INTERNATIONAL STANDARD

ISO 21809-3

First edition
2008-12-15

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 21809-3:2008(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 21809-3 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

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: Fusion-bonded epoxy coatings*

— *Part 3: Field joint coatings*

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

— *Part 5: External concrete coatings*

A Part 6, dealing with bitumen, asphalt and coaltar coatings, a Part 7, dealing with liquid coatings, a Part 8, dealing with thermal insulation coatings, and a Part 9, dealing with epoxy polyamide powder coatings (2-layer) are under preparation.

Introduction

Users of this part of ISO 21809 should 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 should identify any variations from this part of ISO 21809 and provide details.

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 pipeline transportation systems in the petroleum 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 pipes and fittings (components) are joined by welding.

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

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

NOTE Pipes 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 31-0:1992, *Quantities and units — Part 0: General principles*

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 1431-1:2004, *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 — Determination of the effect of liquids*

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

ISO 2781:2008, *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 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 (all parts), *Rubber, vulcanized or thermoplastic — Determination of indentation hardness*

ISO 8501-1:2007, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8502-3:1992, *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*

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 8503-5:2003, *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 8504-3, *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 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature*

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 and submerged pipelines used in pipeline transportation systems — Part 2: Fusion-bonded epoxy coatings*

ASTM D 70 [1)], *Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)*

ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*

ASTM D 127, *Standard Test Method for Drop Melting Point of Petroleum Wax, Including Petrolatum*

ASTM D 149, *Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies*

ASTM D 257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*

ASTM D 695, *Standard Test Method for Compressive Properties of Rigid Plastics*

ASTM D 937, *Standard Test Method for Cone Penetration of Petrolatum*

ASTM D 938, *Standard Test Method for Congealing Point of Petroleum Waxes, Including Petrolatum*

ASTM D 1000, *Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications*

ASTM D 1141, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D 1321, *Standard Test Method for Needle Penetration of Petroleum Waxes*

---

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

ASTM D 2084, *Standard Test Method for Rubber Property — Vulcanization Using Oscillating Disk Cure Meter*

ASTM D 4285, *Standard Test Method for Indicating Oil or Water in Compressed Air*

ASTM D 4541, *Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*

SSPC-SP1 [2], *Surface preparation specification No.1 — Solvent cleaning*

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

AWS C2.25/C2.25M [3], *Specification for Thermal Spray Feedstock Solid and Composite Wire and Ceramic Rods*

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 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

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

3.6
certificate of compliance
one of the types of inspection documents defined by ISO 10474, issued in accordance with the purchasing requirements

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

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

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

3.10
field joint area
⟨weld zone⟩ 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 document

3.14
manufacturer
company responsible for the manufacture of coating material

3.15
maximum design temperature of field joint coating
T_{max}
maximum continuous temperature that the field joint coating can resist

3.16
maximum operating temperature
maximum temperature that can be reached during operation of pipeline

3.17
overlap
length of the field joint coating over the plant-applied coating including the coating bevel

3.18
pipeline
those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances, up to and including the isolating valves

[ISO 13623:—, 3.14]

3.19
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

[ISO 13623:—, 3.16]

3.20
pre-production trial
PPT
application of coating and inspection/testing of its properties, to confirm that the APS is able to produce a field joint coating with the specified properties, carried out in the field immediately prior to start of production

3.21
primer
material applied as a film on substrate (metal and/or plant coating) to ensure adhesion of the subsequent protective coating

3.22
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

3.23
purchaser
company responsible for providing the product order requirements

3.24
wraparound sleeve
sleeve that is wrapped, circumferentially, around the steel pipe area being coated

4 Symbols and abbreviated terms

4.1 Symbols

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
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	thickness
T_{max}	maximum design 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

5 General requirements

5.1 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 31-0:1992, Annex B, Rule A.

NOTE For the purposes of this provision, the rounding method of ASTM E 29 is equivalent to ISO 31-0:1992, Annex B, Rule A.

5.2 Compliance to standard

A quality system should be applied to assist compliance with the requirements of this part of ISO 21809.

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

The applicator shall be responsible for complying with the requirements of this part of ISO 21809. It shall be permissible for the purchaser to make any investigation necessary in order to be assured of compliance by the applicator and to reject any material that does not comply.

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 and year of publication (ISO 21809-3:2008);

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

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

— maximum operating 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 being coated;

— type and frequency of certificate of compliance in accordance with ISO 10474 (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);

— 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;

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

— requirements for traceability and marking;

— requirements for documentation and schedule of supply of documentation;

— 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).

7 Application procedures and qualification

7.1 Application procedure specification (APS)

Prior to the start of production and any agreed PQT and/or PPT (see 7.3 and 7.4), the applicator shall prepare an APS, including

— identification of the coating;

— manufacturer's instructions for application;

— 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 design 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);

— 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.

If specified, the APS shall be approved prior to the start of production and prior to any agreed PQT and/or PPT. Once approved, the APS shall not be changed by the applicator without prior written authorization of the purchaser.

7.2 Coating materials

7.2.1 The applicator shall provide the data sheets specified in Clauses 10 to 17 for each coating material from the manufacturer.

7.2.2 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, and 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).

7.2.3 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 O. Acceptance criteria are given in the relevant clauses referred to in Annex O.

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.

Qualification tests shall be carried out on representative pipes having the same diameter and thickness as the production pipes.

NOTE Rejected pipe or pipe that has been used for other testing (e.g. welding qualification) is not considered representative.

Tests shall be carried out on test zones distributed along a pipe coated with the actual parent (plant-applied) coating. The length of the test zones shall be equivalent to the field joint coating length.

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

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 (except if coating repairs are not 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, similarity of, or differences in, lifting equipment.

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

— coating system;

— coating materials;

— application procedure;

— equipment being used for surface preparation and coating application;

— application of the coating system;

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

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 O. Acceptance criteria are given in the relevant clauses to which reference is made in Annex O.

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).

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 at a PQT, during PPT, via 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.

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 O. Acceptance criteria are given in the relevant clauses to which reference is made in Annex O.

7.7 Certificates of compliance and traceability

The inspection documents shall be in accordance with ISO 10474. 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 certificates of compliance signed by the applicator (and the inspector, if applicable) shall be transmitted to the purchaser at a frequency defined in the purchase order. Cumulative production records shall be maintained daily.

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

Code	Clause	Type of field joint coating
1A	10	Hot-applied bituminous tapes
1B		Petrolatum tapes
1C		Wax tapes
1D		Cold-applied polymeric tapes
2A	11	Heat-shrinkable materials, polyethylene-based
2B		Heat-shrinkable materials, polyethylene-based, applied over a liquid or fusion-bonded epoxy layer
2C		Heat-shrinkable materials, polypropylene-based, applied over a liquid or fusion-bonded epoxy layer
3A	12	Single-layer fusion-bonded epoxy powder
3B		Two-layer fusion-bonded epoxy powder
4A	13	Liquid epoxy or derivatives
4B		Liquid polyurethane or derivatives
4C		Fibre-reinforced epoxy
4D		Fibre-reinforced vinylester
4E		Cast polyurethane
5A	14	Flame-sprayed polypropylene powder applied over an epoxy layer
5B		Polypropylene tapes/sheets hot-applied over an epoxy layer
5C		Injection-moulded polypropylene over an epoxy layer
5D		Flame-sprayed polyethylene powder applied over an epoxy layer
5E		Polyethylene tapes/sheets hot-applied over an epoxy layer
6	15	Thermal spray aluminium (TSA)
7	16	Hot-applied microcrystalline wax coatings
8A	17	Elastomeric coatings, polychloroprene-based
8B		Elastomeric coatings, EPDM-based

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 design temperature, T_{max}, of the FJC shall be greater than the maximum operating temperature 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.

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, etc.) 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.

Steel defects and irregularities (e.g. arc strikes, scratches, weld spatter, slag and burrs) shall be removed by an approved grinding method or filing techniques. 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.

Dust contamination shall be measured in accordance with ISO 8502-3. Acceptance criteria are given for each FJC type in Clauses 10 to 17.

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.

9.1.2.2 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 D 4285.

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 17.

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 17. 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 $\leqslant$ 20 mg/m^2 for coating types 2B, 2C, 3, 4, 5 and 8 or $\leqslant$ 50 mg/m^2 for coating type 6. It is not necessary to measure the level of soluble salts on the steel surface for the coating types 1A, 1B, 1C, 1D, 2A and 7.

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.

9.1.2.3 Wire-brush cleaning

If wire brushing is permissible (see 9.1.1), this shall be in accordance with ISO 8501-1:2007, grade St 3 using mechanical rotary wire brushes. Manual wire-brush cleaning shall be allowed only if the manufacturer of the FJC requires a degree of cleanliness of ISO 8501-1:2007, grade St 2 and if defined in the APS.

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 17 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 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.

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 17 for different FJC types. Testing frequencies are given in Annex O.

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 repair procedures shall be included in the APS.

9.6 Verification 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 storage instructions are followed.

10 Bituminous, petrolatum, wax and polymeric tape coatings

10.1 Coating identification

Tape coatings shall be identified in the APS in accordance with Table 2 and shall meet the requirements of Tables 3, 4, 5 or 6.

Data sheets for the coating materials shall be in accordance with Table 7 (primer) and Table 8 (tapes).

Application instructions shall be provided by the manufacturer in accordance with Table 9.

10.2 Description of the coatings

10.2.1 Bituminous tapes (Type 1A)

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

10.2.2 Petrolatum tapes (Type 1B)

Petrolatum tape coatings consist of a primer and a single layer or multiple layers of petrolatum tapes. Maximum design temperature is 30 °C.

10.2.3 Wax tapes (Type 1C)

Wax tape coatings consist of a primer and a single layer or multiple layers of wax tapes. Maximum design temperature is 30 °C.

10.2.4 Polymeric tapes (Type 1D)

Cold-applied polymeric tape coatings consist of a primer and multiple layers of one or several polymeric tapes. Maximum design temperature is 50 °C or 80 °C depending on the material.

Specific polymeric tapes allowing a higher maximum design temperature may be used subject to qualification.

