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

Part 2: Fusion-bonded epoxy coatings

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

Partie 2: Revêtements à base de résine époxydique appliquée par fusion

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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.

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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

ISO 21809 consists of the following parts, under the general title *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems*:

— *Part 1: Polyolefin coatings (3-layer PE and 3-layer PP)*

— *Part 2: Fusion-bonded epoxy coatings*

— *Part 3: Field joint coatings*

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

— *Part 5: External concrete coatings*

Bitumen, asphalt and coaltar, liquid, thermal insulation, and epoxy polyamide powder coatings are to form the subjects of future parts 6, 7, 8 and 9.

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Introduction

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

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

Part 2: Fusion-bonded epoxy coatings

1 Scope

This part of ISO 21809 specifies the requirements for qualification, application, testing and handling of materials for plant application of single-layer fusion-bonded epoxy (FBE) coatings applied externally for the corrosion protection of bare steel pipe for use in pipeline transportation systems for the petroleum and natural gas industries as defined in ISO 13623.

High-temperature coatings with a glass transition of above 120 °C or FBE primer coatings for three- or multi-layer polyethylene or polypropylene coatings are not covered by this part of ISO 21809.

NOTE Pipes coated in accordance with this part of ISO 21809 are considered suitable for additional protection by means of cathodic protection.

2 Normative references

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

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

ISO 8130-2, *Coating powders — Part 2: Determination of density by gas comparison pyknometer (referee method)*

ISO 8130-3, *Coating powders — Part 3: Determination of density by liquid displacement pyknometer*

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

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

ISO 8502-6, *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness — Part 6: Extraction of soluble contaminants for analysis — The Bresle method*

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

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ISO 8503-4, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile — Stylus instrument procedure*

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

ISO 10474:1991, *Steel and steel products — Inspection documents*

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

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

ISO 13623:2000, *Petroleum and natural gas industries — Pipeline transportation systems*

EN 10204:2004, *Metallic products — Types of inspection documents*

SSPC-AB 1[1)], *Mineral and Slag Abrasives*

SSPC-AB 2, *Cleanliness of Recycled Ferrous Metallic Abrasives*

SSPC-AB 3, *Ferrous Metallic Abrasive*

SSPC-SP 1, *Solvent cleaning*

3 Terms and definitions

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

3.1
applicator
company that undertakes the coating application in accordance with the provisions of this part of ISO 21809

3.2
batch
quantity of epoxy powder produced using the same formulation and raw materials of the same source during a continuous production run of not more than 8 h

3.3
batch certificate
certificate of analysis issued by the manufacturer

3.4
by agreement
agreed between manufacturer and purchaser

[ISO 14313:—]

3.5
certificate of compliance
document issued according to ISO 10474 or EN 10204 stating compliance with the purchase order for coated pipes, but without mention of any test results, issued in accordance with the purchasing requirements

3.6
cutback
length of pipe left uncoated at each end for joining purposes

1) SSPC: The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburg. PA 15222-4656, USA.

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3.7
glass transition
reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one

[ISO 11357-2:1999]

3.8
glass transition temperature
approximate midpoint of the temperature range over which the glass transition takes place

NOTE The assigned glass transition temperature, T_g, can vary, depending on the specific property and on the method and conditions selected to measure it.

[ISO 11357-2:1999]

3.9
holiday
coating discontinuity that exhibits electrical conductivity when exposed to a specific voltage

3.10
laboratory-coated test specimen
specimen taken from a laboratory-prepared panel

3.11
manufacturer
company responsible for the manufacture of coating material(s)

3.12
manufacturer's specification
document that specifies the characteristics, test requirements and application recommendations for the coating materials

3.13
pipe diameter length
any length along the pipe axis equal to the specified outside diameter of the pipe

3.14
pipeline
those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances, up to and including the isolating valves

[ISO 13623:2000]

3.15
pipeline transportation system
pipeline with compressor or pump stations, pressure control stations, flow control stations, metering, tankage, supervisory control and data acquisition system (SCADA), safety systems, corrosion protection systems, and any other equipment, facility or building used in the transportation of fluids

3.16
purchaser
company responsible for providing the product order requirements

3.17
test report
document that provides the quantitative test results for tests conducted in accordance with the requirements of this part of ISO 21809

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3.18
test ring
sample taken from production-coated pipe

3.19
Inspection certificate 3.1.B
Inspection certificate 3.1
document in accordance with ISO 10474 or EN 10204 giving the results of the testing of coated pipes, supplied and signed by a representative of the applicator authorized to issue such documents

4 Symbols and abbreviated terms

4.1 Symbols

C percentage conversion of FBE coating

d thickness

ΔH exothermic heat of reaction

M mass

T_g glass transition temperature in degrees Celsius (°C)

ΔT_g variation of the glass transition temperature in degrees Celsius (°C)

w_{ep} mass fraction of the epoxy power retained on a sieve, expressed as a percent of total sample

w_m mass fraction of moisture, expressed as a percent

4.2 Abbreviations

d.c. direct current

DSC differential scanning calorimetry

FBE fusion-bonded epoxy

HRC Rockwell “C” scale hardness

ID inner diameter

OD outer diameter

ppd per pipe diameter

5 General requirements

5.1 Rounding

Unless otherwise stated in this part of ISO 21809, to determine conformance with the specified requirements, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with ISO 31-0:1992, Annex B, Rule A.

NOTE For the purposes of this provision, the rounding method of ASTM E29 is equivalent to ISO 31-0:1992, Annex B, Rule A.

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5.2 Compliance to standard

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

NOTE ISO/TS 29001 gives sector-specific guidance on quality management systems and ISO 14001 gives guidance on the selection and use of an environmental management system.

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

6 Information supplied by the purchaser

6.1 General information

The purchase order shall include the following information:

a) number of this part of ISO 21809 and year of publication (ISO 21809-2:2007);

b) pipe quantity, outside diameter, minimum wall thickness, minimum, maximum and nominal length, grade of steel;

c) bare pipe standard or specification designation, e.g. ISO 3183;

d) minimum thickness and maximum permissible thickness of the coating;

e) cutback length and tolerances for both ends of pipe;

f) maximum pipeline design temperature (°C).

6.2 Additional information

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

a) additional surface treatments;

b) plant inspection by the purchaser;

c) increased test ring length;

d) test ring location;

e) test frequency for additional test rings;

f) additional markings;

g) handling procedures;

h) storage procedures;

i) waiver of test reports;

j) other special requirements.

7 Materials

7.1 Pipe

The pipe being coated shall conform to the pipe standard or specification that is specified in the purchase order.

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CAUTION — Pipe conforming to such standards or specifications does not necessarily have a surface condition that is appropriate for the application of FBE coating, e.g. temporary coating, salt contamination, slivers.

7.2 Epoxy powder

7.2.1 General

The applicator shall use epoxy powder that is

a) certified by the powder manufacturer to be in accordance with the requirements of 7.2.2 and 8.1, and compatible with the requirements of 10.2.2;

b) identified with the following:

- powder manufacturer's name,
- product description,
- mass of material,
- batch number,
- location of manufacture,
- manufacturing identification number,
- temperature requirements for transportation and storage,
- year, month and day of manufacture,
- expiry date;

c) handled, transported, and stored prior to use in accordance with the powder manufacturer's recommendations.

7.2.2 Properties

Each batch of epoxy powder shall be tested by the manufacturer in accordance with the requirements of Table 1. Test results shall be reported in accordance with ISO 10474 and shall be made available to the applicator upon request. A batch certificate shall be provided by the manufacturer to the applicator.

Table 1 — Minimum requirements for epoxy powder

Properties	Requirements	Test method
Cure time	within the manufacturer's specification	Clause A.2
Gel time	within the manufacturer's specification	Clause A.3
Total volatile/moisture content by mass	$\leqslant$ 0,6 %	Clause A.5
Particle size	maximum retained on 150 µm and 250 µm sieves within the manufacturer's specification	Clause A.6
Density	within the manufacturer's specification	Clause A.7
Thermal characteristics	within the manufacturer's specification	Clause A.8

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7.2.3 Packaging

The powder shall be contained in packaging that is clearly labelled to identify the items specified in 7.2.1 b).

