cylinder, plastic, 150 mm long, with an interior diameter of 75 mm ± 3 mm or (heated) vessel large enough to accommodate the circumferential or ring specimens;

— knife, pointed, sharp;

— adhesive, elastomeric, e.g. silicone sealant;

— hacksaw blade, small, “Junior” type or similar;

— tensile testing machine, or spring balance, or digital load cell with a clamp (for specimens to be tested by Peel Test method — Annex H);

— Air driven disc cutter (for specimens to be tested by Peel Test method — Annex H);

— Pull Off test apparatus conforming to ISO 4624 for liquid coatings.

I.3 Sample preparation

I.3.1 Laboratory prepared samples

I.3.1.1 FBE and liquid coatings

Cold cut 100 mm × 100 mm × 6 mm plates and apply the FJC material under conditions of application similar to those for a field joint coating.

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I.3.1.2 Other coatings

Cold cut 150 mm long, 100 mm diameter pipe sections (coated or bare) and coat these samples with the FJC under conditions of application similar to those for a field joint coating.

I.3.2 Samples from qualification trials

I.3.2.1 FBE and liquid coatings

Cold cut 100 mm × 100 mm samples with direct-to-metal joint coating and joint coating applied onto plant coating.

I.3.2.2 Other coatings

Cold cut 150 mm wide pipe rings with direct to metal joint coating and joint coating on plant coating. The rings may be cut into 220 mm circumferential lengths where the diameter and specific coating system allows; otherwise the rings shall be left intact.

I.4 Preparation of test area

To ensure freedom from holidays, test the prepared panels or rings for holidays with the holiday detector set at the required voltage for the coating system.

I.5 Test procedure

I.5.1 For 100 mm × 100 mm specimens to be tested in accordance with Annex Q or ISO 4624, the following steps shall be followed.

— Use four samples per coating for evaluation.

— Carry out an initial adhesion test on one sample, as described in I.6.

— Attach plastic cylinders onto three samples using the elastomeric adhesive, lightly abrade or flame oxidize the coating surface if required to form a water-resistant seal.

— Allow sealant to set or cure fully. On samples cut from pipes, it can be necessary to cut the bottom of the plastic cylinder to conform to the curvature of the panel.

— Fill the cylinder with 400 ml ± 50 ml of tap water pre-heated to the test temperature and seal the top opening with a plastic film or similar to limit evaporation. Place samples into the oven set at test temperature.

— Remove the three samples after the specified duration depending on the FJC tested.

— Allow them to cool to ambient temperature and test adhesion as specified in I.6.

I.5.2 For the 150 mm long (100 mm diameter) pipe sections, the 150 mm wide full pipe rings or the 150 mm × 220 mm circumferential specimens, the following steps shall be followed.

— Use four samples per coating for evaluation.

— Carry out an initial adhesion test on one sample as described in I.6.

— Attach plastic cylinders onto three samples using the elastomeric adhesive, lightly abrade or flame oxidize the coating surface if required to form a water-resistant seal.

— Allow sealant to set or cure fully. It can be necessary to cut the bottom of the plastic cylinder to conform to the curvature of the pipe section.

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— Fill the cylinder with 400 ml × 50 ml of tap water pre-heated to the test temperature and seal the top opening with a plastic film or similar to limit evaporation. Place samples into the oven set at test temperature.

— Alternatively, and if practical, the samples could be fully immersed in a heated vessel. In this case, seal the cut edges of the specimens using the silicone or epoxy sealant and allow it to fully cure. This is to prevent water ingress from the side.

— Fill the vessel with pre-heated tap water and place it in the oven to equilibrate to the required test temperature.

— Fully submerge the specimens under the water in the heated vessel.

— Report whether the testing happened with the plastic cylinders or with full immersion of the samples.

— Remove the three samples after the specified duration depending on the FJC tested.

— Allow them to cool to ambient temperature and test adhesion as specified in I.6.

I.6 Results

For coatings 11A and 11B, record whether it leaves a film of compound during the peel test on the steel substrate and on the plant-applied coating.

For FBE coatings, adhesion testing shall be carried out in accordance with Annex Q.

For liquid coatings, adhesion testing shall be carried out in accordance with ISO 4624. The sample shall be dried for a minimum of one hour at 25 °C. The surface of the coating shall be roughened with emery paper and the dollies attached using a rapid setting adhesive capable of curing within 1 h. The adhesion test shall be carried out within 24 h of removal from the water.

— When adhesion test is carried out using pull-off method (ISO 4624) the adhesive used for gluing the dollies shall be selected to limit the total duration of test to a maximum of 24 h.

NOTE Some recommendations on adhesives are given in ASTM D4541.

If there is glue failure at a value greater than the minimum acceptance value, it shall be accepted as a pass. If glue failure occurs at a value less than the minimum acceptance criteria, the adhesion test shall be repeated provided it can be done within 24 h from removal from the water.

