CSA Z245.20 Series:22

Plant-applied external coatings for steel pipe

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Preface

This is the fourth edition of the CSA Z245.20 Series, *Plant-applied external coatings for steel pipe,* which consists of the ninth edition of CSA Z245.20, *Plant-applied external fusion bond epoxy coating for steel pipe,* the eighth edition of CSA Z245.21, *Plant-applied external polyethylene coating for steel pipe,* and the fourth edition of CSA Z245.22, *Plant-applied external polyurethane foam insulation coating for steel pipe.* This edition of CSA Z245.20 supersedes the previous editions published in 2018, 2014, 2010, 2006, 2002, 1998, 1992, and 1986; this edition of CSA Z245.21 supersedes the previous editions published in 2018, 2014, 2010, 2006, 2002, 1998, and 1992; and this edition of CSA Z245.22 supersedes the previous editions published in 2018, 2014, and 2010.

These Standards cover the requirements for CSA Z662, Clause 9.2, Selection of external coatings for buried or submerged piping.

CSA Z245.20 deals with the requirements for plant-applied external fusion bond epoxy coating for steel pipe. The major changes to this edition are as follows:

- new definition for the term “plant”;
- revised requirements for quality and compliance;
- revised requirements for epoxy powder properties;
- revised wording for verification of coating thickness gauges;
- revised requirements for the calibration and verification of holiday detectors;
- revised requirements for coating repairs;
- revised test specimens size requirements for impact resistance test;
- revised requirements for gouge resistance test;
- added number of specimens required for epoxy powder properties tests;
- revised acceptance criteria for 28 d cathodic disbondment at 65 °C and 95 °C qualification tests;
- updated requirement for the evaluation of gel time versions of epoxy powder formulations; and
- revised production coating test requirements for 24 h cathodic disbondment at 65 °C test.

CSA Z245.21 deals with the requirements for plant-applied external polyethylene coating for steel pipe. The major changes to this edition are as follows:

- revised wording for verification of coating thickness gauges;
- revised requirements for the calibration and verification of holiday detectors;
- revised requirements for coating repairs; and
- added number of specimens required for all tests.

CSA Z245.22 deals with the requirements for plant-applied external polyurethane foam insulation coating for steel pipe. The major changes to this edition are as follows:

- revised requirements for external polyethylene jacket thickness;
- revised requirements for coating repairs;
- added number of specimens required for all tests;
- revised wording for verification of coating thickness gauges; and
- revised requirements for the calibration and verification of holiday detectors.

These Standards were prepared by the Subcommittee on Coatings, under the jurisdiction of the Technical Committee on Petroleum and Natural Gas Industry Pipeline Systems and Materials and the Strategic Steering Committee on Petroleum and Natural Gas Industry Systems, and have been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*
3) *This Standard was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Standard.*
4) *To submit a request for interpretation of this Standard, please send the following information to inquiries@csagroup.org and include "Request for interpretation" in the subject line:*
   a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
   b) *provide an explanation of circumstances surrounding the actual field condition; and*
   c) *where possible, phrase the request in such a way that a specific "yes" or "no" answer will address the issue.*

   Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are available on the* Current Standards Activities *page at standardsactivities.csa.ca.*
5) *This Standard is subject to review within five years from the date of publication. Suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line:*
   a) *Standard designation (number);*
   b) *relevant clause, table, and/or figure number;*
   c) *wording of the proposed change; and*
   d) *rationale for the change.*

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Plant-applied external fusion bond epoxy coating for steel pipe

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CSA Z245.20:22
Plant-applied external fusion bond epoxy coating for steel pipe

1 Scope

1.1
This Standard covers the qualification, application, inspection, testing, handling, and storage of materials required for plant-applied fusion bond epoxy (FBE) coating applied externally to bare steel pipe. The coated pipe is intended primarily for buried or submerged service for oil or gas pipeline systems.

1.2
This Standard covers the following coating systems:
a) System 1A: single-layer FBE with a glass transition temperature of 115 °C or less;
b) System 1B: single-layer FBE with a glass transition temperature greater than 115 °C;
c) System 2A: two-layer FBE with an anti-corrosion coating and a protective overcoat;
d) System 2B: two-layer FBE with an anti-corrosion coating and an abrasion-resistant overcoat;
e) System 2C: two-layer FBE with an anti-corrosion coating and an anti-slip overcoat; and
f) System 3: three-layer FBE with an anti-slip overcoat applied over an anti-corrosion coating and a protective overcoat.

1.3
In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the Standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the Standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the editions listed below.

Note: *In cases where the editions listed below are amended, replaced by new editions, or superseded by another standard during the life of this referencing Standard, it is the responsibility of the users of this Standard to investigate the possibility of applying those amendments, new editions, or superseding standards.*

CSA Group
CAN/CSA-ISO 9001:16 (R2020)
Quality management systems — Requirements

Z245.30:22
Field-applied external coatings for steel pipeline systems

Z662:19
Oil and gas pipeline systems

ASTM International
E29-13 (2019)
Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ISO (International Organization for Standardization)
9001:2015
Quality management systems — Requirements

SSPC (The Society for Protective Coatings)/NACE International
SP 5/NACE No. 1-2007
White Metal Blast Cleaning

SP 10/NACE No. 2-2007
Near-White Metal Blast Cleaning

3 Definitions

The following definitions shall apply in this Standard:

Abrasion-resistant overcoat — an FBE coating applied over an FBE coating system for the purpose of abrasion or damage resistance.

Anti-corrosion coating — an FBE coating applied directly on steel for the purpose of corrosion protection.

Anti-slip overcoat — an FBE coating applied over an FBE coating system for the purpose of increasing the shear resistance between concrete coating and the coated steel pipe.

Applicator — the company responsible for the actual application of the coating.

Batch — the quantity of epoxy powder produced during a continuous production run of not more than 8 h.

Certificate of compliance — a document provided by the epoxy powder manufacturer or coating applicator certifying that the epoxy powder or the coating, as applicable, is in compliance with the requirements of this Standard.

Coating — FBE coating.

Defect — an imperfection of sufficient magnitude to warrant rejection based on the requirements of this Standard.

Epoxy powder — a thermosetting coating material based on epoxy resin.

Glass transition temperature — the approximate midpoint of the temperature range over which the glass transition takes place.

Holiday — a discontinuity in the coating that exhibits electrical conductivity when exposed to a specific voltage.

Imperfection — a material discontinuity or irregularity that is detectable by inspection in accordance with the requirements of this Standard.

Laboratory-coated test specimen — a specimen taken from a laboratory-prepared panel.

Pipe diameter length — any length along the pipe axis equal to the specified outside diameter (OD) of the pipe.

Plant — any building, structure, or installation, including the surrounding yard, containing process equipment that continuously applies external coating on steel pipe in accordance with CSA Z245.20 Series.

Protective overcoat — an FBE coating applied directly over an FBE anti-corrosion coating for the purpose of increasing the functional performance of the system.

Test report — a document that provides the quantitative test results for tests conducted in accordance with the requirements of this Standard.

Test ring — a sample taken from production-coated pipe.

Vehicle shipment of epoxy powder — an individual container received at the site of the applicator with a total weight of epoxy powder not to exceed 25 000 kg.

Working shift — a period of production, to a maximum of 12 h, at the application facility.

4 General requirements

4.1 Product ordering requirements

4.1.1 Standard requirements

The following information shall be included in purchase orders for coating for pipe:

a) CSA Standard designation and year of publication (CSA Z245.20:22);
b) pipe quantity, OD, wall thickness, and nominal length;
c) coating system (1A, 1B, 2A, 2B, 2C, or 3; see Clause 1.2);
d) bare pipe standard or specification designation (see Clause 5.1);
e) nominal thickness and maximum permissible thickness of the coating system, and individual layers if applicable (see Clause 6.2.4);
f) cutback length and tolerance for both ends of pipe (see Clause 6.2.5); and
g) test temperature for the flexibility test [–30, –18, or 0 °C; see Clause 12.11.3 b)].

4.1.2 Optional requirements

Where applicable, purchase orders shall include the following information:

a) additional surface treatments (see Clause 6.2.2.8);

b) plant inspection by the purchaser (see Clause 7.1);
c) location of laboratory testing (see Clause 7.3.1.1);
d) increased test ring length (see Clause 7.3.3.2);
e) test ring location (see Clause 7.3.3.2);
f) test frequency and retest procedures (see Clause 7.3.3.3.1);
g) test frequency for additional test rings (see Clause 7.3.3.3.2);
h) additional markings (see Clause 9.1);
i) handling procedures (see Clause 10.1.1);
j) storage procedures (see Clause 10.2);
k) waiver of test reports (see Clause 11.1);
l) gouge test (see Clause 12.15); and
m) other special requirements.

4.2 Rounding procedure

Except as otherwise required by this Standard, 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 the rounding method of ASTM E29.

4.3 Requirements for quality

The applicator and epoxy manufacturer shall comply with the requirements of a nationally or internationally recognized quality management system and the requirements of Clause 4.4.

Note: *CAN/CSA-ISO 9001 or ISO 9001 provides suitable quality management systems.*

4.4 Compliance

The applicator and epoxy manufacturer shall comply with the requirements of this Standard for which each is responsible. The purchaser may make any investigation necessary to confirm compliance by the applicator and may reject any material that does not comply. The applicator may make any investigation necessary to confirm compliance by the epoxy manufacturer and may reject any material that does not comply.

5 Materials

5.1 Pipe

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

Note: *Pipe conforming to such standards or specifications will, in some cases, not have a surface condition that is appropriate for the application of coating.*

5.2 Epoxy powders

5.2.1 General

The applicator shall use epoxy powders that are

a) certified by the epoxy powder manufacturer to be in accordance with the requirements of Clauses 5.2.2 and 6.1.3, and compatible with the requirements of Clause 7.3.1. Test reports shall be supplied with each batch of materials;

b) identified with the following:
   i) epoxy powder manufacturer's name;
   ii) product description;
   iii) mass of material;
   iv) batch number;
   v) location of manufacture;
   vi) manufacturing identification number;
   vii) temperature requirements for transportation and storage;
   viii) qualified minimum flexibility test temperature of –30, –18, or 0 °C; and
   ix) the year and month of manufacture; and
c) handled, transported, and stored prior to use in accordance with the epoxy powder manufacturer's recommendations.

5.2.2 Properties

5.2.2.1 Epoxy powder properties

The epoxy powder properties shall be in accordance with the requirements of Table 1 for Systems 1A and 1B and Table 5 for Systems 2A, 2B, 2C, and 3. The epoxy powder manufacturer shall conduct tests for each epoxy powder type and provide the applicator with a test report of the epoxy powder properties specified in Table 1 for Systems 1A and 1B and, if applicable, Table 5 for Systems 2A, 2B, 2C, and 3. The date of the tests performed by the epoxy powder manufacturer for the epoxy powder being applied shall not be more than 365 d prior to the date of application of the coating by the applicator. Test reports shall be supplied with each batch of materials.