8 Coating qualification

8.1 Qualification by manufacturer

The coating shall be qualified by the manufacturer through testing laboratory-coated test specimens for each applicable test and by meeting the acceptance criteria. Laboratory-coated test specimens shall be prepared in accordance with 8.3.

The qualification shall be repeated if there is a change in one or both of the following:

a) coating formulation;

b) location of product manufacture.

The tests conducted, the number of test specimens, the test methods used and the acceptance criteria shall be as given in Table 2. These test results shall be reported in accordance with ISO 10474 and shall be made available to the applicator upon request.

Table 2 — Minimum requirements for coating qualification testing

Properties	Acceptance criteria	Number of test specimens	Test method
Thermal characteristics	meets the manufacturer's specification and be at least 5 °C above maximum pipeline design temperature	1	Clause A.8
Cathodic disbondment: 24 h, 6 °C ± 3 °C, – 3,5 V	⩽ 8 mm disbondment	3	Clause A.9
24 h hot-water adhesion 65 °C ± 3 °C	Rating of 1 to 2	3	Clause A.15
28 day hot-water adhesion 65 °C ± 3 °C	Rating of 1 to 3	3	Clause A.15
Cathodic disbondment: 28 day, 20 °C ± 3 °C, – 1,5 V	⩽ 8 mm disbondment	3	Clause A.9
Cathodic disbondment: 28 day, 65 °C ± 3 °C, – 1,5 V	⩽ 15 mm disbondment	3	Clause A.9
Cross-section porosity	less than or equal to that illustrated in Figure A.10	1	Clause A.11
Interface porosity	less than or equal to that illustrated in Figure A.11	1	Clause A.11
Flexibility at 0 °C	no cracking at 2,0°ppd length	5	Clause A.12
Impact	⩾ 1,5 J	3	Clause A.13
Strained coating, cathodic disbondment 28 day, 20 °C ± 3 °C, – 1,5 V	no cracking	3	Clause A.14

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8.2 Qualification by applicator

The production coating shall be qualified by the applicator for each coating line. Applicator shall use coating materials qualified in accordance with the requirements of 8.1.

Qualification shall be achieved by successful evaluation of laboratory-coated specimens and pipe coated using the specified coating line. The requirements for testing of laboratory-coated specimens are given in Table 3 and the requirements for testing pipe samples are given in Table 4.

The qualification shall be repeated in case of essential modifications of the coating line, coating materials and coating procedures.

Table 3 — Minimum requirements for laboratory-applied coating testing by the applicator

Properties	Requirements	Number of specimens	Test method
Cathodic disbondment: 24 h, 65 °C ± 3 °C, – 3,5 V	⩽ 8 mm disbondment	1	Clause A.9
Cross-section porosity	less than or equal to that illustrated in Figure A.10	1	Clause A.11
Interface porosity	less than or equal to that illustrated in Figure A.11	1	Clause A.11
Flexibility at 0 °C	no cracking at 2,0°ppd length	3	Clause A.12
Hot-water adhesion: 24 h, 65 °C ± 3 °C	Rating 1 to 3	1	Clause A.15

Table 4 — Minimum requirements for qualification and production-coating testing

Properties	Requirements	Number of specimens	Test method
Degree of cure [a]: DSC – ΔT_g	meets manufacturers specification	1	Clause A.8
Porosity	less than or equal to that illustrated in Figures A.10 and A.11	1	Clause A.11
Dry adhesion [a]	rating of 1 or 2	1	Clause A.4
Impact	⩽ 1,5 J [c]	1	Clause A.13
Flexibility [b] at 0 °C; for coating thickness of 350 µm – 500 µm	no cracking at 2,0°ppd length	3	Clause A.12
Hot-water adhesion: 24 h, 65 °C	rating of 1 to 3	1	Clause A.15
Cathodic disbondment: 24 h, 65 °C ± 3 °C, – 3,5 V	8 mm maximum disbondment	1	Clause A.9
Interface contamination	30 % maximum	1	Clause A.10

[a] This test can be done on the pipe or on a test ring.

[b] For greater coating thicknesses, testing is done by agreement between the purchaser and applicator.

[c] There shall be no holiday.

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8.3 Preparation of laboratory-coated test specimens

Test specimens shall be mild steel and shall have dimensions in accordance with the applicable test method (see Annex A). The substrate shall be abrasively blast cleaned with steel grit (ISO 11124-3) to provide a cleanliness in accordance with the minimum requirements of ISO 8501-1:2007, grade Sa 2½.

The surface profile shall have a peak-to-trough height of between 50 µm and 100 µm as measured in accordance with the requirements of ISO 8503-4 (Stylus method), or ISO 8503-5 (Replica tape method).

The thickness of coating on the completed test specimen shall be 350 µm to 500 µm. This should be measured by a calibrated coating thickness gauge verified to ± 5 % of full scale range.

9 Production application practices and equipment

9.1 General

The coating to be applied during production shall have been previously qualified in accordance with the requirements of 8.2.

9.2 Surface preparation

9.2.1 Initial preparation

All dirt, deleterious matter and contaminants, such as oil and grease, shall be removed from the pipe prior to coating. If necessary, pipe shall be cleaned in accordance with the requirements of SSPC-SP 1.

All steel defects and irregularities (e. g. laminations, slivers, scratches) shall be removed by an approved grinding method. Grinding of steel defects shall not reduce the wall thickness below the specified minimum wall thickness of the pipe.

All pipe shall be dry prior to entering the abrasive blast cleaning unit(s). Pipe temperature shall be at least 3 °C above the dew point immediately prior to abrasive blast cleaning.

9.2.2 Abrasive blast cleaning

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

NOTE If the pipe being coated is of a high-strength grade, e.g. X80, X100 or X120, harder abrasives can be needed to provide the required cleanliness and surface profile.

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

The cleanliness achieved at entry to the application line shall be in accordance with the requirements of ISO 8501-1:2007, grade Sa 2½ (“near white metal”).

The height of the surface profile attained shall be within 50 µm and 100 µm as measured in accordance with the requirements of ISO 8503-4 (Stylus method) or ISO 8503-5 (Replica tape method).

If grinding is required after blast cleaning, the maximum allowable area of grinding shall be 10 cm^2 per metre of pipe length.

9.2.3 Surface cleanliness

The surface cleanliness shall be measured in accordance with the requirements of ISO 8502-3 (Pressure-sensitive tape method). The maximum allowable level shall be class 2.

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9.2.4 Surface pre-treatment

If the applicator chooses a surface pre-treatment (e. g. deionized water, phosphoric acid and/or chromate pre-treatment) the pre-treatment process shall be agreed with the purchaser.

If surface pre-treatment is used for qualification, it shall be used for production.

If surface pre-treatment is not used, testing for the presence of soluble salts on pipe shall be undertaken in accordance with the requirements of ISO 8502-6 or ISO 8502-9. The maximum allowable level shall be 20 mg/m^2 after blasting.

If high levels (above 20 mg/m^2) of soluble salts are measured, a surface pre-treatment cleaning process shall be agreed upon by the applicator and the purchaser.

9.3 Application and curing temperatures

Application and curing temperatures of the external pipe surface shall be as selected by the applicator within the manufacturer's recommendation and shall not exceed 275 °C. The coating shall be allowed to cure in accordance with the qualified coating procedure before being quenched in water, to permit handling if required.

CAUTION — For grades over X80, the maximum curing temperature can effect the pipe properties.

9.4 Coating thickness

The minimum thickness of the coating and the maximum permissible thickness of the coating shall be as specified in the purchase order. Except as allowed by 10.2.3.5, the minimum permissible thickness of the coating shall be 350 µm.

9.5 Cutback

The cutback length and tolerances for the FBE coating on both ends of the pipe shall be as specified in the purchase order.

10 Inspection and testing

10.1 Inspection

If specified in the purchase order, inspection shall be undertaken by the purchaser. All inspections shall be made at the place of application prior to shipment and shall be conducted without undue interference with the operation of the plant. The purchaser may require that the applicator set aside pipe as requested for inspection or testing, or both.

10.2 Testing

10.2.1 Gel time testing of incoming epoxy powder

For each pipe-coating order, gel-time tests shall be successfully completed on each batch of epoxy powder prior to its use for production coating. Such tests shall be conducted in accordance with the requirements of Clause A.3, and the acceptance criteria shall be as given in Table 1.

