
**Petroleum, petrochemical and natural
gas industries — External corrosion
protection of risers by coatings and
linings —**

**Part 2:
Maintenance and field repair coatings
for riser pipes**

*Industries du pétrole, de la pétrochimie et du gaz naturel —
Protection de la corrosion externe des tubes de production par
revêtements et doublures —*

Partie 2: Entretien et réparation in situ des tubes de production



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Foreword

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

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

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

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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A list of all parts in the ISO 18797 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document has been developed in response to worldwide demand for minimum specifications for field applied maintenance and repair coatings for riser pipes. ISO 18797-1 specifies the shop applied coatings for risers. Coated offshore risers are intermittently exposed to varying conditions. These include – but are not limited to – sunlight, rain, snow, hail, water spray, salt spray, high humidity, fluctuating ambient temperatures (varying from sub-zero to high temperature), water currents, and impacts from waves, drifting debris and marine growth. Exposure to such conditions can cause severe coating deterioration in time, resulting in ineffective corrosion prevention of the steel riser pipe.

Users of this document are advised that further or differing requirements can be utilized for individual applications. This document can also be used for the maintenance and repair of coatings on other types of structures in the offshore splash zone, such as jetty piles and platform legs. This document does not limit the contractor or the manufacturer from proposing, or from accepting, alternative engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is proposed, the specification issuer is expected to identify any deviations from this document and provide details.

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Petroleum, petrochemical and natural gas industries — External corrosion protection of risers by coatings and linings —

Part 2: Maintenance and field repair coatings for riser pipes

1 Scope

This document specifies the selection criteria and minimum requirements for protective coating systems for maintenance and field repair of risers exposed to conditions in the splash zone. It is applicable for maintenance requirements and field repairs of riser coatings.

This document does not apply to the selection of techniques and materials used to restore integrity of the risers to be coated, nor does it apply to the selection of additional mechanical protective materials that are not part of the coating systems described in this document.

New construction shop applied riser coatings are covered in ISO 18797-1. Compatible maintenance and repair coating systems specified in ISO 18797-1 are covered in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 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 48-2, *Rubber, vulcanized or thermoplastic — Determination of hardness — Part 2: Hardness between 10 IRHD and 100 IRHD*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

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 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

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

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

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

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

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

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

ISO 3233-1, *Paints and varnishes — Determination of percentage volume of non-volatile matter — Part 1: Method using a coated test panel to determine non-volatile matter and to determine dry-film density by the Archimedes' principle*

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

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, *Paints and varnishes — Pull-off test for adhesion*

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 4628-6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 6: Assessment of degree of chalking by tape method*

ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 6502-2, *Rubber — Measurement of vulcanization characteristics using curemeters — Part 2: Oscillating disc curemeter*

ISO 6964, *Polyolefin pipes and fittings — Determination of carbon black content by calcination and pyrolysis — Test method*

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

ISO 8501-4, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 4: Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting*

ISO 8502-3, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

ISO 8502-4, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 4: Guidance on the estimation of the probability of condensation prior to paint application*

- 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 water soluble contaminants for analysis (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 the conductometric determination of water-soluble salts*
- 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 8503-5, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 5: Replica tape method for the determination of the surface profile*
- ISO 10474, *Steel and steel products — Inspection documents*
- ISO 11357-1, *Plastics — Differential scanning calorimetry (DSC) — Part 1: General principles*
- ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and step height*
- ISO 11357-3, *Plastics — Differential scanning calorimetry (DSC) — Part 3: Determination of temperature and enthalpy of melting and crystallization*
- ISO 12944-9:2018, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures*
- ISO 16474-3, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*
- ISO 18797-1, *Petroleum, petrochemical and natural gas industries — External corrosion protection of risers by coatings and linings — Part 1: Elastomeric coating systems-polychloroprene or EPDM*
- ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*
- ISO 21809-3:2016, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 3: Field joint coatings*
- ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*
- ISO 80000-1:2009, *Quantities and units — Part 1: General*
- ASTM D149, *Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies*
- ASTM D991, *Standard Test Method for Rubber Property — Volume Resistivity Of Electrically Conductive and Antistatic Products*
- ASTM D1141, *Standard Practice for the Preparation of Substitute Ocean Water*
- ASTM D5894, *Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)*
- ASTM F22, *Standard Test Method for Hydrophobic Surface Films by the Water-Break Test*
- NACE SP0274, *High-Voltage Electrical Inspection of Pipeline Coatings*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 application procedure specification

APS

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

3.2 applicator

contractor (3.6) or subcontractor having the technical capability, knowledge, equipment and qualified personnel that is approved by the *client* (3.4) for the coating process

3.3 atmospheric zone

external *surface* (3.26) of a *riser* (3.19) that extends upward from the *splash zone* (3.22) up to the top decks of the platform which are exposed to sun, wind, sprays and rains

3.4 client

organization for which professional services are rendered or person that receives a product

3.5 complete coating

installed coating ready for commissioning comprising all individual parts of the coating material

3.6 contractor

organization that agrees to furnish materials and/or perform specific services to the *client* (3.4)

3.7 dry film thickness

DFT

thickness of a coating remaining over the peaks of a rough *surface* (3.26) when the coating has hardened

[SOURCE: ISO 19840:2012, 3.1]

3.8 failure mechanism

process that leads to failure

Note 1 to entry: ISO 14224:2016, B.2.2 and Table B.2, define failure causes for all equipment classes.

3.9 failure mode

manner in which failure occurs

Note 1 to entry: ISO 14224:2016, B.2.6, contains tables with relevant failure modes defining failure modes to be used for each equipment class.

3.10 holiday

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

3.11 inspection and testing plan ITP

document providing an overview of the sequence of inspections and tests, including standard references, recommended apparatuses (tools) and testing procedures

3.12 maintenance and repair of a coating

activities dedicated to retaining or restoring the integrity of the existing coating in order to reach a level of protection against corrosion that enables a metallic structure to continue in service operation safely and economically for a determinate period

Note 1 to entry: Maintenance of a coating can refer to the activities to restore either the damages that are localized on small areas and do not require the complete removal of existing coating, or damage over larger areas that require the complete removal of existing coating and installation of field repair coating.

Note 2 to entry: For the purposes of this document, all types of coating used for maintenance and repair of riser coatings are designated as "repair coating".

Note 3 to entry: In ISO 14224:2016, 3.49, "maintenance" is defined as a combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required.

Note 4 to entry: In ISO 14224:2016, 3.8, "corrective maintenance" is defined as maintenance carried out after fault detection to effect restoration.

Note 5 to entry: "Repair" is a type of maintenance activity as defined in ISO 14224:2016, Table B.5.

3.13 manufacturer

organization responsible for the manufacture of coating material(s)

3.14 nominal dry film thickness NDFT

dry film thickness (3.7) specified for each coat or for the whole paint system to achieve the required durability

[SOURCE: ISO 19840:2012, 3.6]

3.15 nominal strain at break elongation at break

nominal strain at the last recorded data point before the stress is reduced to less than or equal to 10 % of the strength if the break occurs after yielding

Note 1 to entry: Nominal strain is the representation of strain calculated from grip displacement and the gripping distance.

[SOURCE: ISO 527-1:2019, 3.8 and 3.8.1]

3.16 nominal thickness

dimension as specified by the *manufacturer* (3.13)

Note 1 to entry: The nominal thickness of the complete coating is the calculated sum of the nominal thicknesses of all the layers of the coating before application.

3.17

pre-production trial

PPT

application of coating and subsequent inspection and testing of its properties, to confirm that the *application procedure specification* (3.1) contains all necessary instructions to install the coatings in conformity with specific minimum requirements, carried out at the job site immediately prior to production

3.18

procedure qualification trial

PQT

application of coating and subsequent inspection and testing of its properties, to confirm that the *application procedure specification* (3.1) contains all necessary instructions to install the coatings in conformity with minimum requirements, carried out at the premises of the *contractor* (3.6) or another agreed location

3.19

riser

section of pipeline carrying crude oil or gas between the ocean floor and the upper decks of the platform on offshore structures

Note 1 to entry: In ISO 14224:2016, "riser" is a specific equipment class as per ISO 14224:2016, Table A.4 (level 6) and "coating" is a "maintainable item" for risers, as per ISO 14224:2016, Table A.93.

3.20

self-healing

ability of a coating to restore its original film thickness (leaving no *holidays* (3.10) as a result), after a 6 mm diameter defect is made down to bare metal

3.21

shift

time period when a crew of workers is at work

3.22

splash zone

external *surface* (3.26) of a *riser* (3.19) area above and below the mean water level that is periodically wet and dry due to the influence of the astronomical tides, winds and waves

Note 1 to entry: The limits are as defined by the contract specifications.

3.23

strain at break

strain at the last recorded data point before the stress is reduced to less than or equal to 10 % of the strength if the break occurs prior to yielding

[SOURCE: ISO 527-1:2019, 3.7.2, modified — Note 2 to entry has been deleted.]

3.24

stress at break

stress at which the specimen breaks

Note 1 to entry: Expressed in megapascals (MPa).

[SOURCE: ISO 527-1:2019, 3.6.4, modified — Note 2 to entry has been deleted.]

3.25

submerged zone

external *surface* (3.26) of a *riser* (3.19) below the water level

3.26

surface

interface between *substrate* (3.28) and environment where coating is applied

3.27**surface preparation**

method of preparing a *surface* (3.26) for coating application

Note 1 to entry: ISO 12944-4:2017, Clause 6, contains a comprehensive overview of suitable methods for surface preparation.

3.28**substrate**

material from which the *riser* (3.19) is made

3.29**technical assessment****TA**

application of coating and subsequent inspection and testing of its properties to confirm that the coatings are meeting the minimum requirements

Note 1 to entry: Technical assessment is usually carried out under controlled laboratory conditions.

3.30**weld cap**

outermost *surface* (3.26) of the weld

4 Symbols and abbreviated terms**4.1 Symbols**

T_{\max}	maximum service temperature of coating
ε_b	strain at break
ε_{tb}	nominal strain at break
σ_b	stress at break

4.2 Abbreviated terms

HDPE	high-density polyethylene
HSE	health, safety and environment
NACE	NACE International—The Corrosion Society (formerly: National Association of Corrosion Engineers). NACE has merged with SSPC to form the Association for Materials Protection and Performance AMPP
SDS	safety data sheet
SSPC	the Society for Protective Coatings (formerly: the Steel Structures Painting Council)

5 Coating types

The coating types covered by this document are listed in [Table 1](#). [Clauses 6](#) to [9](#) provide requirements that apply to all coating types. [Clauses 10](#) to [13](#) provide coating-specific requirements.

Table 1 — Coating types

Type of coating	Clause	Code	Substrate
Non-crystalline low-viscosity polyolefin-based coating with polymeric tape outer wrap, applied under dry conditions	10	10A	Dry
Non-crystalline low-viscosity polyolefin-based coating with outer wrap such as polymeric tape or moisture curing composite wrap material, applied under wet or immersed conditions		10B	Wet and immersed
Petrolatum tape wrap systems	11	11A	Dry, wet and immersed
Wax-based tape wrap systems		11B	Dry, wet and immersed
Polychloroprene-based elastomeric coating	12	12	Dry
Liquid-applied epoxy coatings	13	13	Dry, wet and immersed

6 General requirements

6.1 Client's requirements

6.1.1 Approval of repair coating and repair method

The client shall be responsible for approving and possibly making the appropriate selection of the repair coating, including application and surface preparation methods, in accordance with the expected working, environmental and service conditions.

The repair coating utilized shall be compatible with the shop applied coating system mentioned in ISO 18797-1.

6.1.2 Specification of purchase order mandatory information

The purchase order shall include the following information:

- a) designation of this document, i.e. ISO 18797-2:2021;
- b) type and number of risers to be coated;
- c) details of each individual (group of) riser(s) including:
 - minimum and maximum operating and design temperature;
 - length of riser zone(s) to be coated;
 - material grade of riser;
 - outer diameter and wall thickness of riser;
 - surface condition of riser;
 - confirmation of conformity with minimum requirements regarding structural integrity of riser;
 - technical specifications of existing coating system, including thickness and permissible minimum overlap of repair coating onto existing coating system;
 - inspection and test reports regarding condition of the existing coating.
- d) type(s) of allowed coating system(s) to be used for each individual riser zone in accordance with [Table 1](#);

- e) minimum requirements per type of coating system as listed in this document and supplemental requirements, if applicable;
- f) job site environmental conditions, including information about air and water temperature (range) and relative humidity (range).

6.1.3 Specification of purchase order additional information

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

- a) coating material qualification trials and organizations to be involved;
- b) (non-)permissible coating repairs;
- c) installation of additional coatings, mechanical protection materials or infill (specification needed);
- d) requirements for traceability and marking;
- e) requirements for documentation and schedule of supply of documentation;
- f) qualification of the applicator's personnel who apply and/or inspect the coating;
- g) availability of TA;
- h) PQT and organizations to be involved;
- i) PPT and organizations to be involved;
- j) time constraints for application and number and dimensions of working stations, if relevant;
- k) constraints regarding execution of works, for example in hazardous areas (explosion hazards) and status of the riser (operational or shut down) ;
- l) constraints regarding the use of certain surface preparation techniques and coating application techniques;
- m) any qualification process and application procedure that is waived by the client.

6.2 Contractor's requirements

6.2.1 Documented information

The contractor shall provide the client with the following documented information for each coating material from the manufacturer:

- a) PDS;
- b) SDS;
- c) application instructions;
- d) batch certificates;
- e) packaging, transport and storage requirements of coating materials;
- f) range of application conditions, including minimum and maximum application temperatures (for materials and substrate) and relative humidity.

6.2.2 Marking of coating materials

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

- a) manufacturer name;
- b) name and complete identification of material, including plant of origin;
- c) reference to applicable coating-material standards, if any;
- d) production batch number;
- e) mass or size;
- f) date of production;
- g) shelf life or expiry date.

6.3 Rounding

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

6.4 Conformity to requirements

Systems for quality and environmental management, and the competence of testing and calibration laboratories may be applied to assist conformity with the requirements of this document. The following documents can be used for these purposes:

- ISO 29001 gives sector-specific guidance on quality management systems.
- ISO 14001 gives requirements with guidance for the use of environmental management systems.
- ISO/IEC 17025 gives general requirements for the competence of testing and calibration laboratories.