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 (10.4.6).

The area being coated shall be cleaned according to ISO 8501-1:2007, grade St 3, by power-tool cleaning as described in ISO 8504-3, except that

— for wax or petrolatum tapes, the area being coated may be cleaned according to ISO 8501-1:2007, grade St 2, by hand-tool cleaning as described in ISO 8504-3;

— for polymeric tapes, the area being coated should be cleaned according to ISO 8501-1:2007, grade Sa 2, by abrasive blast cleaning. The profile/roughness shall be in accordance with the manufacturer's application instructions.

Dust contamination shall be a maximum of grade 3, measured in accordance with ISO 8502-3:1992.

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.

10.4.3 Application of 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.

— Preheat 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, preheat 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 all stripes necessary side by side and follow the right overlap to 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 Application of petrolatum or wax 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 by brush, by hand or by another applicable tool.

— 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 recommended by the manufacturer or specified by the purchaser.

10.4.5 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.

— 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).

10.4.6 Overlap

The minimum tape overlaps are shown in Table 10. The applicator shall always follow the manufacturer's required overlap (Table 9) if greater than that given in Table 10.

The overlap of tapes on plant-applied coating is given by the manufacturer's application instructions (Table 9). For all materials, this overlap 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 should 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 10.5.13 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.

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

10.5.3 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 15 kV according to the method defined in Annex B.

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 G and shall meet the requirements of Tables 3, 4, 5 or 6.

10.5.5 Indentation resistance

The indentation resistance shall be measured using the method given in Annex H and shall meet the requirements of Tables 3, 4, 5 or 6.

10.5.6 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured using the method given in Annex K and shall meet the requirements of Tables 3, 4, 5 or 6.

10.5.7 Cathodic disbondment

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

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Tables 3, 4, 5 or 6. For polymeric tapes, a test duration of 48 h instead of 28 days may be used for PPT provided that the test temperature is increased to 65 °C and a comparison of results is performed during PQT.

For polymeric tapes, the maximum cathodic disbondment after 28 days at maximum design temperature shall be agreed between the end user and the applicator.

10.5.8 Peel strength between tape layers of polymeric tapes

The peel strength between tape layers shall be measured using the method given in Annex M and shall meet the requirements of Table 6.

10.5.9 Peel strength to pipe surface and plant coating

10.5.9.1 General

The minimal waiting period between application of the coating and the peel strength test shall be as given in Table 11, unless specified otherwise by the coating manufacturer.

10.5.9.2 Petrolatum and wax tapes (Types 1B and 1C)

Petrolatum and wax tapes shall leave a film of compound on the substrate when peeled off.

10.5.9.3 Bituminous and polymeric tapes (Types 1A and 1D)

The peel strength shall be measured using the methods given in Annex D and shall meet the requirements of Table 3 or 6 for types 1A and 1D, respectively. The method given in Clause D.1 shall be used for PQT. The method given in Clause D.2 may 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 Tables 3 and 6.

10.5.10 Hot-water immersion test

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

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

For polymeric and bituminous tapes, the peel strength after the hot-water immersion test shall be measured using the method given in Clause D.1 and shall meet the requirements of Tables 3 or 6, respectively.

10.5.11 Lap shear strength of bituminous and polymeric tapes

The lap shear strength resistance of bituminous and polymeric tapes shall be measured using the method given in Annex L and shall meet the requirements of Table 3 or 6 for types 1A and 1D, respectively.

10.5.12 Thermal ageing resistance of polymeric tapes

The thermal ageing resistance shall be measured using the method given in Annex N and shall meet the requirements of Table 6.

10.5.13 Drip resistance

No dripping of the compound shall occur when the tape is tested in accordance with Annex J for types 1B and 1C as listed in Tables 4 and 5, respectively.

Table 2 — Coating identification

Property	Reference
Coating trade name	—
Basic type of coating material	Table 1
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 coating that have been tested successfully with the coating.

Table 3 — Requirements for Type 1A — Hot-applied bituminous tape

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

[a] It is necessary that this requirement (R_{S100}/R_{S70} ⩾ 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.

[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.

Table 4 — Requirements for Type 1B — Petrolatum tape

Property	Test temperature °C	Unit	Requirements	Test method
Thickness	—	mm	⩾ 0,9 × nominal value	Annex A
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday	Annex B
Impact resistance	20	J/mm	⩾ 0,8	Annex G
Indentation resistance, pressure – Holiday detection at 5 kV/mm + 5 kV – Residual thickness	23	N/mm^2 — mm	0,1 no holiday ⩾ 0,6	Annex H
Specific electrical insulation resistance – R_{S100} – R_{S100}/R_{S70} [a]	23	Ω·m^2 —	⩾ 10^6 ⩾ 0,8	Annex K
Cathodic disbondment resistance at 28 days	23	mm	⩽ 20	Annex F
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 J

[a] It is necessary that this requirement (R_{S100}/R_{S70} ⩾ 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.

Table 5 — Requirements for Type 1C — Wax tape and primer

Property	Test temperature °C	Unit	Requirements	Test method
Primer				
Congeal point	—	°C	55 to 70	ASTM D 938
Flash point	—	°C	⩾ 65	ASTM D 92
Specific gravity	25	g/cm^3	0,9 to 1,25	ASTM D 70
Cone penetration	25	0,1 mm	75 to 225	ASTM D 937
Dielectric strength	—	V/µm	⩾ 4	ASTM D 149
Tape				
Congeal point of saturant	—	°C	65 to 70	ASTM D 938
Flash point of saturant	—	°C	⩾ 60	ASTM D 92
Thickness	—	mm	> 1,75	ASTM D 1000
Dielectric strength	—	V/µm	> 6,7	ASTM D 149
Impact resistance	20	J/mm	⩾ 0,8	Annex G
Indentation resistance, pressure – Holiday detection – Residual thickness	23	N/mm^2 — mm	0,1 no holiday ⩾ 0,6	Annex H
Specific electrical insulation resistance – R_{S100} – R_{S100}/R_{S70} [a]	—	Ω·m^2 —	⩾ 10^6 ⩾ 0,8	Annex K
Cathodic disbondment resistance at 28 days	23	mm	< 12	Annex F
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 J
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday	Annex B

[a] This requirement ($R_{S100}/R_{S70} \geqslant 0,8$) must 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.

Table 6 — Requirements for Type 1D — Polymeric tapes

Property	Test temp.	Unit	Requirements (up to 50 °C)	Requirements (up to 80 °C)	Test method
Thickness	—	mm	$\geqslant$ 0,9 × nominal value		Annex A
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday		Annex B
Impact resistance	20 °C	J/mm	$\geqslant$ 4		Annex G
Indentation resistance, pressure – Holiday detection at 5 kV/mm + 5 kV – Residual thickness	23 °C and T_{max}	N/mm^2 mm	10,0 no holiday $\geqslant$ 0,6	1,0 no holiday $\geqslant$ 0,6	Annex H
Specific electrical insulation resistance – R_{S100} – R_{S100}/R_{S70} [a]	23 °C	Ω·m^2 —	$\geqslant 10^8$ $\geqslant$ 0,8	$\geqslant 10^8$ $\geqslant$ 0,8	Annex K
Cathodic disbondment resistance at 28 days	23 °C T_{max}	mm mm	$\leqslant$ 15 [b]	$\leqslant$ 15 [b]	Annex F
Peel strength between tape layers – inner/inner, inner/outer – inner/inner, inner/outer – outer/outer – outer/outer	 23 °C T_{max} 23 °C T_{max}	 N/mm N/mm N/mm N/mm	 $\geqslant$ 1,50 $\geqslant$ 0,30 $\geqslant$ 0,20 $\geqslant$ 0,20	 $\geqslant$ 1,50 [c] $\geqslant$ 0,20 [c] 	Annex M
Peel strength – to steel surface – to steel surface – to plant coating – to plant coating – to plant coating after 28-day hot-water immersion test at 50 °C – to steel surface after 28-day hot-water immersion test at 50 °C or 80 °C	 23 °C T_{max} 23 °C T_{max} 23 °C 23 °C	 N/mm N/mm N/mm N/mm N/mm N/mm	 $\geqslant$ 1,00 $\geqslant$ 0,10 $\geqslant$ 0,40 $\geqslant$ 0,04 $\geqslant$ 0,40 $\geqslant$ 0,40	 $\geqslant$ 1,00 [c] $\geqslant$ 0,40 [c] $\geqslant$ 0,40 $\geqslant$ 0,40	Annex D Annex I Annex I
Lap shear strength	23 °C T_{max}	N/mm^2 N/mm^2	$\geqslant$ 0,050 $\geqslant$ 0,050	$\geqslant$ 0,050 $\geqslant$ 0,020	Annex L
Thermal ageing resistance Ratio of – elongation at break – peel strength between tape layers – peel strength to pipe surface 	— — — — — — —	 — — — — — —	 $1{,}25 \geqslant E_{70}/E_{70} \geqslant 0{,}75$ $E_{100}/E_{70} \geqslant 0{,}8$ $P'_{100}/P'_0 \geqslant 0{,}75$ $P'_{100}/P'_{70} \geqslant 0{,}8$ $P_{100}/P_0 \geqslant 0{,}75$ $P_{100}/P_{70} \geqslant 0{,}8$		Annex N

[a] It is necessary that this requirement ($R_{S100}/R_{S70} \geqslant 0{,}8$) 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.

[b] By agreement after qualification.

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

Table 7 — 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 – temperature, maximum	 °C °C	 — —
Shelf life at storage temperature	month	—

Table 8 — Data sheet [a] — Tape

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

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

Table 10 — Overlap of tape

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

Table 11 — Waiting period before peel-strength test

Material	Waiting period h
Petrolatum and wax tape	1
Bituminous tape	⩾ 24
Polymeric tape	⩾ 120 [a]
[a] 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.	

11 Heat-shrinkable coatings

11.1 Coating identification

Heat-shrinkable coatings shall be identified in the APS as per Table 12 and shall meet the requirements of Table 13 or 14 (depending on coating type).