5.2.2.2 Epoxy powder composition

The epoxy powder manufacturer shall perform a Fourier transform infrared (FTIR) spectroscopy scan between 500 cm^{-1} and 4000 cm^{-1} in percent transmission for the batch selected for testing required in Clause 5.2.2.1 and for each subsequent batch of epoxy powder. The epoxy powder manufacturer shall provide a report of the test results to the applicator for the applicator's approval.

5.2.3 Packaging

The epoxy powder shall be delivered in containers that are clearly labelled to identify the items specified in Clause 5.2.1 b).

6 Coating application

6.1 Coating qualification

6.1.1 General

The coating system shall be qualified for production by testing laboratory-coated test specimens for each applicable test (see Clause 6.1.3) and by meeting the acceptance criteria. The coating shall be requalified where there is a change in one or more of the following:

a) epoxy powder manufacturer;
b) coating chemical composition; or
c) manufacturing location of the epoxy powder.

6.1.2 Preparation of laboratory-coated test specimens

6.1.2.1

Test specimens shall be mild steel and shall have dimensions specified for the applicable test method (see Clause 12). Two samples shall be required for multi-layer coating systems: one sample of the anti-corrosion coating and a second sample of the full coating system.

6.1.2.2

The surface shall be blast cleaned using an acceptable steel grit in accordance with SSPC SP 5/NACE No. 1. The surface profile, measured from peak to trough, shall be 40 to 110 µm and in accordance with the epoxy powder manufacturer's recommendations.

6.1.2.3

Coating application and curing temperatures shall be in accordance with the epoxy powder manufacturer's recommendations and shall not exceed 275 °C.

Note: *Heat applied to pipe during coating application can have an aging effect on the mechanical properties of steel pipe.*

6.1.2.4

The thickness of anti-corrosion coating on the completed test specimen shall be 350 ± 50 µm, measured by a coating thickness gauge verified against a thickness standard that is within 20% of the specified nominal coating thickness of 350 µm. For multi-layer coating systems, the thickness of the individual layers shall be in accordance with the epoxy powder manufacturer's recommendation, with the anti-corrosion coating being at least 250 µm thick.

6.1.3 Coating qualification test requirements

Systems 1A and 1B shall be evaluated in accordance with Table 2, and Systems 2A, 2B, 2C, and 3 shall be evaluated in accordance with Table 6. The tests to be conducted, the number of test specimens, the test methods to be used, and the acceptance criteria shall be as specified in Tables 2 and 6. The epoxy powder manufacturer shall conduct tests and provide the applicator with a test report for the coating properties specified in Table 2 for Systems 1A and 1B and Table 6 for Systems 2A, 2B, 2C, and 3. The anti-corrosion coating shall be qualified in accordance with the requirements of Table 2 for Systems 2A, 2B, 2C, and 3. The date of the tests performed by the epoxy powder manufacturer for the epoxy powder being applied shall not be more than 365 d prior to the date of application of the coating by the applicator.

6.2 Production application practices and equipment

6.2.1 General

The coating shall be qualified for production in accordance with the requirements of Clause 6.1.

6.2.2 Surface preparation

6.2.2.1 General

The external surfaces of the pipe shall be free of any injurious levels of contaminants such as oil, grease, and salts prior to the application of the coating.

Prior to blast cleaning, the purchaser and applicator shall determine the necessity, methods, acceptance criteria, and frequency of testing the subject pipe for contaminants. This determination shall consider the amount of pipe, transport conditions, and retention history to ensure contaminants are removed and do not interfere with the coating application or contaminate the coating process equipment.

6.2.2.2 Preheating before blast cleaning

Prior to blast cleaning, the pipe shall be preheated to remove moisture. The pipe surface shall be maintained at a temperature at least 3 °C above the dew point, but less than 150 °C during blast cleaning and inspection. During and after blast cleaning, the pipe surface shall be protected from contact with materials and equipment that can contaminate the pipe at the pipe surface's processing temperature.

6.2.2.3 Surface cleanliness and profile

Except where allowed by Clause 6.2.2.5, the external pipe surface to be coated shall be blast cleaned to at least SSPC SP 10/NACE No. 2 specifications. The surface profile, measured from peak to trough, shall be 40 to 110 µm and in accordance with the epoxy powder manufacturer's recommendations.

6.2.2.4 Residual blast products

Residual blast products from the interior and exterior surfaces of the pipe shall be suitably removed.

6.2.2.5 Post-blast inspection

Prior to the coating application, the cleaned pipe shall be inspected in accordance with the requirements of Clause 7.3.2, and imperfections that might cause holidays in the coating shall be removed in a manner that gives a surface finish suitable for subsequent application of coating.

Notes:

1) *Disposition of pipe with imperfections that cannot be removed during the normal production cycle should be subject to agreement between the applicator and the purchaser.*
2) *Surface defects include, but are not limited to, gouges, grooves, arc burns, dents, and surface laminations. See CSA Z662, Clause 6.3, for more information on pipe surface requirements applicable to steel piping.*

6.2.2.6 Pretreatment

6.2.2.6.1

To ensure that the blast-cleaned pipe surface is not contaminated with injurious levels of soluble salts, the applicator shall utilize a phosphoric acid pretreatment system, unless otherwise agreed between purchaser and applicator in accordance with Clauses 6.2.2.6.2 to 6.2.2.6.5.

6.2.2.6.2

The blasted steel pipe surface shall be tested for the presence of soluble salts prior to the application of the coating, at the beginning of production and at least once every 4 h during production. The blasted pipe surface shall be sampled and tested with purchaser-agreed test methods appropriate for the anticipated salts. The maximum allowable level of soluble salts found on the pipe surface shall be 20 mg/m^2. If soluble salts are detected above the allowable level, the pre-treatment shall be modified to improve the steel cleanliness.

6.2.2.6.3
Details of the pretreatment process shall be agreed upon by the purchaser and the applicator, following the manufacturer's requirements. The pretreatment process shall include purified water, such as distilled or reverse osmosis-treated water, post-rinse.

6.2.2.6.4
The specified pretreatment parameters shall be monitored with due consideration for pipe temperature, concentration of the phosphoric acid solution at application, and acidity of the post-rinse solution at pipe surface. Post-rinse water shall be monitored for purity in accordance with the manufacturer's specifications for dissolved solids, and/or conductivity, and/or other suitable methods.

6.2.2.6.5
Soluble salt levels shall be retested following pretreatment to ensure soluble salt levels satisfy the 20 mg/m^2 criterion. This testing shall be conducted at a frequency agreed upon between the purchaser and applicator.

6.2.2.7 Pretreatment exception verification

6.2.2.7.1
If phosphoric acid pretreatment is not applied in accordance with Clause 6.2.2.6, the applicator shall test and treat the surface of the pipe in accordance with Clause 6.2.2.7.2.

6.2.2.7.2
The blasted steel pipe surface shall be tested for the presence of soluble salts prior to the application of the coating, at the beginning of production and at least once every 4 h during production. The blasted pipe surface shall be sampled and tested with purchaser-agreed test methods appropriate for the anticipated salts. The maximum total allowable level of soluble salts found on the pipe surface shall be 20 mg/m^2. If soluble salts are detected above the allowable level, a pre-treatment shall be used to clean the blasted steel pipe surface. Pretreatment may utilize phosphoric acid solution or suitable high-pressure water cleaning (addressing required substrate temperatures and ensuring flash rust does not occur) to achieve an acceptable level. Soluble salt levels shall be retested following pretreatment to ensure soluble salt levels satisfy the 20 mg/m^2 criterion. This testing shall be conducted at a frequency agreed upon between the purchaser and applicator.

6.2.2.8 Additional surface treatments
Unless otherwise specified in the purchase order, the applicator may use additional surface treatments prior to the application of the coating.

Note: *The purchaser should be satisfied that the applicator's quality control program for such treatments is acceptable.*

6.2.3 Application and curing temperatures
Application and curing temperatures of the external pipe surface shall be as selected by the applicator and shall not exceed 275 °C. FBE overcoats shall not be applied directly to steel, and precautions shall be taken to prevent these materials from contaminating the anti-corrosion coating layer.

Note: *Such temperatures should be in accordance with the epoxy powder manufacturer's recommendations.*

6.2.4 Coating thickness

The nominal thickness of the coating system and the maximum permissible thickness of the coating system shall be as specified in the purchase order. Except as allowed by Clause 7.3.2.7.3, the minimum permissible thickness of the anti-corrosion coating shall be 300 µm. The individual layer coating thickness for Systems 2A, 2B, 2C, and 3 shall be in accordance with the manufacturer's recommendations or the purchaser's specification, with the anti-corrosion coating being at least 250 µm thick.

6.2.5 End finish

The cutback length and tolerance for both ends of the pipe shall be specified in the purchase order. The pipe surface shall be free of coating within the full length of the cutback as measured from the end of the pipe.

7 Inspection and testing

7.1 Inspection notice

When it is specified in the purchase order that the inspector representing the purchaser intends to inspect the coating or witness the tests, the applicator shall give the purchaser reasonable notice of the production schedule.

7.2 Plant access

While work on the contract of the purchaser is being performed, the inspector representing the purchaser shall have unrestricted entry at all times to all parts of the applicator's plant that relate to the storage, application, testing, and handling of the pipe and coating. The applicator shall afford the inspector all reasonable facilities in order to be satisfied that the coating is being applied in accordance with the requirements of this Standard. 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, testing, or both.

7.3 Tests

7.3.1 Epoxy powder and coating

7.3.1.1

The applicator shall conduct the sample preparation, testing, and evaluation of the epoxy powder and coating in accordance with the requirements of Tables 3 and 4 for Systems 1A and 1B and Tables 7 and 8 for Systems 2A, 2B, 2C, and 3. Tests shall be done at the application facility unless otherwise agreed by the purchaser.

7.3.1.2

The minimum testing frequency shall be one sample taken from every vehicle shipment of epoxy powder received. The acceptance criteria and the tests to be conducted shall be in accordance with the requirements of Clauses 7.3.1.3 and 7.3.1.4.

7.3.1.3

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, but not necessarily before production starts. Such tests

shall be conducted in accordance with the requirements of Clause 12.2, and the acceptance criterion shall be as specified in Table 1 for the anti-corrosion coating and, if applicable, Table 5 for the overcoats. Where 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. Where both retests conform to the specified gel time requirement, the epoxy powder batch shall be accepted. Where one or both retests fail to conform to the specified requirements, the epoxy powder batch shall be rejected.