The applicator shall be responsible for conforming with all applicable requirements for the application of this document. The client shall be allowed to make any investigation necessary to ensure conformity by the applicator and to reject any material and/or coating that does not conform.

6.5 Criteria for the condition assessment of an existing coating

6.5.1 General – Evaluation of coating condition

For the determination of the coating condition the following overall work programme should be considered:

- a) determine the condition of the existing coating by external and/or internal surveys;
- b) analyse the survey data and select locations (if foreseen) for direct assessment of coating and any metal loss;
- c) analyse inspection data to determine a repair program and decide which riser sections require coating repair and/or cathodic protection improvements, and which sections can remain as they are;
- d) select suitable repair coating(s) for repair of existing coating;
- e) design cathodic protection system improvement;

- f) develop a repair strategy that prioritizes the remediation works required and schedules the repair program, in which the program can extend over several years to provide an acceptable combination of operational safety and long-term requirements;

NOTE An example of a priority matrix for coating assessment activities can be found in ISO 21809-11:2019.

6.5.2 Applicable inspection techniques

Inspection techniques that can be used to assess the condition of an existing coating include:

- a) visual inspection to provide information about:
 - the coating condition such as presence of visible damages, such as cracks, wrinkles and blisters, and presence of detrimental microbial activity and biological growth;
 - the riser condition such as degree of corrosion, pit depths and remaining wall thickness.
- b) internal inspection by in line inspection techniques to provide information about wall thickness of the riser;
- c) through-coating inspection by non-destructive techniques, such as pulsed eddy current to provide information about wall thickness of the riser and degree of corrosion under coating;
- d) cathodic protection potential surveys as described in ISO 15589-1 to provide information about the effectiveness of cathodic protection and to localize coating defects;
- e) direct assessment of existing coating thickness by suitable techniques as for example described in ISO 19840;
- f) direct assessment of adhesion of existing coating to riser surface.

7 Qualification processes and application procedures

7.1 General

Qualification of coating system(s) for maintenance and repair of riser coatings shall follow the consecutive steps as indicated in [Table 2](#).

Table 2 — Qualification processes and application procedures

Step	Description	Responsible
1	Identification for need of coating repair, see 6.4	Client
2	Approved project coating specification, see 6.1 ^a	Client
3	TA demonstrating conformity with coating specification as tested under laboratory conditions ^{b c d}	Manufacturer
4	Coating-specific APS and coating specific ITP ^{d e}	Applicator
5	PQT using APS and ITP ^{a d}	Applicator
6	PPT using APS and ITP ^{d f}	Applicator
7	Production – Coating installation at job site using APS and ITP ^{d e}	Applicator
a	Input from manufacturer and contractor is recommended.	
b	Client can require execution of tests by independent third-party laboratory.	
c	Client can require witnessing of tests at manufacturer’s laboratory by independent third party or client or both.	
d	Approval from client is required.	
e	Input from manufacturer is required.	
f	Witnessing by client is required. Client can require witnessing by manufacturer or third-party inspector.	

7.2 APS and ITP

7.2.1 General

The APS and ITP shall be prepared by the applicator based upon documentation provided by the manufacturer, such as PDS, instructions for use, and SDS. The APS and ITP shall be approved by the client. Once approved, the APS or ITP shall not be changed without prior written authorization of the client.

The APS and ITP shall be coating specific.

All coating work shall be carried out according to the APS using the dedicated ITP.

7.2.2 APS

The APS shall address at least the following items, as applicable:

- a) coating material identification;
- b) precautionary measures to prevent health, safety and environmental issues at all stages of coating works;
- c) tools, consumables and equipment required to apply the coating system;
- d) equipment set-up and evidence of calibration;
- e) cleaning agents to be used to clean the steel and adjacent existing coating prior to surface preparation;
- f) method used for the surface preparation of steel, including inspection of the prepared surface before application of coating, such as:
 - visual assessment of surface cleanliness in accordance with ISO 8501-1 or ISO 8501-4, or as otherwise agreed between the manufacturer, the applicator, and the client;
 - if applicable, tests for the assessment of surface cleanliness in accordance with ISO 8502-3, ISO 8502-4, ISO 8502-6, and ISO 8502-9;
 - inspection of surface profile in accordance with ISO 8503-2 or ISO 8503-5.
- g) method used for the surface preparation of existing coatings (e.g. cutback, bevel, repairs and precaution measures, when necessary), including inspection of the prepared surface before application of coating;
- h) compatibility with existing coating;
- i) preheating methods for existing coating and repair coating material;
- j) minimum and maximum substrate, product and ambient temperature for application and cure;
- k) ambient conditions considering dew point temperature at the surface to be coated;
- l) coating mixing, pot life and thinning procedures;
- m) coating thickness range;
- n) coating application method;
- o) coating overlap on existing coating;
- p) in the case of wrap-around materials such as tapes, minimum overlap between successive layers;
- q) coating curing or cooling schedule and conditions;

- r) overcoat time and repair method;
- s) time to inspection;
- t) time to bringing back in service;
- u) handling and storage requirements for coating materials, including the following, as applicable:
 - temperature limitations (e.g. freezing, excessive heat);
 - humidity;
 - protection from the elements (e.g. snow, rain, sunlight);
 - protection from contaminants (e.g. dust, water, chemicals);
 - expiration date;
 - protection from physical damage.

7.2.3 ITP

The ITP shall reflect all the process items, the items to be inspected and tested (and frequency thereof) and acceptance criteria as described by the APS. The ITP shall address at least the following subject, as applicable:

- a) description of the works;
- b) identification of coated item and substrate;
- c) selected coating system;
- d) inspection points for each of the activities;
- e) applicable reference documents;
- f) applicable check procedures and methods as identified in [Clauses 9](#) to [13](#);
- g) acceptance criteria as identified in [Clauses 10](#) to [13](#);
- h) frequency of the checks as identified in [Clauses 9](#) to [13](#);
- i) remedial actions;
- j) persons required to be present at the inspections;
- k) reporting.

7.3 Technical assessment of coating conformity

The properties of each individual allowed repair coating shall be tested by the manufacturer in accordance with [Clauses 9](#) to [13](#), and, if applicable, the supplemental requirements as agreed between manufacturer and client. Conformity with the minimum requirements shall be evaluated. A TA report shall be submitted to the client.

7.4 Procedure qualification trial

The APS shall be validated by a PQT performed by the applicator, unless otherwise agreed between client and contractor. Test methods and frequencies suggested for PQT are identified in [Clauses 9](#) to [13](#). Acceptance criteria are given in [Clauses 10](#) to [13](#).

The main purpose of the PQT is to demonstrate that the provided surface preparation and application procedure, equipment and personnel (or the level of skills required for the personnel that will be

undertaking the coating application) are able to apply the coating in accordance with the client's requirements to achieve the stated performance of the coating. It is not intended to validate the selection of the coating.

If performed by the same contractor, the evaluation of the method intended to be used for the removal of the deteriorated or damaged coating shall be part of the PQT in order to verify that the selected method does not cause damage to the metallic substrate. HSE issues for coating removal should be addressed in the same PQT.

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

The PQT can be carried out independently for any project. In this case, similar pipes having the same diameter, thickness and existing coating as agreed upon between manufacturer, applicator and client shall be used.

Unless otherwise agreed, the conditions during PQT shall reflect all the conditions (e.g. low temperature, wet surface and immersion) anticipated during the actual project.

If heating of the area to be coated is specified in the APS, it shall be demonstrated that there is at least no detrimental effect, such as blistering or disbondment of the existing coating to be overlapped.

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

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

The tests shall be repeated whenever a modification to equipment to material composition or to any other production process affecting the specified characteristics. This includes a change in the line crew.

The applicator shall submit a complete report of the qualification test results to the client for approval before the start of the PPT.

7.5 Pre-production trial

A PPT shall be performed by the applicator on site before starting production, unless otherwise agreed between client and contractor. It shall at least include the following:

- a) surface condition and adhesion of the existing coating on steel;
- b) repair coating materials;
- c) surface preparation and application procedure;
- d) equipment being used for surface preparation and coating application;
- e) application of the coating system;
- f) qualification of the coating applicators and inspectors who will undertake the work;
- g) properties of the applied repair coating.

The PPT shall be in accordance with this document and the results of any previous PQT.

Test methods and frequencies for PPT are specified in [Clauses 9](#) to [13](#). Acceptance criteria are given in [Clauses 10](#) to [13](#).

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

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

7.6 Production, testing and inspection

7.6.1 General

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

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

Test methods and frequencies are identified in [Clauses 9 to 13](#). Acceptance criteria are given in [Clauses 10 to 13](#).

7.6.2 Inspection documents and traceability

The inspection documents shall be in accordance with ISO 10474. The type of certificate of conformity shall be defined in the purchase order.

NOTE For the purposes of this document, EN 10204 is equivalent to ISO 10474.

Reports should identify each inspected section by a unique identifier. Reports shall document the related material batch number for traceability. Test results shall be linked to the exact locations on which they were performed. Documented information shall be retained on a shift and daily basis. Documented information shall be available for inspection by the client.

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

8 Selection criteria for repair coatings

8.1 General

The selection of suitable repair coatings is, from a technical point of view, the major decision to be made for a riser coating repair project. There are a wide variety of coating systems available, and a wide variety of test methods are required to evaluate the performance of a coating.

The fundamental requirement of coatings is that they must form a long-lasting effective barrier to prevent corrosion, thereby separating the riser from its environment.

To specify the requirements for repair coatings, the long-term performance and potential failure mechanisms under the expected riser application and operating conditions shall be taken into account. The use of accelerated ageing tests is helpful (but not always definitive) in predicting the long-term performance of coatings. Supplemental information from validated field performance of the selected coatings can support the results of long-term performance laboratory tests.

NOTE 1 ISO 14224:2016, Tables B.2 and B.10, provide potential failure mechanisms and potential failure modes, respectively.

Coating repair implies a coating application on site on an existing riser. External conditions at the job site that can impact the success of the coating application should be considered.

Selection of repair coatings includes more criteria than normally apply for a new riser. A wide variety of test methods are used to evaluate the performance of coatings, as described in this document.

The following criteria should be considered when selecting repair coatings:

- a) the repair coating shall have long-term barrier properties to separate the riser from the environment to prevent water and oxygen ingress, and to resist mechanical forces such as impact, indentation and shear;

NOTE 2 Parameters influencing initial adhesion include surface cleanliness and surface profile prior to coating application.

- b) the repair coating shall be capable of being applied under the prevailing environmental conditions;
- c) the repair coating shall allow repairs;
- d) the repair coating shall have the required and durable adhesion to the substrate without disbondment and loss of adhesion from steel surface and, if applicable, from existing coating;
- e) the coating and application techniques shall be compatible with existing coatings, if applicable;
- f) the repair coating shall be resistant to cathodic disbondment, when applicable;
- g) the repair coating shall have appropriate and required long-term performance based on chemical and physical characteristics.

The criteria listed in [8.2](#) and [8.3](#) shall also be taken into account when selecting repair coatings.

8.2 Application constraints

8.2.1 Wet substrates

Many types of coating require a dry surface and do not allow water to be present on the substrate. Condensation can appear on the substrate when the substrate temperature is below the dew point of ambient air, although it cannot always be “visible moisture”.

Dew point and probability of condensation should be checked in accordance with a recognized standard (e.g. ISO 8502-4), and as agreed between manufacturer and contractor.

Presence of continuous condensation can be reduced by using special drying systems. Alternatively, reducing (or stopping) the flow of medium through the riser can mitigate this condition. Depending on the conditions and dew point, drying systems might not be able to successfully prevent condensation on a riser with active flow.

Water can also originate from different sources such as rain or submersion. Water or moisture can be mitigated by waiting for the surface to dry or by creating a water-tight habitat (when necessary). Raising the substrate temperature is another option, but this can often not be accomplished on live risers.

If the riser cannot be isolated from water, the coating shall be applicable in wet conditions. Compatibility with wet substrates shall be demonstrated in a TA by manufacturer. Specific application instructions shall be specified by manufacturer. Water present on substrates can contain varying levels of dissolved salts. In the TA, the type and concentration of dissolved salt(s) shall be agreed between manufacturer and client.

8.2.2 Contamination by soluble salts

Soluble salts present on substrates mainly originate from salts containing chloride. Soluble salt contamination is therefore often designated and measured as chloride contamination. They can have a detrimental effect on the long-term coating performance and should be limited on the substrate and adjacent coating to a quantity that does not affect the performance of the new coating. Compatibility with substrates having determined levels of salt contamination shall be demonstrated in a TA by the manufacturer. Specific application instructions shall be specified by the manufacturer. The PDS of each individual type of coating should specify maximum allowable concentration of soluble salts or chloride.

Contamination by soluble salts should be tested in accordance with a recognized standard (e.g. ISO 8502-5, ISO 8502-6 or ISO 8502-9), and as agreed between manufacturer and contractor.

Contamination by soluble salts can be mitigated by washing the substrate according to instructions provided by the APS. Habitat conditions should be considered to prevent recurrence.

8.2.3 Dust contamination

Dust is a type of contamination that can originate from different sources. These include, but are not limited to, soil, abrasives used for surface cleaning, removed corrosion products and old coating. They all have in common that they are rather loosely attached to the substrate. Dust can have a number of detrimental effects on the coating performance, e.g. adhesion strength and occurrence of coating voids during application. The PDS of each individual type of coating can specify maximum allowable dust concentration.

Dust contamination should be tested in accordance with a recognized standard (e.g. ISO 8502-3), and as agreed between manufacturer and contractor.

This contamination can be mitigated by cleaning the substrate according to instructions provided by the manufacturer. Habitat conditions should be considered to prevent recurrence.

8.2.4 Contamination by oil, grease and other petroleum-like products

Oil and grease predominantly consist of hydrocarbons. They all have in common that they are relatively non-polar compounds being insoluble in water, and that they stick very well to the substrate. They form a film on the substrate that impairs proper adhesion with many types of coating, or – when adhesion can be realized – impairs long-term proper performance of the coating. The PDS of each individual type of coating can specify maximum allowable concentration of oil, grease and other petroleum-like products.