For other coatings, parallel circumferential cuts down to steel or plant coating shall be made 50 mm apart, or where the cylinder sat, in each of the specimens so that an approximately equal distance of coating is present between each cut and each outer edge. Peel testing shall be carried out in accordance with Annex H. The report shall state the peel strength, expressed in newtons per millimetre or the degree of disbondment from the steel substrate and the plant-applied coating. If applicable for the specified coating system, the ratio P_{100}/P_0 should be calculated for every of the three samples.

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Annex J
(normative)

Lap shear strength

J.1 Lap shear strength of tape coatings

J.1.1 General

The test consists of measuring the lap shear strength (maximum force per unit area) obtained in shearing a single overlap joint between a plate with metallic surface or plant coating and the FJC by applying a tensile force that is parallel to the bond area and to the major axis of the sample.

J.1.2 Equipment

The equipment consists of the following:

— tensile testing machine, in accordance with ISO 5893, allowing the shear force to be recorded and capable of operating at a constant rate of separation of 10 mm/min;

— temperature-maintenance equipment, capable of maintaining the sample in the tensile testing machine at the test temperature;

— steel plates, 100 mm long and 50 mm wide, or of tape width in the case of narrower tapes.

J.1.3 Preparation of the test samples

The metal surface of the steel plate shall be blast cleaned in accordance with ISO 8501-1, grade Sa 2 1/2, to give a medium profile in accordance with ISO 8503-2. The steel plates shall be kept clean and dry. Primer and/or coating shall be applied within 8 h.

The plant coating shall be cleaned in accordance with the tape manufacturer's instructions. The cleaning procedure shall be agreed upon with the manufacturer of the plant coating.

Apply the coating systems (all layers) to one side of the plates in accordance with the manufacturer's instructions, such that the coating overhangs one end by 30 mm to 40 mm, to allow clamping in the testing machine. Store the test samples for a minimum of seven days at 23 °C ± 2 °C under a load of 0,01 N/mm^2.

Prior to testing, cut the coating transversely so that the effective shear length is 20 mm.

J.1.4 Procedure

The lap shear strength test shall be carried out on

— five test samples at 23 °C ± 2 °C, or

— five test samples at the maximum service temperature, T_{max}, ±3 °C if this is higher than 30 °C.

Clamp the test sample into the tensile testing machine, ensuring that the plate (metal surface) and the coating system are in the same plane.

For the test at a temperature ≥30 °C, precondition the test sample at the specified test temperature for at least 0,5 h.

Maintain the test sample at the specified test temperature throughout the test.

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Set the tensile testing machine to a constant rate of separation of 10 mm/min. Record the maximum force.

If the tape breaks instead of shearing, prepare new test samples so that the effective shear length is 10 mm. Repeat for five test samples.

J.1.5 Results

Calculate the arithmetic mean of the five results of the lap shear strength, expressed in newtons per square millimetre.

If the tape breaks, express the lap shear strength as greater than the breaking force, expressed in newtons per square millimetre of bonded area.

J.2 Lap shear strength of shrinkable material coatings

J.2.1 General

The test consists of measuring the maximum stress obtained in shearing a single overlap joint between two metallic plates with the adhesive of the shrinkable material by applying a tensile force that is parallel to the bond area and to the major axis of the test sample.

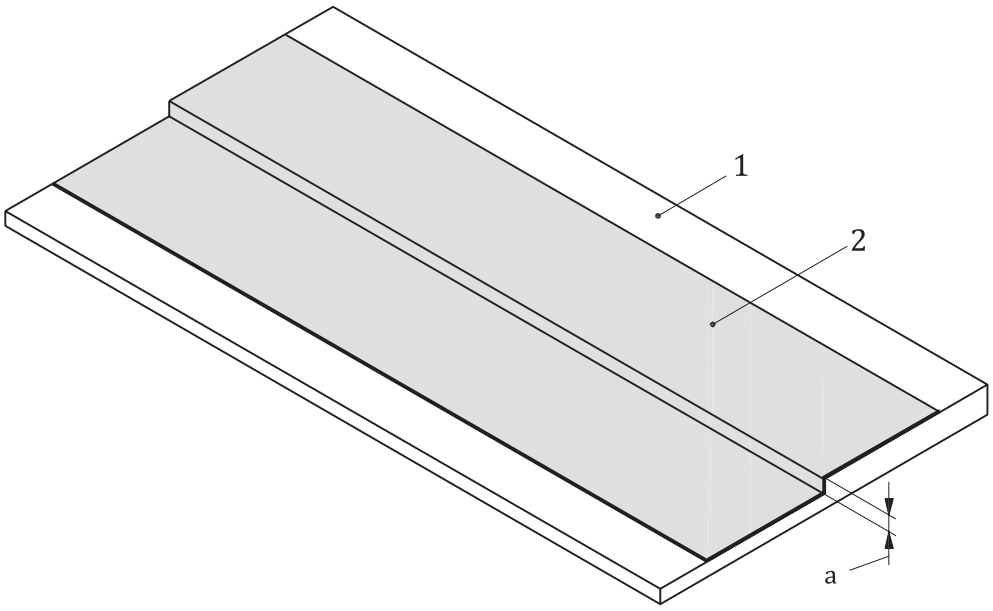
J.2.2 Apparatus

— Tensile testing machine, in accordance with ISO 5893, allowing the shear force to be recorded and capable of operating at a constant rate of separation of 10 mm/min.