Data sheets for the coating materials shall be in accordance with Table 15 (liquid primer), ISO 21809-2 (epoxy powder) or Table 16 (shrinkable materials).

Application instructions shall be provided by the manufacturer in accordance with Table 17.

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

11.2 Description of the coatings

11.2.1 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.

Heat-shrinkable materials are available in the following forms:

— tubular sleeve;

— wrap-around sleeve;

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

— tapes.

11.2.2 Type 2A

Type 2A coatings are cross-linked, heat-shrinkable materials based on polyethylene, applied without primer, which can be further subdivided into

— 2A-1: mastic-adhesive based, typically with a low design temperature of up to 50 °C;

— 2A-2: high shear-strength mastic adhesive, bitumen- or butyl-based, with a design temperature of up to 80 °C;

— 2A-3: high shear-strength hybrid or hot-melt adhesive, with a design temperature of up to 120 °C.

11.2.3 Types 2B and 2C

Types 2B and 2C are coatings applied with a liquid epoxy or FBE primer with the following characteristics:

— 2B: cross-linked heat-shrinkable material based on polyethylene, with a design temperature of up to 120 °C;

— 2C: cross-linked heat-shrinkable material based on polypropylene, with a design temperature of up to 130 °C.

11.3 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 11.4.4).

The area being coated shall be cleaned according to ISO 8501-1:2007, grade St 3, by power-tool cleaning as described in ISO 8504-3, except that

— for a high design temperature (> 50 °C) or Type 2A-3, the surface preparation should be carried out by abrasive cleaning to grade Sa 2½;

— If epoxy primer is used (Types 2B and 2C), the surface preparation shall be carried out by abrasive cleaning to grade Sa 2½.

When abrasive blast cleaning is used, the profile/roughness shall be in accordance with the manufacturer's application instructions.

Dust contamination shall be a maximum of grade 3, measured in accordance with ISO 8502-3:1992.

11.4 Application of the coatings

11.4.1 General

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

11.4.2 Application of the primer

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

11.4.3 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.

— Preheat the area to be coated as per manufacturer recommendations.

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

— Heat the sleeve to the specified surface temperature with a gas torch or other heat source [e.g. infra-red (IR) heater].

If heating is carried out using a gas torch, the heat shall be applied progressively and regularly, starting from the middle of the sleeve and going towards the ends to avoid forming air pockets.

Care shall be taken to ensure a uniform heat pattern as specified in the APS and demonstrated by the applicator in the PPT, if performed. In addition, the 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

a) 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

b) damage the plant-applied coating.

11.4.4 Overlap

The overlap of shrinkable materials on the plant-applied coating is given by the manufacturer's information (Table 17). For all materials, this overlap shall be at least 50 mm after shrinking.

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 manufacturer shall specify the as-supplied product thickness that achieves the minimum thickness required by the purchaser as the applied coating.

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

The minimum thickness of the coating on the body of the joint shall not be less than 85 % of the specified minimum thickness.

The minimum thickness of the coating measured on top of the weld cap shall not be less than 50 % 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.

11.5.3 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 B.

Holidays shall be repaired in accordance with the APS.

11.5.4 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 D and shall meet the requirements of Table 13 or Table 14. The method given in Clause D.1 shall be used for PQT. The method given in Clause D.2 may be used for PPT and production testing.

Failure shall not occur at the interface between steel and adhesive, nor between adhesive and polyolefin backing, for 2A-1 and 2A-2 types, except for coatings with a peeling strength 50 % higher than the values listed in Table 13.

11.5.5 Cathodic disbondment

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

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 13 or Table 14. A test duration of 48 h instead of 28 days may 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 design temperature (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 13 or 14.

11.5.6 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I, the test temperature being the maximum design temperature of the joint coating, limited as specified in Annex I. The peel strength shall be measured using method given in Clause D.1 and shall meet the requirements in Tables 13 and 14.

11.5.7 Impact resistance

The impact resistance shall be measured using the method given in Annex G and shall meet the requirements of Table 13 or 14.

11.5.8 Indentation resistance

The indentation resistance shall be measured using the method given in Annex H and shall meet the requirements of Table 13 or 14.

11.5.9 Lap shear strength

The lap shear strength resistance shall be measured using the method given in Annex L and shall meet the requirements of Table 13 or 14.

11.5.10 Thermal ageing resistance

The thermal ageing resistance shall be measured using the method given in Annex N and shall meet the requirements of Table 13 or 14.

Table 12 — Coating identification

Property	Reference
Coating trade name	—
Basic type of coating material	Table 1
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 coating that have been tested successfully with the coating.	

Table 13 — Requirements for type 2A joint coatings — PE backed, without primer

Property	Test temp.	Unit	Type 2A-1 up to 50°C	Type 2A-2 up to 80°C	Type 2A-3 up to 120°C	Test method
Thickness	—	mm	⩾ 0,85 × nominal value			Annex A
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday			Annex B
Impact resistance (holiday detection at 5 kV/mm + 5 kV after recovery)	20 °C	J/mm	⩾ 5	⩾ 5	⩾ 5	Annex G
Indentation resistance (holiday detection at 5 kV/mm + 5 kV after recovery)	23 °C	N/mm^2	1,0	10,0	10,0	Annex H
	T_{max}	N/mm^2	1,0	5,0	1,0	—
residual thickness	—	mm	⩾ 0,60	⩾ 0,60	⩾ 0,60	—
Cathodic disbondment at 28 days	23 °C	mm	⩽ 10	⩽ 10	⩽ 15	Annex F
	T_{max} limited to 95 °C	mm	[a]	[a]	[a]	—
Peel strength at 10 mm/min:	—	N/mm	—	—	—	Annex D
– to pipe surface and to plant coating	23 °C	N/mm	⩾ 0,40	⩾ 1,0	⩾ 2,50	—
	T_{max}	N/mm	[b]	[b]	⩾ 0,20	—
– to pipe surface after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	N/mm	⩾ 0,20	⩾ 0,50	⩾ 1,50	Annex I
– to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	N/mm	⩾ 0,40	⩾ 1,0	⩾ 1,50	Annex I
Lap shear strength at 10 mm/min	23 °C	N/mm^2	⩾ 0,05	⩾ 0,10	⩾ 1,0	Annex L
	T_{max}	N/mm^2	[a]	[a]	[a]	
Thermal ageing resistance (aged at T_{max} + 20 °C)	—	—	—	—	—	Annex N
Elongation at break E_{100}/E_0	23 °C	—	⩾ 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] By agreement after qualification.

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

Table 14 — Requirements for type 2B and 2C joint coatings — PE- or PP-backed, with primer

Property	Test temp.	Unit	Type 2B polyethylene	Type 2C polypropylene	Test method
Thickness	—	mm	⩾ 0,85 × nominal value		Annex A
Holiday detection at 5 kV/mm + 5 kV	—	—	no holiday		Annex B
Impact resistance (holiday detection at 5 kV/mm + 5 kV after recovery)	20 °C	J/mm	⩾ 5	⩾ 8	Annex G
Indentation resistance (holiday detection at 5 kV/mm + 5 kV after recovery)	T_{max}	N/mm^2	10,0	10,0	Annex H
Residual thickness	—	mm	⩾ 0,6	⩾ 0,6	
Cathodic disbondment at 28 days	23 °C	mm	⩽ 8,0	⩽ 8,0	Annex F
	T_{max} limited to 95 °C	mm	⩽ 15	⩽ 15	
Peel strength at 10 mm/min to pipe surface primed with epoxy and to plant coating	23 °C	N/mm	⩾ 2,50	⩾ 4,0	Annex D
	T_{max}	N/mm	⩾ 0,20	⩾ 2,0	
Peel strength at 10 mm/min to pipe surface and to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	23 °C	N/mm	⩾ 1,50	⩾ 2,0	Annex I
Lap shear strength at 10 mm/min	23 °C	N/mm^2	⩾ 1,0	⩾ 2,0	Annex L
	T_{max}	N/mm^2	⩾ 0,07	⩾ 0,50	
Thermal ageing resistance (aged at T_{max} + 20 °C) – Elongation at break (E_{100}/E_0)	23 °C	E_{100}/E_{70}	⩾ 0,75	⩾ 0,75	Annex N
– Peel strength to pipe surface (P_{100}/P_{100})	23 °C	P_{100}/P_{70}	⩾ 0,75	⩾ 0,75	

Table 15 — 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 16 — Data sheet — Shrinkable materials

Property	Unit	Test method
Trade name	—	—
Description of coating material	—	—
Colour	—	—
Shrinkable material type	—	Table 1
Nominal thickness (as supplied)	mm	ISO 4591 and ISO 4593
Adhesive type	—	—
Storage temperature, min., max.	°C	—
Shelf life at storage temperature	month	—

Table 17 — 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	—
Preheat temperature range	°C
Application of primer	—
Mixing ratio	—
Pot life	—
Cure temperature profile (temperature vs. time)	—
Application of heat-shrinkable material	—
Surface preheat temperature	—
Method of preheat	—
Shrink procedure	—
Overlap on plant coating (minimum)	—
Repair procedures	—

12 Fusion-bonded epoxy (FBE) powder coatings

12.1 Coating identification

The epoxy powder for a single-layer coating and for the base layer of a two-layer coating 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.

12.2 Description of the coatings

The coating consists of one (type 3A) or two (type 3B) layers of FBE powder applied to the pipe and cured.

Maximum design temperature shall be established by agreement between end user or purchaser and applicator.

For type 3B, application conditions, tests and acceptable results shall be established by agreement between end user or purchaser and applicator.

12.3 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 2½. 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 a maximum of grade 2, measured in accordance with ISO 8502-3:1992.

12.4 Application of the coatings

12.4.1 General

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

12.4.2 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.

12.4.3 Heating

The field joint area shall be uniformly preheated, 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 uniformity of the heat pattern 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 pipe temperature shall not exceed 275 °C.

CAUTION — For pipe grades over X80, the heating temperature can affect the pipe properties.

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.

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

12.4.4 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 preheated 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.