Substrate contamination by oil, grease and other petroleum-like products should be tested in accordance with a recognized standard (e.g. ASTM F22), and as agreed between manufacturer and contractor.

This contamination can be mitigated either by washing the substrate with water jetting techniques using detergents or by solvent cleaning with an agreed solvent, or both, according to instructions provided by the APS. Habitat conditions should be considered to prevent recurrence. Precautionary measures should be considered to prevent HSE issues.

8.2.5 Compatibility with existing coating

If the selected coating overlaps the existing coating, the repair coating shall be compatible with the existing coating and shall show proper adhesion to prevent air or water ingress.

Compatibility between repair coatings and existing coatings shall be demonstrated by assessing at least adhesion before and after accelerated ageing procedures at room temperature and at maximum service temperature, as described in this document.

Attention should be given to existing coatings with irregular surface profile.

8.2.6 Feasibility of surface cleaning

Suitable surface preparation techniques shall be used to ensure the best possible bonds to steel and existing coatings. Available techniques include, but are not limited to, high-pressure water jetting, abrasive blast cleaning, wire brushing, grinding, needle guns and bristle blasting.

The level of possible surface preparation can be impacted by local regulations, environmental concerns and skills of the work forces.

If it is impossible to remove all traces of the former coating (e.g. primer or paint that cannot be removed by suitable techniques), the selected repair coating shall be compatible with any existing coating.

When surfaces of corroded riser sections or components are recoated, these surfaces can be polluted (e.g. by bacteria), which can have detrimental effects on long-term performance of the repair coating and corrosion prevention.

8.2.7 Space and riser access constraints

The space required to perform the surface preparation and coating application should be taken into account when selecting surface preparation method and coating type. The space around the riser shall be sufficient and facilities such as scaffolds and platforms shall be strong enough to ensure a safe and proper work area. Engines and heavy equipment requiring access to the riser to be repaired can also be a concern.

8.2.8 Time constraints

The coating should be compatible with time constraints as determined by operational factors and environmental factors such as allowed down-time of facility operations, tidal changes, and weather variations during and immediately after installation. Some coatings need time to completely adhere or cure and these factors can have detrimental effects on the performance of the installed coatings.

8.2.9 Temperatures and relative humidity

During the coating application (installation and curing, if needed), temperatures shall be within limits as stated by manufacturer:

- a) Substrate temperature, during application, shall not exceed the minimum or maximum temperature specified in the PDS. This is of specific interest with live risers. Substrate temperature should be considered in the coating material selection. High or low temperature can be mitigated by creating a habitat around the riser.
- b) Product temperature during application and curing shall not exceed the minimum or maximum temperature specified in the PDS. To mitigate this risk (e.g. in case of extreme weather conditions) conditioning of the product shall be organized before application, e.g. by storing the product under temperature-controlled conditions.
- c) Ambient temperature can be of interest for the coating application process and shall not exceed the minimum or maximum temperature as specified in the PDS.
- d) Relative humidity can be of interest for the coating application process and shall not exceed the minimum or maximum humidity as specified in the PDS. In cases when the relative humidity exceeds permissible limits, habitats, tents or other containments should be set to allow the air treatment inside.

8.2.10 Coating continuity

The APS should contain consecutive and feasible application steps that result in a coating continuity providing good long-term barrier properties to separate the riser from the environment. A check for coating discontinuities should be carried out as specified in the APS. Any discontinuity should be repaired prior to commissioning.

8.3 Operational conditions

8.3.1 Resistance to ageing, weathering and water

Coatings can deteriorate in time from exposure to various influences such as heat, sunlight and water. Depending on the location of the riser, the composition of water can vary, e.g. fresh water, brackish water or sea water. Coating can prematurely deteriorate and exhibit changes in visual appearance, reduction of adhesion properties and tensile strength, and defects such as pinholes, voids or blisters, which can result in failure.

Deterioration from heat, sunlight and water should be tested to get an impression of the durability of the coating. Such tests will also aid in determining coating inspection and maintenance intervals.

8.3.2 Resistance to mechanical loads

Static and dynamic loads can damage or even puncture coatings, potentially exposing the bare substrate to the environment. Resistance to mechanical loads, such as impact and indentation, should therefore be tested.

8.3.3 Interaction with cathodic protection

Many – if not all – steel structures in the splash zone are equipped with cathodic protection, which serves as a backup to protect steel from corrosion in case of coating damages.

For a proper design of the cathodic protection system, the coating should have good electrical insulation properties under the prevailing conditions. Furthermore, the electrochemical reactions taking place at bare steel with cathodic protection can also cause disbondment of the coating. Specific electrical insulation resistance and resistance to cathodic disbondment should therefore be tested.

9 Test programs

9.1 Substrate conditions used for tests

If tests need to be conducted on existing coating, it is often not possible to obtain pipes with same coating conditions as expected at riser location. They have often been in service for a long time and possibly suffered from deterioration by exposure to conditions as specified in [Annex A](#). The following substrates are considered as adequate to be used for testing:

- For laboratory testing in TA and for PQT: pipes with new coating that has the same or a similar composition and construction as existing coating at riser location.
- For PPT: risers with existing coating, representative of all risers in the scope of work.

Preparation of test specimens shall be carried out on substrates that have been prepared according to the APS for the respective systems, e.g. regarding minimum surface cleanliness, dust grade, application temperature, and dwell conditions between application and testing.

9.2 Inspections, tests and frequencies

The inspections and test frequencies for TA, PQT, PPT and production testing, as defined in [7.3](#), [7.4](#), [7.5](#) and [7.6](#), are given in [Table 3](#) and in [Clauses 10](#) to [13](#). The test frequencies are defined as follows, unless specified otherwise:

- TA: number of test specimens prepared under laboratory conditions;
- PQT: number of pipes to be coated by the applicator;
- PPT: number of trial lengths to be coated on-site by the applicator;

— production: frequency of inspections and tests on-site.

For TA, the same test frequencies shall be used as specified for PQT.

Alternative test regimes and frequencies can be used by agreement.

Requirements for PQT and PPT shall be defined in the purchase order.

Some of the requirements for production testing might not be achievable on site, e.g. offshore. The production test program may therefore be adapted to suit the site conditions based on comparative testing during PQT or PPT.

There are no standards available that provide verified test methods and requirements for coatings applied on wet substrates. [Annex B](#) provides guidance on test methods, acceptance criteria, and inspections and test frequencies. Performing these tests is optional and should be agreed between client and manufacturer.

Any test required that is not mentioned in the test programs shall be documented by the manufacturer. This covers long-term tests related to the material itself, such as specific electrical insulation resistance.

Table 3 — Coating application prerequisites — Frequency of testing and inspection

Coating types	Clause	Property	Method	Test frequency ^a		
				PQT	PPT	Production ^b
10, 12	8.2.1	Substrate dry or wet	Visual	Immediately before application		
All	8.2.9	Substrate temperature	Temp. probe	Hourly	Hourly	Hourly
10A, 12	8.2.1	Dew point (dry substrates)	ISO 8502-4	Hourly	Hourly	Hourly
All	8.2.6	Substrate cleanliness	ISO 8501-1 ^c ISO 8501-4 ^c	100 %	100 %	100 %
12	8.2.2	Substrate contamination: soluble salts (dry substrates)	ISO 8502-6 ISO 8502-9	By agreement	By agreement	By agreement
All	8.2.3	Substrate contamination: dust level (dry substrates)	ISO 8502-3	By agreement	By agreement	By agreement
All	8.2.4	Substrate contamination: oil, grease and petroleum-like products	ASTM F22	By agreement	By agreement	By agreement
All	8.2.9	Coating materials temperature	Temp. probe	100 %	100 %	100 %
All	8.2.9	Ambient temperature	Temp. probe	Hourly	Hourly	Hourly

^a Test frequencies indicated as "by agreement" shall be in accordance with ITP.

^b Shall be agreed prior to production, e.g. once per batch, 1 in 20 repairs.

^c Alternate approximately equivalent standards and guides available from NACE and SSPC may be used.

9.3 Thickness testing

Thickness testing is included in the various test programs as a quality control parameter that gives an impression whether the performance requirements can be met. Performing thickness tests shall be agreed between client and manufacturer.

9.4 Retest

The test shall be repeated if one of the required tests fails. No further failure is allowed.

10 Non-crystalline low-viscosity polyolefin-based coatings

10.1 Coating identification

Non-crystalline low-viscosity polyolefin-based coatings (types 10A and 10B) shall be identified in the APS in accordance with [Table 4](#) and shall meet the requirements of [Table 6](#).

Datasheets for the individual materials shall be in accordance with [Table 5](#).

Application instructions shall be provided by the manufacturer in accordance with [7.2](#) and shall be included in the APS.

10.2 Description of the coatings

Non-crystalline low-viscosity polyolefin-based coatings are divided in two separate classes, depending on the application condition of the substrates:

- a) Type 10A: description of the complete coating for dry substrates
 - a non-crystalline (fully amorphous) low-viscosity (non-crosslinked) non-reactive polyolefin (e.g. polyisobutylene, other polybutenes or atactic polypropylene)-based compound layer, with a direct bond to the dry substrate, which can be either reinforced by fabrics or covered by a backing film, or both;
 - one or more types of outer wrap material in the form of a polymeric outer wrap tape or sheet, or any other agreed material.
- b) Type 10B: description of the complete coating for wet or immersed substrates
 - a non-crystalline (fully amorphous) low-viscosity (non-crosslinked) non-reactive polyolefin (e.g. polyisobutylene, other polybutenes or atactic polypropylene)-based compound layer, with a direct bond to the wet substrate, which can be either reinforced by fabrics or covered by a backing film, or both;
 - one or more types of outer wrap material capable of being applied in wet or immersed conditions, such as polymeric tape or moisture curing composite wrap material, or any other agreed material.

NOTE According to the manufacturer's instructions, application of interleave wrapping materials can be necessary between the individual coating layers. This document does not cover minimum requirements for such interleave layers.

The purposes of the compound are to prevent corrosion of the pipe surface, prevent voids and repair small coating defects. The purposes of the outer wrap are to provide additional radial compression, support self-healing and provide additional mechanical protection for the coating system.

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

- tapes;
- wraparound sheets;
- pre-formed shapes;
- mouldable compounds;
- pourable liquids.

10.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS as specified in [7.2](#). Coating type 10A shall be applied on dry substrates only, while coating type 10B can be applied on both dry and wet substrates.

10.4 Application of coatings

10.4.1 General

Application of coatings shall be carried out in accordance with the manufacturer's instructions and shall be specified in the APS. The following application procedure should be followed:

- a) prepare the surface in accordance with [10.3](#);
- b) apply the non-crystalline low-viscosity polyolefin-based compound by either wrapping or moulding in place, or both, assuring coverage and adhesion on any compatible substrate;
- c) apply the outer wrap with tension to provide radial compression in accordance with the manufacturer's instructions.

10.4.2 Overlap

The minimum overlap between successive layers of compound shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

If applicable, the minimum overlap of the compound on existing coating shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

A double thickness of the compound shall be applied in areas with protruding parts, such as weld caps to ensure sufficient layer thickness after completion of coating installation.

The outer wrap shall cover the non-crystalline low-viscosity polyolefin compound layer.

If applicable, the minimum overlap of the outer wrap onto existing coating shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

10.5 Testing of coatings

10.5.1 General

If required, the tests in [10.5.2](#) to [10.5.15](#), summarized in [Table 6](#), shall be carried out for the TA, PQT, PPT and production testing.

Test and inspection frequencies for TA, PQT, PPT and production testing are included in [Table 3](#) and [Table 7](#).

[Annex B](#) provides the tests, acceptance criteria, and inspections and test frequencies for coatings applied on wet substrates, if required.

Unless otherwise specified, the tests shall be carried out on pipes coated with the complete coating. Samples cut from coated pipe or flat surfaces are not allowed, unless otherwise specified.

Where applicable, the substrate conditions used for tests shall be in accordance with [9.1](#).

10.5.2 Thickness

The thickness requirement applies to all types of coating applied to dry substrate as specified in [10.2](#).

[Annex B](#) provides guidance for the thickness of coating type 10B applied to wet substrate.

The thickness of the compound and the thickness of the complete coating shall be measured in accordance with ISO 21809-3:2016, Annex B, and shall meet the requirements of [Table 6](#) as per manufacturer recommendation to meet the performance requirements.

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

The shape and dimensions of the thickness measurement probe shall be designed to avoid indentation of the coating.

10.5.3 Glass transition temperature and crystallization temperature

The glass transition temperature and crystallization temperature requirement applies to all types of coating specified in [10.2](#).

The glass transition temperature and crystallization temperature of the non-crystalline polyolefin shall be determined by differential thermal analysis of a sample of the material in accordance with ISO 11357-1, ISO 11357-2 and ISO 11357-3, and shall meet the requirements of [Table 6](#).

10.5.4 Holiday detection

The holiday detection requirement applies to coating type 10A only.

In the atmospheric zone, the entire dry surface of the riser coated with repair coating shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm + 5 kV at a maximum of 25 kV, in accordance with ISO 21809-3:2016, Annex C, and shall meet the requirements of [Table 6](#). This test shall be carried out after application of the compound and may be repeated after completion of the coating when required by the client.

Holidays shall be repaired in accordance with the APS.

10.5.5 Drip resistance

The drip resistance requirement applies to all types of coating that contain reinforcement as specified in [10.2](#).

No dripping of the compound shall occur when the compound is tested in accordance with ISO 21809-3:2016, Annex K, with a modified test temperature of $T_{\text{max}} + 20$ °C and a minimum test temperature of 80 °C. Drip resistance shall meet the requirements of [Table 6](#).

10.5.6 Adhesion to pipe surface and existing coating

The adhesion to pipe surface and existing coating requirement applies to all types of coating applied to dry pipe surface and dry existing coating specified in [10.2](#).

[Annex B](#) provides guidance for the adhesion of coating type 10B to wet pipe surface and wet existing coating.