— Temperature-maintenance equipment, capable of maintaining the sample in the tensile testing machine at the test temperature.

— Steel plates, 100 mm long, 50 mm wide.

— Lap shear alignment jig (See Figure J.1).



Key

1 aluminium

2 polytetrafluoroethylene (PTFE) type

a Jig height shall be set to ensure that the adhesive thickness is 1 mm, based on available steel plate thickness.

Figure J.1 — Lap shear alignment jig

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J.2.3 Preparation of the test samples

The metal surface of the steel plate shall be blast cleaned in accordance with ISO 8501-1, grade Sa 2 1/2, to give a medium profile in accordance with ISO 8503-2. The steel plates shall be kept clean and dry before application of the primer (if any) and/or adhesive which shall be applied within 8 h.

Coat one side of the plates with the adhesive of the shrinkable material to a thickness of 1 mm. The jig shall be constructed to ensure a 1 mm thickness of adhesive based on standard available steel plate thickness closest to that stated in J.2.2.

Position a second plate in such a way that the overlap of the two plates is 20 mm using the lap shear alignment jig. Bond the test samples in accordance with the manufacturer's instructions (pressure, temperature and time). Store the test samples for at least 24 h at 23 °C ± 3 °C after bonding.

Remove any adhesive that has extruded at the sides during preparation.

J.2.4 Procedure

The lap shear strength test shall be carried out on

— five test samples at 23 °C ± 2 °C, or

— five test samples at the maximum service temperature, T_{max}, ±3 °C if this is higher than 30 °C.

Clamp the test sample into the tensile testing machine, ensuring that the plate (metal surface) and the coating system are in the same plane.

For the test at a temperature higher than 30 °C, precondition the test sample at the specified test temperature for at least 0,5 h.

Maintain the test sample at the specified test temperature throughout the test.

Set the tensile testing machine to a constant rate of separation of 10 mm/min. Record the maximum force.

J.2.5 Results

Calculate the arithmetic mean of the five results of the lap shear strength, expressed in Newtons per square millimetre.

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Annex K
(normative)

Drip resistance

K.1 General

The test consists of determining whether any components of the petrolatum, wax-based tape or non-crystalline low-viscosity polyolefin-based coatings drip at elevated temperature.

K.2 Equipment

K.2.1 Oven, thermostatically controlled in accordance with ISO 188 (normal oven method), capable of maintaining a temperature of 45 °C ± 3 °C, 80 °C ± 3 °C, or higher temperature with the same tolerance

The oven shall be of sufficient size to allow the vertical suspension of test samples without restriction.

K.3 Preparation of the test sample

Cut three samples of tape 150 mm long and 50 mm wide, or use a whole tape in the case of narrower tapes.

K.4 Procedure

The test is carried out at the temperature specified.

Suspend the three samples of petrolatum or wax-based tape freely in the oven for 48 h.

After this period, observe any components that have dripped. The appearance, dimension of the samples should remain unchanged.

If any material has dripped, the test shall be repeated with five other samples. No further dripping of components is allowed.

K.5 Results

Report: pass or fail.

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Annex L
(normative)

Peel strength between layers

L.1 General

The test consists of measuring the peel strength (peeling force per unit width) between two layers of tapes or shrinkable materials.

Peel strength to be determined for

— inner layer to inner layer,

— outer layer to inner layer, and

— outer layer to outer layer.

L.2 Equipment

The equipment consists of the following:

— a tensile testing machine, in accordance with ISO 5893, allowing the peeling force to be recorded and capable of operating at a constant rate of separation of 100 mm/min;

— a temperature-maintenance equipment, capable of maintaining the sample in the tensile testing machine at the test temperature;

— a lower support plate, rigid, e.g. of glass, about 50 mm × 300 mm × 5 mm;

— an upper plate, rigid, e.g. of steel, about 50 mm × 200 mm × 5 mm, with a smooth cellular rubber 1 mm to 3 mm thick on its lower side;

— a load, capable of producing, together with the upper plate, a combined pressure of 0,01 N/mm^2;

— pipe sections, 100 mm in diameter, 100 mm long, for shrinkable material only.

— a release paper.

L.3 Preparation of the test sample

L.3.1 General

Condition the samples for a minimum of 24 h at 23 °C ± 2 °C.