12.4.5 Field joint coating repairs

Holidays and damaged areas in the FBE coating shall be repaired using two-part epoxy or PU-based repair materials in accordance with the APS.

Prior to coating, the surface of the area being repaired shall be prepared using abrasive paper or pads, cleaned and roughened.

All repairs shall have a minimum dry film thickness at least equal to the minimum specified coating thickness for the FJC. The overlap of the repair coating onto the FJC shall be a minimum of 25 mm.

All repairs shall be holiday tested as described in 12.5.4.

12.5 Testing of the applied coatings

12.5.1 General

The tests in 12.5.2 to 12.5.10 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.

12.5.2 Visual appearance

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

12.5.3 Thickness

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

For type 3A coatings, the thickness shall be between 350 µm and 700 µm unless otherwise agreed between the end user and/or purchaser and the applicator. 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.

For type 3B coatings, the minimum thickness shall be equal to the plant-applied coating thickness.

12.5.4 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 B.

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

12.5.5 Adhesion

The adhesion of the FBE to the steel surface shall be tested in accordance with the method defined in Annex C and shall be a rating 1 or 2.

12.5.6 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 E 4.

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

12.5.7 Impact resistance

The impact resistance shall be measured using the method given in Annex G and shall exceed 1,5 J.

12.5.8 Cathodic disbondment

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

The average radius of disbondment shall not exceed

— 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;

— 15 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.

12.5.9 Hot-water immersion test

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

12.5.10 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.

13 Liquid coatings

13.1 Coating identification

Liquid coatings shall be identified in the APS in accordance with Table 18 and shall meet the requirements of Table 19 or 20.

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

Data sheets for the coating materials shall be in accordance with Table 21.

Application instructions shall be provided by the manufacturer in accordance with Table 22.

13.2 Description of the coatings

13.2.1 Liquid epoxy — 4A

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

13.2.2 Liquid polyurethane — 4B

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

13.2.3 Fibre reinforced epoxy — 4C

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

13.2.4 Fibre reinforced vinyl ester — 4D

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.

13.2.5 Cast polyurethane — 4E

The coating consists of a polyurethane resin applied by casting.

13.3 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 2½. 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 (13.4.3). The plant-applied coating shall not be removed or contaminated by abrasive dust.

Dust contamination shall be a maximum of grade 2, measured in accordance with ISO 8502-3:1992.

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.

13.4 Application of the coatings

13.4.1 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.

13.4.2 Heating

If applicable, heating using an induction coil or open flame or any other 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;

— damage the plant-applied coating.

13.4.3 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.

13.5 Testing of the applied coatings

13.5.1 General

The tests in 13.5.2 to 13.5.14 shall be carried out for production quality control, and for PQT and PPT if required.

13.5.2 Thickness

The minimum thickness of the coating 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 A.

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 at a maximum of 25 kV, according to the method defined in Annex B.

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

13.5.4 Adhesion

The adhesion to the steel surface shall be tested in accordance with ISO 4624 (pull-off test) and shall meet the requirements of Table 19 or 20. For production testing, the method defined in Annex C may be used for types 4A and 4B, unless otherwise agreed. The results shall meet the requirements of Table 19.

The adhesion to the plant-applied coating shall be tested in accordance with Annex C for types 4A and 4B and ISO 4624 for types 4C, 4D and 4E, and shall meet the requirements of Table 19 or 20. For PQT and PPT, alternatively, the adhesion test may be carried out using ISO 4624 and shall meet the requirements of Table 19 or 20.

For production testing, the method defined in Annex C may be used for types 4A and 4B, unless otherwise agreed. The results shall meet the requirements of Table 19.

13.5.5 Impact resistance

The impact resistance shall be measured for types 4A, 4B, 4C and 4D using the method given in Annex G and shall meet the requirements of Table 19.

NOTE This test is not applicable for type 4E.

13.5.6 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.

13.5.7 Cathodic disbondment

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

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 19 or 20. A test duration of 48 h instead of 28 days may 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 design temperature (subject to an upper temperature limit of 95°C) shall meet the requirements of Table 19 or 20.

13.5.8 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I, the test temperature being the maximum design temperature of the joint coating, limited as specified in Annex I. The adhesion to the steel surface shall be tested in accordance with ISO 4624 (pull-off test) during PQT and PPT and shall meet the requirements of Table 19 or 20.

The adhesion to plant-applied coating shall be tested in accordance with Annex C during PQT and PPT for types 4A and 4B and in accordance with ISO 4624 for types 4C, 4D and 4E, and shall meet the requirements of Table 19 or 20. Alternatively, the adhesion test may be carried out using ISO 4624 (pull-off test) and shall meet the requirement of Table 19 or 20.

13.5.9 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.

13.5.10 Indentation resistance

The indentation resistance shall be measured for types 4A, 4B, 4C and 4D using the method given in Annex H and shall meet the requirements of Table 19.

NOTE This test is not applicable for type 4E.

13.5.11 Specific electrical insulation resistance

The specific electrical insulation resistance shall be measured for types 4A, 4B, 4C and 4D using the method given in Annex K and shall meet the requirements of Table 19.

NOTE This test is not applicable for type 4E.

13.5.12 Compressive strength

For type 4E, the compressive strength shall be measured in accordance with ASTM D 695 and shall meet the requirements of Table 20.

13.5.13 Electrical volume resistivity

For type 4E, the electrical volume resistivity shall be measured in accordance with ASTM D 257 and shall meet the requirements of Table 20.

13.5.14 Water absorption

For type 4E, the water absorption shall be measured in accordance with ISO 62 and shall meet the requirements of Table 20.

Table 18 — Coating identification

Property	Reference
Coating trade name	—
Basic type of coating material	Table 1
Minimum thickness of the applied coating system	—
Compatible plant coatings [a]	—
Maximum design temperature	—
[a] State all types of plant coating that have been tested successfully with the coating.	

Table 19 — Requirements for types 4A, 4B, 4C and 4D liquid coatings

Property	Test temp.	Unit	Type 4A Liquid epoxy	Type 4B Liquid PU	Type 4C Reinforced epoxy	Type 4D Reinforced vinyl ester	Test method
Minimum thickness	—	µm	By agreement				Annex A
Visual inspection	—	—	Continuous and uniform film free of sags runs and colour striations (when applicable)		—	—	—
Holiday detection	—	kV/mm	5				Annex B
Impact resistance (holiday detection at 5 kV/mm)	20 °C –5 °C	J/mm	⩾ 3 ⩾ 1,5	⩾ 5 ⩾ 2,0	⩾ 5 ⩾ 1,5	⩾ 5 ⩾ 1,5	Annex G
Indentation resistance at 10 N/mm^2 (holiday detection at 5 kV/mm)	T_{max}	% DFT	⩽ 30	⩽ 30	⩽ 10	⩽ 10	Annex H
Cathodic disbondment at 28 days	23 °C T_{max} limited to 95 °C	mm	⩽ 8 ⩽ 15	⩽10 ⩽ 20	⩽ 8 ⩽ 15	⩽ 8 ⩽ 15	Annex F
Hardness (Shore A or D)	23 °C	—	As per manufacturer specification				ISO 868
Adhesion to pipe surface	20 °C	MPa	⩾ 10,0	⩾ 10,0	⩾ 10,0	⩾ 10,0	ISO 4624
Adhesion to pipe surface	2 °C	—	Rating 1	Rating 1	Not applicable	Not applicable	Annex C
Adhesion to plant coating	20 °C	—	Rating 1	Rating 1	Not applicable	Not applicable	Annex C
Adhesion to plant coating	20 °C	MPa	⩾ 3,5	⩾ 3,5	⩾ 3,5	⩾ 3,5	ISO 4624
Adhesion to pipe surface after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °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	20 °C	—	Rating 2	Rating 2	Not applicable	Not applicable	Annex I plus Annex C
Adhesion to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °C	MPa	⩾ 2,0	⩾ 2,0	⩾ 2,0	⩾ 2,0	ISO 4624
Specific electrical insulation resistance (R_{S100})	23 °C	Ω·m^2	10^6	10^6	10^6	10^6	Annex K
R_{S100}/R_{S70}	—	—	0,80	0,80	0,80	0,80	—

Table 20 — Requirements for cast polyurethane — 4E

Property	Test temp.	Unit	Type 4E Cast polyurethane	Test method
Minimum thickness	—	—	20 mm	Annex A
Holiday detection	—	kV/mm	> 5	Annex B
Compressive strength	23 °C	MPa	⩾ 30	ASTM D 695
Cathodic disbondment at 28 days	23 °C	mm	⩽ 10	Annex F
	T_{max} limited to 95 °C	—	⩽ 20	—
Cathodic disbondment at 48 h	60 °C	mm	⩽ 10	Annex F
Hardness (Shore A or D)	23 °C	—	As per manufacturer specification	ISO 868
Adhesion to pipe surface	20 °C	MPa	⩾ 10	ISO 4624
Adhesion to plant coating	20 °C	MPa	⩾ 3,5	ISO 4624
Adhesion to plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °C	MPa	⩾ 2,0	Annex I plus 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
Electrical volume resistivity	23 °C	Ω·cm	⩾ 10^{12}	ASTM D 257
Water absorption at 7 days	23 °C	mass %	⩽ 0,1	ISO 62

Table 21 — Data sheet

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

Table 22 — 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	—
Preheat temperature range	—
Application of liquid coatings	—
Mixing ratio	—
Pot life	—
Cure temperature profile (temp. vs. time)	—
Overlap on plant coating (minimum)	—
Repair procedures	—

14 Polyolefin-based coatings

14.1 Coating identification

Coatings made from polypropylene (PP) or polyethylene (PE) and with an innermost layer of epoxy resin shall be identified in the APS in accordance with Table 23 and shall meet the requirements of Tables 24 or 25.

Data sheets for the coating materials shall be in accordance with Table 26 (epoxy material), Table 27 (modified PP or PE powder) and Table 28 (PP or PE top coat material).

Application instructions shall be provided by the manufacturer in accordance with Table 29.