If the average gel time fails to conform to the specified requirements, the gel test shall be repeated using two additional samples taken from the batch. If both retests conform to the specified gel time requirement, the powder batch shall be accepted. If one or both retests fail to conform to the specified requirements, the powder batch shall be rejected.

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10.2.2 Coating testing

The applicator shall conduct the sample preparation, testing, and evaluation of coating in accordance with the requirements of Table 3 using coating with thicknesses complying to purchase requirements [see 6.1 d)].

The minimum testing frequency shall be one sample on every batch of epoxy powder received.

Prior to the use of the powder for production coating, laboratory-coated test specimens shall be prepared by the applicator at the proposed plant application temperature. The tests conducted, the number of test specimens used, the test methods used and the acceptance criteria shall be as given in Table 3.

If a Table 3 test fails to conform to the specified requirements, the applicator shall have the option of repeating that specific test using two additional samples taken from the batch. If both retests conform to the specified test requirements, the powder batch shall be accepted. If one or both retests fail to conform to the specified requirements, the specific powder batch shall be rejected.

Any batch of powder stored outside the manufacturer's specified storage conditions shall be retested to the requirements of 10.2.1 and 10.2.2.

10.2.3 In-process inspection/measurement by applicator

10.2.3.1 Surface finish

The surface finish shall be monitored and recorded a minimum of every 2 h during production to determine whether the cleanliness is in accordance with the requirements of 9.2.3 and 9.2.4.

10.2.3.2 Surface profile

At least once every 4 h of production, the external surface profile on two pipes shall be measured and recorded using a profilometer, replicating film or purchaser-approved equivalent. The profile shall be in accordance with the requirements of 9.2.2.

10.2.3.3 Visual inspection

After cleaning, each pipe shall be visually inspected for surface defects and surface imperfections that can cause holidays in the coating. Such surface imperfections shall be removed by grinding, provided that the remaining wall thickness is within specified limits. Pipe containing surface defects shall be rejected or repaired at the purchaser's option.

10.2.3.4 Application temperature

The surface temperature of the pipe during the epoxy-powder application shall be monitored and controlled within the limits agreed upon by the applicator, the purchaser and the powder manufacturer.

The method for measuring the pipe surface temperature shall also be agreed upon by the applicator, purchaser and powder manufacturer.

Once the coating temperature is established, the pipe temperature shall be measured and recorded at least once every hour.

10.2.3.5 Coating thickness

The coating thickness shall be measured at three random locations along each pipe length using a coating thickness gauge that is calibrated at least once every working shift (to a maximum of 12 h) against a thickness standard that is within $\pm$ 20 % of the nominal coating thickness specified in the purchase order. Such measured thickness values shall be recorded.

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If individual measured thickness values are less than 350 µm, the coating thickness of the affected pipes shall be measured along the pipe length at intervals not exceeding 1 m. The average of such measured values for each pipe shall be at least 350 µm and no individual value shall be less than 300 µm.

If the coated pipe does not meet the requirements of this subclause, it shall be stripped and recoated in accordance with the requirements of 11.3.

10.2.3.6 Holiday inspection

10.2.3.6.1 General

The entire coated surface of each length of pipe shall be inspected with a holiday detector having a search electrode made of conducting rubber or phosphor bronze wire.

For inspection, the direct current potential of the detector shall be set to exceed 5 V for each micrometre of nominal coating thickness. The detector shall be calibrated at least once every working shift (to a maximum of 12 h).

Inspection shall be performed when the temperature of the coating is less than 100 °C or as agreed upon between purchaser and applicator.

10.2.3.6.2 Acceptance criteria

No holidays shall be permitted in finished coating.

Coated pipe having holidays shall be repaired in accordance with the requirements of 11.2, provided that the number of holidays does not exceed the following:

a) for pipe smaller than 355,6 mm OD, 1,0 per metre length, determined by dividing the total number of holidays by the total pipe length, expressed in metres, for the individual pipe tested; or

b) for pipe 355,6 mm OD or larger, 0,7 per square metre, determined by dividing the total number of holidays by the total outside surface area, expressed in square metres, for the individual pipe tested.

If the quantity of holidays exceeds the applicable limit as specified above, or if the area of an individual holiday is equal to or greater than 250 cm^2, the affected pipe shall be stripped and recoated in accordance with the requirements of 11.3.

10.2.4 Production test rings

10.2.4.1 Facilities

The applicator shall have facilities available for the preparation, testing and evaluation of test ring samples for the tests required in Table 4.

10.2.4.2 Test rings

Test rings shall be obtained from locations at least 300 mm from the end and shall be of sufficient size to provide the mandatory tests as described in Table 4.

Heat-affected or cold-hardened zones shall be considered when preparing test specimens.

10.2.4.3 Testing requirements

The minimum test frequency, for each production line, shall be one test ring per pipe diameter and specified wall thickness every working shift (to a maximum of 12 h).

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For pipe that is stripped and recoated, at least one test ring of the stripped and recoated pipe shall be taken for each order item. If specified in the purchase order, additional test rings shall be taken.

For each test ring, the tests conducted, the number of test specimens used, the test method used and the acceptance criteria shall be as given in Table 4.

10.2.4.4 Retests

If a test fails to conform to the specified requirements, either

a) the test (see Table 4, Column 2) that fails shall be repeated using two additional test samples (see 10.2.4.2) taken from the originally tested end of the affected pipe, or

b) all pipe coated after the previous acceptable test and prior to the next acceptable test shall be stripped and recoated in accordance with the requirements of 11.3.

If both retests conform to the specified requirements, the coated pipe shall be accepted.

If one or both of the retests fail to conform to the specified requirements, either

a) all pipe coated after the previous acceptable test and prior to the next acceptable test shall be stripped and recoated in accordance with the requirements of 11.3, or

b) subject to the approval of the purchaser, further retesting may be performed to determine which pipes coated after the previous acceptable test are acceptable. Pipes that are not acceptable shall be stripped and recoated in accordance with the requirements of 11.3.

If interface-contamination test results are inaccurate due to the influence of pre-treatment (e.g. colour), the coating may be deemed acceptable by agreement between purchaser and applicator.

10.3 Test results

Regardless of any waiver of test reports specified in the purchase order, the results of all tests required in 10.2 shall be available to the purchaser on request.

11 Repair of coated pipe

11.1 General

If required in Clause 9 or Clause 10, coated pipe shall be repaired in accordance with the requirements of 11.2 or by stripping or recoating in accordance with the requirements of 11.3, whichever is applicable.

11.2 Repair of holidays

The repair of holidays shall conform to the manufacturer's recommended procedures and the following requirements.

a) Areas of 6 mm in diameter or smaller shall be repaired with the powder manufacturer's recommended hot-melt patch stick, two-part coating or the purchaser approved equivalent.

b) Areas greater than 6 mm in diameter and less than 250 cm^2 in area shall be repaired with the powder manufacturer's recommended two-part coating, or the purchaser-approved equivalent;

c) The minimum thickness of the repaired coating shall be in accordance with the requirements of 9.4.

d) All repairs shall be holiday-tested in accordance with the requirements of 10.2.3.6.

e) The number of repairs per length of pipe shall be recorded.

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11.3 Stripping and recoating

The pipe surface shall be cleaned by a combination of heating to a temperature not to exceed 275 °C, scraping brushing and or abrasive blast cleaning. All previous coating shall be removed prior to the normal cleaning and coating process. Recoating shall be performed in accordance with the requirements of Clauses 9 and 10.

CAUTION — For grades over X80, the maximum stripping temperature can affect the pipe properties. The identity of each stripped pipe shall be recorded.

12 Markings

12.1 General

Coated pipe shall be marked in accordance with the requirements of 12.2 and with any additional markings specified in the purchase order. Additional markings as desired by the applicator shall be by agreement.

12.2 Required markings

The following markings shall be placed on the coating:

— applicator's name or mark;

— number of this part of ISO 21809 and year of publication (ISO 21809-2:2007);

— markings required by the applicable pipe specification or standard;

— date of coating application; and

— pipe manufacturer, pipe number, pipe OD and wall thickness.