L.3.2 Tapes

Discard the three outer turns from the roll. Cut strips 250 mm to 280 mm long and 50 mm wide, or of tape width in the case of narrower tapes. Locate one strip of the first tape (Figure L.1, key item 6), adhesive side down, on release paper (key item 3) on the lower plate (key item 4). Apply the second tape strip (key item 5) with the same dimensions exactly over the first. At one end, insert a piece of release paper between the two tape strips for 50 mm to 80 mm. Place release paper (key item 3), the rubber coating (key item 2) and the upper plate with the load onto the sample (with a pressure of 0,01 N/mm^2) (key item 1) and store for seven days at 23 °C ± 2 °C.

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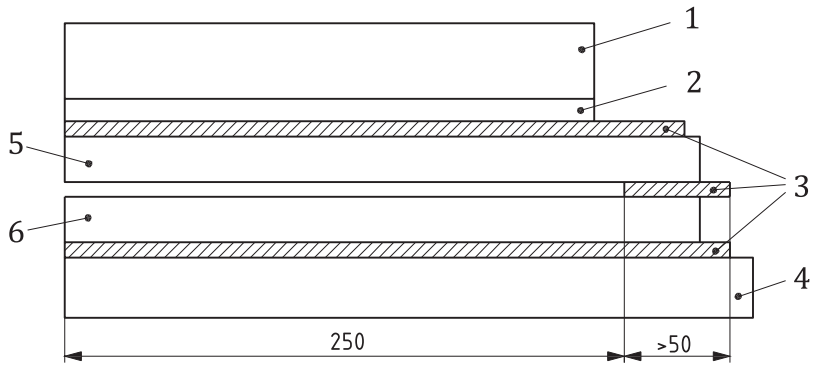
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It is permissible to apply additional supporting films to the outer surfaces of the samples to prevent excessive elongation during the test.

L.3.3 Shrinkable materials

Wrap the pipe section circumferentially with two layers of the shrinkable material one after another, in accordance with the manufacturer's instructions. Store for a minimum of 24 h at 23 °C ± 2 °C.

Dimensions in millimetres



Key

1	plate with load	4	plate
2	rubber coating	5	tape 2
3	release paper	6	tape 1

Figure L.1 — Assembly of the test sample for testing the peel strength between layers

L.4 Procedure

L.4.1 General

The peel strength test is carried out on

— three samples, layer to layer, at 23 °C ± 2 °C, or

— three samples, layer to layer, at the maximum service temperature, T_{max}, ±3 °C if this is higher than 30 °C.

L.4.2 Tapes

Clamp the end of the two tapes into the grips of the tensile testing machine. Precondition the test sample at the specified test temperature for at least 0,5 h and maintain the specified test temperature throughout the test.

Set the tensile testing machine in operation at a constant rate of separation of 100 mm/min. Record the peeling force continuously.

L.4.3 Shrinkable materials

Cut the coating with a double saw or knife around the circumference down to the pipe wall to an inside width of 50 mm. Cut the resulting outer strip with a knife perpendicular to the circumference of the pipe and lift the end of the outer strip from the inner strip over a length of about 20 mm.

Clamp the test sample into the grips of the tensile testing machine.

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Precondition the sample at the specified test temperature for at least 1 h and maintain the test temperature throughout the test.

Set the tensile testing machine in operation at a constant rate of separation of 100 mm/min. Record the peeling force continuously.

L.4.4 Results

Calculate the mean value of the peel strength, expressed in newtons per millimetre of width, using at least 20 points at regular intervals. Disregard the first and last 50 mm of the peeling length. If any values are less than 75 % of the specified peel strength, test a further three samples. No further failure is allowed.

The arithmetic mean value of the values for the three test samples shall be recorded.

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Annex M
(normative)

Thermal ageing resistance

M.1 Elongation at break

M.1.1 General

The test consists of measuring the effect of exposing test samples of coating materials to dry heat in a thermostatically controlled oven.

The effect of ageing is assessed by the change in elongation at break in accordance with ISO 527-2.

M.1.2 Equipment

The equipment consists of an oven, in accordance with ISO 188 (normal oven method), thermostatically controlled, capable of being set to a temperature of T_{max} + 20 °C ± 3 °C.

The oven shall be of sufficient size to allow the vertical suspension of test samples without restriction.

M.1.3 Preparation of the test samples

Prepare three sheets of backing material (shrinkable materials after free shrinking according to the manufacturer's instructions), sufficiently large to prepare at least five test samples from each in accordance with ISO 527-3.

Identify each sheet as (a), (b) or (c).

M.1.4 Procedure

Precondition the test sheets for 7 days at the ageing temperature before testing.

Age the test sheets at T_{max} + 20 °C as follows.

— Store sheet (a) indoors at room temperature for 100 days.

— Hang sheet (b) in an oven at the ageing temperature for 70 days, followed by 30 days of storage at room temperature indoors.

— Hang sheet (c) in an oven at the ageing temperature for 100 days.