7.3.1.4

Prior to the use of the epoxy powder for production coating, laboratory-coated test specimens shall be prepared by the applicator at the proposed plant application temperature in accordance with the requirements of Clause 6.1.2. The tests to be conducted, the number of test specimens to be used, the test methods to be used, and the acceptance criteria shall be as specified in Table 3 for Systems 1A and 1B and Table 7 for Systems 2A, 2B, 2C, and 3. Where a test from Table 3 or 7 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. Where both retests conform to the specified test requirements, the epoxy powder batch shall be accepted. Where one or both retests fail to conform to the specified requirements, the epoxy powder batch shall be rejected. The applicator shall test another batch or test each batch to qualify the vehicle shipment or reject the vehicle shipment.

7.3.2 In-line inspection and measurement

7.3.2.1 General

The inspections and measurements required by Clauses 7.3.2.2 to 7.3.2.9 shall be made by the applicator.

7.3.2.2 Surface finish

The surface finish shall be monitored a minimum of every 2 h during production to determine whether the cleanliness is in accordance with the requirements of Clause 6.2.2.3.

7.3.2.3 Surface profile

At least once every 4 h of production, the external surface profile on two pipes shall be measured using a profilometer, replicating film, or purchaser-approved equivalent. The profile shall be in accordance with the requirements of Clause 6.2.2.3.

7.3.2.4 Visual inspection

After cleaning, each pipe shall be visually inspected for surface defects and surface imperfections that might 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.

7.3.2.5 Application temperature

The surface temperature of the pipe immediately prior to epoxy powder application shall be monitored and controlled within the limits recommended by the epoxy powder manufacturer. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

7.3.2.6 Curing

The post-application temperature and the time interval between application and quenching shall be measured, recorded, and controlled to ensure that the coating is being adequately cured. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

7.3.2.7 Coating thickness

7.3.2.7.1

The total coating thickness shall be measured in at least three random locations along each pipe length using a coating thickness gauge that has been verified at least once every working shift against a thickness standard that is within 20% of the nominal coating thickness specified in the purchase order. Where the pipe being coated has a raised weld, one of the three required thickness measurements shall be on the raised weld. Such measured thickness values shall be recorded at least once every 4 h per working shift.

7.3.2.7.2

For Systems 2A, 2B, 2C, and 3, the thickness of each individual layer shall be measured either by progressive removal of layers and measuring the remaining thickness with a verified thickness gauge or a Tooke gauge, or by microscopic measurements of the cross-section of a representative sample near the end of a selected pipe. Verification of gauges shall be completed once per working shift, and measured thickness values shall be recorded at least once every 4 h per shift. Areas where the overcoat has been removed shall be repaired in accordance with Clause 8.

7.3.2.7.3

For Systems 1A and 1B, where individual measured thickness values are less than 300 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 300 µm, and no individual value shall be less than 250 µm.

7.3.2.7.4

For Systems 2A, 2B, 2C, and 3, where the total or individual coating thickness is less than the specified minimum, additional measurements shall be carried out near each end. The average of such measured values for each pipe shall be at least the minimum coating thickness specified. No individual measured thickness value for the total coating thickness or individual coating thickness shall be less than 85% of the specified minimum.

7.3.2.7.5

Coated pipe that does not meet the requirements of Clause 7.3.2.7.3 shall be stripped and recoated in accordance with the requirements of Clause 8.3.

7.3.2.8 Holiday inspection

7.3.2.8.1 General

7.3.2.8.1.1

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.

7.3.2.8.1.2

The detector shall be

a) calibrated at least once in a 12-month period; and
b) verified and tested at the beginning of each day of use and not less than once every 12 h against a voltmeter that has been calibrated to recognized standards within the previous six months.

For inspection, the direct current potential of the detector shall be set to exceed 5 V for each micrometre of nominal coating thickness, to a maximum of 5000 V.

7.3.2.8.1.3

Inspection shall be performed when the temperature of the coating is less than 100 °C.

7.3.2.8.2 Acceptance criteria

7.3.2.8.2.1

There shall be no holidays in the finished coating.

7.3.2.8.2.2

The repair of coating shall be performed in accordance with the minimum requirements of Clauses 8.2 and 8.3, Table 9, and any other additional requirements as agreed upon by the purchaser and the applicator.

7.3.2.8.2.3

Where the quantity of holidays exceeds the applicable limit specified in Clause 7.3.2.8.2.2, or where 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 Clause 8.3. See Table 9.

7.3.2.9 Residual magnetism

Notes:

1) *These requirements apply only to measurements made within the coating facility during final coating inspection. Measurements of residual magnetism made subsequent to shipment can be affected by procedures and conditions imposed on the coated pipe during and after shipment.*
2) *The coating applicator may check the residual magnetism of the incoming pipe.*

7.3.2.9.1

The longitudinal magnetic field shall be measured on the root face or square cut face of coated pipe.

7.3.2.9.2

Measurements shall be made using a Hall-effect magnetic flux density meter or another type of calibrated instrument; however, in case of dispute, measurements made with the Hall-effect magnetic flux meter shall govern. The magnetic flux meter shall be operated in accordance with the applicator's documented procedures that have been demonstrated by the coating applicator to produce accurate results.

7.3.2.9.3

Measurements shall be made on each end of a coated pipe, to be selected at least once every 4 h per operating shift.

7.3.2.9.4
Residual magnetism on the coated pipe shall be measured in the coating facility. For coated pipe handled with magnetic equipment after the measurement of residual magnetism, such handling shall be performed in a manner demonstrated not to cause residual magnetism in excess of the levels specified in Clause 7.3.2.9.5.

7.3.2.9.5
For coated pipe smaller than 168.3 mm OD, at least two readings shall be taken approximately 180° apart around the circumference of each end of the coated pipe. For coated pipe 168.3 mm OD or larger, at least four readings shall be taken approximately 90° apart around the circumference of each end of the coated pipe. The average of such readings shall not exceed an absolute value of 3.0 mT, and no individual reading shall exceed an absolute value of 3.5 mT.

Measurements made on coated pipe in stacks or bundles shall not be accepted.

7.3.2.9.6
Any coated pipe that fails to meet the requirements specified in Clause 7.3.2.9.5 shall be considered defective. In addition, except as allowed by Clause 7.3.2.9.7, all pipe coated between the defective coated pipe and the last acceptable coated pipe shall be individually measured.

7.3.2.9.7
If the coating sequence is documented, coated pipe may be measured in reverse sequence, beginning with the pipe coated immediately prior to the defective coated pipe, until at least three consecutively coated pipes meet the requirements. Pipe coated prior to the three acceptable coated pipes need not be measured.

7.3.2.9.8
Pipe coated after the defective coated pipe shall be measured individually until at least three consecutive coated pipes meet the specified requirements.

7.3.2.9.9
Defective coated pipe shall be segregated, demagnetized, and remeasured.

7.3.2.10 Visual coating anomalies
Each pipe shall be visually inspected for anomalies such as blisters, runs, sags, and craters (fish-eyes) in the coating, and these anomalies shall be addressed by the applicator's quality system. Imperfections in the coating caused by steel defects or debris captured under the coating and that fail to be detected by the holiday testing specified in Clause 7.3.2.8 shall be repaired in accordance with Clause 8.2. The defect and/or debris shall be removed and coating repair shall be applied to the defect area.

7.3.3 Production test rings

7.3.3.1 Facilities
The applicator shall have suitable facilities available for the preparation, testing, and evaluation of test ring samples for Type A tests required in Tables 4 and 8.

7.3.3.2 Test rings

Unless otherwise specified in the purchase order, test rings for Systems 1A and 1B shall be no more than 500 mm long. Test rings for Systems 2A, 2B, 2C, and 3 shall be no more than 800 mm long. The rings shall be obtained from locations at least 300 mm from a pipe end. Removal of pipe exceeding the specified lengths for test rings shall be by agreement between the applicator and the purchaser.

7.3.3.3 Testing requirements

7.3.3.3.1

The minimum test frequency shall be one test ring per pipe diameter and specified wall thickness every working shift. Where specified in the purchase order for Systems 2A, 2B, 2C, and 3, additional test rings shall be taken with only the anti-corrosion coating. Such test rings shall be obtained by turning off the overcoat epoxy powder application. The requirements of Table 4 shall be met. The purchaser shall specify test frequency and retest procedures.

7.3.3.3.2

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. Where specified in the purchase order, additional test rings shall be taken.

7.3.3.3.3

For each test ring, the tests to be conducted, the number of test specimens to be used, the test method to be used, and the acceptance criteria shall be as specified in Tables 4 and 8. Systems 1A and 1B shall be evaluated in accordance with Table 4. Systems 2A, 2B, 2C, and 3 shall be evaluated in accordance with Table 8.

7.3.3.4 Retests — Type A test failures

7.3.3.4.1

Where a Type A test fails to conform to the specified requirements (see Tables 4 and 8),

a) the test that failed shall be repeated using two additional test samples (see Clause 7.3.3.2) 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 Clause 8.3.

7.3.3.4.2

Where both retests conform to the specified requirements, the lot of coated pipe shall be accepted.

Where at least one retest fails to conform to the specified requirements,

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 Clause 8.3; or
b) subject to the approval of the purchaser, the lot shall be subjected to further retesting to determine those portions of the affected lot that are acceptable, based on obtaining test results for both the first and last pipes in the portion that conform to the specified requirements. Pipe in those portions of the affected lot that are not acceptable shall be stripped and recoated in accordance with the requirements of Clause 8.3.

7.3.3.5 Retests — Type B test failures

Where a Type B test (see Tables 4 and 8) fails to conform to the specified requirements, the application process parameters shall be adjusted, and where required by the purchaser, the applicator shall limit the application process until the cause of the failure has been remedied.

Note: *The process parameters need not be adjusted in those instances where inaccurate interface contamination and interface porosity test results have resulted due to the influence of the particular pretreatment used on the surface of the pipe prior to epoxy powder application.*

8 Repair of coated pipe

8.1 General

8.1.1

Where required by Clause 7 or 10, coating holidays shall be repaired in accordance with the requirements of Clause 8.2 or by stripping and recoating in accordance with the requirements of Clause 8.3, whichever is applicable.

8.1.2

Coating repair applicators shall be qualified in accordance with CSA Z245.30, Clause 6.1.2. The applicable repair materials shall be applied in accordance with the manufacturer's qualified application procedure (MQAP) and qualified in accordance with CSA Z245.30, Clause 5.