The adhesion test shall be carried out on the complete coating after cooling where heat has been applied.

The adhesion to dry steel and dry existing coating of compound containing reinforcement shall be tested at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, Annex H. The force required for peeling shall be documented.

The peel force, separation mode and substrate coverage shall meet the requirements given in [Table 6](#). A cohesive separation mode is required (the reinforcement is pulled out of the compound) and the coating shall leave a film of compound on ≥ 95 % of the substrate. The method given in ISO 21809-3:2016, H.1, shall be used for PQT. The method given in ISO 21809-3:2016, H.2, can be used for PPT and production testing.

The adhesion to steel and existing coating of compound without reinforcement shall meet the requirements given in [Table 6](#). Adhesion testing shall be carried out at the coated pipe sample by using a utility knife to attempt to lift the coating material from the steel surface. The coating shall leave a film of compound on the substrate.

When applicable, adhesion to existing coating of the outer wrap polymeric tape or composite wrap material shall be measured using the peel strength method given in ISO 21809-3:2016, Annex H, and shall meet the requirements given in [Table 6](#).

10.5.7 Lap shear resistance

The lap shear resistance requirement applies to all types of coating applied to dry substrate as specified in [10.2](#).

The lap shear strength of the compound applied to dry substrate shall be measured at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, J.1, for reinforced compound and ISO 21809-3:2016, J.2, for compound without reinforcement, and shall meet the requirements of [Table 6](#).

To improve accuracy of lap shear strength test results, the test area can be increased to 2 500 mm² by transversely cutting of the coating for an effective shear length of 50 mm (see ISO 21809-3:2016, J.1), and by creating an overlap of 50 mm between the steel plates (see ISO 21809-3:2016, J.2).

A cohesive separation mode is required. The coating shall leave a film of compound on ≥ 95 % of the substrate. There shall be no evidence of adhesive failure.

10.5.8 Specific electrical insulation resistance

The specific electrical insulation resistance requirement applies to all types of coating applied to dry pipe surface as specified in [10.2](#).

[Annex B](#) provides guidance for the specific electrical insulation resistance of coating type 10B applied to wet pipe surface.

The specific electrical insulation resistance shall be measured in accordance with ISO 21809-3:2016, Annex F, and shall meet the requirements of [Table 6](#) as follows:

- for type 10A: on the compound layer;
- for type 10B: on the complete coating.

10.5.9 Impact resistance

The impact resistance requirement applies to all types of coating applied to dry pipe surface as specified in [10.2](#).

The impact resistance shall be measured on the complete coating in accordance with ISO 21809-3:2016, Annex D, and shall meet the requirements of [Table 6](#).

10.5.10 Indentation resistance

The indentation resistance requirement applies to all types of coating applied to dry pipe surface as specified in [10.2](#).

The indentation resistance shall be measured on the complete coating at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, Annex E, and shall meet the requirements of [Table 6](#).

If the coating outer layer consists of a polymeric outer wrap, a test pressure of 1,0 N/mm² shall be used. If the coating outer layer consists of a composite wrap material, a test pressure of 10,0 N/mm² shall be used.

10.5.11 Cathodic disbondment resistance

The cathodic disbondment resistance requirement applies to all types of coating applied to dry pipe surface as specified in [10.2](#).

[Annex B](#) provides guidance for the cathodic disbondment resistance of coating type 10B applied to wet pipe surface.

The cathodic disbondment resistance shall be measured on the complete coating.

The cathodic disbondment test shall run for a period of 28 days at 23 °C and at maximum service temperature (limited to 95 °C maximum) in accordance with ISO 21809-3:2016, Annex G, for small-diameter pipe. The 6 mm hole through the coating shall be obtained by using a 6 mm hollow hammer punch, followed by surface cleaning to bare steel.

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

The cathodic disbondment resistance shall be measured as the radius of disbondment and shall meet the requirements of [Table 6](#). For type 10A, the thickness of the coating in the area of the artificial defect after termination of the test shall be restored to at least its original film thickness (self-healing) as specified in the APS as per [10.5.2](#), and there shall be no holidays as per [10.5.4](#).

10.5.12 Resistance to ageing and weathering

The resistance to ageing and weathering requirement applies to all types of coating specified in [10.2](#).

For outer mechanical protection layers comprised of polyolefin, ISO 6964 shall be used to determine carbon black content.

NOTE For the purposes of this document, ASTM D1603 and ASTM D4218 are equivalent to the test method described in ISO 6964.

For outer mechanical protection layers not comprising polyolefin, an ageing and weathering test shall be carried out in accordance with ISO 4892-2 under the following conditions:

- method A: exposure using daylight filters (artificial weathering);
- relative humidity: (65 ± 5) %;
- total radiant energy: 5 GJ/m².

After this test, specimens shall be tested before and after ageing for ratio of strain at break (ϵ_b) and ratio of stress at break (σ_b) in case extensometers are used in accordance with ISO 527-1.

In case no extensometers are used, specimens shall be tested before and after ageing for ratio of nominal strain at break (ϵ_{tb}) and ratio of stress at break (σ_b).

The test specimens shall be prepared in accordance with one of the types specified in ISO 527-2 or ISO 527-3, respectively.

Ratios shall be calculated as arithmetic mean after ageing divided by arithmetic mean before ageing.

The requirements for resistance to ageing and weathering shall meet the requirements of [Table 6](#).

10.5.13 Peel strength between layers of outer wrap

The peel strength between layers of outer wrap requirement applies to all types of coating specified in [10.2](#).

The peel strength between the outer wrap layers shall be measured at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, Annex L, and shall meet the requirements of [Table 6](#).

10.5.14 Thermal ageing resistance

The thermal ageing resistance requirement applies to all types of coating specified in [10.2](#).

[Annex B](#) provides guidance for the thermal ageing resistance of coating type 10B applied to wet pipe surface and wet existing coating.

A thermal ageing test of the complete system applied to dry pipe surface and dry existing coating shall be carried out in accordance with ISO 21809-3:2016, M.3, for 100 days at $T_{max} + 20\text{ °C}$ as follows:

- for type 10A: on the complete coating applied to dry substrate;
- for type 10B: on the complete coating applied to dry substrate.

After this test, the adhesion of the compound to the pipe surface and the existing coating shall be measured as specified in [10.5.6](#) and shall meet the requirements of [Table 6](#).

The thermal ageing test for the outer wrap polymeric tape or composite outer wrap material shall be carried out in accordance with ISO 21809-3:2016, Annex M, for 100 days at $T_{max} + 20\text{ °C}$ using the method given in:

- a) ISO 21809-3:2016, M.1, for nominal strain at break (see ISO 527-1, ISO 527-2 and ISO 527-3);
- b) ISO 21809-3:2016, M.2, for peel strength between layers;
- c) if applicable, ISO 21809-3:2016, M.3, for peel strength to existing coating.

The thermal ageing resistance shall meet the requirements of [Table 6](#).

10.5.15 Hot-water immersion test

The hot-water immersion test requirement applies to all types of coating specified in [10.2](#).

[Annex B](#) provides guidance for the hot water immersion test of coating type 10B applied to wet pipe surface and wet existing coating.

A hot-water immersion test of the complete coating applied to dry pipe surface and dry existing coating shall be carried out in accordance with ISO 21809-3:2016, Annex I, for 100 days at $T_{max} + 20\text{ °C}$ as follows, limited as specified in ISO 21809-3:2016, Annex I.

After this test, the adhesion of the compound to the pipe surface and the existing coating shall be measured as specified in [10.5.6](#) and shall meet the requirements of [Table 6](#).

A hot-water immersion test of the outer wrap shall be carried out in accordance with ISO 21809-3:2016, Annex I, for 100 days at T_{max} , limited as specified in ISO 21809-3:2016, Annex I. The peel strength between layers of outer wrap shall be measured as specified in [10.5.13](#) and shall meet the requirements of [Table 6](#). When applicable, the adhesion of the outer wrap to the existing coating shall be measured as specified in [10.5.6](#) and shall meet the requirements of [Table 6](#).

Table 4 — Coating identification

Type of coating in accordance with Table 1
Coating manufacturer
Coating trade name
Minimum and maximum service temperature
Types, trade names, number and supplied thicknesses of individual layers
Nominal thickness of complete coating
Compatible existing coatings (state all types of existing coating that have been tested successfully)

Table 5 — Product data sheets of individual materials

Property	Units	Test method
Manufacturer	—	—
Trade name	—	—
Non-crystalline low-viscosity polyolefin compound: – generic type of non-crystalline low-viscosity polyolefin – generic type of reinforcement material, if applicable	— —	— —
Outer wrap material: – generic type of outer wrap material – generic type of polymer	— —	— —
Colour	—	—
Thickness, as supplied	mm	ISO 4593 ^a
Density	g/cm ³	ISO 1183-1
Minimum and maximum service temperature	°C	—
Storage conditions, including temperature range	°C	—
Shelf life at storage conditions	months	—

^a Probes and other equipment parts shall be constructed in such a way that indentation or deformation of soft coatings will not occur during thickness measurement.

Table 6 — Requirements for non-crystalline low-viscosity polyolefin-based coatings

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
Non-crystalline low-viscosity polyolefin compound						
10A 10B	10.5.2	Thickness of coating applied to dry substrate	23 °C	mm	≥ 0,9 × nominal value ^d	ISO 21809-3:2016, Annex B
— 10B	10.5.2	Thickness of coating applied to wet substrate ^d	This test is optional, see Annex B for guidance.			
10A 10B	10.5.3	Glass transition temperature	—	°C	At least 20 °C below minimum application temperature	ISO 11357-2
10A 10B	10.5.3	Crystallization temperature	—	°C	No evidence of melting or crystallization	ISO 11357-3
10A —	10.5.4	Holiday detection at 5 kV/mm + 5 kV, max 25 kV	—	—	No holiday	ISO 21809-3:2016, Annex C
10A 10B	10.5.5	Drip resistance at $T_{max} + 20$ °C, min ≥ 80 °C	≥ 80 °C	—	No dripping of compound	ISO 21809-3:2016, Annex K
10A —	10.5.8	Specific electrical insulation resistance of coating applied to dry steel – RS_{100} – RS_{100}/RS_{70}	23 °C	Ω.m ² —	≥ 1,0E+08 ≥ 0,8 ^b	ISO 21809-3:2016, Annex F
Lap shear resistance						
10A 10B	10.5.7	Reinforced compound applied to dry steel	23 °C T_{max}	N/mm ²	≥ 0,004 0 ≥ 0,001 0	Cohesive separation ISO 21809-3:2016, J.1
10A 10B	10.5.7	Compound without reinforcement applied to dry steel	23 °C T_{max}		≥ 0,004 0 ≥ 0,001 0	

Table 6 (continued)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
Complete coating						
Adhesion tests of reinforced compound with respect to various substrates before ageing, after thermal ageing, and after hot water immersion, both for 100 days at $T_{max} + 20\text{ °C}$						
10A 10B	10.5.6 10.5.14 10.5.15	Coating applied to dry steel and dry existing coating ^a	23 °C T_{max}	N/mm	$\geq 0,040$ $\geq 0,020$	Cohesive separation Coverage $\geq 95\%$ ISO 21809-3:2016, Annex H Annex I M.3
-- 10B	10.5.6 10.5.14 10.5.15	Coating applied to wet steel and wet existing coating ^{a d}	This test is optional, see Annex B for guidance.			
Adhesion tests of compound without reinforcement with respect to various substrates before ageing, after thermal ageing, and after hot water immersion, both for 100 days at $T_{max} + 20\text{ °C}$						
10A 10B	10.5.6 10.5.14 10.5.15	Coating applied to dry steel and dry existing coating ^a	23 °C and T_{max}	N/mm	The coating shall leave a film of compound on the substrate	10.5.6 ISO 21809-3:2016, Annex I M.3
-- 10B	10.5.6 10.5.14 10.5.15	Coating applied to wet steel and wet existing coating ^{a d}	This test is optional, see Annex B for guidance.			
— 10B	10.5.8	Specific electrical insulation resistance of coating applied to dry steel – RS_{100} – RS_{100}/RS_{70}	23 °C	$\Omega \cdot m^2$ —	$\geq 1,0E+08$ $\geq 0,8^b$	ISO 21809-3:2016, Annex F
— 10B	10.5.8	Specific electrical insulation resistance of coating applied to wet steel ^d	This test is optional, see Annex B for guidance.			
10A 10B	10.5.9	Impact resistance	23 °C	J	≥ 15	ISO 21809-3:2016, Annex D
10A —	10.5.10	Indentation resistance at test pressure 1,0 N/mm ²	23 °C and T_{max}	mm	Residual thickness $\geq 0,6$	ISO 21809-3:2016, Annex E
— 10B	10.5.10	Indentation resistance at test pressure 10,0 N/mm ²				
10A —	10.5.11	Cathodic disbondment resistance of coating applied to dry steel	23 °C and T_{max}	mm —	Disbondment 0 No holiday (self-healing)	10.5.11 ISO 21809-3:2016, Annex G
— 10B	10.5.11	Cathodic disbondment resistance of coating applied to dry steel	23 °C T_{max}	mm mm	Disbondment ≤ 20 ^d	ISO 21809-3:2016, Annex G
— 10B	10.5.11	Cathodic disbondment resistance of coating applied to wet steel ^d	This test is optional, see Annex B for guidance.			
Outer wrap polymeric tape						
10A 10B	10.5.12	Resistance to ageing and weathering - carbon black content ^c	—	m/m %	≥ 2 and ≤ 3	ISO 6964
10A 10B	10.5.13	Peel strength between layers of outer wrap tape	23 °C T_{max}	N/mm	$\geq 0,20$ $\geq 0,020$	ISO 21809-3:2016, Annex L
10A 10B	10.5.14 10.5.13	Ratio of peel strength between layers of outer wrap tape before and after thermal ageing for 100 days at $T_{max} + 20\text{ °C}$	23 °C	—	$P'100/P'0 \geq 0,50$	ISO 21809-3:2016, M.2
10A 10B	10.5.15 10.5.13	Ratio of peel strength between layers of outer wrap tape before and after hot water immersion for 100 days at T_{max} , restricted to max. 95 °C	23 °C	—	$P''100/P''0 \geq 0,75$	ISO 21809-3:2016, Annex I Annex L