14.2 Description of the coatings

14.2.1 Flame-sprayed polypropylene — Type 5A

The coating consists of two or three layers:

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

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

— an optional top layer of PP powder applied by flame spraying.

Maximum design temperature is 110 °C.

14.2.2 Hot-applied polypropylene tapes/sheets — Type 5B

The coating consists of three layers:

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

— a layer of modified PP powder, applied by spraying;

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

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

14.2.3 Injection-moulded polypropylene — Type 5C

The coating consists of three layers:

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

— a layer of modified PP powder, applied by spraying;

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

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

14.2.4 Flame-sprayed polyethylene — Type 5D

The coating consists of three layers:

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

— a layer of modified PE powder, applied by spraying or flame spraying;

— a top layer of PE powder, applied by flame spraying; this powder may be the same modified PE powder applied on top of the first layer.

Maximum design temperature is 70 °C.

14.2.5 Hot-applied polyethylene tapes/sheets — Type 5E

The coating consists of three layers:

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

— a layer of modified PE powder applied by spraying;

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

Maximum design temperature is 80 °C.

14.3 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 2½. 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 (14.4.4). The plant-applied coating shall not be removed or contaminated by abrasive dust.

Dust contamination shall be a maximum of grade 2, measured in accordance with ISO 8502-3:1992.

14.4 Application of the coating

14.4.1 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 12.4.2 apply.

14.4.2 Heating

The field joint area shall be uniformly preheated, 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.

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

14.4.3 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.

14.4.4 Application of the modified PP or PE powder

If applied directly after or together with epoxy powder in one consecutive process, the modified PP or PE powder shall not overlap the plant 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 powder should be applied within the epoxy gel time and shall be applied before the epoxy is fully cured.

14.4.5 Application of the polyolefin top coat

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.

14.4.5.1 Types 5A and 5D

The 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 14.5.11 are met.

Additional heat may be added during application of the powder via low-pressure hot air or gas flame heated guns.

14.4.5.2 Types 5B and 5E

The PP or PE shall be applied by wrapping a preheated 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.

14.4.5.3 Type 5C

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.

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

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 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 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 A.

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 10 kV/mm at a maximum of 25 kV, according to the method defined in Annex B.

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

14.5.4 Peel strength

The peel strength shall be measured using methods given in Annex D and shall meet the requirements of Table 24 or Table 25. The method given in D.1 shall be used for PQT. The method given in D.2 may be used for PPT and production testing.

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.

14.5.5 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.

14.5.6 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I, the test temperature being the maximum design 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 C and shall meet the requirements of Table 24 or 25.

14.5.7 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 Clause E.4.

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

14.5.8 Cathodic disbondment

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

The cathodic disbondment after 28 days at 23 °C shall meet the requirements of Table 24 or 25. A test duration of 48 h instead of 28 days may 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 design temperature (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 24 or 25.

14.5.9 Impact resistance

The impact resistance shall be measured using the method given in Annex G and shall meet the requirements of Table 24 or 25.

14.5.10 Indentation resistance

The indentation resistance shall be measured using the method given in Annex H and shall meet the requirements of Table 24 or 25.

14.5.11 Oxidation induction time

The oxidation induction time shall be measured in accordance with ISO 11357-6 at a temperature of 200 °C for PE and at 220 °C for PP. The minimum acceptable value of the intercept in the tangent method shall be 15 min.

14.5.12 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 23 — Coating identification

Property	Reference
Basic type of coating material	Table 1
Minimum thickness of coating system	—
Compatible plant coatings	—

Table 24 — Requirements for types 5A, 5B and 5C — PP

Property	Test temperature	Unit	Requirements	Test method
Total coating thickness	—	mm	By agreement	Annex A
Epoxy layer thickness	—	mm	By agreement	Annex A
Holiday detection at 10 kV/mm	—	—	No holiday	Annex B
Peel strength	90 °C	N/mm	$\geqslant 4$	Annex D
	T_{max}	N/mm	$\geqslant 1{,}5$	Annex D
Adhesion to pipe surface and plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °C	—	Rating 3	Annex I plus Annex C
Degree of cure	—	°C	ΔT_g given by the manufacturer	Annex E
Cathodic disbondment at 28 days	23 °C	mm	$\leqslant 7$	Annex F
	T_{max} limited to 95°C	mm	$\leqslant 10$	Annex F
Impact resistance [a]	20 °C	J/mm	$7 \times \alpha \times \beta$ [a]	Annex G
Indentation resistance at a pressure of 10 N/mm^2	T_{max}	mm	$\leqslant 0{,}9$	Annex H
Flexibility	[b]	—	[b]	[b]
Oxidation induction time at 220 °C (intercept in the tangent method) [c]	—	min	$\geqslant 15$	ISO 11357-6

[a] $\alpha = 0{,}7$ for coating thickness less than or equal to 2 mm;
$\alpha = 1$ for coating thickness greater than 2 mm;
$\beta = 0{,}7$ for pipe with nominal diameter less than 65 mm;
$\beta = 0{,}85$ for pipe with nominal diameter from 65 mm to less than 200 mm;
$\beta = 1{,}0$ for pipe with nominal diameter from 200 mm.

[b] By agreement, if applicable.

[c] May be omitted for types 5B and 5C if agreed between end user or purchaser and applicator.

Table 25 — Requirements for types 5D (flame-sprayed PE) and 5E (PE tapes)

Property	Test temperature	Unit	Value	Test method
Total coating thickness	—	mm	By agreement	Annex A
Epoxy layer thickness	—	mm	By agreement	Annex A
Holiday detection	—	kV/mm	> 10	Annex B
Peel strength	T_{max}	N/mm	$> 1{,}5$	Annex D
Adhesion to pipe surface and plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °C	—	Rating 3	Annex I plus Annex C
Degree of cure	—	°C	ΔT_g given by the manufacturer	Annex E
Cathodic disbondment at 28 days	23 °C	mm	$\leqslant 7$	Annex F
	T_{max}	mm	$\leqslant 10$	Annex F
Impact resistance [a]	20 °C	J/mm	$5 \times \alpha \times \beta$	Annex G
Indentation resistance at a pressure of 10 N/mm^2	T_{max}	mm	$\leqslant 1{,}0$	Annex H
Flexibility	[b]	—	[b]	[b]
Oxidation induction time at 200 °C (intercept in the tangent method) [c]	—	min	$\geqslant 15$	ISO 11357-6

[a] $\alpha = 0{,}7$ for coating thickness less than or equal to 2 mm;
$\alpha = 1$ for coating thickness greater than 2 mm;
$\beta = 0{,}7$ for pipe with nominal diameter less than 65 mm;
$\beta = 0{,}85$ for pipe with nominal diameter from 65 mm to less than 200 mm;
$\beta = 1{,}0$ for pipe with nominal diameter from 200 mm.

[b] By agreement, if applicable.

[c] May be omitted for types 5B and 5C if agreed between end user or purchaser and applicator.

Table 26 — 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)	—	—
Minimum thickness	mm	Annex A
Storage conditions max	°C	—
Shelf life at storage temperature	month	—

Table 27 — Data sheet — Modified PP or PE powder

Property	Unit	Test method
Trade name	—	—
Description of the powder	—	—
Colour	—	—
Minimum thickness	mm	Annex A
Type	—	—
Storage conditions	—	—
Shelf life	month	—

Table 28 — Data sheet — PP or PE top coat material

Property	Unit	Test method
Trade name	—	—
Description of the top coat material	—	—
Colour	—	—
Minimum thickness	mm	Annex A
Storage conditions	—	—
Shelf life	month	—

Table 29 — 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 preheat temperature range	°C	×	—
Mixing ratio (if any)	—	×	—
Pot life (if any)	min	×	—
Curing temperature	—	×	—
Application of the modified PP or PE powder	—	—	×
Method of preheat of PE or PP materials	—	—	×
Application of the PP or PE materials	—	—	×
Minimum overlap on plant coating	mm	—	×
Holiday inspection voltage	kV	—	×
Repair procedures	—	×	×

15 Thermal spray aluminium (TSA) coatings

15.1 Coating identification

TSA field joint coatings shall be applied only in conjunction with TSA plant-applied coating and shall meet the requirements of Table 30.

Data sheets for the coating materials shall be in accordance with Table 31.

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.

15.2 Description of the coating

The coating consists of

— 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.

15.3 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.

15.4 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 a maximum of grade 2, measured in accordance with ISO 8502-3:1992.

The chloride ion content, measured in accordance with ISO 8502-6 and ISO 8502-9, shall be less than 50 mg/m^2.

15.5 Application of the coating

15.5.1 General

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

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

15.5.2 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.

15.5.3 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.

15.6 Testing of the applied coating

15.6.1 General

The tests in 15.6.2 to 15.6.7 shall be carried out for PQT, PPT and production quality control. Companion coupons necessary for performing tests described in 15.6.3 and 15.6.5 shall be prepared during application according to the APS.

15.6.2 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.

15.6.3 TSA porosity

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

15.6.4 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 30.

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.

15.6.5 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.

15.6.6 Pull-off adhesion test

Pull-off adhesion strength to substrate shall be measured on unsealed TSA, in accordance with ISO 4624 (in the lab), or ASTM D 4541 (in the field) and shall meet the requirements of Table 30.

15.6.7 Sealer penetration

Sealer shall be inspected at 30× power magnification and shall exhibit no voids or missed areas in coverage.

Table 30 — 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 D 4541)	⩾ 7 MPa

Table 31 — 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	—	—

16 Hot-applied microcrystalline wax coatings

16.1 Coating identification

Coatings made from hot-applied microcrystalline wax shall be identified in the APS as per Table 32 and shall meet the requirements of Table 33.

Data sheets for the coating materials shall be in accordance with Table 34.

Application instructions shall be provided by the manufacturer, in accordance with Table 34.

16.2 Description of the coating

The coating consists of

— a microcrystalline wax applied directly to the surface;

— an outer wrap;

— a final layer of hot-applied wax.

Maximum design temperature is 50 °C.

16.3 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 (16.4.2). The plant-applied coating shall not be removed.