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

13 Handling and storage in the coating area

13.1 Handling

Coated pipe shall be handled in a manner that avoids damage to the pipe, pipe ends and coating. If specified in the purchase order, the applicator shall submit details of the handling procedures; such procedures shall include loading requirements where the applicator is responsible for loading.

Pipe that is damaged during processing shall be repaired in accordance with the requirements of the applicable pipe specification or standard.

Coating that is damaged after the holiday inspection (see 10.2.3.6) shall be repaired in accordance with the requirements of Clause 11.

Coated pipe shall have full encirclement separators around each length. Such separators shall be sized and located in order to prevent damage to the coating.

13.2 Storage

If specified in the purchase order, the applicator shall submit details of the facilities and the methods to be used for yard storage.

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14 Test reports and certificate of compliance

Unless specified otherwise in the purchase order, an Inspection certificate of type 3.1.B according to ISO 10474:1991 (or type 3.1 according to EN 10204:2004) shall be issued by the applicator, which provides the results from the inspection and testing of the coated pipes in accordance with the requirements of this part of ISO 21809 and any other requirements specified in the purchase order. If, however, in the purchase order, the purchaser does waive the requirement for an Inspection certificate, then the applicator should provide a certificate of compliance.

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Annex A
(normative)

Test methods

A.1 General

This annex contains the test methods referenced in ISO 21809-2.

A.2 Cure time of the epoxy powder

A.2.1 Equipment

The equipment shall consist of the following:

A.2.1.1 **Hotplate**, controllable to within 3 °C.

A.2.1.2 **Metal plate**, approximately 25 mm × 150 mm × 150 mm.

A.2.1.3 **Contact thermometer**.

A.2.1.4 **Timing device**.

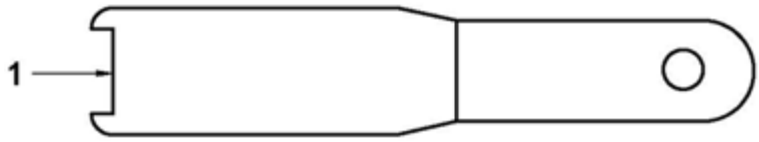
A.2.1.5 **Draw-down tool** (see Figure A.1).

A.2.1.6 **Spatula**.

A.2.1.7 **Differential scanning calorimeter (DSC)**, with cooling accessory.

A.2.1.8 **Utility knife**, having a length, without the blade, of 135 mm ± 20 mm and a one-piece metal blade, 0,65 m ± 0,1 m thick, with an exposed cutting edge of 25 mm ± 5 mm with other dimensions as shown in Figure A.2.

Dimensions in millimetres



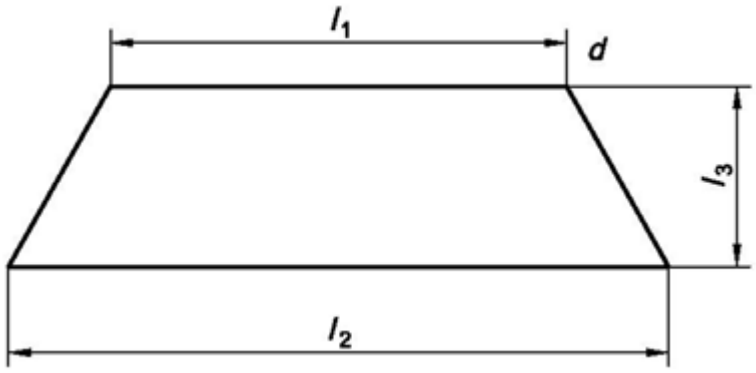
Key

1 notch: (25 ± 1) mm × (0,9 ± 0,1) mm

Figure A.1 — Draw-down tool

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Dimensions in millimetres



l_1 30 mm ± 5 mm

l_2 57 mm ± 5 mm

l_3 18 mm ± 3 mm

Figure A.2 — Utility knife blade

A.2.2 Procedure

A.2.2.1 Heat and maintain the metal plate temperature at 232 °C ± 3 °C.

A.2.2.2 Use the draw-down tool to deposit a film of epoxy powder on the metal plate to achieve a film thickness of 350 µm to 500 µm. Start the timing device at the instant of powder deposition on the hotplate surface.

A.2.2.3 Before the film has gelled completely, scribe the film generally as shown in Figure A.3, using the utility knife or spatula to produce 10 strips of coating.

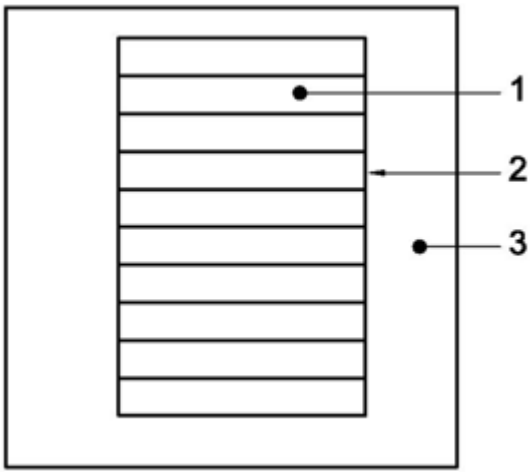
A.2.2.4 Following 30 s ± 1 s after the timing device has started, using the utility knife, remove a strip of coating and immediately quench it in cold water.

A.2.2.5 For each additional 30 s ± 1 s of elapsed time, repeat the operation required by A.2.2.4. Remove the coating strips in sequential order following the direction of film drawn, starting at the beginning of the draw.

A.2.2.6 Using the differential scanning calorimeter, determine the change in glass transition value, ΔT_g, or the percentage conversion, C, in accordance with the requirements of A.8.4.3.1 or A.8.4.3.2, respectively.

A.2.2.7 As specified by the powder manufacturer, plot time versus ΔT_g or time versus the percentage conversion.

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Key

1 coating
2 division made with knife or spatula
3 metal plate

Figure A.3 — Cure film

A.2.3 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— time, in seconds, corresponding to a ΔT_g of 2 °C, or the time in seconds corresponding to a conversion, C, of 99 %.

A.3 Gel time of the epoxy powder

A.3.1 Equipment

The equipment shall consist of the following:

A.3.1.1 **Hotplate**, controllable to within 3 °C.

A.3.1.2 **Metal plate**, for placing on top of the hotplate.

A.3.1.3 **Stopwatch** or **electric timing device**, capable of measuring 0,1 s intervals.

A.3.1.4 **Draw down tool** (see Figure A.1).

A.3.2 Procedure

A.3.2.1 Conduct three tests and average the results.

A.3.2.2 Heat and maintain the temperature of the metal plate surface that will be in contact with the powder at a temperature of 205 °C ± 3 °C.

A.3.2.3 Cover the bottom 25 mm of the draw-down tool with epoxy powder.

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A.3.2.4 In a smooth motion, deposit and draw the epoxy powder across the metal plate while holding the tool at an angle of approximately 45° to the metal plate, thereby creating a tongue of epoxy powder approximately 25 mm wide.

NOTE The target thickness of the cured film is 350 µm to 500 µm.

A.3.2.5 Start the timing device at the instant of powder deposition on the metal plate.

A.3.2.6 The draw-down tool is held at an angle of approximately 45° to the hot plate surface, in a manner that allows most of the tool's weight to be borne on the plate. Repeatedly draw the edge of the tool through the melted epoxy powder. Stop the timing device when the tool rides up on the gelled powder and no longer contacts the metal plate, as illustrated in Figure A.4.

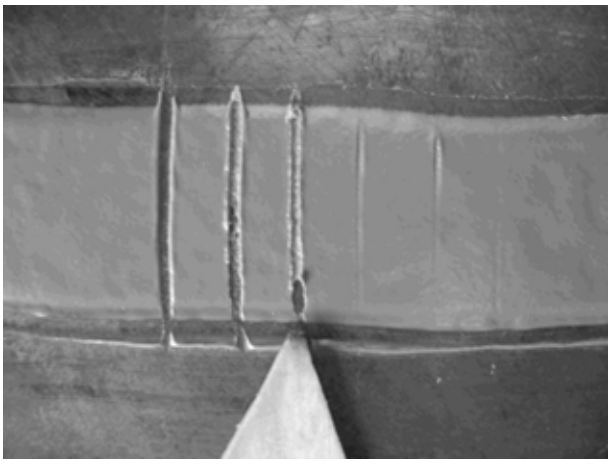


Figure A.4 — Gel time assessment

A.3.3 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— gel time, expressed in seconds.