Table 6 (continued)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
10A 10B	10.5.6	Peel strength to existing coating (if applicable, see 10.4.2) ^a	23 °C T_{max}	N/mm	$\geq 1,0$ $\geq 0,10$	ISO 21809-3:2016, Annex H
10A 10B	10.5.14 10.5.6	Ratio of peel strength to existing coating before and after thermal ageing for 100 days at $T_{max} + 20$ °C (if applicable, see 10.4.2) ^a	23 °C	—	$P'100/P'0 \geq 0,75$	ISO 21809-3:2016, M.3
10A 10B	10.5.15 10.5.6	Ratio of peel strength to existing coating before and after hot water immersion for 100 days at T_{max} , restricted to max. 95 °C (if applicable, see 10.4.2) ^a	23 °C	—	$P''100/P''0 \geq 0,75$	ISO 21809-3:2016, Annex H Annex I
10A 10B	10.5.14	Ratio of nominal strain at break before and after thermal ageing	23 °C	—	$\epsilon_{tb}(y)/\epsilon_{tb}(0) \geq 0,75$	ISO 21809-3:2016, M.1 ISO 527-1 ISO 527-2 ISO 527-3
Outer mechanical protection other than polymeric tape						
10A 10B	10.5.12	Resistance to ageing and weathering ^c – ratio of strain at break – ratio of stress at break or – ratio of nominal strain at break – ratio of stress at break	23 °C	—	$1,25 \geq \epsilon_{b(y)}/\epsilon_{b(0)} \geq 0,75$ $1,25 \geq \sigma_{b(y)}/\sigma_{b(0)} \geq 0,75$ $1,25 \geq \epsilon_{tb(y)}/\epsilon_{tb(0)} \geq 0,75$ $1,25 \geq \sigma_{b(y)}/\sigma_{b(0)} \geq 0,75$	ISO 4892-2 Method A ISO 527-1 ISO 527-2 ISO 527-3
^a Specify type(s) of existing coating tested. ^b This requirement shall be fulfilled only if the specific electrical insulation resistance after 70 days is less than 10 times the requirement of the specific electrical insulation resistance after 100 days ($RS_{70} < 1,0^{E+09} \Omega \cdot m^2$). ^c See 10.5.12 for adequate type of test to be conducted. ^d By agreement						

Table 7 — Frequency of testing and inspection

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^e
Non-crystalline low-viscosity polyolefin compound						
10A 10B	10.5.2	Thickness of coating applied to dry substrate	ISO 21809-3:2016, Annex B	3	3	c
-- 10B	10.5.2	Thickness of coating applied to wet substrate ^c	This test is optional, see Annex B for guidance.			
10A 10B	10.5.3	Glass transition temperature and crystallization temperature	ISO 11357-2 ISO 11357-3	3	—	—
10A —	10.5.4	Holiday detection	ISO 21809-3:2016, Annex C	3	--	--
10A 10B	10.5.5	Drip resistance	ISO 21809-3:2016, Annex K	3	—	—
10A 10B	10.5.7	Lap shear resistance of reinforced compound to dry steel at 23 °C and at T_{max}	ISO 21809-3:2016, J.1	5	—	—
10A 10B	10.5.7	Lap shear resistance of compound without reinforcement to dry steel at 23 °C and at T_{max}	ISO 21809-3:2016, J.2	5	—	—

Table 7 (continued)

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^e
10A —	10.5.8	Specific electrical insulation resistance to dry steel	ISO 21809-3:2016, Annex F	3	—	—
Complete coating						
10A 10B	10.5.2	Thickness of coating applied to dry substrate	ISO 21809-3:2016, Annex B	3	3	c
-- 10B	10.5.2	Thickness of coating applied to wet substrate ^c	This test is optional, see Annex B for guidance.			
10A 10B	10.5.6	Adhesion to dry steel and dry existing coating ^d at 23 °C	ISO 21809-3:2016, Annex H 10.5.6	3	c	a c
10A 10B	10.5.6	Adhesion to dry steel and dry existing coating ^d at T_{max}	ISO 21809-3:2016, Annex H 10.5.6	3	—	—
-- 10B	10.5.6	Adhesion to wet steel and wet existing coating ^d at 23 °C and at T_{max}	This test is optional, see Annex B for guidance.			
10A 10B	10.5.14	Adhesion to dry steel and dry existing coating ^d at 23 °C and at T_{max} after thermal ageing for 100 days at $T_{max} + 20$ °C	ISO 21809-3:2016, M.3 10.5.6	3	—	—
-- 10B	10.5.14	Adhesion to wet steel and wet existing coating ^d at 23 °C and at T_{max} after thermal ageing for 100 days at $T_{max} + 20$ °C	This test is optional, see Annex B for guidance.			
10A 10B	10.5.15	Adhesion to dry steel and dry existing coating ^d at 23 °C and at T_{max} after hot water immersion for 100 days at $T_{max} + 20$ °C	ISO 21809-3:2016, Annex I Annex H 10.5.6	3	—	—
-- 10B	10.5.15	Adhesion to wet steel and wet existing coating ^d at 23 °C and at T_{max} after hot water immersion for 100 days at $T_{max} + 20$ °C	This test is optional, see Annex B for guidance.			
10A 10B	10.5.9	Impact resistance at 23 °C	ISO 21809-3:2016, Annex D	3	—	—
10A 10B	10.5.10	Indentation resistance at 23 °C and at T_{max}	ISO 21809-3:2016, Annex E	3	—	—
10A 10B	10.5.11	Cathodic disbondment resistance to dry steel at 23 °C and at T_{max}	ISO 21809-3:2016, Annex G	3	—	—
10A 10B	10.5.11	Cathodic disbondment resistance to wet steel at 23 °C and at T_{max}	This test is optional, see Annex B for guidance.			
— 10B	10.5.8	Specific electrical insulation resistance of coating applied to dry steel	ISO 21809-3:2016, Annex F	3	—	—
— 10B	10.5.8	Specific electrical insulation resistance of coating applied to wet steel	This test is optional, see Annex B for guidance.			
Outer wrap polymeric tape						
10A 10B	10.5.12	Resistance to ageing and weathering - carbon black content	ISO 6964	c	--	--
10A 10B	10.5.13	Peel strength between layers at 23 °C	ISO 21809-3:2016, Annex L	3	—	—
10A 10B	10.5.13	Peel strength between layers at T_{max}	ISO 21809-3:2016, Annex L	3	—	—
10A 10B	10.5.14	Peel strength between layers after thermal ageing for 100 days at $T_{max} + 20$ °C	ISO 21809-3:2016, M.2	3	—	—

Table 7 (continued)

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^e
10A 10B	10.5.15	Peel strength between layers after hot water immersion for 100 days at T_{max}	ISO 21809-3:2016, Annex I Annex L	3	—	—
10A 10B	10.5.6	Peel strength to existing coating ^d at 23 °C ^b	ISO 21809-3:2016, Annex H	3	a c	—
10A 10B	10.5.6	Peel strength to existing coating ^d at T_{max} ^b	ISO 21809-3:2016, Annex H	3	—	—
10A 10B	10.5.14	Peel strength to existing coating ^d after thermal ageing for 100 days at $T_{max} + 20$ °C ^b	ISO 21809-3:2016, M.3	3	—	—
10A 10B	10.5.15	Peel strength to existing coating ^d after hot water immersion for 100 days at T_{max} ^b	ISO 21809-3:2016, Annex I Annex H	3	—	—
10A 10B	10.5.14	Elongation at break before and after thermal ageing for 100 days at $T_{max} + 20$ °C	ISO 21809-3:2016, M.1 ISO 527-1 ISO 527-2 ISO 527-3	5	—	—
Outer mechanical protection other than polymeric tape						
10A 10B	10.5.12	Resistance to ageing and weathering ^c – ratio of strain at break – ratio of stress at break or – ratio of nominal strain at break – ratio of stress at break	ISO 4892-2 Method A ISO 527-1 ISO 527-2 ISO 527-3	c	--	--
^a In practice with PPT and production, the substrate temperature can significantly deviate from ideal conditions, e.g. as caused by transport of medium through an operational riser. This will influence results of peel strength. ^b When applicable. ^c By agreement. ^d Specify type(s) of existing coating tested. ^e Shall be agreed prior to production e.g. once per batch, 1 in 20 repairs.						

11 Petrolatum and wax-based tape wrap systems

11.1 Coating identification

Petrolatum tape wrap systems shall be identified in the APS in accordance with [Table 8](#) and shall meet the requirements of [Table 12](#) for petrolatum tape wrap systems (coating type 11A).

Wax-based tape wrap systems shall be identified in the APS in accordance with [Table 8](#) and shall meet the requirements of [Table 13](#) for wax-based tape wrap systems (coating type 11B).

Data sheets for the coating materials shall be in accordance with [Table 9](#) (primer, if applicable), [Table 10](#) (petrolatum and wax-based tape) and [Table 11](#) (outer mechanical protection).

Application instructions shall be provided by the manufacturer in accordance with [7.2](#) and shall be included in the APS.

11.2 Description of the tape wrap systems

11.2.1 Petrolatum tape wrap systems (type 11A)

Petrolatum tape wrap systems consist of a single inner layer or multiple inner layers of petrolatum tapes, with or without a primer, that form the corrosion prevention layer, which is then protected with an outer mechanical protection layer.

The outer mechanical protection consists of a polymeric tape, a polymeric sheet, a polymeric jacket or other agreed material. In accordance with the manufacturer's instructions, the outer mechanical protection may or may not overlap the existing coating adjacent to the area covered with petrolatum tape. Outer mechanical protective layers that are applied with tension can also provide radial compression of the petrolatum tape thereby accelerating the bond to the substrate.

The petrolatum tape wrap system can be applied on wet, immersed and dry substrates.

11.2.2 Wax-based tape wrap systems (type 11B)

Wax-based tape wrap systems consist of a primer and a single inner layer or multiple inner layers of wax-based tapes that form the corrosion prevention layer, which is then protected with an outer mechanical protection layer.

The outer mechanical protection consists of a polymeric tape, a polymeric sheet, a polymeric jacket or other agreed material. In accordance with the manufacturer's instructions, the outer mechanical protection may or may not overlap the existing coating adjacent to the area covered with wax-based tape. Outer mechanical protective layers that are applied with tension can also provide radial compression of the wax-based tape thereby accelerating the bond to the substrate.

The wax-based tape wrap system can be applied on wet, immersed and dry substrates.

11.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS as specified in [7.2](#). As the system can be applied above and below the water line, the surface does not need to be dry.

11.4 Application of coating systems

11.4.1 General

Application of the coating systems shall be carried out in accordance with the manufacturer's instructions and shall be specified in the APS. The following application procedure should be followed:

- a) prepare the surface in accordance with [11.3](#);
- b) when applicable, apply an adequate coat of compatible primer by brush, by hand or using other applicable tools;
- c) spirally wrap the area being coated with petrolatum or wax-based tapes of recommended width, following the manufacturer's instructions and client approval regarding overlap;
- d) ensure that the tape is in contact with the entire pipe surface;
- e) apply the outer mechanical protection layer in accordance with the APS.

11.4.2 Overlap

The minimum overlap of the petrolatum or wax-based tape layer and, if applicable, the outer mechanical polymeric tape shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

If applicable, the overlap of tapes on existing coatings shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

Depending on the structural situation, for example protruding parts or welded joints, the tape shall be applied in a sufficient thickness to ensure sufficient layer thickness after completion of system installation.

An appropriate width of tape, considering the overlap, shall be chosen to assist in application and prevent wrinkling of the tape.

11.5 Testing of the coating systems

11.5.1 General

If required, the tests in [11.5.2](#) to [11.5.12](#), summarized in [Table 12](#) (coating type 11A) and [Table 13](#) (coating type 11B), shall be carried out for the TA, PQT, PPT and production testing.

Test and inspection frequencies for TA, PQT, PPT and production testing are included in [Table 3](#) and [Table 14](#).

[Annex B](#) provides the tests, acceptance criteria, and inspections and test frequencies for coatings applied on wet substrates, if required.

Unless otherwise specified, the tests shall be carried out on coated pipes. Samples cut from coated pipe or flat surfaces are not allowed, unless otherwise specified.

Where applicable, the substrate conditions used for tests shall be in accordance with [9.1](#).

For the purposes of this subclause, the coating systems have been subdivided as follows:

- Type 11A-1: petrolatum tape wrap system applied on dry substrate;
- Type 11A-2: petrolatum tape wrap system applied on wet or immersed substrate;
- Type 11B-1: wax-based tape wrap system applied on dry substrate;
- Type 11B-2: wax-based tape wrap system applied on wet or immersed substrate.

NOTE If polymeric tapes are used as outer mechanical protection, additional requirements can apply, e.g. peel strength between layers. These additional requirements are agreed between manufacturer and client.

11.5.2 Density

The density requirement applies to coating type 11B only.

The density of the primer and the inner layer wax-based tape shall be measured in accordance with ISO 2811-1 and shall meet the requirements of [Table 13](#) (type 11B).

11.5.3 Dielectric strength

The dielectric strength requirement applies to coating type 11B only.

The dielectric strength of the primer and the inner layer wax-based tape shall be measured in accordance with ASTM D149 and shall meet the requirements of [Table 13](#) (type 11B).

11.5.4 Thickness

The thickness requirement applies to all types of coating applied to dry substrate as specified in [11.5.1](#).

[Annex B](#) provides guidance for the thickness of coating type 11A-2 and 11B-2 applied to wet substrate.

The complete system thickness shall be measured in accordance with ISO 21809-3:2016, Annex B, and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B) as per manufacturer recommendation to meet the performance requirements.

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

The shape and dimensions of the thickness measurement probe shall be designed to avoid indentation of the coating.

11.5.5 Holiday detection

The holiday detection requirement applies to coating type 11A-1 and coating type 11B-1 only.

In the atmospheric zone, the entire dry surface of the riser coated with repair coating shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm to a maximum of 25 kV in accordance with ISO 21809-3:2016, Annex C, and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B). This test should be carried out after application of the petrolatum or wax-based tape and may be repeated after completion of the system when required by the client.