Dust contamination shall be a maximum of grade 3, measured in accordance with ISO 8502-3:1992.

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.

16.4 Application of the coating

16.4.1 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 preheating is used to eliminate surface moisture, the heating time and the temperature shall not damage the plant-applied coating.

16.4.2 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.

At the beginning of each shift, adhesion shall be checked in accordance with 16.5.4. 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.

16.4.3 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.

16.4.4 Application of wax top coat

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

16.5 Testing of the applied coatings

16.5.1 General

The tests in 16.5.2 to 16.5.5 shall be carried out for production quality control, and for PQT and PPT if required, after cooling of the material.

16.5.2 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.

NOTE It is necessary that the outer wax layer be only visually uniform, with no minimum thickness necessary.

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

16.5.3 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 B.

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

16.5.4 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 design 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.

16.5.5 Hardness

Coating hardness shall be measured by needle penetration in accordance with ASTM D 1321 and shall meet the requirements of Table 33.

Table 32 — 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 design temperature	°C
Minimum thickness	mm
Outer wrap composition and thickness	—

Table 33 — Requirements for hot-applied wax for design temperatures to 50 °C

Property	Unit	Requirements	Test method
Microcrystalline wax			
Specific gravity at 25 °C	—	0,85 to 0,92	ASTM D 70
Needle penetration at 25 °C	—	26 to 50	ASTM D 1321
Melting point	°C	70 to 80	ASTM D 127
Flash point	°C	⩾ 260	ASTM D 92
Dielectric strength	V/µm	⩾ 4	ASTM D 149
Cathodic disbondment at 25 °C, 28 days	mm	⩽ 14	Annex F
Outer wrap — Wax-laminated plastic film on spun-bonded plastic mat			
Plastic film thickness	µm	13 to 25	ASTM D 1000
Wax melt point	°C	71 to 99	ASTM D 127
Average thickness	µm	305	ASTM D 1000
Dielectric strength	V/µm	⩾ 14	ASTM D 149
Outer wrap — Wax-saturated spun-bonded plastic mat			
Wax melt point	°C	71 to 99	ASTM D 127
Total thickness	µm	250 to 635	ASTM D 1000
Dielectric strength	V/µm	⩾ 14	ASTM D 149

Table 34 — 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 design temperature	°C
Minimum thickness	mm
Outer wrap composition and thickness	—

17 Elastomeric coatings

17.1 Coating identification

Elastomeric coatings using polychloroprene or EPDM shall be identified in the APS as per Table 35 and shall meet the requirements of Table 36.

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 37 (polychloroprene) or Table 38 (EPDM).

Application instructions shall be provided by the manufacturer in accordance with Table 39.

17.2 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 8A), a solid synthetic rubber;

— EPDM (Type 8B), a synthetic ethylene-propylene-diene rubber with a higher temperature resistance.

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

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

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

17.3 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 2½. 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 a maximum of grade 2, measured in accordance with ISO 8502-3:1992.

17.4 Application of the coatings

17.4.1 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.

17.4.2 *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.

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.

17.4.3 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.

17.5 Testing of the applied coatings

17.5.1 General

The tests in 17.5.2 to 17.5.16 shall be carried out for production quality control, and for PQT and PPT if required.

17.5.2 Visual appearance

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

17.5.3 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 A.

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 6 kV/mm at a maximum of 25 kV, according to the method defined in Annex B.

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 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 36.

17.5.6 Adhesion

The peel strength shall be measured using the method given in Clause D.2 and shall meet the requirements of Table 36.

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

17.5.7 Hot-water immersion test

A hot-water immersion test shall be carried out in accordance with Annex I, the test temperature being the maximum design 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 Clause D.2 and shall meet the requirements of Table 36.

17.5.8 Cathodic disbondment

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

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 may 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 design temperature, (subject to an upper temperature limit of 95 °C) shall meet the requirements of Table 36.

17.5.9 Specific gravity

Specific gravity of the cured elastomer shall be measured in accordance with ISO 2781:2008, method A. The value shall be within ± 2 % of the manufacturer's stated value.

17.5.10 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.

17.5.11 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 37 or 38.

17.5.12 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 37 or 38.

17.5.13 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 37 or 38.

17.5.14 Volume resistivity

The volume resistivity shall be measured using the method in accordance with ASTM D 257 and shall meet the requirements of Table 37 or 38.

17.5.15 Ozone resistance

The ozone resistance shall be measured using the method in accordance with ISO 1431-1:2004, procedure A, with an ozone concentration of 0,5 µl/l [4)] for 72 h at 40 °C. The elastomer shall show no cracks or other detrimental effects when held at a fixed 20 % strain.

---

4) At low concentrations, the concentration expressed in microlitres per litre approximately equals that expressed in parts per million (ppm), a deprecated unit.

17.5.16 Resistance to seawater

The seawater resistance shall be measured using the method in accordance with ISO 1817 with substitute seawater, in accordance with ASTM D 1141.

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 17.5.11.

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 35 — Coating identification

Property	Reference	Unit
Date of issue	—	—
Name of manufacturer	—	—
Commercial name of the material	—	—
Basic type of coating material	Table 1	—
Application methods and conditions (ambient conditions)	—	—
Maximum design temperature	—	°C
Name of and thickness of primer	—	—
Name of and thickness of bonding agent	—	—
Nominal thickness of coating system	—	mm

Table 36 — Requirements for elastomer FJC

Property	Test temperature	Unit	Requirements	Test method
Visual appearance of coating	—	—	17.5.2	Visual
Coating thickness	—	—	Same as main pipe coating	ISO 2178
Holiday detection at 6 kV/mm at a maximum of 25 kV	—	—	No holiday	Annex B
Hardness	—	Shore A	60 to 70	ISO 7619-1
Adhesion (peel strength)	20 °C	N/mm	Cohesive and > 12	Clause D.2
Adhesion to pipe surface and plant coating after 28-day hot-water immersion test at T_{max} limited as per Annex I	20 °C	N/mm	Cohesive and > 10	Clause D.2
Cathodic disbondment at 28 days	23 °C	mm	⩽ 7	Annex F
	T_{max} limited to 95°C	mm	⩽ 10	Annex F

Table 37 — Data sheet for polychloroprene

Property	Unit	Requirements	Test method
Hardness, Shore A	—	60 to 70	ISO 7619-1
Specific gravity	—	Stated value ± 2 %	ISO 2781
Rheometer curve	—	Standard curve	ASTM D 2084
Tensile strength	N/mm^2	> 14	ISO 37
Elongation at break	%	> 350	ISO 37
Tear strength	N/mm	> 40	ISO 34-1
Volume resistivity	Ω·cm	$> 10^{11}$	ASTM D 257
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 38 — Data sheet for EPDM

Property	Unit	Requirements	Test method
Hardness, Shore A	—	70	ISO 7619-1
Specific gravity	—	Stated value ± 2 %	ISO 2781
Rheometer curve	—	Standard curve	ASTM D 2084
Tensile strength	N/mm^2	> 16	ISO 37
Elongation at break	%	> 350	ISO 37
Tear strength	N/mm	> 40	ISO 34-1
Volume resistivity	Ω·cm	$> 10^{11}$	ASTM D 257
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 39 — 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 preheat 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	—	×	—	×

Annex A
(normative)

Inspection of thickness

A.1 General

The inspection consists of measuring the thickness of the FJC.

A.2 Equipment

A.2.1 **Magnetic**, **electromagnetic** or **ultrasonic measuring instrument**, with ± 10 % reading accuracy, calibrated for the range of coating thickness being measured.

A.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.

A.4 Results

The minimum value for the body and for the weld bead shall be recorded.

Annex B
(normative)

Holiday detection test

B.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.

B.2 Equipment

B.2.1 Holiday detector, adjustable, high-voltage, with ± 10 % reading accuracy, equipped with a sound and/or light signal.

B.2.2 Scanning electrode, in the form of a metal brush, coiled spring with continuous spirals or conductive rubber conforming to the shape of the joints.

B.2.3 Conductors, connecting the joint to an earth electrode.

B.3 Procedure

The test shall be performed only on a coating that is free from surface moisture.

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.

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.

At the start of each shift, the instrument shall be verified by a certified voltmeter and adjusted if necessary.

B.4 Results

The number of holidays shall be recorded. All holidays shall be marked.

Annex C
(normative)

Adhesion test — Resistance to removal

C.1 General

The test consists of determining the adhesion of the FJC by a destructive process.

C.2 Equipment

C.2.1 **Utility knife**, e.g. with a stiff, straight blade.

C.2.2 **Steel rule**, if required.

C.2.3 **Steel rod**, if required.

C.3 Procedure

The adhesion test shall be done at 20 °C ± 5 °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.

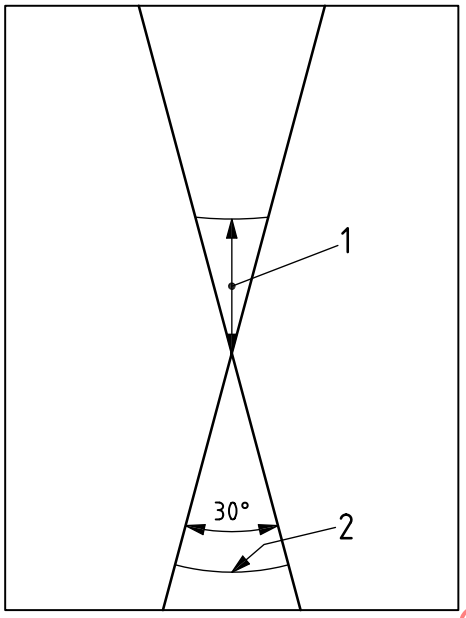
Using a sharp-bladed utility knife, against a steel rule if necessary, straight, 30 mm to 50 mm cuts shall be made in the coating through to the metal surface to form an “X” with an angle of approximately 30° at the intersection point.

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.

C.4 Results

The adhesion of the coating shall be determined by the rating system shown in Figure C.1.



Key

1 adhesive loss of coating (rating 1 to 5) [a]
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 C.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.