8.2 Holiday repairs

The repair of holidays shall conform to the following requirements:

a) Holidays shall be cleaned by removing all rust, scale, dirt, other foreign material, and loose coating.
b) The areas shall be suitably roughened in accordance with the repair material manufacturer's recommendations for epoxy repair melt stick or the MQAP for the selected two-part liquid epoxy.
c) Dust shall be removed with a clean, dry cloth or brush, or dried compressed air blast.
d) Holidays less than or equal to 2.0 mm maximum diameter or width shall be repaired with the epoxy powder manufacturer's recommended epoxy repair melt stick or two-part liquid epoxy, or a purchaser-approved equivalent.
e) Areas greater than 2.0 mm in diameter or width and less than 250 cm^2 in area shall be repaired with the epoxy powder manufacturer's recommended two-part liquid epoxy or a purchaser-approved equivalent.
f) Epoxy repair melt stick shall be applied in accordance with the repair material manufacturer's recommendations. Two-part liquid epoxy shall be applied in accordance with the MQAP for the selected product
g) The minimum thickness of repaired coating shall be in accordance with the requirements of Clause 6.2.4.
h) All repairs shall be holiday tested in accordance with the requirements of Clause 7.3.2.8.
i) The number of patch repairs per length of pipe shall be recorded.

Note: *See Table 9.*

8.3 Stripping and recoating

The pipe surface shall be cleaned by a combination of heating to a temperature not to exceed 275 °C, scraping, and abrasive blasting. All coating shall be removed prior to the recoating process. Recoating

shall be performed in accordance with the requirements of Clauses 6.2 and 7. The identity of each stripped and recoated pipe shall be recorded.

Notes:

1) *See Table 9.*
2) *Heat applied to pipe during coating application can have an aging effect on the mechanical properties of steel pipe.*

8.4 Repair of pipe ends

When the applicator cuts the pipe, steel pipe ends shall be refinished in accordance with the original pipe manufacturing specification, or as agreed upon by the purchaser and the applicator.

9 Markings

9.1 General

Coated pipe shall be marked in accordance with the requirements of Clause 9.2 and with any additional markings specified in the purchase order. Additional markings desired by the applicator may be used.

Note: *Additional markings include barcode markings. One-dimensional barcode markings should be of the Code 39 type or Code 128 type. Two-dimensional barcode markings should be of the PDF417 type.*

9.2 Required markings

9.2.1

The following markings shall be placed on the coating:

a) applicator's name or mark;
b) CSA Standard designation and year of publication (CSA Z245.20:22);
c) markings required by the applicable pipe specification or standard, whether or not such specification or standard requires such markings to be applied to the outside surface;
d) date of coating application;
e) coating system (1A, 1B, 2A, 2B, 2C, or 3); and
f) flexibility test temperature. The temperature shall be marked using the designation "FM30C" for the –30 °C test, "FM18C" for the –18 °C test, or "F0C" for the 0 °C test.

9.2.2

Required markings shall be at least 300 mm from the coating cutback unless otherwise specified in the purchase order.

10 Handling and storage

10.1 Handling

10.1.1

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

10.1.2
Pipe that is damaged during processing shall be repaired in accordance with the requirements of the applicable pipe specification or standard.

10.1.3
Coating that is damaged after the holiday inspection (see Clause 7.3.2.8) shall be repaired in accordance with the requirements of Clause 8.2 or by stripping and recoating in accordance with the requirements of Clause 8.3.

10.1.4
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.

Note: *The use of vacuum lifting equipment for subsequent handling could be affected by the location of separators on the pipe. In such cases, the locations of the separators should be discussed between the applicator and the purchaser.*

10.1.5
Repairs to coating at the coating cutback shall not exceed 250 cm^2 in area and shall be repaired with two-part liquid epoxy.

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

11 Test reports and certificates of compliance

11.1
Unless the purchase order specifies that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses 7.3 and 8.

11.2
The applicator shall furnish certificates of compliance stating that the coating has been manufactured, applied, inspected, and tested in accordance with the requirements of this Standard and any other requirements specified in the purchase order, and that the results of the coating tests and other required tests have been found to conform to such requirements.

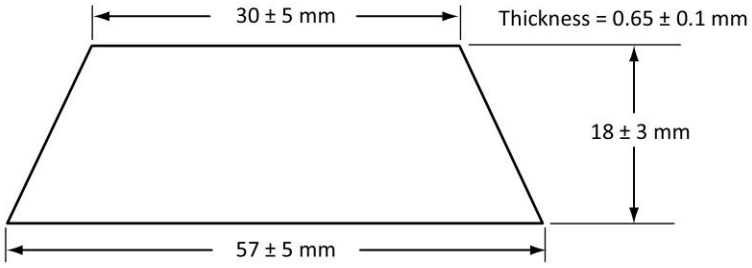
12 Test procedures

12.1 Cure time of the epoxy powder

12.1.1 Equipment
The equipment shall consist of the following:

a) a hot plate controllable to within 3 °C;
b) a metal plate approximately 25 × 150 × 150 mm in size;
c) a contact thermometer;

d) a timing device;
e) a draw-down tool (see Figure 1);
f) a spatula; and
g) a utility knife having a length, without the blade, of 135 ± 20 mm and a one-piece metal blade having the dimensions shown in the following sketch and an exposed cutting edge of 25 ± 5 mm.



12.1.2 Procedure

The test procedure for cure time of the epoxy powder shall be as follows:

a) Heat the metal plate to the manufacturer-specified application temperature or 232 ± 3 °C and maintain that temperature.
b) Use the draw-down tool to deposit a film of epoxy powder on the metal plate. The film should be 300 to 400 µm thick.
c) Start the timing device at the instant of epoxy powder deposition on the hot plate surface.
d) Before the film has gelled completely, scribe the film generally as shown in Figure 2, using the utility knife or spatula to produce ten strips of coating.
e) Using the utility knife 30 ± 3 s after the timing device has started, remove a strip of coating and immediately quench it in cold water. For each additional 30 ± 3 s of elapsed time, repeat this operation. Remove the coating strips in sequential order following the direction of film drawn, starting at the beginning of the draw.
f) Using the differential scanning calorimeter (DSC), determine the change in *Tg* value, Δ*Tg*, or the percentage conversion, *C*, in accordance with the requirements of Clause 12.7.3.3.2 or 12.7.3.3.3, respectively.
g) As specified by the epoxy powder manufacturer, plot time versus Δ*Tg* or time versus the percentage conversion.

12.1.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the time in seconds corresponding to a Δ*Tg* of 2 °C, or the time in seconds corresponding to a conversion of 99%;
d) the test temperature; and
e) the tested film thickness range, to within ±50 µm.

12.2 Gel time of the epoxy powder

12.2.1 Equipment

The equipment shall consist of the following:

a) a hot plate controllable to within 3 °C;
b) a metal plate approximately 25 × 150 × 150 mm in size;
c) a stopwatch or electric timing device capable of measuring 0.1 s intervals; and
d) a draw-down tool (see Figure 1).

12.2.2 Procedure

The test procedure for the measurement of gel time of the epoxy powder shall be as follows:

a) Conduct three tests and average the results.
b) Heat the metal plate surface that will be in contact with the epoxy powder to the manufacturer-specified application temperature or 205 ± 3 °C, and maintain that temperature.
c) Cover the bottom 25 mm of the draw-down tool with epoxy powder.
d) 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. The cured film should be 300 to 400 µm thick.
e) Start the timing device and deposition of epoxy powder on the metal plate surface simultaneously.
f) Applying light pressure on the draw-down tool, repeatedly draw the edge of the tool through the melted epoxy powder.
g) Stop the timing device when the tool rides up on the gelled epoxy powder and no longer makes contact with the metal plate.

12.2.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the gel time in seconds;
d) the test temperature; and
e) the tested film thickness range, to within ±50 µm.

12.3 Moisture content of the epoxy powder — Titration

Note: *Moisture content may be determined in accordance with this Clause or Clause 12.4. The test method to be used is at the manufacturer's option. See Table 1.*

12.3.1 Equipment

The equipment shall consist of the following:

a) an aquameter apparatus;
b) a laboratory mill;
c) an analytical balance;
d) a 50 mL automatic burette;
e) a metal pipette holder (1 mL);
f) a 10 mL plastic syringe;
g) a 110 mm hypodermic needle;
h) a 15 mL serum bottle and cap;
i) a 1 mL Luer lock syringe; and
j) a spatula.

12.3.2 Reagents

The reagents shall consist of the following:

a) vessel solution Part A (a mixture of pyridine and sulphur dioxide);
b) vessel solution Part B (Karl Fischer reagent in methyl alcohol);
c) chloroform; and
d) generator solution.

Note: *Avoid breathing the vapours and perform all operations in a well-ventilated area.*

12.3.3 Procedure

The test procedure for the measurement of moisture content of the epoxy powder by the direct titration method shall be as follows:

a) Run duplicate samples, following the detailed procedures appropriate for the particular aquameter being used.
b) Determine the percentage of moisture content by direct titration to an electrometric end point.

12.3.4 Report

Where test reports are not waived as specified in Clause 11.1, the applicator shall report the following information to the purchaser:

a) the epoxy powder batch number;
b) the date of testing;
c) the apparatus used; and
d) the percentage of moisture content for each sample and the average moisture content of all samples.

12.4 Moisture content of the epoxy powder — Mass loss

Note: *Moisture content may be determined in accordance with this Clause or Clause 12.3. The test method to be used is at the manufacturer's option. See Table 1.*

12.4.1 Procedure A

12.4.1.1 Equipment

The equipment shall consist of the following:

a) an oven controllable to within 3 °C;
b) a balance accurate to 0.001 g;
c) a desiccator;
d) a sample container;
e) a timing device; and
f) a contact pyrometer/thermometer.

12.4.1.2 Procedure

The test procedure to measure the moisture content of the epoxy powder by the mass loss method using Procedure A shall be as follows:

a) Weigh the sample container to the nearest 0.001 g.
b) Transfer approximately 10 g of epoxy powder into the sample container.
c) Weigh the sample container and epoxy powder to the nearest 0.001 g.
d) Place the sample container with the epoxy powder into the oven for a maximum of 2 h at 105 ± 3 °C.
e) Remove the container from the oven and place it in the desiccator to cool.

f) Weigh the sample container when it has cooled to 20 ± 3 °C and then return it to the desiccator; weigh again at intervals of 1 h ± 10 min until two consecutive mass determinations are within 0.001 g.
g) Calculate the percentage of moisture using the following formula:

$$M = \frac{B - C}{B - A} \times 100$$

where
M = percentage of moisture
B = initial mass of sample container and epoxy powder, g
C = final mass of sample container and epoxy powder, g
A = mass of sample container, g

12.4.2 Procedure B

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

12.4.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the epoxy powder batch number;
b) the date of testing;
c) the procedure used; and
d) the percentage of moisture content.