Holidays shall be repaired in accordance with the APS.

11.5.6 Impact resistance

The impact resistance requirement applies to coating type 11A-1 and coating type 11B-1 only.

The impact resistance shall be measured on the complete system applied to dry substrate in accordance with ISO 21809-3:2016, Annex D, and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

11.5.7 Specific electrical insulation resistance

The special electrical insulation resistance requirement applies to coating type 11A-1 and coating type 11B-1 only.

The specific electrical insulation resistance of the complete coating applied to dry substrate shall be measured in accordance with ISO 21809-3:2016, Annex F, and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

11.5.8 Cathodic disbondment resistance

The cathodic disbondment resistance requirement applies to coating type 11A-1 and coating type 11B-1 only.

The cathodic disbondment shall be measured on the complete system applied to dry substrate over a period of 28 days at 23 °C and, if agreed between client and manufacturer, at maximum service temperature (limited to 95 °C maximum), in accordance with ISO 21809-3:2016, Annex G.

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 23 °C and at maximum service temperature shall be measured as the radius of disbondment and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

11.5.9 Adhesion to pipe surface and existing coating

The adhesion to pipe surface and existing coating requirement applies to all types of coating applied to dry pipe surface and dry existing coating specified in [11.5.1](#).

[Annex B](#) provides guidance for the adhesion of coating type 11B to wet pipe surface and wet existing coating.

The adhesion of the petrolatum tape (type 11A) and wax-based tape (type 11B) to dry steel and dry existing coating shall be tested at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, Annex H. The adhesion shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

Petrolatum and wax-based tape wrap systems shall leave a film of compound on ≥ 95 % of the substrate, visible without magnification, when the system is peeled off.

The minimum waiting period between application of the coating materials and the adhesion test shall be 1 hour, unless specified otherwise by the manufacturer.

11.5.10 Drip resistance

The drip resistance requirement applies to coating type 11A-1 and coating type 11B-1 only.

The petrolatum tapes and wax-based tapes shall be tested for drip resistance. No dripping of the compound shall occur when the tape is tested in accordance with ISO 21809-3:2016, Annex K, at a test temperature of $T_{\max} + 6$ °C (or as otherwise agreed with client), as specified in [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

11.5.11 Hot water immersion test

The hot-water immersion test requirement applies to coating type 11A-1 and coating type 11B-1 only.

A hot-water immersion test of the complete system, applied in dry conditions shall be carried out in accordance with ISO 21809-3:2016, Annex I, for 28 days at T_{\max} . After this test, the adhesion of the petrolatum or wax-based tape to the pipe surface and the existing coating shall be measured as specified in [11.5.9](#) and shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

11.5.12 Resistance to ageing and weathering

The resistance to ageing and weathering requirement applies to all types of coating specified in [11.5.1](#).

For outer mechanical protection layers comprised of polyolefin, ISO 6964 shall be used to determine carbon black content.

NOTE For the purposes of this document, ASTM D1603 and ASTM D4218 are equivalent to the test method described in ISO 6964.

For outer mechanical protection layers not comprising polyolefin, an ageing and weathering test shall be carried out in accordance with ISO 4892-2 under the following conditions:

- method A: exposure using daylight filters (artificial weathering);
- relative humidity: (65 ± 5) %;
- total radiant energy: 5 GJ/m².

After this test, specimens shall be tested before and after ageing for ratio of strain at break (ϵ_b) and ratio of stress at break (σ_b) in case extensometers are used in accordance with ISO 527-1. In case no extensometers are used, specimens shall be tested before and after ageing for ratio of nominal strain at break (ϵ_{tb}) and ratio of stress at break (σ_b).

The test specimens shall be prepared in accordance with one of the types specified in ISO 527-2 or ISO 527-3 respectively.

Ratios shall be calculated as arithmetic mean after ageing divided by arithmetic mean before ageing.

Alternatively, for outer mechanical protection layers not comprising polyolefin, an ageing and weathering test can be carried out in accordance with ISO 16474-3, method A, cycle 1, under the following conditions:

- alternating periods of 4 h exposure to UVA-340 lamps at $(60 \pm 3) ^\circ\text{C}$ and 4 h exposure to condensation at $(50 \pm 3) ^\circ\text{C}$;
- total duration 225 cycles, which conforms to 900 h of exposure to UVA-340 lamps and 900 h exposure to condensation.

After this test, the specimen shall be tested for ratio of Shore hardness in accordance with ISO 868.

The requirements for resistance to ageing and weathering shall meet the requirements of [Table 12](#) (type 11A) or [Table 13](#) (type 11B).

Table 8 — Coating identification

Type of coating in accordance with Table 1
Coating manufacturer
Coating system trade name
Minimum and maximum service temperature
Types, trade names, number and supplied thicknesses of individual layers
Nominal thickness of complete coating
Compatible existing coatings (state all types of existing coating that have been tested successfully)

Table 9 — Product data sheets of primer (if applicable)

Property	Unit	Test method
Manufacturer	—	—
Trade name	—	—
Solid content	%	ISO 3251
Type of solvent, if applicable	—	—
Flash point, if applicable	$^\circ\text{C}$	ISO 1523
Density	g/cm^3	ISO 2811-1
Coverage area	m^2/l	—
Dry film thickness	μm	ISO 2808
Storage conditions, including temperature range	$—/^\circ\text{C}$	—
Shelf life at storage conditions	months	—

Table 10 — Product data sheet of petrolatum and wax-based tape

Property	Unit	Test method
Manufacturer	—	—
Trade name	—	—
Generic type of coating material	—	Petrolatum or wax-based
Colour	—	—
Thickness as supplied; or surface density	mm g/m^2	ISO 4591 or ISO 4593 ISO 3801
Type of reinforcement, when applicable: – generic type of polymeric film backing – generic type of incorporated reinforcement material	— —	— —
Storage conditions, including temperature range	$^\circ\text{C}$	—

Table 10 (continued)

Property	Unit	Test method
Shelf life at storage conditions	months	—

Table 11 — Product data sheet of outer mechanical protection

Property	Unit	Test method
Manufacturer	—	—
Trade name	—	—
Generic type of coating material: – polymeric outer wrap tape and type of polymer – polymeric jacket and type of polymer – others, including chemical description of material	—	—
Colour	—	—
Thickness as supplied	mm	(to be specified)
Storage conditions, including temperature range	°C	—
Shelf life at storage conditions	months	—

Table 12 — Requirements for petrolatum tape wrap systems (type 11A)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
Inner layer – petrolatum tape						
11A-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)		—	No holiday	ISO 21809-3:2016, Annex C
11A-1 —	11.5.7	Specific electrical insulation resistance – Rs_{100} – Rs_{100}/Rs_{70}	23 °C	$\Omega \cdot m^2$ —	$\geq 1,0^{E+06}$ $\geq 0,8^a$	ISO 21809-3:2016, Annex F
11A	11.5.10	Drip resistance	$T_{max} + 6$ °C		No dripping of compound	ISO 21809-3:2016, Annex K
11A-1 ..	11.5.9	Adhesion to dry pipe surface and dry existing coating ^d	23 °C and T_{max}	—	Coating shall leave a film of compound on substrate with a coverage of ≥ 95 %	ISO 21809-3:2016, Annex H
11A-1 —	11.5.11	Adhesion to dry pipe surface and dry existing coating ^d after hot water immersion for 28 days at T_{max}				ISO 21809-3:2016, Annex I Annex H
.. 11A-2	11.5.9	Adhesion to wet pipe surface and wet existing coating ^{c,d}	This test is optional, see Annex B for guidance.			
Outer mechanical protection layer						
11A	11.5.12	Carbon black content ^b	—	m/m %	≥ 2	ISO 6964
		Resistance to ageing and weathering ^b – ratio of strain at break – ratio of stress at break or – ratio of nominal strain at break – ratio of stress at break	23 °C	—	$1,25 \geq \epsilon_{b(y)}/\epsilon_{b(0)} \geq 0,75$ $1,25 \geq \sigma_{b(y)}/\sigma_{b(0)} \geq 0,75$ $1,25 \geq \epsilon_{tb(y)}/\epsilon_{tb(0)} \geq 0,75$ $1,25 \geq \sigma_{b(y)}/\sigma_{b(0)} \geq 0,75$	ISO 4892-2 Method A ISO 527-1 ISO 527-2 ISO 527-3
		Resistance to ageing and weathering ^b ratio of Shore hardness	23 °C	—	$1,25 \geq H_{(y)}/H_{(0)} \geq 0,75$	ISO 16474-3 ISO 868

Table 12 (continued)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
Complete coating with HDPE-based outer mechanical protection						
11A-1 ..	11.5.4	Thickness of coating applied to dry substrate	23 °C	mm	≥ 0,9 × sum of nominal values of individual layers ^c	ISO 21809-3:2016, Annex B
.. 11A-2	11.5.4	Thickness of coating applied to wet substrate ^c	This test is optional, see Annex B for guidance.			
11A-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	—	—	No holiday	ISO 21809-3:2016, Annex C
11A	11.5.6	Impact resistance	23 °C	J	≥ 15	ISO 21809-3:2016, Annex D
11A-1 —	11.5.8	Cathodic disbondment resistance at 28 days	23 °C	mm	Disbondment ≤ 20 mm	ISO 21809-3:2016, Annex G
Complete coating (excluding HDPE-based outer mechanical protection)						
11A-1 ..	11.5.4	Thickness	23 °C	mm	≥ 0,9 × sum of nominal values of individual layers ^c	ISO 21809-3:2016, Annex B
.. 11A-2	11.5.4	Thickness of coating applied to wet substrate ^c	This test is optional, see Annex B for guidance.			
11A-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	—	—	No holiday	ISO 21809-3:2016, Annex C
11A-1 —	11.5.8	Cathodic disbondment resistance at 28 days	23 °C <i>T</i> _{max}	mm	Disbondment ≤ 20 mm	ISO 21809-3:2016, Annex G

^a This requirement shall only be fulfilled if the specific electrical insulation resistance after 70 days is less than 10 times the requirement for specific electrical insulation resistance after 100 days.

^b See [11.5.12](#) for adequate type of test to be conducted.

^c By agreement.

^d Specify all types of existing coating tested.

Table 13 — Requirements for wax-based tape wrap systems (type 11B)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
Primer						
11B	11.5.2	Density	25 °C	g/cm ³	< 1,0	ISO 2811-1
11B	11.5.3	Dielectric strength	—	V/μm	> 4,0	ASTM D149
Inner layer – wax-based tape						
11B	11.5.2	Density	25 °C	g/cm ³	< 1,0	ISO 2811-1
11B	11.5.3	Dielectric strength	—	V/μm	> 6,6	ASTM D149
11B-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	—	—	No holiday	ISO 21809-3:2016, Annex C
11B-1 —	11.5.7	Specific electrical insulation resistance <i>R</i> _{S100} <i>R</i> _{S100} / <i>R</i> _{S70}	23 °C	Ω.m ² —	≥ 1,0 ^{E+06} ≥ 0,8 ^a	ISO 21809-3:2016, Annex F
11B	11.5.10	Drip resistance	<i>T</i> _{max} + 6 °C	—	No dripping of compound	ISO 21809-3:2016, Annex K

^a This requirement shall only be fulfilled if the specific electrical insulation resistance after 70 days is less than 10 times the requirement for specific electrical insulation resistance after 100 days.

^b See [11.5.12](#) for adequate type of test to be conducted.

^c By agreement.

^d Specify type(s) of existing coating tested.

Table 13 (continued)

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
11B-1 ..	11.5.9	Adhesion to dry pipe surface and dry existing coating ^d	23 °C and T_{max}	—	Coating shall leave a film of compound on substrate with a coverage of $\geq 95\%$	ISO 21809-3:2016, Annex H
11B-1 —	11.5.11	Adhesion to dry pipe surface and dry existing coating ^d after hot water immersion for 28 days at T_{max}				ISO 21809-3:2016, Annex I Annex H
-- 11B-2	11.5.9	Adhesion to wet pipe surface and wet existing coating ^{c,d}	This test is optional, see Annex B for guidance.			
Outer mechanical protection layer						
		Carbon black content ^b	—	m/m %	≥ 2 and ≤ 3	ISO 6964
11A	11.5.12	Resistance to ageing and weathering ^b	23 °C	—	$1,25 \geq \epsilon_{b(y)}/\epsilon_{b(0)} \geq 0,75$ $1,25 \geq \sigma_{b(y)}/\sigma_{b(0)} \geq 0,75$ $1,25 \geq \epsilon_{tb(y)}/\epsilon_{tb(0)} \geq 0,75$ $1,25 \geq \sigma_{tb(y)}/\sigma_{tb(0)} \geq 0,75$	ISO 4892-2 Method A
		– ratio of strain at break				ISO 527-1
		– ratio of stress at break				ISO 527-2
		or				ISO 527-3
		Resistance to ageing and weathering ^b ratio of Shore hardness	23 °C	—	$1,25 \geq H_{(y)}/H_{(0)} \geq 0,75$	ISO 16474-3 ISO 868
Complete coating with HDPE-based outer mechanical protection						
11B-1 ..	11.5.4	Thickness of coating applied to dry substrate	23 °C	mm	$\geq 0,9 \times$ sum of specified minimum values of individual layers ^c	ISO 21809-3:2016, Annex B
-- 11B-2	11.5.4	Thickness of coating applied to dry substrate ^c	This test is optional, see Annex B for guidance.			
11B-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	—	—	No holiday	ISO 21809-3:2016, Annex C
11B	11.5.6	Impact resistance	23 °C	J	≥ 15	ISO 21809-3:2016, Annex D
11B-1 —	11.5.8	Cathodic disbondment resistance at 28 days	23 °C	mm	Disbondment ≤ 12 mm	ISO 21809-3:2016, Annex G
			T_{max}		^c	
Complete coating (excluding HDPE-based outer mechanical protection)						
11B-1 ..	11.5.4	Thickness	23 °C	mm	$\geq 0,9 \times$ sum of nominal values of individual layers ^c	ISO 21809-3:2016, Annex B
-- 11B-2	11.5.4	Thickness of coating applied to dry substrate ^c	This test is optional, see Annex B for guidance.			
11B-1 —	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	—	—	No holiday	ISO 21809-3:2016, Annex C
11B-1 —	11.5.8	Cathodic disbondment resistance at 28 days	23 °C	mm	Disbondment ≤ 12 mm	ISO 21809-3:2016, Annex G
			T_{max}		^c	
^a This requirement shall only be fulfilled if the specific electrical insulation resistance after 70 days is less than 10 times the requirement for specific electrical insulation resistance after 100 days. ^b See 11.5.12 for adequate type of test to be conducted. ^c By agreement. ^d Specify type(s) of existing coating tested.						