After the 100 days ageing period, prepare from each sheet at least five samples in accordance with ISO 527-3 and test all within 8 h for elongation at break under identical conditions in accordance with ISO 527-3 at a test temperature of 23 °C ± 2 °C.

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M.1.5 Results

For the coating material, calculate the ratios of the elongation at break, E:

E_{100}/E_0

E_{100}/E_{70}

where

E_0 is the elongation at break without heat ageing (arithmetic mean of five results);

E_{70} is the elongation at break after heat ageing for 70 days (arithmetic mean of five results);

E_{100} is the elongation at break after heat ageing for 100 days (arithmetic mean of five results).

M.2 Peel strength between layers

M.2.1 General

The test consists of measuring the effect of exposing test samples, prepared in accordance with L.3, to dry heat in a thermostatically controlled oven.

The effect of ageing shall be assessed by the change in peel strength between layers in accordance with Annex L.

M.2.2 Equipment

See M.1.2.

M.2.3 Preparation of the test samples

Prepare three test samples of the following types for each ageing test in accordance L.3:

— inner layer to inner layer;

— outer layer to inner layer;

— outer layer to outer layer.

Identify each sample as (a), (b) or (c).

M.2.4 Procedure

Precondition the test samples for 7 days at the ageing temperature before testing.

Age the test samples at T_{max} + 20 °C as follows:

— Hang sample (a) indoors at room temperature for 100 days;

Hang sample (b) for 70 days in an oven at the ageing temperature, followed by 30 days of storage at room temperature indoors;

Hang sample (c) for 100 days in an oven at the ageing temperature.

After the 100 days ageing period, test all samples within 8 h for peel strength between layers under identical conditions in accordance with L.4 at a test temperature of 23 °C ± 2 °C.

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M.2.5 Results

Calculate the arithmetic mean of the peel strength in accordance with L.4.4.

Calculate the following ratios of peel strengths:

P'_{100}/P'_0

P'_{100}/P'_{70}

where

P'_0 is the peel strength between layers at 23 °C without heat ageing;

P'_{70} is the peel strength between layers at 23 °C after heat ageing for 70 days;

P'_{100} is the peel strength between layers at 23 °C after heat ageing for 100 days.

M.3 Peel strength to pipe surface

M.3.1 General

The test consists of measuring the effect of exposing test pipes with a coated metallic surface to dry heat in a thermostatically controlled oven.

The effect of ageing is assessed by the change in peel strength to the pipe surface, in accordance with Annex H.

M.3.2 Apparatus

See M.1.2.

M.3.3 Preparation of the test samples

Prepare three samples for testing peel strength to the pipe surface in accordance with the method described in H.1 for each ageing test.

Identify each sample as (a), (b) or (c).

M.3.4 Procedure

Precondition the test samples for 7 days at the ageing temperature before testing.

Age the test samples at T_{max} + 20 °C as follows.

— Store sample (a) indoors at room temperature for 100 days.

— Store sample (b) for 70 days in an oven at the ageing temperature, followed by 30 days of storage at room temperature indoors.

— Store sample (c) for 100 days in an oven at the ageing temperature.

After the 100 days ageing period, test all test samples within 8 h for peel strength under identical conditions in accordance with D.1 at the test temperature of 23 °C ± 2 °C.

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M.3.5 Results

Calculate the arithmetic mean of the peel strenghth in accordance with H.1.

P_{100}/P_0

P_{100}/P_{70}

where

P_0 is the elongation at break without heat ageing (arithmetic mean of five results);

P_{70} is the elongation at break after heat ageing for 70 days (arithmetic mean of five results);

P_{100} is the elongation at break after heat ageing for 100 days (arithmetic mean of five results.

M.4 Bursting strength of reinforced backing

M.4.1 General

The test consists of measuring the effect of exposing test samples of reinforced backing materials to dry heat in a thermostatically controlled oven.

The effect of ageing is assessed by the change in bursting strength in accordance with Annex O.

M.4.2 Equipment

See M.1.2.

M.4.3 Preparation of the test samples

Prepare 9 samples as described in Annex O, coming from separate sheets identified as (a), (b), (c).

M.4.4 Procedure

Age the reinforced test sheets at T_{max} + 20 °C as follows.

— Store sheet (a) indoors at room temperature for 100 days;

— Hang sheet (b) in an oven at the ageing temperature for 70 days, followed by 30 days of storage at room temperature indoors;

— Hang sheet (c) in an oven at the ageing temperature for 100 days.

After the 100 days ageing period, prepare from each sheet 3 samples and test all within 8 h for bursting strength at temperature of 23 °C ± 2 °C in accordance with Annex O.

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M.4.5 Results

For the coating material, calculate the ratios of the bursting strength, B:

B_{100}/B_{70} and B_{100}/B_0

where

B_0 is the bursting strength without heat ageing (arithmetic mean of 3 results);

B_{70} is the bursting strength after heat ageing for 70 days (arithmetic mean of 3 results);

B_{100} is the bursting strength after heat ageing for 100 days (arithmetic mean of 3 results).