A.4 Dry adhesion test

A.4.1 Equipment

The following equipment is required

A.4.1.1 **Utility knife**, see A.2.1.8.

A.4.2 Test specimens

Test can be carried out *in situ* on pipe or on a laboratory sample/test ring.

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A.4.3 Procedure

A.4.3.1 Inscribe a V-cut with two 20 mm lines intersecting at approximately 5 mm from their ends at 30° to 45°.

A.4.3.2 Insert the blade of the knife at the point of the V-cut, 45° to the surface, then with an upward flicking action attempt to dislodge the coating within the V. If little or no coating is removed, repeat this action within the V at least four times to confirm the integrity of the coating.

A.4.3.3 Examine the appearance of the disbonded surface and compare with the following ratings.

— Rating 1: Coating is not removed cleanly at any point in the V-cut. The entire profile contains some adherent coating.

— Rating 2: Coating is removed in small chips with some difficulty. Substantial coating remains adhered to the surface profile.

— Rating 3: Coating is removed in chips that are slightly larger in area than the knife point inserted under the coating. Some of the coating remains adhered to the surface of the steel within the V-cut.

— Rating 4: Coating is removed with no chipping of the coating and minimal resistance. No coating remains adhered to the steel within the V-cut.

A.4.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— adhesion rating.

Testing of production coating requires pipe number or identification.

A.5 Total volatile/moisture content of the epoxy powder — Mass loss

A.5.1 **Procedure A** (manual procedure)

A.5.1.1 Equipment

The equipment shall consist of the following:

A.5.1.1.1 **Oven**, controllable to within 3 °C.

A.5.1.1.2 **Balance**, accurate to 0,001 g.

A.5.1.1.3 **Desiccator**.

A.5.1.1.4 **Sample container**.

A.5.1.2 Procedure

A.5.1.2.1 Weigh the sample container to the nearest 0,001 g. Transfer approximately 10 g of epoxy powder into the sample container and spread evenly. Weigh the sample container and epoxy powder to the nearest 0,001 g.

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A.5.1.2.2 Place the sample container with the epoxy powder into the oven for a maximum of 2 h at 105 °C ± 3 °C.

Remove the container from the oven, and place it in a desiccator to cool. Weigh the sample container when it has cooled to 20 °C ± 3 °C, and then return it to the desiccators; repeat at intervals of 60 min ± 10 min until two consecutive mass determinations are within 0,001 g.

A.5.1.2.3 Calculate the percentage moisture, w_m, expressed in percent, using Equation (A.1):

$$w_m = \frac{M_i - M_f}{M_i - M_c} \times 100 \quad \text{(A.1)}$$

where

M_i is the initial mass of sample container and epoxy powder, expressed in grams;

M_f is the final mass of sample container and epoxy powder, expressed in grams;

M_c is the mass of sample container, expressed in grams.

A.5.2 **Procedure B** (automatic procedure)

The moisture content of the epoxy powder shall be determined using a machine that automatically determines moisture content by mass loss.

A.5.3 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— procedure used;

— percentage of moisture content.

A.6 Particle size of the epoxy powder

A.6.1 Equipment

The equipment required shall consist of the following:

A.6.1.1 **Air-jet sieving unit**, with vacuum cleaner attachment and 150 µm and 250 µm screens.

A.6.1.2 **Balance**, accurate to 0,01 g.

A.6.2 Procedure

A.6.2.1 Weigh the sieve and one screen to the nearest 0,01 g. Place approximately 20 g of epoxy powder onto the top of the screen, and record the weight of the powder to the nearest 0,01 g.

A.6.2.2 Place the sieve into the sieving unit, cover the unit, and secure it. Operate the sieving unit for 3 min and remove the cover.

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A.6.2.3 Remove the sieve, and weigh it to the nearest 0,01 g.

A.6.2.4 Calculate the percentage of epoxy powder, w_{ep}, retained on the screen as given in Equation (A.2):

$$w_{ep} = \frac{M_r - M_s}{M_p} \times 100 \quad \text{(A.2)}$$

where

M_p is the initial mass of powder placed on screen, expressed in grams;

M_r is the final mass of sieve, screen and retained powder, expressed in grams;

M_s is the initial mass of sieve and screen, expressed in grams.

A.6.2.5 Repeat, using the other screen.

A.6.3 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— percentage of powder retained for each screen size.

A.7 Density of the epoxy powder

A.7.1 General

At the option of the applicator, the density of the epoxy powder shall be determined using the procedure described in either A.7.2 or A.7.3. The test temperature shall be 20 °C ± 3 °C.

A.7.2 **Procedure A** (manual procedure)

A.7.2.1 Equipment

The equipment shall consist of the following:

A.7.2.1.1 **Balance**, accurate to 0,01 g.

A.7.2.1.2 **Flask**, 100 ml volumetric.

A.7.2.1.3 **Mineral spirits**.

A.7.2.2 Procedure

A.7.2.2.1 Weigh the flask to the nearest 0,01 g.

A.7.2.2.2 Add approximately 20 g of epoxy powder to the flask and weigh the flask plus epoxy powder to the nearest 0,01 g.

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A.7.2.2.3 Add sufficient mineral spirits to cover and wet the epoxy powder. Stopper the flask, and agitate it for several minutes, ensuring that neither air pockets nor lumps of powder exist. Wash the stopper and walls of the flask with mineral spirits until they are free of powder and the flask is filled to the 100 ml level. Weigh the flask plus epoxy powder and mineral spirits to the nearest 0,01 g.

A.7.2.2.4 Empty the flask. Clean and dry the flask, add 100 ml of mineral spirits and weigh the flask plus mineral spirits to the nearest 0,01 g.

A.7.2.2.5 Calculate the density of the mineral spirits, ρ_s, expressed in grams per litre, using Equation (A.3):

$$\rho_s = \frac{\left(M_{fs} - M_f\right)}{0{,}1} \tag{A.3}$$

where

M_{fs} is the mass of flask plus mineral spirits, expressed in grams;

M_f is the mass of flask, expressed in grams.

A.7.2.2.6 Calculate the density of the epoxy powder, ρ_p, expressed as grams per litre, using Equation (A.4):

$$\rho_p = \frac{M_{fp} - M_f}{0{,}1 - \left(M_{fps} - M_{fp}\right)/\rho_s} \tag{A.4}$$

where

M_{fp} is the mass of flask plus epoxy powder, expressed in grams;

M_f is the mass of flask, expressed in grams;

M_{fps} is the mass of flask plus epoxy powder and mineral spirits, expressed in grams;

ρ_s is the density of mineral spirits, expressed in grams per litre.

A.7.3 **Procedure B** (automatic procedure)

The density of the epoxy powder shall be determined using an air or helium pyknometer in accordance with ISO 8130-2 or ISO 8130-3.

A.7.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— procedure used;

— type of pyknometer used for Procedure B;

— density of the epoxy powder, expressed in grams per litre.

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A.8 Thermal analysis of epoxy powder and cured coating film

A.8.1 General

Thermal analysis is used to characterize the uncured epoxy powder and the cured coating film.

The method that shall be used is differential scanning calorimetry (DSC). The general procedure and definitions are given in ISO 11357-1. General handling and calibration shall be performed as in ISO 11357-1 unless otherwise stated in this part of ISO 21809.

A.8.2 Equipment

The equipment shall consist of the following:

A.8.2.1 **Differential scanning calorimeter (DSC)**, with cooling accessory.

A.8.2.2 **Balance**, accurate to 0,1 mg.

A.8.2.3 **Press**, for sample encapsulation.

A.8.2.4 **Aluminium pans**, with covers.

A.8.2.5 **Supply of dry N_2**, analytical grade.

A.8.3 Procedure and measurement for epoxy powder

A.8.3.1 Measurement

The following heating cycles, starting with run (a) as the conditioning run, shall be performed.