12.5 Particle size of the epoxy powder

12.5.1 Equipment

The equipment shall consist of the following:
a) an air-jet sieving unit with a vacuum cleaner attachment and 150 µm and 250 µm screens; and
b) a balance accurate to 0.01 g.

12.5.2 Procedure

The test procedure to measure the particle size of the epoxy powder shall be as follows:
a) Weigh the sieve and one screen to the nearest 0.01 g.
b) Place approximately 20 g of epoxy powder onto the top of the screen, and record the weight of the epoxy powder to the nearest 0.01 g.
c) Place the sieve into the sieving unit, cover the unit, and secure it.
d) Operate the sieving unit for 3 min ± 10 s and remove the cover.
e) Remove the sieve and weigh it to the nearest 0.01 g.
f) Calculate the percentage of epoxy powder retained on the screen using the following formula:

$$P = \frac{F - I}{M} \times 100$$

where
P = percentage of epoxy powder retained
F = final mass of sieve, screen, and retained epoxy powder, g
I = initial mass of sieve and screen, g

M = initial mass of epoxy powder placed on screen, g

g) Repeat the procedure specified in Items a) to f) using the other screen.

12.5.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing; and
c) the percentage of epoxy powder retained for each screen size.

12.6 Density of the epoxy powder

12.6.1 Equipment

The equipment shall consist of the following:

a) a balance accurate to 0.01 g;
b) a 100 mL volumetric flask; and
c) mineral spirits.

12.6.2 Procedure

12.6.2.1 General

The density of the epoxy powder shall be determined using the procedure specified in Clause 12.6.2.2 or 12.6.2.3. The test temperature shall be 20 ± 3 °C.

12.6.2.2 Procedure A

The test procedure to measure the density of the epoxy powder using Procedure A shall be as follows:

a) Weigh the flask to the nearest 0.01 g.
b) Add approximately 20 g of epoxy powder to the flask and weigh the flask and the epoxy powder to the nearest 0.01 g.
c) Add sufficient mineral spirits to cover and wet the epoxy powder.
d) Stopper the flask and agitate it for several minutes, ensuring that neither air pockets nor lumps of epoxy powder exist.
e) Wash the stopper and the walls of the flask with mineral spirits until they are free of epoxy powder and the flask is filled to the 100 mL level.
f) Weigh the flask and the epoxy powder and mineral spirits to the nearest 0.01 g.
g) Empty the flask.
h) Clean and dry the flask, add 100 mL of mineral spirits, and weigh the flask and the mineral spirits to the nearest 0.01 g.
i) Calculate the density of the mineral spirits using the following formula:

$$P_s = 10(M_{FS} - M_F)$$

where

P_S = density of mineral spirits, g/L

M_{FS} = mass of flask plus mineral spirits, g

M_F = mass of flask, g

j) Calculate the density of the epoxy powder using the following formula:

$$P_p = \frac{M_{FP} - M_F}{0.1^{\frac{(M_{FPS} - M_{FP})}{P_S}}}$$

where

P_P = density of epoxy powder, g/L

M_{FP} = mass of flask plus epoxy powder, g

M_F = mass of flask, g

M_{FPS} = mass of flask plus epoxy powder and mineral spirits, g

P_S = density of mineral spirits, g/L

12.6.2.3 Procedure B

The density of the epoxy powder using Procedure B shall be determined using an air or helium pycnometer.

12.6.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the procedure used;
d) the type of pycnometer used for Procedure B, if applicable; and
e) the density of the epoxy powder in grams per litre.

12.7 Thermal characteristics of the epoxy powder and coating

12.7.1 General

This test is used to determine

a) the glass transition temperature and the exothermic heat of reaction of epoxy powders and coating; and
b) the percentage conversion of coatings.

12.7.2 Equipment

The equipment shall consist of the following:

a) a DSC with cooling accessory;
b) a balance accurate to 0.1 mg;
c) a sample encapsulating press; and
d) aluminum pans with covers.

12.7.3 Procedure

12.7.3.1 General

12.7.3.1.1 Sample preparation

The test procedure for evaluation of materials shall be as follows:

a) Tare an aluminum sample pan and matching cover on the balance.
b) Place a 10 ± 1 mg sample of epoxy powder or coating, whichever is applicable, into the tared aluminum pan. Applied coatings shall be sampled in accordance with Clause 12.7.3.2.2.

c) Crimp the cover into place with the encapsulating press.
d) Weigh the encapsulated sample (excluding the tared mass of the pan and cover) to determine the sample mass to an accuracy of 0.1 mg.

12.7.3.1.2 Test environment

The sample and a reference shall be placed in the DSC cell.

Note: *The DSC cell should be purged with a dry non-reactive gas.*

12.7.3.1.3 Test temperatures

For unknown material, the DSC run conditions shall be established in accordance with Clause 12.7.3.2.1 for epoxy powder and Clause 12.7.3.2.2 for cured coating.

12.7.3.2 Run conditions

12.7.3.2.1 Epoxy powder

The test procedure to measure the relaxation temperature of the epoxy powder shall be as follows:

a) For unknown samples, make a preliminary run with a 10 ± 1 mg sample, scanning from 10 ± 3 °C to 285 ± 3 °C. Cool immediately to 10 °C, and then run sample again from 10 ± 3 °C to 200 ± 3 °C (Figure 3).
b) Once run conditions have been established for a particular epoxy powder, the preliminary run is no longer necessary for future or known samples.
c) Pick starting and end temperatures for the three DSC scans required to characterize the epoxy powder based on Figures 3 and 4.

12.7.3.2.2 Cured sample

The test procedure to measure the relaxation temperature of the cured sample shall be as follows:

a) Obtain coating samples using the method described in Clause 12.10.3 or with a cold chisel. The samples shall be representative of the full thickness of the coating. All non-FBE materials shall be removed with a knife or equivalent prior to cutting and weighing. For System 2A, 2B, 2C, or 3, the outer layer(s) shall be removed in a manner that does not heat the anti-corrosion coating above the temperature *Tgz* + 10 °C as shown in Figure 5.
b) Make a preliminary run with a 10 ± 1 mg sample, scanning from room temperature 25 ± 3 °C to 285 ± 3 °C.
c) Once run conditions have been established for a particular epoxy powder, the preliminary run is no longer necessary for future or known samples.
d) Pick starting and end temperatures for the three DSC scans required to characterize the epoxy powder based on Figure 5.

12.7.3.3 Calculations

12.7.3.3.1

For each of the thermal scans required by Items b) and c) of Clause 12.7.3.2.1 and Items c) and d) of Clause 12.7.3.2.2, the following shall be determined:

a) the applicable *Tg* values (which are the half height distances between the onset points before and after the *Tg*); and

b) the applicable exothermic heats of reaction (see ΔH and $\Delta H1$ in Figures 4 and 5).

Note: *The Tg (also known as relaxation temperature or glass transition temperature) causes a deviation from the DSC heat flow curve. For some FBE coatings, there is an additional endotherm immediately following the Tg. This endotherm tends to skew the Tg value higher if the inflection method is used to determine Tg.*

Consistent determination of ΔTg requires establishing a rigorous procedure for picking the temperature limits. These limits should be a temperature on the baseline, 15 to 20 °C before the transition region and a temperature on the baseline, 15 to 20 °C after the transition region. The half height method of calculation should be selected in the DSC software (using the step transition analysis method).

12.7.3.3.2

For coatings, the change in *Tg* value shall be determined using the following formula:

$$\Delta Tg = |Tg4 - Tg3|$$

where

ΔTg = change in *Tg* value, °C

$Tg4$ = *Tg* value for the thermal scan required by Clause 12.7.3.2.2 b), °C

$Tg3$ = *Tg* value for the thermal scan required by Clause 12.7.3.2.2 b), °C

12.7.3.3.3

For coatings, the percentage conversion shall be determined using the following formula:

$$C = \frac{\Delta H - \Delta H1}{\Delta H} \times 100$$

where

C = percentage conversion

ΔH = exothermic heat of reaction for the thermal scan required by Clause 12.7.3.2.1 b), J/g

$\Delta H1$ = exothermic heat of reaction for the thermal scan required by Clause 12.7.3.2.2 b), J/g

12.7.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the type of DSC;
d) for epoxy powder, *Tg*1, *Tg*2, and ΔH; and
e) for coating, *Tg*3, *Tg*4, and ΔTg.

12.8 Cathodic disbondment of the coating

12.8.1 Equipment

The equipment shall consist of the following:

a) a dc power supply with controlled voltage output;
b) a hot plate with a steel tray containing sand or steel grit/shot controllable to within 3 °C, or an oven controllable to within 3 °C;
c) a reference electrode, either calomel electrode with saturated KCl solution (≤80 °C), or silver/silver chloride with saturated KCl solution (all temperatures);
d) platinum wire or a carbon electrode;
e) a 75 ± 3 mm inside diameter (ID) plastic cylinder;
f) a 3% sodium chloride solution in purified water (such as distilled or reverse osmosis-treated water);

g) a utility knife [see Clause 12.1.1 g)]; and
h) a ruler, vernier caliper, or other distance measurement device capable of evaluating distances accurate to 0.5 mm.

12.8.2 Test specimens

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

12.8.3 Procedure

12.8.3.1

Only test specimens that are confirmed to be holiday-free with a DC holiday detector set at 1750 ± 250 V or a wet-sponge holiday detector set at 67.5 ± 4.5 V shall be used.

12.8.3.2

The test procedure to measure the resistance of the coating to cathodic disbondment shall be as follows:

a) Drill a 3.0 or 3.2 mm diameter holiday in the centre of the test specimen through the coating to expose the steel substrate.
b) Centre the plastic cylinder over the holiday, and apply a sealant to form a water-resistant seal.
c) Add to the cylinder at least 300 mL of the sodium chloride solution that has been preheated to the test temperature.
d) Mark the solution level on the cylinder.
e) Insert the electrode into the solution, and connect it to the positive wire from the dc power supply.
f) Attach the negative wire from the dc power supply to a bare spot prepared on the test specimen.
g) Apply voltage (negative with respect to the reference electrode) to the test specimen and maintain constant temperature under one or more of the following test conditions, as specified in Tables 2 to 4 for Systems 1A and 1B and Tables 7 and 8 for Systems 2A, 2B, 2C, and 3:
   i) 1.5 ± 0.15 V, 20 ± 3 °C, for a minimum of 28 d;
   ii) 3.5 ± 0.15 V, 65 ± 3 °C, for a minimum of 24 h;
   iii) 1.5 ± 0.15 V, 65 ± 3 °C, for a minimum of 28 d; and
   iv) 1.5 ± 0.15 V, 95 ± 3 °C, for a minimum of 28 d.
h) Maintain the solution level by the addition of purified water (such as distilled or reverse osmosis-treated water) as required. For the test conditions specified in Items g) iii) and iv), the solution shall be replaced after 7, 14, and 21 d.
i) Upon test completion, dismantle the test cell, air cool the specimen to 20 ± 3 °C, and evaluate the cathodic disbondment characteristics of the test specimen within 1 h of removal of heat.
j) Make eight evenly spaced radial cuts through the coating to the substrate as shown in Figure 7. Ensure that such cuts extend at least 20 mm from the centre of the holiday.
k) Insert the tip of the blade of the utility knife under the coating at the holiday.
l) Using a levering action, chip off the coating. Continue until the coating demonstrates a definite resistance to the levering action.
m) Measure the disbonded distance from the edge of the original holiday along each radial cut and average the measured values.