Table 14 — Frequency of testing and inspection

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^e
Primer (if applicable)						
11B	11.5.2	Density	ISO 2811-1	3	—	—
11B	11.5.3	Dielectric strength	ASTM D149	3	—	—
Inner layer – petrolatum or wax-based tape						
11B	11.5.2	Density	ISO 2811-1	3	—	—
11B	11.5.3	Dielectric strength	ASTM D149	3	—	—
11A-1 11B-1	11.5.5	Holiday detection at 5 kV/mm, max. 25 kV (if applicable)	ISO 21809-3:2016, Annex C	3	—	—
11A-1 11B-1	11.5.7	Specific electrical insulation resistance	ISO 21809-3:2016, Annex F	3	—	—
11A 11B	11.5.10	Drip resistance	ISO 21809-3:2016, Annex K	3	—	—
11A-1 11B-1	11.5.9	Adhesion to dry steel and dry existing coating ^d at 23 °C	ISO 21809-3:2016, Annex H	3	a	ab
11A-1 11B-1	11.5.9	Adhesion to dry steel and dry existing coating ^d at T_{max}	ISO 21809-3:2016, Annex H	3	—	—
11A-2 11B-2	11.5.9	Adhesion to wet steel and wet existing coating ^{a d} at 23 °C and at T_{max}	This test is optional, see Annex B for guidance.			
11A-1 11B-1	11.5.11	Adhesion to dry steel and dry existing coating ^d at 23 °C and at T_{max} after hot water immersion for 28 days at T_{max}	ISO 21809-3:2016, Annex I Annex H	3	—	—
Outer mechanical protection layer						
11A 11B	11.5.12	Carbon black content ^c	ISO 6964	3	—	—
11A 11B	11.5.12	Resistance to ageing and weathering ^c	ISO 4892-2 Method A ISO 527-1 ISO 527-2 ISO 527-3	3	—	—
11A 11B	11.5.12	Resistance to ageing and weathering ^c	ISO 16474-3 ISO 868	3	—	—
Complete coating						
11A-1 11B-1	11.5.4	Thickness of coating applied to dry substrate	ISO 21809-3:2016, Annex B	3	3	a
11A-2 11B-2	11.5.4	Thickness of coating applied to wet substrate ^a	This test is optional, see Annex B for guidance.			
11A 11B	11.5.5	Holiday detection	ISO 21809-3:2016, Annex C	3	—	—
11A 11B	11.5.6	Impact resistance	ISO 21809-3:2016, Annex D	3	—	—
^a By agreement. ^b In practice with PPT and production, the substrate temperature can significantly deviate from ideal conditions, e.g. as caused by transport of medium through an operational riser. This will influence results of adhesion. ^c See 11.5.12 for adequate type of test to be conducted. ^d Specify type(s) of existing coating tested. ^e Shall be agreed prior to production e.g. once per batch, 1 in 20 repairs or otherwise						

Table 14 (continued)

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^e
11A-1 11B-1	11.5.8	Cathodic disbondment resistance at 23 °C	ISO 21809-3:2016, Annex G	3	—	—
11A-1 11B-1	11.5.8	Cathodic disbondment resistance at T_{max}	ISO 21809-3:2016, Annex G	a	—	—
<p>^a By agreement.</p> <p>^b In practice with PPT and production, the substrate temperature can significantly deviate from ideal conditions, e.g. as caused by transport of medium through an operational riser. This will influence results of adhesion.</p> <p>^c See 11.5.12 for adequate type of test to be conducted.</p> <p>^d Specify type(s) of existing coating tested.</p> <p>^e Shall be agreed prior to production e.g. once per batch, 1 in 20 repairs or otherwise</p>						

12 Polychloroprene-based elastomeric coatings

12.1 Coating identification

Polychloroprene-based elastomeric coatings shall be identified in the APS in accordance with [Table 15](#) and shall meet the requirements of [Table 17](#).

Datasheets for the individual materials shall be in accordance with [Table 16](#).

Application instructions shall be provided by the manufacturer in accordance with [7.2](#) and shall be included in the APS.

12.2 Description of the coatings

Polychloroprene-based elastomeric coatings consist of one or more layers of polychloroprene rubber lining applied to a substrate that has been treated with a primer and a bonding agent. The rubber lining is vulcanized in situ at elevated temperature by the use of external heat sources such as steam pressure autoclave or electrical heat tracing. Alternatively, self-vulcanizing polychloroprene rubber linings are available that vulcanize at ambient temperature without the use of external heat sources. During the vulcanization process, cross-links between intersecting polymer chains are formed. After completion of this process, a rigid and durable coating is formed on the substrate that protects it from corrosion.

12.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS as specified in [7.2](#). Polychloroprene-based elastomeric coatings specified in this document shall be applied on dry substrates only. They are not suitable for application on wet substrates.

12.4 Application of the coating

12.4.1 General

Application of the coatings shall be carried out in accordance with the manufacturer's instructions and shall be specified in the APS. The following application procedure should be followed:

- a) prepare the surface in accordance with [12.3](#);
- b) apply primer adhesive and bonding agent;
- c) apply one or more layers of a polychloroprene rubber lining;

- d) apply temporary polyamide tape tightly over the rubber lining;
- e) if applicable, install external heat sources and apply heat in order to vulcanize the rubber lining;
- f) after vulcanization is complete, remove external heat sources (if applicable) and temporary polyamide tape.

12.4.2 Overlap

If applicable, the overlap of the self-vulcanizing chloroprene-based elastomeric coatings on existing coatings shall be in accordance with the manufacturer's instructions and shall be specified in the APS.

12.5 Testing of the coatings

12.5.1 General

If required, the tests in [12.5.2](#) to [12.5.18](#), summarized in [Table 17](#), shall be carried out for the TA, PQT, PPT and production testing.

Test and inspection frequencies for TA, PQT, PPT and production testing are included in [Table 3](#) and [Table 18](#).

The tests shall be carried out on coated pipes. When agreed between client and manufacturer, samples cut from coated pipe or flat surfaces can be used.

Where applicable, the substrate conditions used for tests shall be in conformity with [9.1](#).

12.5.2 Visual appearance

The coating shall be visually inspected and shall have continuous and uniform appearance free from anomalies such as blisters, pores and delaminations.

12.5.3 Thickness

The thickness of the coating shall be measured in accordance with ISO 21809-3:2016, Annex B, and shall meet the requirements of [Table 17](#).

When the repair material is polychloroprene-based elastomeric coatings, its thickness shall be at least 80 % of existing coating.

12.5.4 Holiday detection

The entire dry surface of the riser coated with repair coating shall be checked for holidays or other discontinuities in accordance with NACE SP0274 and shall meet the requirements of [Table 17](#).

Holidays shall be repaired in accordance with the APS.

12.5.5 Hardness

Hardness Shore A of the coating shall be checked using a suitable hardness gauge in accordance with ISO 48-2 and shall meet the requirements of [Table 17](#).

12.5.6 Adhesion to pipe surface and existing coating

The adhesion of the coating applied to steel and to existing coating, if applicable, shall be tested at 23 °C in accordance with ISO 21809-3:2016, Annex H, and shall meet the requirements of [Table 17](#).

12.5.7 Cathodic disbondment resistance

The cathodic disbondment of the coating shall be measured over a period of 28 days at 23 °C and at maximum service temperature (limited to 95 °C maximum) in accordance with ISO 21809-3:2016, Annex G.

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 23 °C and at maximum service temperature shall be measured as the radius of disbondment and shall meet the requirements of [Table 17](#).

12.5.8 Density

Density of the cured elastomer shall be measured in accordance with ISO 2781, method A. The value shall be within ± 2 % of the manufacturer specification and shall be included in the datasheet as specified in [Table 16](#).

12.5.9 Rheometer curve

A rheometer curve shall be established for the uncured elastomer in accordance with ISO 6502-2 and shall be used to define the acceptance limits of the following parameters:

- a) minimum torque, expressed in deciNewton-metres (dN.m);
- b) time to a 1 dN.m rise above minimum torque, expressed in minutes;
- c) time to 90 % of the torque increase, expressed in minutes;
- d) maximum torque at which the curve plateaus, expressed in deciNewton-metres (dN.m).

A standard curve with these parameters shall be established by the manufacturer and approved by the contractor in accordance with [Table 16](#). All subsequent curves shall fall within these limits.

12.5.10 Tensile strength

The tensile strength of the coating shall be measured in accordance with ISO 37 and shall meet the requirements of [Table 17](#).

12.5.11 Elongation at break

The elongation at break of the coating shall be measured in accordance with ISO 37 and shall meet the requirements of [Table 17](#).

12.5.12 Tear strength

The tear strength of the coating shall be measured in accordance with ISO 34-1 and shall meet the requirements of [Table 17](#).

12.5.13 Electrical volume resistivity

The electrical volume resistivity of the coating shall be measured in accordance with ASTM D991 and shall be included in the datasheet as specified in [Table 16](#).

12.5.14 Ozone resistance

The ozone resistance of the coating shall be measured in accordance with ISO 1431-1, procedure A, with an ozone concentration of 0,5 µg/l for 72 hours at 40 °C when held at a fixed strain of 20 %. The ozone resistance shall meet the requirements of [Table 17](#).

12.5.15 Resistance to seawater

The resistance to seawater of the coating shall be tested for 28 days at 85 °C in accordance with ISO 1817, using substitute ocean water in accordance with ASTM D1141. After this test, the coating shall show no evidence of cracking or splitting. The change in volume, hardness (12.5.5) and tensile strength (12.5.10) shall be measured and shall meet the requirements of Table 17.

12.5.16 Hot-water immersion test

A hot-water immersion test of the coating shall be carried out for 28 days at T_{max} in accordance with ISO 21809-3:2016, Annex I. After this test, the adhesion of the coating to the pipe surface and the existing coating shall be measured as specified in 12.5.6. The adhesion to pipe surface and existing coating shall meet the requirements of Table 17.

12.5.17 Thermal ageing resistance

A thermal ageing test of the coating shall be carried out for 28 days at $T_{max} + 20$ °C in accordance with ISO 21809-3:2016, M.1 and ISO 21809-3:2016, M.3. After this test, the hardness (12.5.5), adhesion to pipe surface and existing coatings (12.5.6), tensile strength (12.5.10) and elongation at break (12.5.11) shall be measured. The thermal ageing resistance shall meet the requirements of Table 17.

12.5.18 Resistance to ageing and weathering

The resistance to ageing and weathering of the coating shall be measured on flat samples in accordance with ASTM D5894, and requirements shall be agreed between manufacturer and client.

Table 15 — Coating identification

Type of coating in accordance with Table 1
Coating manufacturer
Coating trade name
Minimum and maximum service temperature
Types, trade names, number and supplied thicknesses of individual layers
Minimum thickness of installed coating
Compatible existing coatings (state all types of existing coating that have been tested successfully)

Table 16 — Product data sheets of individual materials

Property	Units	Test method
Manufacturer	—	—
Trade name	—	—
Generic type of coating material	—	—
Colour	—	—
Thickness, as supplied	mm	ISO 23529
Density (12.5.8)	g/cm ³	ISO 2781
Rheometer curve (12.5.9)	—	ISO 6502-2
Electrical volume resistivity (12.5.13)	Ω.cm	ASTM D991
Minimum and maximum service temperature	°C	—
Storage conditions, including temperature range	—/°C	—
Shelf life at storage conditions	months	—

Table 17 — Requirements for polychloroprene-based elastomeric coatings

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
12	12.5.2	Visual appearance	—	—	Continuous, uniform, free of anomalies	—
12	12.5.3	Thickness	23 °C	mm	$\geq 0,9 \times$ nominal value	ISO 21809-3:2016, Annex B
12	12.5.4	Holiday detection	—	—	No holiday	NACE SP0274
12	12.5.5	Hardness Shore A	23 °C	IRHD	$60 \leq H_0 \leq 70$	ISO 48-2
12	12.5.15 12.5.5	Hardness after seawater resistance test for 28 days at 85 °C	23 °C	IRHD	$60 \leq H_{28} \leq 75$	ISO 1817 ISO 48-2
12	12.5.17 12.5.5	Hardness after thermal ageing resistance test for 28 days at $T_{max} + 20$ °C	23 °C	—	$0,75 \leq H_{28}/H_0 \leq 1,5$	ISO 21809-3:2016, M.3 ISO 48-2
12	12.5.6	Adhesion to pipe surface and existing coating ^b	23 °C	N/mm —	≥ 12 Cohesive separation	ISO 21809-3:2016, Annex H
12	12.5.16 12.5.6	Adhesion to pipe surface and existing coating ^b after hot water immersion test for 28 days at T_{max}	23 °C	N/mm —	≥ 10 Cohesive separation	ISO 21809-3:2016, Annex I Annex H
12	12.5.17 12.5.6	Adhesion to pipe surface and existing coating ^b after thermal ageing resistance test for 28 days at $T_{max} + 20$ °C	23 °C	N/mm —	≥ 10 Cohesive separation	ISO 21809-3:2016, M.3 Annex H
12	12.5.7	Cathodic disbondment resistance at 28 days	23 °C T_{max}	mm	≤ 7 mm ≤ 10 mm	ISO 21809-3:2016, Annex G
12	12.5.10	Tensile strength	23 °C	N/mm ²	$S_0 \geq 14$	ISO 37
12	12.5.15 12.5.10	Tensile strength after seawater resistance test for 28 days at 85 °C	23 °C	—	$0,8 \geq S_{28}/S_0 \geq 1,2$	ISO 1817 ISO 37
12	12.5.17 12.5.10	Tensile strength after thermal ageing resistance test for 28 days at $T_{max} + 20$ °C	23 °C	—	$0,75 \geq S_{28}/S_0 \geq 1,25$	ISO 21809-3:2016, M.1 ISO 37
12	12.5.11	Elongation at break	23 °C	%	$E_0 \geq 350$	ISO 37
12	12.5.17 12.5.11	Elongation at break after thermal ageing resistance test for 28 days at $T_{max} + 20$ °C	23 °C	N/mm	$0,8 \geq E_{28}/E_0 \geq 1,2$	ISO 21809-3:2016, M.1 ISO 37
12	12.5.12	Tear strength	23 °C	N/mm	≥ 40	ISO 34-1
12	12.5.14	Ozone resistance tested under 20 % strain at concentration of 0,5 µg/l for 72 hours at 40 °C	23 °C	—	No cracks or other detrimental effects	ISO 1431-1
12	12.5.15	Change in volume after seawater resistance test for 28 days at 85 °C	23 °C	—	$V_{28}/V_0 \leq 1,05$	ISO 1817
12	12.5.18	Resistance to ageing and weathering ^a	23 °C	—	By agreement between manufacturer and client	ASTM D5894

^a By agreement.