— run (a): Heat the sample from 25 °C ± 5 °C to 70 °C ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

— run (b): Heat the sample from 25 °C ± 5 °C to 275 °C ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

— run (c): Heat the sample from 25 °C ± 5 °C to T_g + 40 °C (typically 150 °C) at a rate of 20 °C/min, then immediately cool the sample to 25 °C ± 5 °C.

For certain epoxy powders, different heating cycles can be necessary according to the instructions of the epoxy powder manufacturer.

A.8.3.2 Evaluation of results

A.8.3.2.1 Glass transition temperature, T_g

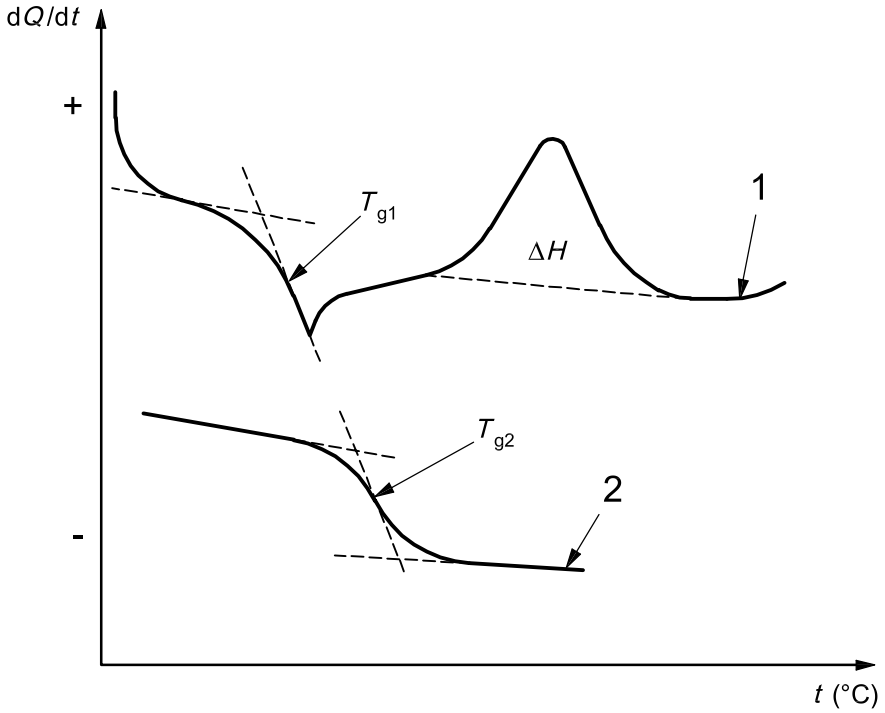
The T_g of the epoxy powder is calculated at the point of inflection intersection (see Figure A.5).

T_{g1}, the glass transition temperature of the uncured powder, is obtained by evaluating run (b) and T_{g2}, the glass transition temperature of the cured material, is obtained by evaluating run (c).

A.8.3.2.2 Heat of reaction of epoxy powder

The exothermic heat of reaction, ΔH, is obtained by integrating the exothermic peak of the DSC-scan.

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Key

1 run (b)
2 run (c)

Figure A.5 — Examples of thermal scans of epoxy powder

A.8.4 Procedure and measurement for coating sample

A.8.4.1 General

A representative sample of the cured film is taken.

Weigh in 10 mg ± 3 mg to an accuracy of 0,1 mg. The pan is sealed with the cover. Determine final weight after sealing.

Place the sample and the reference sample in the DSC cell and purge with dry N_2 gas.

A.8.4.2 Measurement

The following heating cycles, starting with run (a) as the conditioning run, shall be performed.

— run (a): Heat the sample from 25 °C ± 5 °C to 110 °C ± 5 °C at a rate of 20 °C/min and hold for 1,5 min, then cool the sample to 25 °C ± 5 °C.

— run (b): Heat the sample from 25 °C ± 5 °C to 275 °C ± 5 °C at a rate of 20 °C/min, then cool the sample to 25 °C ± 5 °C.

— run (c) Heat the sample from 25 °C ± 5 °C to T_g + 40 °C (typically 150 °C) at a rate of 20 °C/min, then cool the sample to 25 °C ± 5 °C.

For certain epoxy-powders, different heating cycles can be necessary according to instructions of the epoxy-powder manufacturer.

Samples taken from pipes that have been stored or buried shall be dried before testing.

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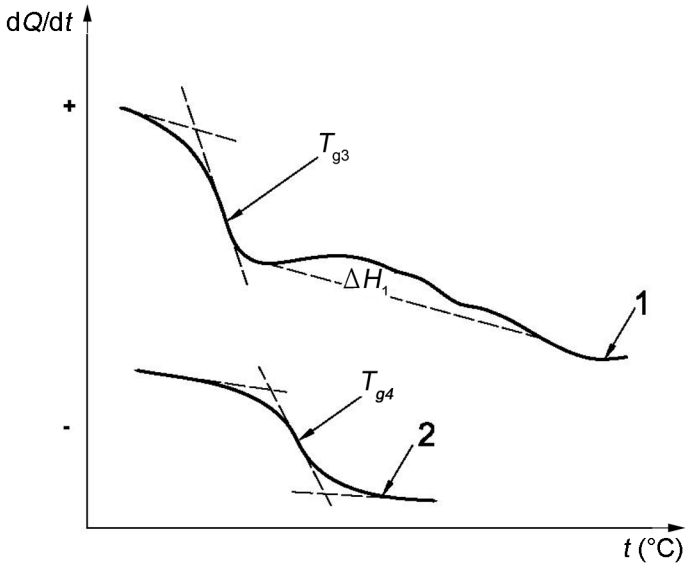
A.8.4.3 Evaluation of results

A.8.4.3.1 Glass transition temperature, T_g

The T_g for the coating is calculated as the inflection point (see Figure A.6), where T_{g3} is the glass transition temperature, expressed in degrees Celsius, of run (b) in A.8.4.2 and T_{g4} is the glass transition temperature, expressed in degrees Celsius, of run (c) in A.8.4.2.

For coatings, determine ΔT_g, the change in the glass transition temperature, expressed in degrees Celsius, value using Equation (A.5):

$$\Delta T_g = T_{g4} - T_{g3} \tag{A.5}$$



Key

1 run (b)
2 run (c)

Figure A.6 — Examples of thermal scans on coating

A.8.4.3.2 Residual heat of reaction of cured coating

The exothermic heat, ΔH_1, of reaction is obtained by integrating the exothermic peak of the DSC scan run (b) in A.8.4.2.

In a fully cured coating film, no residual heat of reaction should be observed.

The degree of conversion, C, can be calculated from Equation (A.6):

$$C = \frac{\Delta H - \Delta H_1}{\Delta H} \times 100 \tag{A.6}$$

where

ΔH is exothermic heat of reaction of the powder; run (b) in A.8.3.1;

ΔH_1 is exothermic heat of reaction of the powder; run (b) in A.8.4.2.

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A.8.5 Results

The following information shall be recorded:

— type of material and batch number;

— date of testing;

— type of DSC equipment;

— for the epoxy powder T_{g1}, T_{g2}, ΔH;

— for the cured coating film T_{g3}, T_{g4}, ΔT_g, ΔH_1 and C.

Testing of production coating requires pipe number or identification.

A.9 Cathodic disbondment of the coating

A.9.1 Equipment

The equipment shall consist of the following:

A.9.1.1 **Power supply**, rectified d.c., with controlled voltage output.

A.9.1.2 **Hotplate**, with a steel tray containing sand or steel grit/shot controllable to within 3 °C, or oven, controllable to within 3 °C.

A.9.1.3 **Calomel reference electrode**.

A.9.1.4 **Platinum wire electrode**, 0,8 mm.

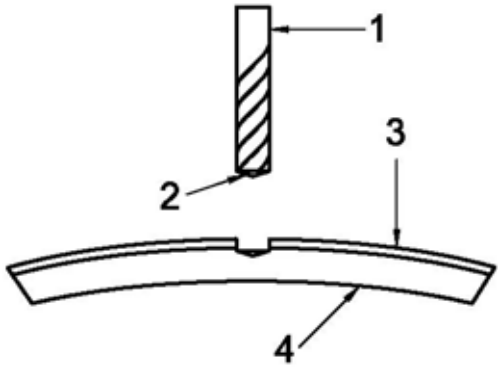
A.9.1.5 **Plastic cylinder**, 75 mm ± 3 mm ID.