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Annex N
(normative)

Thermal stability test (Hot air ageing)

N.1 General

The test consists of measuring the effect of exposing test samples of installed coating materials to dry heat in a thermostatically controlled oven.

The effect of ageing is assessed by the visual control of the samples at given intervals, at room temperature.

N.2 Equipment

The equipment consists of an oven, in accordance with ISO 188 (normal oven method), thermostatically controlled, capable of being set to a temperature of 130 °C ± 3 °C.

The oven shall be of sufficient size to allow storing or hanging coated pipe rings, without any contact to the oven wall.

N.3 Preparation of the test samples

Apply the coating system according to the suppliers instruction on steel pipe(s) of at least 100 mm diameter.

Cold cut 3 rings of at least 100 mm wide from the coated pipe.

Identify each ring.

N.4 Procedure

Hang or store the coated pipe rings in the oven and make sure that the samples do not come into contact with the internal oven walls. Set the oven at 130 °C ± 2 °C.

Leave the samples in the oven for the duration that is specified for the particular coating systems. Do a visual check after one week and also every month as the test continues (take the samples out and let them cool down naturally in the surrounding atmosphere, i.e. without any forced cooling).

After the ageing period, take the samples out, let them cool down naturally in the surrounding atmosphere and assess the final results.

N.5 Results

Inspect the cooled down pipe samples visually and determine if the coating has cracks or any other visual defect.

The test is considered as passed when no cracks are apparent.

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Annex O
(normative)

Bursting strength of reinforced backing

O.1 General

Bursting strength of reinforced fabrics according to ISO 3303-1 is measured using a test piece that is securely clamped between rigid coaxial apertures. The force required to cause failure is recorded.

This Annex is based on ISO 3303-1 with exceptions on samples preparation, sample dimensions and test speed.

O.2 Equipment

Tensile test machine: Power driven and equipped with a suitable dynamometer. It shall be capable of maintaining a constant rate of 100mm/min ± 10mm/min transverse of the moving head during the test.

Oven in accordance with ISO 188 (normal oven method), thermostatically controlled, capable of being set to a temperature of 150 °C ± 3 °C.

The oven shall be of sufficient size to allow storing or hanging test specimens, without any contact to the oven wall.

O.3 Preparation of the test samples

Sampling: Cut out 3 – 30 × 20 cm samples accross the width of the reinforced sheet. Place them in the oven at 150 °C for 15 min until full recovery.

Sample preparation: Allow the samples to cool to 23 °C. Prepare the test samples by cutting a 100 mm square surface of each reinforced sheet.

Conditioning: Conditioning the test samples at 23 °C ± 3 °C for 8 h.

O.4 Procedure

Secure the conditioned test sample in the clamp and move the tests sample-and steel ball towards each other at a rate of 100 mm/min ± 10 mm/min until the test sample ruptures under the pressure being applied by the steel ball.

For each test, record the force in Newton required to cause the rupture of the test sample.

O.5 Results

For all samples record bursting strength *B* in Newton.

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Annex P
(normative)

Thermal analysis of epoxy power and cured coating film (FBE)

P.1 General

The uncured epoxy powder and the cured coating film are characterized by thermal analysis.

The method used is differential scanning calorimetry (DSC). Reference can be made to ISO 11357-2 for a description of the general procedure and definitions. General handling and calibration shall be performed as in ISO 11357-2, unless stated otherwise in this part of ISO 21809.

P.2 Equipment

The equipment consists of the following:

— differential scanning calorimeter (DSC), with cooling accessory;

— balance, accurate to 0,1 mg;

— sample-encapsulating press;

— aluminium pans, with covers;

— N_2 gas supply, dry, analytical grade.

P.3 Procedures and measurement for epoxy powder

P.3.1 Measurement

— Run (a): Heat the sample from 25 °C ± 5 °C to 70 °C ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

— Run (b): Heat the sample from 25 °C ± 5 °C to 275 °C ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

— Run (c): Heat the sample from 25 °C ± 5 °C to T_g + 40 °C (typically 150 °C) at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

For certain epoxy powders, it can be necessary to use a different heating cycle in accordance with the instructions of the epoxy powder manufacturer.

P.3.2 Evaluation of results

P.3.2.1 Glass transition temperature, T_g

The T_g is calculated at the point of the inflection intersection (see Figure P.1).