12.8.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;

b) the date of testing;
c) the average disbondment value in millimetres; and
d) the equipment used from the options listed in Clause 12.8.1 b).

12.9 Interface contamination of the coating

12.9.1 Equipment

The equipment shall consist of the following:
a) a stereo microscope; and
b) a utility knife.

12.9.2 Test specimens

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

12.9.3 Procedure

The test procedure to measure the degree of interface contamination between the metal and the coating shall be as follows:
a) Use the utility knife to remove an approximately 3 × 20 mm piece of coating from the test specimen, bent in accordance with the requirements of Clause 12.10.3 a).
b) Examine the metal interface side of the coating with the stereo microscope at 40× magnification.
c) Estimate the percentage of interface contamination that is non-metallic in accordance with Figure 6.

Note: *Steel particles from the substrate can be distinguished by using copper sulphate solution and are not classified as contamination.*

12.9.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the epoxy powder batch number;
b) the date of testing; and
c) the percentage of interface contamination.

12.10 Porosity of the coating

12.10.1 Equipment

The equipment shall consist of the following:
a) a stereo microscope;
b) a bench vise or guided-bend jig;
c) dry ice or a freezer; and
d) a utility knife.

12.10.2 Test specimens

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

12.10.3 Procedure

The test procedure to measure the degree of porosity within the coating shall be as follows:

a) Cool the test specimen to –30 °C or lower and bend it sufficiently in the bench vise or guided bend jig to facilitate removal of coating pieces for evaluation.
b) Pry off a piece of coating from the bent test specimen and examine the coating for porosity at 40× magnification.
c) Rate the porosity present in the coating in accordance with the rating scale shown in Figures 8 and 9.

12.10.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the cross-section porosity rating; and
d) the interface porosity rating.

12.11 Flexibility of the coating

12.11.1 Equipment

The equipment shall consist of the following:

a) a hydraulic press;
b) bending mandrels with fixed radii; and
c) a freezer controllable to within 3 °C.

12.11.2 Test specimens

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

Where necessary to accommodate bend test apparatus restrictions, the specimen thickness may be reduced by a means that does not affect the coating. The thickness after reduction shall be measured as specified by Clause 12.11.3 d).

12.11.3 Procedure

The test procedure to measure the flexibility of the coating shall be as follows:

a) Smooth the coating on the edge of the sample to remove any potential stress risers.
b) For coating qualification testing in accordance with Table 2 or 6, cool the freezer to the appropriate test temperature, then place the test specimen in the freezer and allow the test specimen to cool within ±3 °C of the material manufacturer's certified minimum flexibility test temperature of –30 °C, –18 °C, or 0 °C [see Clause 5.2.1 b) viii)], and maintain the temperature of the test specimen within that ±3 °C range for a minimum of 1 h.
c) For coating qualification testing other than in accordance with Table 2 or 6, cool the freezer to the appropriate test temperature, then place the test specimen in the freezer, allow the test specimen to cool within ±3 °C of the test temperature specified in the purchase order, and maintain the temperature of the test specimen within that ±3 °C range, or at a lower temperature, for a minimum of 1 h [see Clause 4.1.1 g)].
d) Determine the sample thickness, *t*, which includes the specimen thickness and any curvature, by placing the specimen on a flat surface and measuring the thickness as shown in Figure 10.

e) Determine the mandrel radius that corresponds to the required angle of deflection per pipe diameter length (see Tables 2 to 4 for Systems 1A and 1B and Tables 6 to 8 for Systems 2A, 2B, 2C, and 3) by using the applicable formula from the following list:
   i)

$$R = \left[\frac{57.3 - \left(\frac{D}{2}\right)}{D}\right] t$$

   ii)

$$D = \frac{57.3 \times t}{R + \left(\frac{t}{2}\right)}$$

   where
   R = mandrel radius, mm
   D = required angle of deflection per pipe diameter length
   t = sample thickness, mm

f) Bend the test specimen over a mandrel of radius not larger than that determined in accordance with the applicable requirements of Clause 12.11.3 e). Bend the specimen such that the operation lasts not longer than 10 s and is completed within 30 s of the test specimen having been removed from the freezer.
g) Warm the bent test specimen to 20 ± 5 °C and hold it within this temperature range for a minimum of 2 h.
h) Within the next hour, visually inspect the test specimen for cracks.

12.11.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the epoxy powder batch number;
b) the date of testing;
c) the specified angle of deflection;
d) the test temperature in degrees Celsius; and
e) cracking, if any.

12.12 Impact resistance of the coating

12.12.1 Equipment

The equipment shall consist of the following:
a) an impact tester having the following features:
   i) 1 kg falling mass;
   ii) 15.8 mm diameter ball-bearing tup;
   iii) 1 m long graduated slotted tube;
   iv) for laboratory-coated specimen testing, flat anvils hardened to 55 ± 5 HRC;
   v) for testing specimens from test rings, an anvil of 40 mm radius hardened to 55 ± 5 HRC; and
   vi) an attached solid wooden base measuring at least 600 × 600 × 600 mm, with the top of the base being hardwood (e.g., oak, maple);
b) a dc holiday detector; and
c) a freezer controllable to within 3 °C.

12.12.2 Test specimens

Laboratory-coated test specimens shall measure approximately 25 × 200 × 6 mm, 100 × 100 × 6 mm, or 50 × 200 × 6 mm. Specimens from test rings shall measure approximately 25 × 200 mm × pipe wall thickness or 50 × 200 mm × pipe wall thickness with, for both cases, the 200 mm dimension parallel to the axis of the pipe.

12.12.3 Procedure

The test procedure to measure the resistance of the coating to impact shall be as follows:

a) Cool the freezer to the test temperature of –30 °C, then place the test specimen in the freezer, allow the test specimen to cool to –30 ± 3 °C, and maintain the temperature of the test specimen within that ±3 °C range for a minimum of 1 h.
b) Place the cooled specimen in the impact tester, centred on the applicable anvil.
c) Using an impact energy of at least 1.5 J (or 3.0 J for protective and abrasion-resistant coatings), 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 ten impacts and replaced after a maximum of 200 impacts.
d) Allow the sample to warm to 20 ± 5 °C.
e) Test for the presence of holidays with a dc holiday detector set at 1750 ± 250 V or a wet-sponge holiday detector set at 67.5 ± 4.5 V.

12.12.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the applied impact energy value in joules;
d) the holiday detection voltage; and
e) the number of holidays.

12.13 Cathodic disbondment of strained coating

12.13.1 Equipment

The equipment shall meet the requirements of Clauses 12.8.1 and 12.11.1, except that a 25 ± 2 mm ID plastic cylinder shall be used.

12.13.2 Test specimens

Laboratory-coated holiday-free test specimens shall be 6 ± 0.2 mm thick and cut to the approximate dimensions shown in Figure 11 using either the a) or b) configuration.

12.13.3 Procedure

The test procedure to measure the resistance of the coating to cathodic disbondment under strained conditions shall be as follows:

a) Bend the test specimen at –30 ± 3 °C at an angle of deflection of 2.5° per pipe diameter length in accordance with the applicable requirements of Clause 12.11.3. Except that for multi-layer and high-temperature FBE systems, the angle of deflection shall be 1.5° per pipe diameter length.

b) Test the strained specimen in accordance with the applicable requirements of Clauses 12.8.3.1 to 12.8.3.2 i) for the 28 d cathodic disbondment test, but the minimum volume of sodium chloride solution is 45 mL.
c) Within 24 h of dismantling the cell, visually inspect the tested portion of the specimen for cracks.

12.13.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the epoxy powder batch number;
b) the date of testing; and
c) cracking, if any.

12.14 Adhesion of the coating

12.14.1 Equipment

The equipment shall consist of the following:
a) a temperature-controlled slow cooker, non-corroding water bath, heating element with a condenser and bell bottom, or an autoclave;
b) tap water;
c) sand or steel grit/shot, or liquid (heat transfer media) controllable to within 3 °C;
d) a thermometer;
e) a utility knife [see Clause 12.1.1 g)]; and
f) a scribing tool (e.g., utility knife, rotary cutter).

12.14.2 Test specimens

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

12.14.3 Procedure

The test procedure to measure the adhesion of the coating to the coated surface shall be as follows:
a) For each test, use fresh tap water that has been heated to within 3 °C of the temperature as specified in Tables 2 to 4 for Systems 1A and 1B, and Tables 7 and 8 for Systems 2A, 2B, 2C, and 3. Fully submerge the test sample in the preheated water for the minimum duration specified in Tables 2 to 4 for Systems 1A and 1B, and Tables 7 and 8 for Systems 2A, 2B, 2C, and 3.
b) Upon completion of the immersion duration, remove the specimen from the water and, while the test specimen is still warm, scribe an approximately 30 × 15 mm rectangle through the coating to the substrate, then air cool the test specimen to 20 ± 3 °C.
c) Within 1 h of removal from heat [see Item a)], insert the tip of the utility knife under the coating at a corner of the scribed rectangle.
d) Use a levering action to remove the coating.
e) 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.
f) Rate the adhesion of the coating within the rectangle as follows:
    i) Rating 1: coating cannot be removed cleanly;
    ii) Rating 2: less than 50% of the coating can be removed;
    iii) Rating 3: more than 50% of the coating can be removed, but the coating demonstrates a definite resistance to the levering action;
    iv) Rating 4: the coating can be easily removed in strips or large chips; and

v) Rating 5: the coating can be completely removed as a single piece.

12.14.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy powder batch number;
b) the date of testing;
c) the adhesion rating;
d) the duration of test; and
e) the temperature of test.

12.15 Gouge resistance of coating

12.15.1 General

Where specified in the purchaser order, the gouge resistance for the coating shall be determined.