A.9.1.6 **Sodium chloride**, 3 % solution in distilled water.

A.9.1.7 **Utility knife** (see A.2.1.8).

A.9.1.8 **Drill bit**, 3 mm to 6 mm (see Figure A.7).

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Key

1 fluted and mill-face mil Ø 3 mm to 6 mm
2 conic end
3 coating
4 steel

Figure A.7 — Production of an artificial defect

A.9.2 Test specimens

Laboratory-coated test specimens shall be approximately 6,4 mm × 100 mm × 100 mm. Specimens from test rings shall be approximately 100 mm × 100 mm × pipe wall thickness.

A.9.3 Procedure

A.9.3.1 Use only test specimens that are confirmed to be holiday-free with a holiday detector set at a minimum of 1 800 V.

A.9.3.2 Drill a 3 mm to 6 mm diameter holiday in the centre of the test specimen through the coating to expose the steel substrate (see Figure A.7).

A.9.3.3 Centre the plastic cylinder over the holiday and apply a sealant to form a water-resistant seal.

A.9.3.4 Fill the cylinder to a height of at least 70 mm with the sodium chloride solution that has been preheated to the test temperature. Mark the solution level on the cylinder. Insert the electrode into the solution and connect it to the positive wire from the d.c. power supply. Attach the negative wire from the d.c. power supply to a bare spot prepared on the test specimen.

A.9.3.5 Apply voltage (negative with respect to the calomel reference electrode) to the test specimen, and maintain constant temperature under one or more of the following test conditions, as given in Tables 2, 3 and 4:

a) 1,5 V, 20 °C ± 3 °C, for 28 d;

b) 3,5 V, 65 °C ± 3 °C, for 24 h;

c) 1,5 V, 65 °C ± 3 °C, for 28 d.

Maintain the solution level by the addition of distilled water as required (see Figures A.8 and A.9).

A.9.3.6 Upon test completion, dismantle the test cell, air cool the specimen to 20 °C ± 3 °C, and evaluate the cathodic disbondment characteristics of the test specimen within 1 h of the removal from heat.

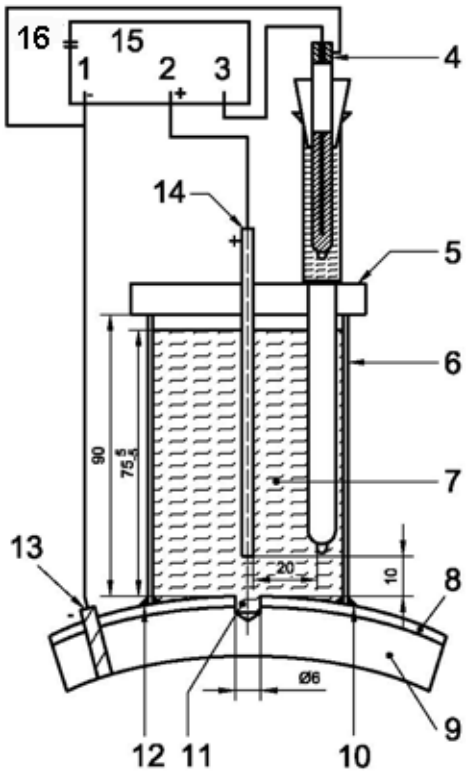
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A.9.3.7 Using the utility knife, make eight radial cuts through the coating to the substrate. Such cuts shall extend at least 20 mm from the centre of the holiday.

A.9.3.8 Insert the tip of the blade of the utility knife under the coating at the holiday. Using a levering action, chip off the coating. Continue until the coating demonstrates a definite resistance to the levering action.

A.9.3.9 Measure the disbonded distance from the edge of the original holiday along each radial cut, and average such measured values.

Dimensions in millimetres

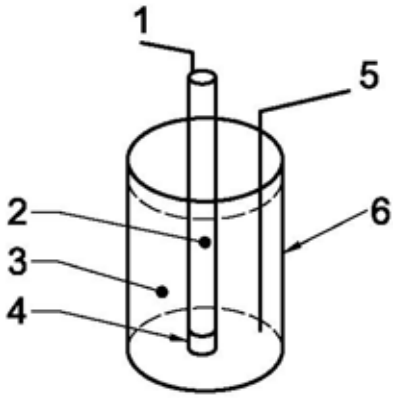


Key

1 working electrode
2 electrode (anode)
3 electrode (reference)
4 reference electrode
5 plastic cover
6 plastic pipe (minimum internal ∅ 75 mm)
7 electrolyte ⩾ 300 ml
8 coating
9 steel test piece
10 sealing material
11 artificial defect
12 sealing material
13 electrode (cathode)
14 platinum electrode ∅ 0,8 mm to 1,0 mm (anode)
15 rectified d.c. source
16 power supply

Figure A.8 — Electrolytic cell for NPS 4 and larger diameter pipe

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Key

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

Figure A.9 — Electrolytic cell for pipe smaller than NPS 4 diameter pipe

A.9.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— average disbondment value, expressed in millimetres.

Testing of production coating requires pipe number or identification.

A.10 Interface contamination of the coating

A.10.1 Equipment

The equipment shall consist of the following:

A.10.1.1 Stereo microscope.

A.10.1.2 Utility knife (see A.2.1.8).

A.10.2 Test specimens

Test specimens shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

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A.10.3 Procedure

A.10.3.1 Use the utility knife to remove a piece of coating approximately 3 mm × 20 mm from the test specimen bent in accordance with the requirements of A.11.3.1.

A.10.3.2 Examine the metal interface side of the coating with the stereo microscope at 40× magnification. Estimate the percentage of interface contamination.

A.10.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— percentage of interface contamination.

Testing of production coating requires pipe number or identification.

A.11 Porosity of the coating

A.11.1 Equipment

The equipment shall consist of the following:

A.11.1.1 **Stereo microscope**, magnification 40×.

A.11.1.2 **Bench vise** or **guided-bend jig**.

A.11.1.3 **Dry ice** or **freezer**.

A.11.1.4 **Utility knife** (see A.2.1.8).

A.11.2 Test specimens

Laboratory-coated test specimens shall be approximately 6,4 mm × 25 mm × 200 mm. Specimens from test rings shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

A.11.3 Procedure

A.11.3.1 Cool the test specimen to at least − 30 °C and bend it approximately 180° in the bench vise or guided-bend jig.

A.11.3.2 Pry off a piece of coating from the bent test specimen and examine the coating for porosity at 40× magnification.

A.11.3.3 Compare the porosity present in the coating to Figures A.10 and Figure A.11. If the porosity is equal to or less than that in the photos, rate the porosity as “pass”. If the porosity greater, then rate as “fail”.

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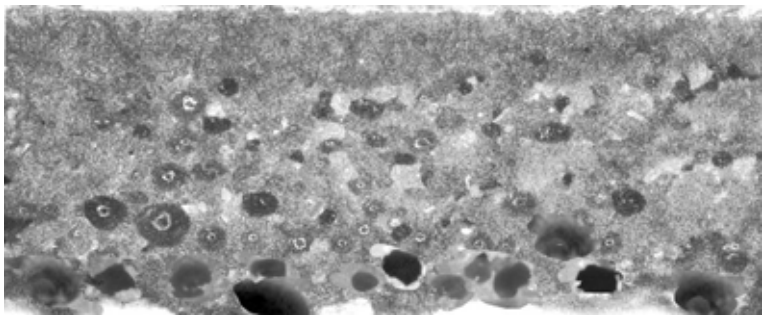


Figure A.10 — Maximum allowable cross-section porosity

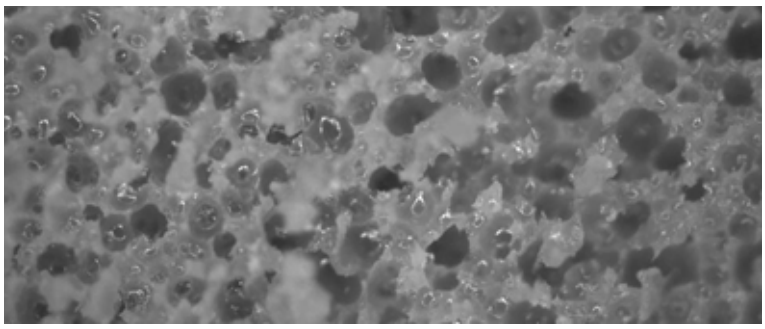


Figure A.11 — Maximum allowable interface porosity

A.11.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— cross-section porosity rating;

— interface porosity rating.