^b Specify type(s) of existing coating tested.

Table 18 — Frequency of testing and inspection

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^c
12	12.5.2	Visual inspection	—	3	3	100 %

^a By agreement.

^b Specify type(s) of existing coating tested.

^c Shall be agreed prior to production e.g. once per batch, 1 in 20 repairs.

Table 18 (continued)

Type	Clause	Property	Method	Frequency		
				PQT	PPT	Production ^c
12	12.5.3	Thickness	ISO 21809-3:2016, Annex B	3	a	a
12	12.5.4	Holiday detection	NACE SP0274	3	--	--
12	12.5.5	Hardness	ISO 48-2	3	—	—
12	12.5.15	Hardness after seawater test	ISO 1817 ISO 48-2	3	—	—
12	12.5.17	Hardness after thermal ageing resistance test	ISO 21809-3:2016, M.3 ISO 48-2	3	—	—
12	12.5.6	Adhesion to pipe surface and existing coating ^b	ISO 21809-3:2016, Annex H	3	a	a
12	12.5.16	Adhesion to pipe surface and existing coating ^b after hot water immersion test	ISO 21809-3:2016, Annex I Annex H	3	—	—
12	12.5.17	Adhesion to pipe surface and existing coating ^b after thermal ageing resistance test	ISO 21809-3:2016, M.3 Annex H	3	—	—
12	12.5.7	Cathodic disbondment resistance at 23 °C	ISO 21809-3:2016, Annex G	3	—	—
12	12.5.7	Cathodic disbondment resistance at T_{max}	ISO 21809-3:2016, Annex G	3	—	—
12	12.5.8	Density	ISO 2781 method A	3	—	—
12	12.5.9	Rheometer curve	ISO 6502-2	3	—	—
12	12.5.10	Tensile strength	ISO 37	3	—	—
12	12.5.15	Tensile strength after seawater resistance test	ISO 1817 ISO 37	3	—	—
12	12.5.17	Tensile strength after thermal ageing resistance test	ISO 21809-3:2016, M.1 ISO 37	3	—	—
12	12.5.11	Elongation at break	ISO 37	3	—	—
12	12.5.17	Elongation at break after thermal ageing resistance test	ISO 21809-3:2016, M.1 ISO 37	3	—	—
12	12.5.12	Tear strength	ISO 34-1	3	—	—
12	12.5.13	Electrical volume resistivity	ASTM D991	3	—	—
12	12.5.14	Ozone resistance	ISO 1431-1 procedure A	3	—	—
12	12.5.15	Resistance to seawater, coating volume change	ISO 1817	3	—	—
12	12.5.18	Resistance to ageing and weathering ^a	ASTM D5894	3	—	—

^a By agreement.

^b Specify type(s) of existing coating tested.

^c Shall be agreed prior to production e.g. once per batch, 1 in 20 repairs.

13 Liquid-applied epoxy coatings

13.1 Coating identification

Liquid-applied epoxy coatings shall be identified in the APS in accordance with [Table 19](#) and shall meet the requirements of [Table 21](#).

Data sheets for the coating materials shall be in accordance with [Table 20](#).

Application instructions shall be provided by the manufacturer in accordance with [7.2](#) and shall be included in the APS.

13.2 Description of the liquid-applied epoxy coating

Liquid-applied epoxy coatings consist of an epoxy-based binder and a reactive hardener that are mixed in an appropriate ratio prior to application to the substrate. After curing, a rigid film is formed on the substrate, protecting it from corrosion.

Epoxy coatings specified in this document can be applied on both wet and dry substrates.

13.3 Surface preparation

Surface preparation shall be carried out in accordance with the APS as specified in [7.2](#). As the system can be applied above and below the water line, the surface does not need to be dry.

13.4 Application of the coatings

13.4.1 General

Application of the coatings shall be carried out in accordance with the manufacturer's instructions and shall be specified in the APS. The following application procedure should be followed:

- a) prepare the surface in accordance with [13.3](#);
- b) mix the binder and hardener in appropriate mix-ratio;
- c) apply the epoxy mixture within the allowable working time to the substrate by applicable techniques such as brush or roller;
- d) check wet-film thickness on a frequent basis using a wet-film thickness gauge and correct insufficient film-thickness within the over-coating time and in accordance with the APS.

13.4.2 Overlap

If applicable, the overlap of the liquid-applied epoxy coating on existing coatings shall be in accordance with the manufacturer's instructions and shall be included in the APS.

13.5 Testing of the coatings

13.5.1 General

If required, the tests in [13.5.2](#) to [13.5.12](#), summarized in [Table 21](#), shall be carried out for the TA, PQT, PPT and production testing.

Test and inspection frequencies for TA, PQT, PPT and production testing are included in [Table 3](#) and [Table 22](#).

[Annex B](#) provides the tests, acceptance criteria, and inspections and test frequencies for coatings applied on wet substrates, if required.

The tests shall be carried out on coated pipes. When agreed between client and manufacturer, samples cut from coated pipe or flat surfaces can be used.

Where applicable, the substrate conditions used for tests shall be in accordance with [9.1](#).

For the purposes of this subclause, the coating has been subdivided as follows:

- Type 13A: liquid epoxy coating applied on dry substrate;
- Type 13B: liquid epoxy coating applied on wet and immersed substrate.

13.5.2 Dry-film thickness

The DFT requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

[Annex B](#) provides guidance for the thickness of coating type 13 applied to wet substrate.

The coating shall be visually inspected and shall have formed a continuous and uniform film free of sags, runs and striations. The DFT of the coating shall be measured using one of the methods as described in ISO 19840 or as otherwise agreed. The used method shall be documented. The thickness shall meet the requirements of [Table 21](#).

13.5.3 Holiday detection

The holiday detection requirement applies to coating type 13A only.

In the atmospheric zone, the entire dry surface of the riser coated with repair coating shall be checked for holidays or other discontinuities at a voltage of 5 kV/mm to a maximum of 25 kV in accordance with ISO 21809-3:2016, Annex C, and shall meet the requirements of [Table 21](#).

Holidays shall be repaired in accordance with the APS.

13.5.4 Hardness

The hardness requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

[Annex B](#) provides guidance for the thickness of coating type 13 applied to wet substrate.

Hardness Shore A or Shore D of the coating shall be checked using a suitable hardness gauge in accordance with ISO 868 and shall meet the requirements of [Table 21](#).

13.5.5 Impact resistance

The impact resistance requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

The impact resistance of the coating shall be measured in accordance with ISO 21809-3:2016, Annex D, and shall meet the requirements of [Table 21](#).

13.5.6 Indentation resistance

The indentation resistance requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

The indentation resistance of the coating shall be measured at 23 °C and at maximum service temperature in accordance with ISO 21809-3:2016, Annex E, and shall meet the requirements of [Table 21](#).

13.5.7 Specific electrical insulation resistance

The specific electrical insulation resistance requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

The specific electrical insulation resistance of the coating applied on dry steel shall be measured in accordance with ISO 21809-3:2016, Annex F, and shall meet the requirements of [Table 21](#).

13.5.8 Cathodic disbondment resistance

The cathodic disbondment resistance requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

The cathodic disbondment of the coating applied on dry steel shall be measured over a period of 28 days at 23 °C and at maximum service temperature (limited to 95 °C maximum), in accordance with ISO 21809-3:2016, Annex G. The cathodic disbondment resistance shall be measured as the radius of disbondment and shall meet the requirements of [Table 21](#).

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.

13.5.9 Adhesion to pipe surface and existing coating

The adhesion to dry pipe surface and dry existing coating requirement applies to all types of coating specified in [13.5.1](#).

[Annex B](#) provides guidance for the adhesion of coating type 13 applied to wet substrate.

The adhesion of the coating applied to dry steel and dry existing coating shall be tested at 23 °C, in accordance with ISO 4624. The adhesion shall meet the requirements of [Table 21](#).

13.5.10 Thermal ageing resistance

The thermal ageing resistance requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

A thermal ageing test of the coating applied in dry conditions shall be carried out in accordance with ISO 21809-3:2016, M.3, for 100 days at $T_{\text{max}} + 20$ °C. After this test, the adhesion of the coating to the pipe surface and the existing coating shall be measured as specified in [13.5.9](#) and shall meet the requirements of [Table 21](#).

13.5.11 Hot-water immersion test

The hot-water immersion test requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

A hot water immersion test of the coating applied in dry conditions shall be carried out in accordance with ISO 21809-3:2016, Annex I. After this test, the adhesion of the coating to the pipe surface and the existing coating shall be measured as specified in [13.5.9](#) and shall meet the requirements of [Table 21](#).

13.5.12 Resistance to ageing and weathering

The resistance to ageing and weathering requirement applies to all types of coating applied to dry substrate as specified in [13.5.1](#).

[Annex B](#) provides guidance for the resistance to ageing and weathering of coating type 13 applied to wet substrate.

The resistance to ageing and weathering of the coating shall be measured in accordance with ISO 12944-9:2018, Table 4, on flat samples and shall meet the requirements as described in [Table 21](#).

Table 19 — Coating identification

Type of coating in accordance with Table 1
Coating manufacturer
Coating trade name
Minimum and maximum service temperature
Type (binder and hardener) and trade names of individual parts
Minimum dry film thickness of installed coating
Compatible existing coatings (state all types of existing coating that have been tested successfully)

Table 20 — Product data sheets

Property	Units	Test method
Manufacturer	—	—
Trade name	—	—
Type of coating material (binder and hardener)	—	—
Colour	—	—
Solid content	% (m/m)	ISO 3233-1
Density	g/cm ³	ISO 2811-1
Mix ratio	—	—
Coverage area	m ² /l	—
Minimum dry film thickness of installed coating	µm	ISO 19840
Storage conditions, including minimum and maximum temperature	—/°C	—
Minimum and maximum application temperature	°C	—
Minimum and maximum service temperature	°C	—
Shelf life at storage conditions	months	—

Table 21 — Requirements for liquid-applied epoxy coatings

Type	Clause	Property	Test temp.	Unit	Requirements	Test method
13A 13B	13.5.2	Visual inspection of coating film	—	—	Continuous, uniform, free of sags, runs, and striations	—
		NDFT	23 °C	mm	Rule 80/20	ISO 19840
13A —	13.5.3	Holiday detection at 5 kV/mm, max 25 kV	—	—	No holiday	ISO 21809-3:2016, Annex C
13A 13B	13.5.4	Hardness (Shore A or D)	—	—	Accordinging manufacturer specification	ISO 868
13A 13B	13.5.5	Impact resistance	23 °C	J/mm	≥ 3	ISO 21809-3:2016, Annex D
13A 13B	13.5.6	Indentation resistance at test pressure 10,0 N/mm	23 °C and T_{max}	% DFT	Indentation ≤ 30 % DFT	ISO 21809-3:2016, Annex E
13A 13B	13.5.7	Specific electrical insulation resistance	23 °C	$\Omega \cdot m^2$	≥ 1,0 ^{E+06}	ISO 21809-3:2016, Annex F
		– Rs_{100} – Rs_{100}/Rs_{70}		—	≥ 0,8 ^b	
13A 13B	13.5.8	Cathodic disbondment resistance at 28 days	23 °C	mm	Disbondment ≤ 8	ISO 21809-3:2016, Annex G
			T_{max}		Disbondment ≤ 15	
13A 13B	13.5.9	Adhesion to dry pipe surface	23 °C	MPa	≥ 10	ISO 4624
13A 13B	13.5.9	Adhesion to dry existing coating other than polyolefin ^a	23 °C	MPa	≥ 10	ISO 4624
13A 13B	13.5.9	Adhesion to dry existing polyolefin coating ^a	23 °C	MPa	≥ 3,5	ISO 4624
13A 13B	13.5.10	Adhesion to dry pipe surface after thermal ageing for 100 days at $T_{max} + 20$ °C	23 °C	MPa	≥ 5	ISO 21809-3:2016, M.3
						ISO 4624
13A 13B	13.5.10	Adhesion to dry existing coating other than polyolefin after thermal ageing for 100 days at $T_{max} + 20$ °C ^a	23 °C	MPa	≥ 5	ISO 21809-3:2016, M.3
						ISO 4624
13A 13B	13.5.10	Adhesion to dry existing polyolefin coating after thermal ageing for 100 days at $T_{max} + 20$ °C ^a	23 °C	MPa	≥ 2	ISO 21809-3:2016, M.3
						ISO 4624
13A 13B	13.5.11	Adhesion to dry pipe surface after hot water immersion for 28 days at T_{max}	23 °C	MPa	≥ 5	ISO 21809-3:2016, Annex I
						ISO 4624
13A 13B	13.5.11	Adhesion to dry existing coating after hot water immersion for 28 days at T_{max} ^a	23 °C	MPa	≥ 2	ISO 21809-3:2016, Annex I
						ISO 4624