12.15.2 Equipment

The equipment shall consist of the following:

a) a shear-scratch test apparatus with the following features:
   i) a variable-speed crosshead-style materials test instrument or variable-speed control drive apparatus, capable of controlling speed within 10%;
   ii) an adjustable loading mechanism for the test beam or carbide tool, capable of applying at least a 50 kg load normal to the carbide tip. The gouge bit assembly shall be securely mounted to minimize lateral displacements and be able to stay perpendicular to the surface of the specimen;
   iii) a sample-holding system able to accommodate samples cut from pipe that ensures no movement of the sample and gouging that is straight and level;
   iv) an SL-1 smooth or SL-1 single burr carbide tip; and
   v) steel shims in various thicknesses;
b) a coating thickness gauge accurate to 1%;
c) a gouge-depth needle dial gauge having an accuracy of 0.01 mm. The tip of the needle probe shall have a diameter of 1.5 mm;
d) a load calibration system such as calibrated weights (including gouge bit, holder, weight tray, etc.) or a load cell with meter/recorder that operates accurately over a 0 to 100 kg range; and
e) a stopwatch.

12.15.3 Test specimens

Laboratory-coated test specimens shall measure approximately 76 × 102 mm (or be sized to suit the test apparatus). Specimens from test rings shall be of the same dimensions as the laboratory-coated samples and cut in such a way that the movement of load over the sample is along the longitudinal axis of the pipe.

12.15.4 Procedure

The test procedure to measure the resistance of the coating to gouging shall be as follows:

a) Visually inspect each specimen for imperfections and ensure that the temperature of the sample is 20 ± 3 °C or other specified test temperature prior to conducting the test. Perform two tests on each specimen.

b) Draw two straight lines in the direction that the gouge test will be run, at least 20 mm apart and 75 mm long. Note that the distance between lines should allow the dial gauge measurements to be made without the gauge base resting on the gouges. Use a calibrated coating thickness gauge to take at least six measurements along each line and report the average thickness for each line.
c) Condition the test sample at test temperature for at least 1 h prior to test. Place and secure the test specimen (coating side facing the gouge tip) on the holding system with the longitudinal direction parallel to the gouge movement direction and the sample positioned such that the gouge will be along one of the drawn lines. If necessary, use steel shims to level the specimen.
d) Install the carbide bit in the bit-holder. If using a load cell, then lower the gouging tip and adjust the load to 50 ± 2.5 kg or other specified load. If load cell is not used, use calibrated weights to result in 50 ± 2.5 kg or other specified load (includes the weight of bit and weight tray assembly). Adjust the materials test machine or drive mechanism to produce a travel speed of 25 ± 2.5 cm/min (or as required ± 10%).
e) Perform the following steps:
    i) Position the gouge bit over the coating surface (without contacting the coating surface) at a sufficient location to allow a minimum gouge travel length of 75 mm. Ensure that the gouge bit is perpendicular to the surface to be tested (if a lever system is used, ensure that the test beam is parallel to the coating surface and that the gouge bit is perpendicular to the surface to be tested).
    ii) Lower the gouge bit onto the coating surface at the marked line, and start the test within 5 s.
    iii) Measure the time to complete the 75 mm gouge length with a stopwatch to confirm the travel speed is achieved.
    iv) Perform the gouge test on the coating along the first test line.
    v) Remove or reposition the test sample to perform additional tests.
f) Mark each gouge approximately 10 mm from the start of the scratch.
Draw a line across all of the scratches, ensuring that the line is always at least 10 mm from the starting point of the scratches. Using this first line as a reference point, draw two more parallel lines that are about 25 mm apart across the width of the specimen. The last line drawn should also be at least 10 mm away from the finish of the gouges. These three lines, which cross the width of the gouges, are measurement reference points.
g) Place the dial gauge over the undamaged area of the test panel and zero the dial reading.
Position the dial gauge over the gouge, ensuring that the contact point drops into the bottom of the scratch. The gauge base should not rest on the gouges or the adjacent deformed coating, but rather rest on either side of this area. Record the depth of the gouges at the area where each gouge is intersected by the marked reference lines.
h) Repeat the steps specified in Items a) to g) at each test temperature, gouge load, and gouge travel speed, if required.

12.15.5 Report

Where a report is required by Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy/overcoat coating and identification and batch numbers;
b) the date of testing;
c) the total and individual coating thickness of applied epoxy powders;
d) the load used for testing (if different from 50 kg);
e) the type of carbide tip used for testing;
f) the speed (if different from 25 cm/min); and
g) the test temperature in degrees Celsius.

12.16 Surface roughness for anti-slip overcoat systems

12.16.1 Equipment

The equipment shall consist of the following:

a) replicating film or a profilometer;
b) a burnishing tool; and
c) a spring micrometer.

12.16.2 Procedure

The test procedure to measure the surface roughness for anti-slip overcoat systems shall be as follows:

a) Choose a place with anti-slip material on the coated exterior of the pipe to take the roughness measurement.
b) Place the replicating film over the selected area.
c) Rub the large end (flat end) of a burnishing tool over the round cut-out portion of the replicating film to obtain an impression. Replicating film will become darker when replicated, so ensure that the entire circle area has uniformly darkened.
d) Remove the replicating film from the pipe and place it between anvils on the spring micrometer. Ensure that the darkened area of the replicating film is centred for accurate micrometer reading.
e) Release the spring and take the reading displayed on the micrometer. The gauge reading shall be taken in accordance with the replicating film manufacturer's recommended practice for measuring the maximum peak-to-valley difference of the selected area in the coating surface profile.

12.16.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the epoxy/overcoat epoxy powder batch numbers;
b) the date of testing;
c) the total and individual coating thickness of applied epoxy powders; and
d) the measured value of the surface profile.

Table 1
Epoxy powder properties for Systems 1A and 1B
(See Clauses 5.2.2.1, 7.3.1.3, 12.3, and 12.4.)

Test	Acceptance criteria	Test method	Number of specimens
Cure time	Meets manufacturer's specification	Clause 12.1	1
Gel time	Within 20% of manufacturer's specified nominal	Clause 12.2	3*
Moisture content†	0.5% maximum 0.6% maximum	Clause 12.3 Clause 12.4	2* 1
Particle size	3.0% maximum epoxy powder retained on 150 µm mesh and 0.2% maximum epoxy powder retained on 250 µm mesh	Clause 12.5	1

(Continued)

Table 1 (Concluded)

Test	Acceptance criteria	Test method	Number of specimens
Density	Meets manufacturer's specification within 50 g/L	Clause 12.6	1
Thermal characteristics	Meets manufacturer's specification	Clause 12.7	1

* *The number of specimens is also defined in the test method.*
† *The specific test method to be used shall be at the manufacturer's option.*

Table 2*
Qualification test requirements for anti-corrosion coatings
(See Clauses 6.1.3, 12.8.3.2, 12.11.3, and 12.14.3.)

Test	Acceptance criteria		Number of test specimens	Test method
	System 1A	System 1B		
Thermal characteristics	Meets manufacturer's specification	Meets manufacturer's specification	3	Clause 12.7
Cure — Δ*Tg*	≤5 °C	≤5 °C	3	Clause 12.7
24 h cathodic disbondment at 65 °C	6.5 mm maximum radius	6.5 mm maximum radius	3	Clause 12.8
28 d cathodic disbondment at 20 °C	8.5 mm maximum radius	8.5 mm maximum radius	3	Clause 12.8
28 d cathodic disbondment at 65 °C	15 mm maximum radius	—	3	Clause 12.8
28 d cathodic disbondment at 95 °C	—	15 mm maximum radius	3	Clause 12.8
Cross-section porosity	Rating of 1–3	Rating of 1–3	3	Clause 12.10
Interface porosity	Rating of 1–3	Rating of 1–3	3	Clause 12.10
2.0° flexibility	—	No cracking	5	Clause 12.11
3.0° flexibility	No cracking	—	5	Clause 12.11
1.5 J impact resistance	No holidays	No holidays	3	Clause 12.12
1.5° strained coating, 28 d cathodic disbondment at 20 °C	—	No cracking	3	Clause 12.13
2.5° strained coating, 28 d cathodic disbondment at 20 °C	No cracking	—	3	Clause 12.13
24 h adhesion at 75 °C	Rating of 1–3	—	3	Clause 12.14

(Continued)

Table 2* (Concluded)

Test	Acceptance criteria		Number of test specimens	Test method
	System 1A	System 1B		
24 h adhesion at 95 °C	—	Rating of 1–3	3	Clause 12.14
28 d adhesion at 75 °C	Rating of 1–3	—	3	Clause 12.14
28 d adhesion at 95 °C	—	Rating of 1–3	3	Clause 12.14

** A minimum of one gel time version of an epoxy powder formulation for Systems 1A and 1B shall be evaluated in accordance with this Table.*

Table 3
Laboratory coating test requirements for Systems 1A and 1B
(See Clauses 7.3.1.1, 7.3.1.4, 12.8.3.2, 12.11.3, and 12.14.3.)

Test	Acceptance criteria		Number of test specimens	Test method
	System 1A	System 1B		
Cure — Δ*Tg*	≤5 °C	≤5 °C	1	Clause 12.7
24 h cathodic disbondment at 65 °C	6.5 mm maximum radius	6.5 mm maximum radius	1	Clause 12.8
Cross-section porosity	Rating of 1–3	Rating of 1–3	1	Clause 12.10
Interface porosity	Rating of 1–3	Rating of 1–3	1	Clause 12.10
1.5° flexibility	—	No cracking	3	Clause 12.11
2.5° flexibility	No cracking	—	3	Clause 12.11
24 h adhesion at 75 °C	Rating of 1–3	—	1	Clause 12.14
24 h adhesion at 95 °C	—	Rating of 1–3	1	Clause 12.14

Table 4
Production coating test requirements for Systems 1A and 1B
(See Clauses 7.3.1.1, 7.3.3.1, 7.3.3.3.1, 7.3.3.3.3, 7.3.3.4.1, 7.3.3.5, 12.8.3.2, 12.11.3, and 12.14.3.)

Test	Test type	Acceptance criteria		Number of test speci-mens	Test method
		System 1A	System 1B		
Cure — Δ*Tg*	B	≤5 °C	≤5 °C	1	Clause 12.7
24 h cathodic disbondment at 65 °C	A	6.5 mm maximum radius	6.5 mm maximum radius	1	Clause 12.8

(Continued)

Table 4 (Concluded)

Test	Test type	Acceptance criteria		Number of test specimens	Test method
		System 1A	System 1B		
Interface contamination	B	30% maximum	30% maximum	1	Clause 12.9
Cross-section porosity	B	Rating of 1–3	Rating of 1–3	1	Clause 12.10
Interface porosity	B	Rating of 1–3	Rating of 1–3	1	Clause 12.10
1.5° flexibility	A	—	No cracking	3	Clause 12.11
2.5° flexibility	A	No cracking	—	3	Clause 12.11
1.5 J impact resistance	A	No holidays	No holidays	1	Clause 12.12
24 h adhesion at 75 °C	A	Rating of 1–3	—	1	Clause 12.14
24 h adhesion at 95 °C	A	—	Rating of 1–3	1	Clause 12.14

Table 5
Epoxy powder properties for Systems 2A, 2B, 2C, and 3
(See Clauses 5.2.2.1 and 7.3.1.3.)