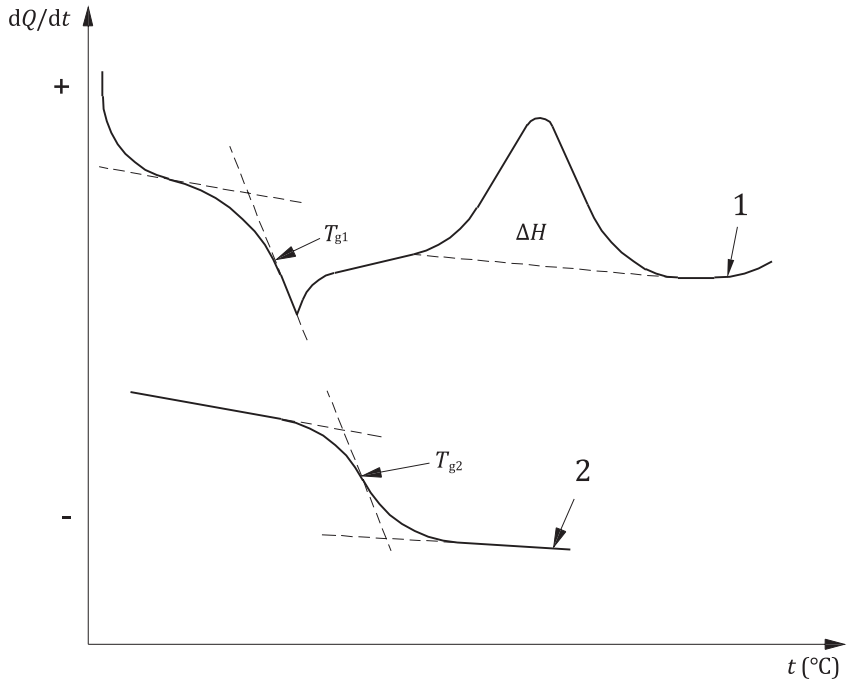
By evaluating run (b), the T_g of the uncured powder, T_{g1}, is obtained. By evaluating run (c), the T_g of the cured material, T_{g2}, is obtained.

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P.3.2.2 Heat of reaction of epoxy powder

The exothermic heat of reaction, ΔH, is obtained by integrating the exothermic peak of the DSC scan.



Key

1 run (b)

2 run (c)

Figure P.1 — Examples of thermal scans of an epoxy powder

P.4 Procedures and measurement for coating sample

P.4.1 General

Take a representative sample of the cured film.

Weigh 10 mg ± 3 mg to an accuracy of 0,1 mg. Seal the pan with the cover. Determine the final mass after sealing.

Place the sample and the reference sample in the DSC cell and purge with dry N_2 gas.

P.4.2 Measurement

— Run (a): Heat the sample from 25 °C ± 5 °C to 110 °C ± 5 °C at a rate of 20 °C/min and hold for 1,5 min, then cool the sample to 25 °C ± 5 °C.

— Run (b): Heat the sample from 25 °C ± 5 °C to 275 °C ± 5 °C at a rate of 20 °C/min, then cool the sample to 25 °C ± 5 °C.

— Run (c): Heat the sample from 25 °C ± 5 °C to T_g + 40 °C (typically 150 °C) at a rate of 20 °C/min, then cool the sample to 25 °C ± 5 °C.

For certain epoxy powders, it can be necessary to use a different heating cycle in accordance with the instructions of the epoxy powder manufacturer.

Samples taken from pipes that have been stored or buried shall be dried before testing.

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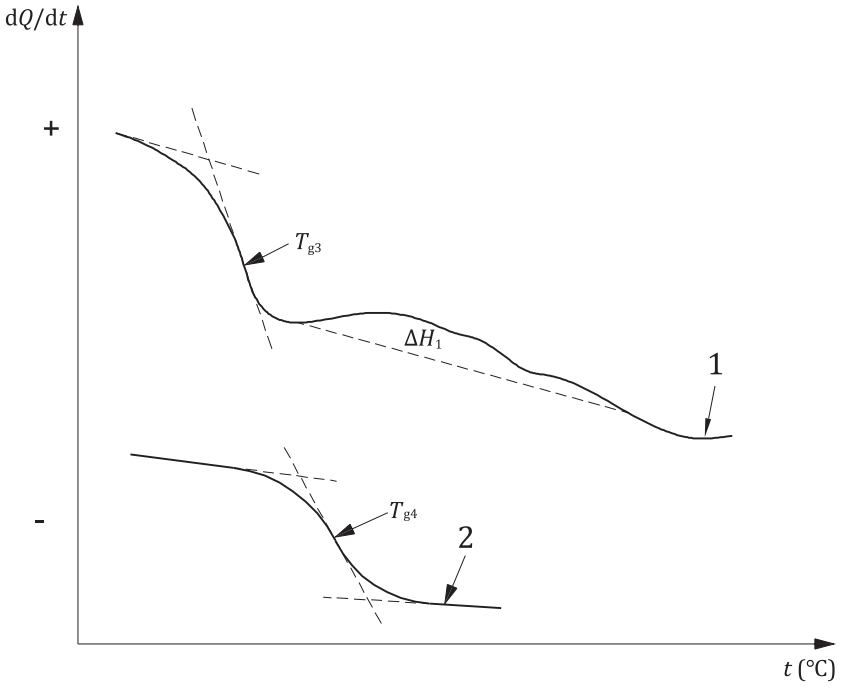
P.4.3 Evaluation of results

P.4.3.1 Glass transition temperature, T_g

The T_g for the coating is calculated as the inflection point (see Figure P.2), for runs (b) and (c), where T_{g3} is the glass transition temperature, expressed in degrees Celsius, of run (b) in P.4.2 and T_{g4} is the glass transition temperature, expressed in degrees Celsius, of run (c) in P.4.2.