Annex D
(normative)

Peel-strength test

D.1 Measurement of the peel strength with a tensile testing machine

D.1.1 General

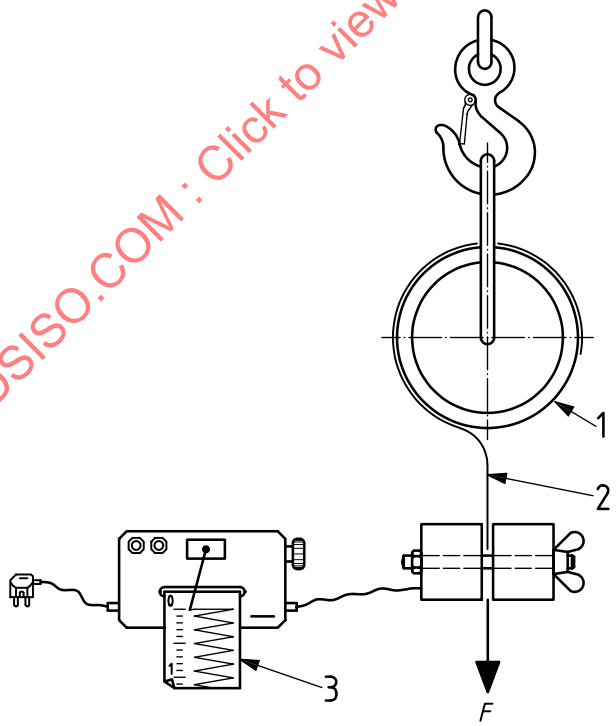
The test consists of measuring the force required for peeling the FJC from the metal substrate of the joint at a constant rate of pull. When specified in Clauses 10 to 17, the same method shall be used to measure the force required for peeling the FJC from the plant coating at overlap.

D.1.2 Equipment

D.1.2.1 **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 D.1 for small diameters or as in Figure D.2 for large diameters.

D.1.2.2 **Cutting tool**, e.g. knife.

D.1.2.3 **Equipment**, as suggested in Figures D.1 or D.2.

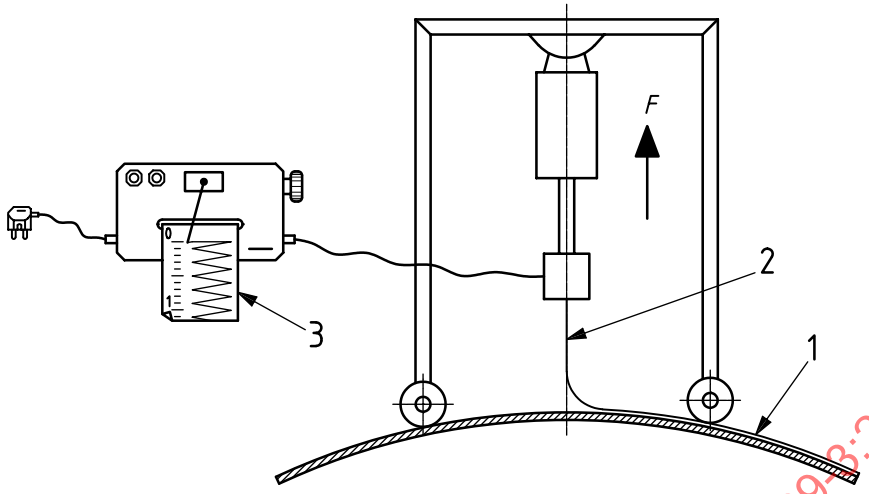


Key

1 pipe ring
2 coating strip
3 registration unit

F peel force

Figure D.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 D.2 — Peel-strength test equipment for a large-diameter joint

D.1.3 Procedure

D.1.3.1 General

The peeling test for ambient temperature shall be performed at the temperature specified in the tables in Clauses 10 to 17.

The peeling test for maximum design temperature shall be carried out if the maximum design 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.

D.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 D.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.

D.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.

D.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 17 and no single recorded peeling value shall be more than 30% below the specified value.

D.2 Measurement of the peel strength with a spring balance

D.2.1 General

The method consists of measuring the force required for peeling the field joint coating from the metal substrate with a spring balance at a constant rate of pull. When specified in Clauses 10 to 17, the same method shall be used to measure the force required for peeling the FJC from the plant coating at overlap.

D.2.2 Equipment

The equipment shall consist of the following:

D.2.2.1 **Spring balance**, with a clamp, accurate to ± 10 %, as shown in Figure D.3.

D.2.2.2 **Cutting tool**, e.g. knife.

D.2.3 Procedure

The test shall be performed at a temperature of 20 °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 joint at the root of the peeled strip (evaluation on 100 mm).

From the joint, a strip of coating 20 mm to 50 mm wide perpendicular to the axis of the joint shall be cut.

The strip shall be separated over a circumferential length of approximately 20 mm.

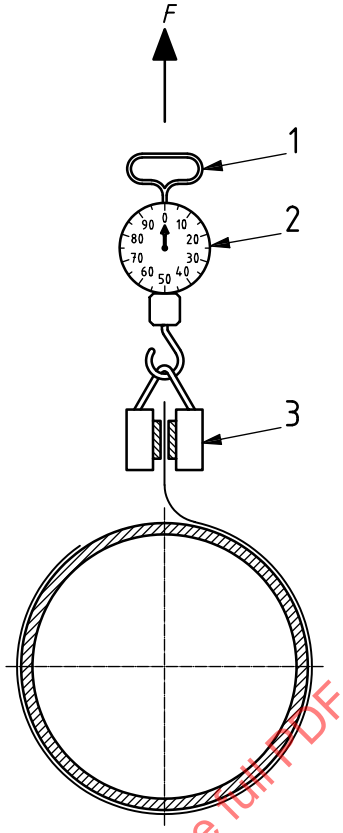
The separated part of the coating shall be secured in the clamp of the spring balance.

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 every 6 s over a distance of 10 mm.

D.2.4 Results

The peel strength, expressed in newtons per millimetre, shall be calculated as the arithmetic mean taken over the 10 recorded peel-force values.

The peel strength, expressed in newtons per millimetre, shall be recorded.



Key

1 handle
2 spring balance
3 clamp

F peel force

Figure D.3 — Peel-strength test equipment with a spring balance

Annex E
(normative)

Thermal analysis of epoxy powder and cured coating film (FBE)

E.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.

E.2 Equipment

E.2.1 **Differential scanning calorimeter** (DSC), with cooling accessory.

E.2.2 **Balance**, accurate to 0,1 mg.

E.2.3 **Sample-encapsulating press**.

E.2.4 **Aluminium pans**, with covers.

E.2.5 **N_2 gas supply**, dry, analytical grade.

E.3 Procedures and measurement for epoxy powder

E.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.

E.3.2 Evaluation of results

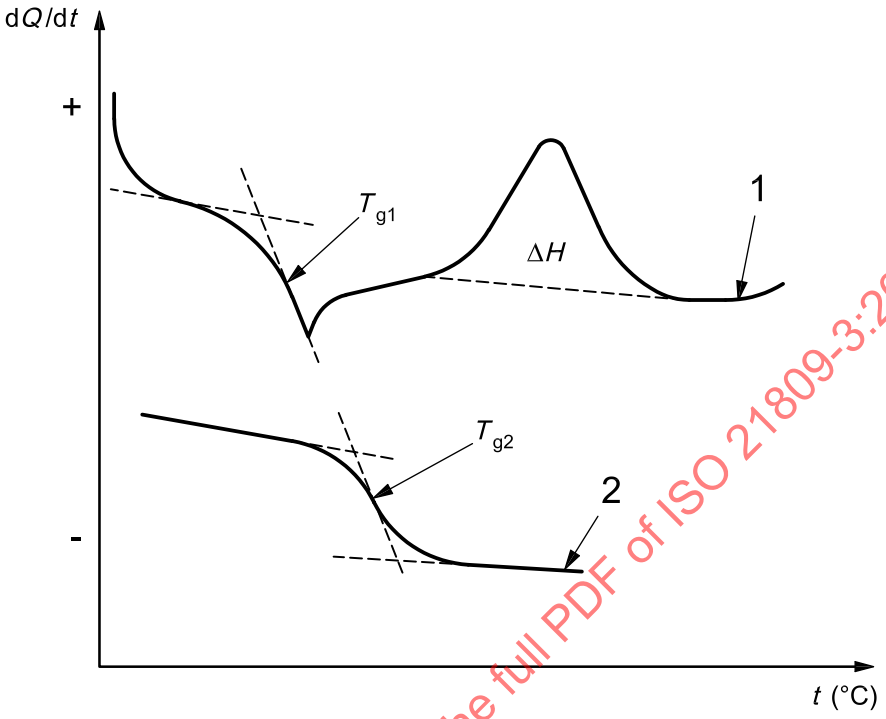
E.3.2.1 Glass transition temperature, T_g

The T_g is calculated at the point of the inflection intersection (see Figure E.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.

E.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 E.1 — Examples of thermal scans of an epoxy powder

E.4 Procedures and measurement for coating sample

E.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.

E.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.

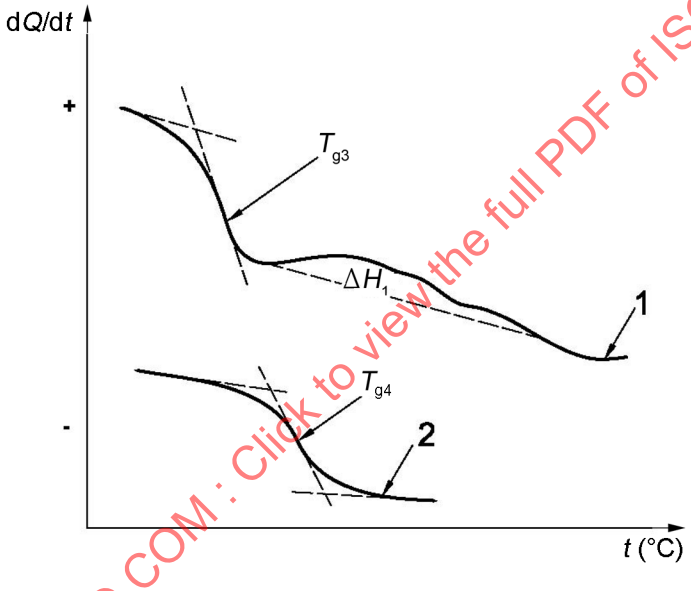
E.4.3 Evaluation of results

E.4.3.1 Glass transition temperature, T_g

The T_g for the coating is calculated as the inflection point (see Figure E.2), for runs (b) and (c), where T_{g3} is the glass transition temperature, expressed in degrees Celsius, of run (b) in E.4.2 and T_{g4} is the glass transition temperature, expressed in degrees Celsius, of run (c) in E.4.2.