Testing of production coating requires pipe number or identification.

A.12 Flexibility of the coating

A.12.1 Equipment

The equipment shall consist of the following:

A.12.1.1 **Hydraulic press**.

A.12.1.2 **Bending mandrels**, with fixed radii.

A.12.1.3 **Freezer**.

A.12.1.4 **Strain gauges** (if applicable).

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A.12.2 Test specimens

Laboratory-coated test specimens shall be approximately 6,4 mm × 25 mm with a minimum length of 200 mm. Specimens from test rings shall be the pipe wall thickness with a width of 25 mm and a minimum length of 200 mm. The length of 200 mm dimension shall be parallel to the axis of the pipe.

A.12.3 Procedure

A.12.3.1 Smooth the coating on the edge of the sample to remove any potential stress risers. Place the test specimen in the freezer, cool it to 0 °C ± 3 °C, and hold for a minimum of 1 h.

A.12.3.2 Determine the sample thickness, d, which includes the specimen thickness and any curvature, by placing the specimen on a flat surface and measuring the thickness as shown in Figure A.12.

A.12.3.3 Determine the mandrel radius, R, that corresponds to an angle of deflection of 2°ppd length from Equation (A.7):

$$R = 28{,}15d \tag{A.7}$$

where

R is the mandrel radius, expressed in millimetres;

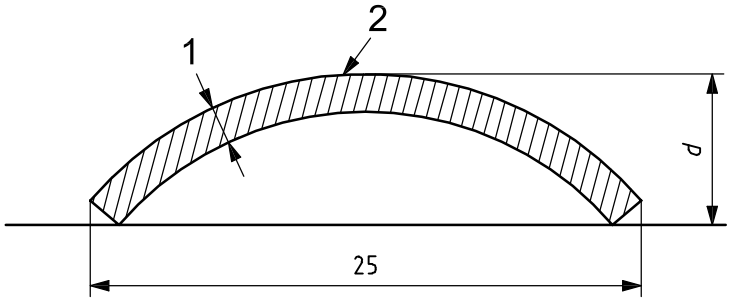
d is the sample thickness, expressed in millimetres.

A.12.3.4 Bend the test specimen over a mandrel whose radius is not larger than that determined in accordance with the applicable requirements of A.12.3.3. Bend the specimen such that the operation lasts no longer than 10 s and is completed within 30 s of the test specimen having been removed from the freezer.

NOTE Where the sample exhibits peaking, the percent strain can be calculated by the use of stain gauges attached to the test specimen.

A.12.3.5 Warm the bent test specimen to 20 °C ± 5 °C, and hold it in this temperature range for a minimum of 2 h. Within the next hour, visually inspect it for the presence of cracks.

Dimensions in millimetres



Key

1 pipe wall thickness
2 coating

Figure A.12 — Effective strap thickness diagram

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A.12.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— specified angle of deflection;

— cracking, if any.

Testing of production coating requires pipe number or identification.

A.13 Resistance to impact of the coating

A.13.1 Equipment

The equipment shall consist of the following:

A.13.1.1 **Impact tester**, with

— 1 kg falling mass,

— 15,8 mm diameter ball-bearing tup,

— 1 m long graduated slotted tube,

— for laboratory-coated specimen testing, flat anvils hardened to 55 HRC ± 5 HRC,

— for testing specimens from test rings, an anvil of 40 mm radius hardened to 55 HRC ± 5 HRC,

— attached wooden base measuring at least 600 mm × 600 mm × 600 mm, with the top of the base being hardwood.

A.13.1.2 **Holiday detector**, d.c.

A.13.1.3 **Freezer**.

A.13.2 Test specimens

Laboratory-coated test specimens shall be approximately 6,4 mm × 25 mm × 200 mm. Specimens from test rings shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

A.13.3 Procedure

A.13.3.1 Place the test specimen in the freezer, cool it to − 30 °C ± 3 °C, and hold it in this temperature range for a minimum of 1 h. Place the cooled specimen in the impact tester, centred on the applicable anvil.

A.13.3.2 Using an impact energy of at least 1,5 J, impact the specimen three times, with the impact points located at least 50 mm from each other. The three impacts shall be completed within 30 s of removal of the test specimen from the freezer. The ball bearing shall be rotated to an unused location after a maximum of 10 impacts and replaced after a maximum of 200 impacts.

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A.13.3.3 Allow the sample to warm to 20 °C ± 5 °C. Test for the presence of holidays with a d.c. holiday detector set at 1 750 V ± 250 V, or a wet-sponge holiday detector set at 67,5 V ± 4,5 V or 90 V ± 5 V.

A.13.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— applied impact energy value, expressed in joules;

— holiday detection voltage;

— number of holidays.

Testing of production coating requires pipe number or identification.

A.14 Cathodic disbondment of strained coating

A.14.1 Equipment

The equipment shall meet the requirements of A.9.1 and A.12.1, except that a 25 mm ± 2 mm internal diameter (ID) plastic cylinder shall be used.

A.14.2 Test specimens

Test sample of at least 50 mm × 300 mm × 6 mm are prepared.

A.14.3 Procedure

A.14.3.1 Bend the test samples in accordance with the method detailed under flexibility test method (Clause A.12) to give a deflection of 2,0°ppd.

A.14.3.2 Test the sample as detailed in the cathodic disbondment 28 day test method (Clause A.9) with the holiday at the apex of the bent sample, i.e. area of maximum strain.

A.14.3.3 After a 28 day polarization, remove the electrolyte and plastics tube and remove excess moisture.

A.14.3.4 The area of coating exposed to the electrolyte shall be examined within 24 h. To pass the test, the sample shall not exhibit signs of cracks, disbondment or pinholes when examined, as detailed in 10.2.3.6.

A.14.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— cracking, if any.

Testing of production coating requires pipe number or identification.

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A.15 Hot-water adhesion of the coating

A.15.1 Equipment

The equipment shall consist of the following:

A.15.1.1 **Slow cooker** or **non-corroding water bath**, temperature-controlled.

A.15.1.2 **Tap water**.

A.15.1.3 **Thermometer**.

A.15.1.4 **Utility knife** (see A.2.1.8).

A.15.2 Test specimens

Laboratory-coated test specimens shall be approximately 6,4 mm × 100 mm × 100 mm. Specimens from test rings shall be approximately 100 mm × 100 mm × pipe wall thickness.

A.15.3 Procedure

A.15.3.1 For each test, use fresh tap water that has been heated to 65 °C ± 3 °C prior to immersion of the test specimens. Place the test specimens in the slow cooker or water bath, and submerge them fully in such preheated water. Submerge the test specimens for a minimum of 24 h at a water temperature of 65 °C ± 3 °C, and then remove them from the slow cooker or water bath.

A.15.3.2 While the test specimen is still warm, use the utility knife to scribe an approximately 30 mm × 15 mm rectangle through the coating to the substrate, then air cool the test specimen to 20 °C ± 3 °C. Within 1 h after removal from heat (see A.15.3.1), insert the tip of the utility knife under the coating at a corner of the scribed rectangle. Use a levering action to remove the coating. Continue inserting the tip of the knife and levering it under the coating until either all of the coating in the rectangle is removed or the coating demonstrates a definite resistance to the levering action.

A.15.3.3 Rate the adhesion of the coating within the rectangle as follows:

— Rating 1: coating cannot be removed cleanly;

— Rating 2: less than 50 % of the coating can be removed;

— Rating 3: more than 50 % of the coating can be removed, but the coating demonstrates a definite resistance to the levering action;

— Rating 4: coating can be easily removed in strips or large chips;

— Rating 5: coating can be completely removed as a single piece.

A.15.4 Results

The following information shall be recorded:

— epoxy-powder batch number;

— date of testing;

— adhesion rating.

Testing of production coating requires pipe number or identification.

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