For coatings, determine ΔT_g, the change in the value of T_g, expressed in degrees Celsius, using Formula (P.1):

$$\Delta T_g = T_{g4} - T_{g3} \quad \text{(P.1)}$$



Key

1 run (b)

2 run (c)

Figure P.2 — Examples of thermal scans of a coating

P.4.3.2 Residual heat of reaction of cured coating

The exothermic heat of reaction, ΔH_1, is obtained by integrating the exothermic peak of run (b) in P.4.2.

In a fully cured coating film there should be no residual heat of reaction visible.

The degree of conversion, C, expressed as a percentage, can be calculated from Formula (P.2):

$$C = \frac{\Delta H - \Delta H_1}{\Delta H_1} \times 100 \quad \text{(P.2)}$$

where

ΔH is the exothermic heat of reaction of the powder in run (b) of P.3.1;

ΔH_1 is the exothermic heat of reaction of the coating film in run (b) of P.4.2.

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P.4.4 Results

The following information shall be recorded:

— the type of material and batch number;

— the date of testing;

— the type of DSC equipment;

— for the epoxy powder: T_{g1}, T_{g2}, ΔH;

— for the cured coating film: T_{g3}, T_{g4}, ΔT_g, ΔH_1 and C.

Testing of production coating requires pipe number or identification.

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Annex Q
(normative)

Adhesion test — Resistance to removal

Q.1 General

The test consists of determining the adhesion of the FJC by a destructive process.

This method is only applicable for coating layers with a thickness less than 0,5 mm.

Q.2 Equipment

The equipment consists of the following:

— a utility knife, e.g. with a stiff, straight blade;

— a steel rule, if required;

— a steel rod, if required.

Q.3 Procedure

The adhesion test shall be done at 23 °C ± 3 °C unless otherwise agreed.

The test area shall consist of any coated area on the component or test sample that is free from all defects and with the correct dry film thickness.

Using a sharp-bladed utility knife, against a steel rule if necessary, straight, 30 mm to 50 mm cuts shall be made in the coating through to the metal surface to form an "X" with an angle of approximately 30° at the intersection point.

The point of the utility knife shall be inserted horizontally (i.e. the flat of the blade) under the coating at the point of intersection of the cuts such that the blade point is at the metal surface.

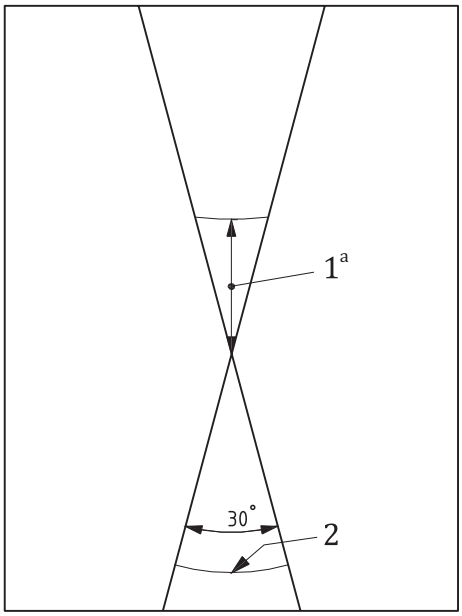
A levering action against a fulcrum (such as a steel rod) shall be used to force the flat point of the blade up from the metal surface describing a single, vertical (i.e. at 90° to the surface) motion in an attempt to prise the coating off.

Q.4 Results

The adhesion of the coating shall be determined by the rating system shown in Figure Q.1.

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Key

1 adhesive loss of coating (rating 1 to 5)

2 cuts

a Ratings 1 to 5:

— rating 1: no removal of coating other than that caused by insertion of the flat point of the knife blade at the intersection point (nominally less than 1 mm);

— rating 2: not more than 2 mm of adhesive loss of coating from the metal surface;

— rating 3: not more than 3 mm of adhesive loss of coating from the metal surface;

— rating 4: not more than 5 mm of adhesive loss of coating from the metal surface;

— rating 5: more than 5 mm of adhesive loss of coating from the metal surface.

Figure Q.1 — Adhesive loss of coating — Ratings 1 to 5

The rating of the coating adhesion is determined by adhesive failure. Limited cohesive rupture within the coating shall be considered a pass, if there is satisfactory adhesion.

Cohesive rupture caused by excessive interface or cross-section porosity leaving a noticeable "honeycomb" structure on the sample surface shall constitute a fail.

The rating shall be recorded.

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