For coatings, determine ΔT_g, the change in the value of T_g, expressed in degrees Celsius, using Equation (E.1):

$$\Delta T_g = T_{g4} - T_{g3} \tag{E.1}$$



Key

1 run (b)
2 run (c)

Figure E.2 — Examples of thermal scans of a coating

E.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 E.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 Equation (E.2):

$$C = \frac{\Delta H - \Delta H_1}{\Delta H_1} \times 100 \tag{E.2}$$

where

ΔH is the exothermic heat of reaction of the powder in run (b) of E.3.1.

ΔH_1 is the exothermic heat of reaction of the coating film in run (b) of E.4.2.

E.4.4 Results

The following information shall be recorded:

— type of material and batch number;

— date of testing;

— 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.

Annex F
(normative)

Cathodic disbondment test

F.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 taken from the coated components previously subjected to holiday detection (see Annex B), and in which an artificial defect of a defined size has been drilled. The test may be performed on the coated component without cutting test samples.

F.2 Equipment

F.2.1 Electrical source, consisting of a controlled voltage d.c. power unit capable of supplying 20 mA to each test area simultaneously.

Except when otherwise specified, a cathodic polarization potential of −1500 mV to a saturated calomel reference electrode (equivalent to UH equal to −1260 mV where UH is the potential of the standard hydrogen electrode) shall be maintained. 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".

F.2.2 Electrolytic cell, having a typical test-cell configuration as shown in Figure F.1 for large-diameter components and as in Figures F.2 and F.3 for small-diameter components.

The electrolytic cell shall comprise of

— 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.

F.2.3 Electrodes

F.2.3.1 Reference electrode, capable of giving a suitable potential (see F.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.

F.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 anode to that of the cathode shall be greater than 1.

F.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 F.4).

F.2.4 **Electrolyte**, consisting of a 3 % solution of NaCl in distilled or deionized water.

The solution shall be made from analar 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 75 mm ± 5 mm.

F.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.

F.3 Sampling

The test sample shall be cold cut from a coated component and shall have a minimum size of 80 mm × 80 mm, unless the test is performed on the body of the coated component.

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 B).

A 6 mm diameter hole (see Figure F.4) shall be drilled through the coating in the centre of the test sample using a standard drill bit. The depth of the drilled 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.

The test area shall be degreased using a suitable solvent and then rinsed with potable water and subsequently dried.

F.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 (F.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 F.1, F.2 and F.3), with an accuracy of ± 10 mV. If a saturated calomel electrode is used, the potential shall be −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.

F.5 Investigation procedure

After the test, the cell with the electrolyte shall be removed. The test sample shall be rinsed with water and dried.

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.

— Detach the plastic pipe from the test site.

— Using a lint-free paper towel, wipe along the surface of the coating and cathode area to remove moisture.

— 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. As loss of adhesion is not always obvious, carefully examine the substrate for signs of residual coatings, which indicates that disbondment has not occurred.

— Repeat with each radial segment.

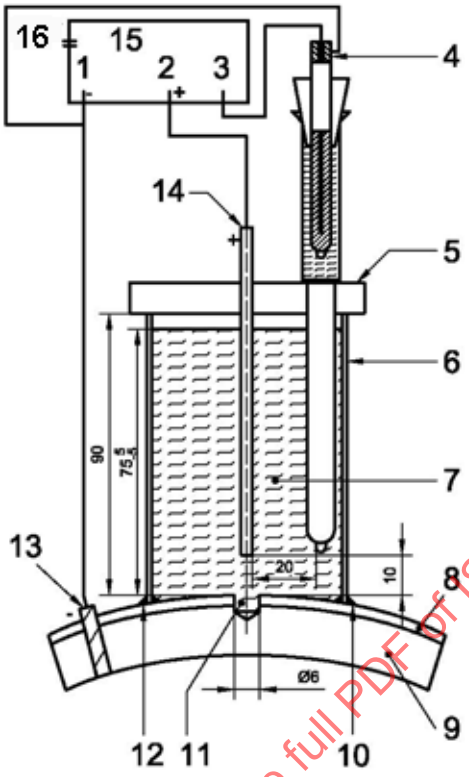
NOTE For thick coatings that cannot be peeled, it is sometimes necessary to remove the coating from the substrate using a chisel to assess the extent of disbondment.

F.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.

Dimensions in millimetres

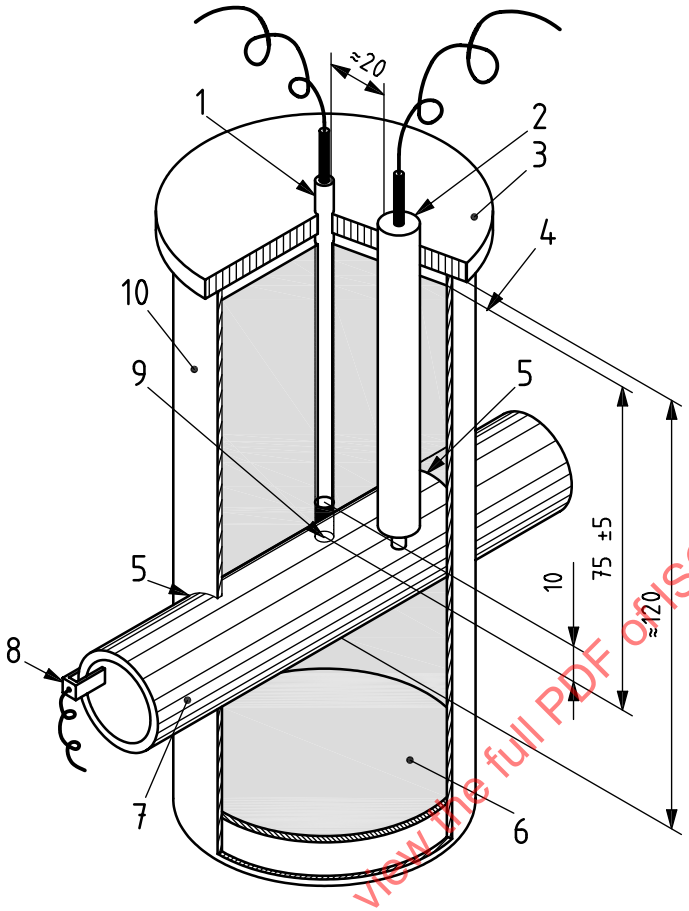


Key

1 working electrode
2 electrode (anode)
3 electrode (reference)
4 reference electrode
5 plastic cover
6 plastic pipe, minimum internal ∅ 50 mm
7 electrolyte ⩾ 150 ml
8 coating
9 steel test piece
10 sealing material
11 artificial defect, ∅ 3 mm to 6 mm if coating thickness is less than 1 mm; ∅ 6 mm in other cases
12 sealing material
13 electrode (cathode)
14 platinum electrode, ∅ 0,8 mm to 1,0 mm (anode)
15 potentiostat
16 220 V power supply

Figure F.1 — Electrolytic cell for large-diameter pipe

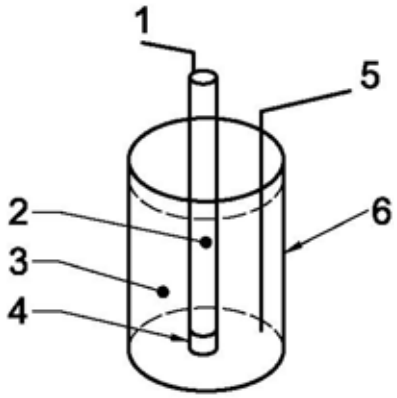
Dimensions in millimetres



Key

1 platinum electrode, ∅ 0,8 mm to 1,0 mm (anode)
2 reference electrode
3 plastic cover
4 electrolyte level
5 sealing material
6 electrolyte
7 coated pipe
8 working electrode (cathode)
9 artificial defect, ∅ 3 mm to 6 mm if coating thickness is less than 1 mm; ∅ 6 mm in other cases
10 plastic pipe, minimum internal ∅ 50 mm

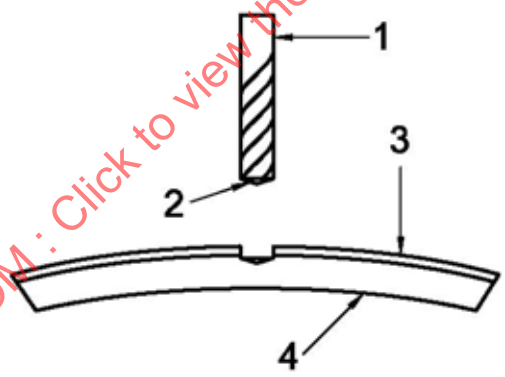
Figure F.2 — Electrolytic cell for small-diameter pipe — Example 1



Key

1 to negative lead (–)
2 holiday
3 electrolyte
4 end cap
5 to positive lead (+)
6 beaker

Figure F.3 — Electrolytic cell for small-diameter pipe — Example 2



Key

1 fluted and mill face mill ∅ 3 mm to 6 mm if coating thickness is less than 1 mm; ∅ 6 mm in other cases
2 conic end
3 coating
4 steel

Figure F.4 — Drilling of artificial defect

Annex G
(normative)

Impact test

G.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.

G.2 Equipment

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 ± 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.

Other guides may be used by agreement.

G.3 Procedure

The test shall be carried out at a temperature of 20 °C ± 5 °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 B) 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.