Test	Acceptance criteria	Test method	Number of test specimens
Cure time	Meets manufacturer's specification	Clause 12.1	1
Gel time	Meets manufacturer's specification	Clause 12.2	3*
Moisture content†	Meets manufacturer's specification	Clause 12.3	2*
		Clause 12.4	1
Particle size	Meets manufacturer's specification	Clause 12.5	1
Density	Meets manufacturer's specification within 50 g/L	Clause 12.6	1
Thermal characteristics	Meets manufacturer's specification	Clause 12.7	1

** The number of specimens is also defined in the test method.*
† The specific test method to be used shall be at the manufacturer's option.

Table 6*
Qualification test requirements for Systems 2A, 2B, 2C, and 3
(See Clauses 6.1.3 and 12.11.3.)

Test	Acceptance criteria	Number of test specimens	Test method
Thermal characteristics	Meets manufacturer's specification	3	Clause 12.7
Cure — Δ*Tg*†	≤5 °C	3	Clause 12.7
Cross-section porosity‡	Rating of 1–3	3	Clause 12.10
Interface porosity†	Rating of 1–3	3	Clause 12.10
2.0° flexibility	No cracking	5	Clause 12.11
3.0 J impact resistance§	No holidays	3	Clause 12.12
1.5° strained coating, 28 d cathodic disbondment at 20 °C	No cracking	3	Clause 12.13
Surface roughness**	>50 µm peak to trough	3	Clause 12.16

* *A minimum of one gel time version of an epoxy powder formulation for Systems 2A, 2B, 2C, and 3 shall be evaluated in accordance with this Table.*
† *Cure and interface porosity tests shall be completed on inner layer of coating system.*
‡ *For individual layers of multi-layer coating systems except anti-slip overcoat.*
§ *For all multi-layer coatings, except for anti-corrosion coating with anti-slip overcoat, use 1.5 J.*
** *Surface roughness for anti-slip overcoat systems only.*

Table 7
Laboratory coating test requirements for Systems 2A, 2B, 2C, and 3
(See Clauses 7.3.1.1, 7.3.1.4, 12.8.3.2, 12.11.3, and 12.14.3.)

Test	Acceptance criteria	Number of test specimens	Test method
Cure — Δ*Tg**	≤5 °C	1	Clause 12.7
24 h cathodic disbondment at 65 °C	6.5 mm maximum radius	1	Clause 12.8
Cross-section porosity†	Rating of 1–3	1	Clause 12.10
Interface porosity*	Rating of 1–3	1	Clause 12.10
1.5° flexibility	No cracking	3	Clause 12.11
24 h adhesion at 75 °C	Rating of 1–3	1	Clause 12.14
3.0 J impact resistance‡	No holidays	1	Clause 12.12
Surface roughness§	>50 µm peak to trough	1	Clause 12.16

* *Cure and interface porosity tests shall be completed on inner layer of coating system.*
† *For individual layers of multi-layer coating systems except anti-slip overcoat.*
‡ *For all multi-layer coatings, except for anti-corrosion coating with anti-slip overcoat, use 1.5 J.*
§ *Surface roughness for anti-slip overcoat systems only.*

Table 8
Production coating test requirements for Systems 2A, 2B, 2C, and 3
(See Clauses 7.3.1.1, 7.3.3.1, 7.3.3.3.3, 7.3.3.4.1, 7.3.3.5, 12.8.3.2, 12.11.3, and 12.14.3.)

Test	Test type	Acceptance criteria	Number of test specimens	Test method
Cure — Δ*Tg**	B	≤5 °C	1	Clause 12.7
24 h cathodic disbondment at 65 °C	A	6.5 mm maximum radius	1	Clause 12.8
Interface contamination	B	30% maximum	1	Clause 12.9
Cross-section porosity†	B	Rating of 1–3	1	Clause 12.10
Interface porosity*	B	Rating of 1–3	1	Clause 12.10
1.5° flexibility	A	No cracking	3	Clause 12.11
3.0 J impact resistance‡	A	No holidays	1	Clause 12.12
24 h adhesion at 75 °C	A	Rating of 1–3	1	Clause 12.14
Surface roughness§	B	>50 µm peak to trough	1	Clause 12.16

* *Cure and interface porosity tests shall be completed on inner layer of coating system.*
† *For individual layers of multi-layer coating systems except anti-slip overcoat.*
‡ *For all multi-layer coatings, except for anti-corrosion coating with anti-slip overcoat, use 1.5 J.*
§ *Surface roughness for anti-slip overcoat systems only.*

Table 9
FBE coating repair criteria
(See Clauses 7.3.2.8.2.2, 7.3.2.8.2.3, 8.2, and 8.3.)

Pipe OD, mm	Acceptance criteria, repair frequency, max area (individual holiday)	Holiday repair (Clause 8.2)	Strip and recoat (Clause 8.3)	Epoxy repair melt stick or two-part liquid epoxy	Liquid epoxy
<355.6	≤1.0/m and <250 cm²	X		≤2.0 mm diameter or width	>2.0 mm diameter or width, and <250 cm²
<355.6	>1.0/m or ≥250 cm²		X	N/A	N/A
≥355.6	≤0.7/m² and <250 cm²	X		≤2.0 mm diameter or width	>2.0 mm diameter or width, and <250 cm²
≥355.6	>0.7/m² or ≥250 cm²		X	N/A	N/A

Figure 1
Draw-down tool
(See Clauses 12.1.1 and 12.2.1.)

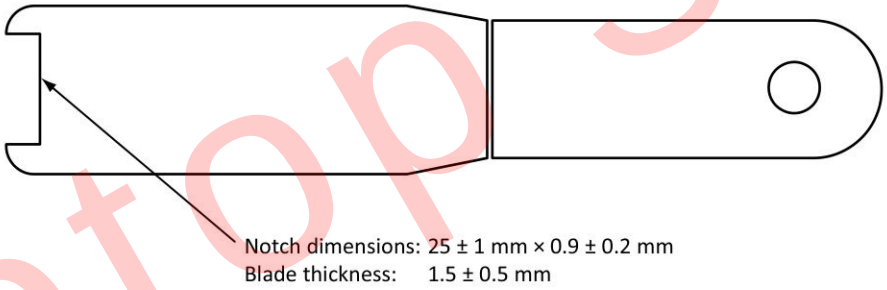


Figure 2
Coated plate configuration
(See Clause 12.1.2.)

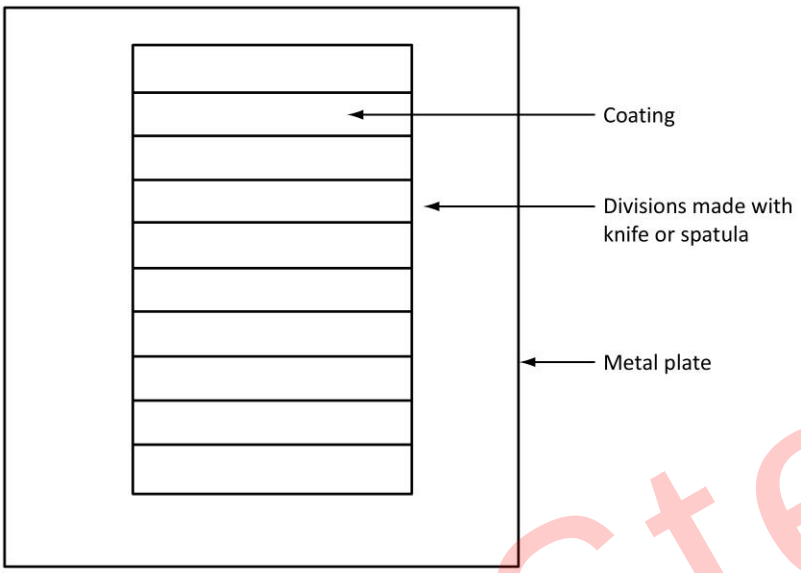
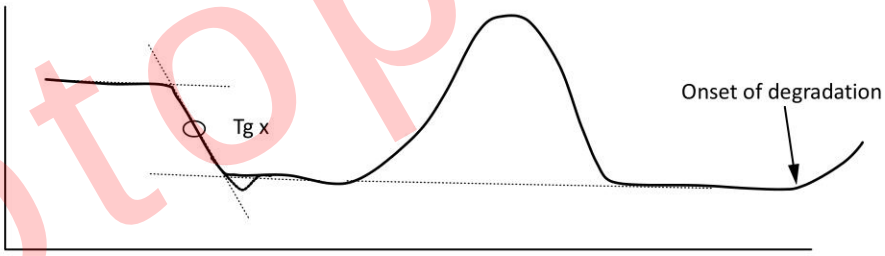
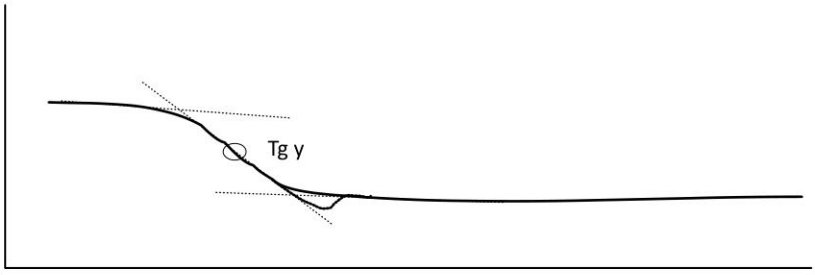


Figure 3
Unknown epoxy powder — Preliminary DSC scans
(See Clause 12.7.3.2.1.)

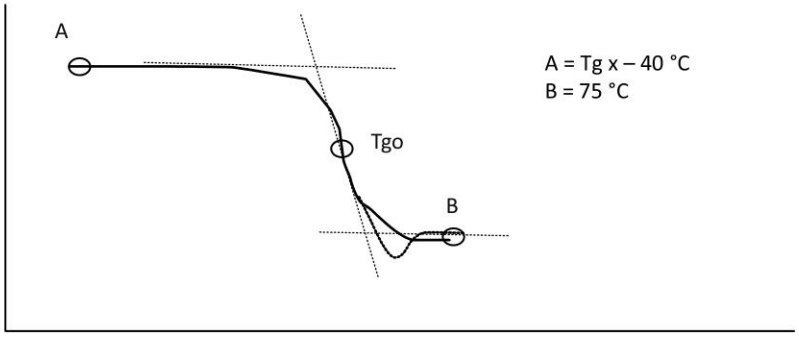


Run 1: Unknown powder run from 10 °C to 285 °C

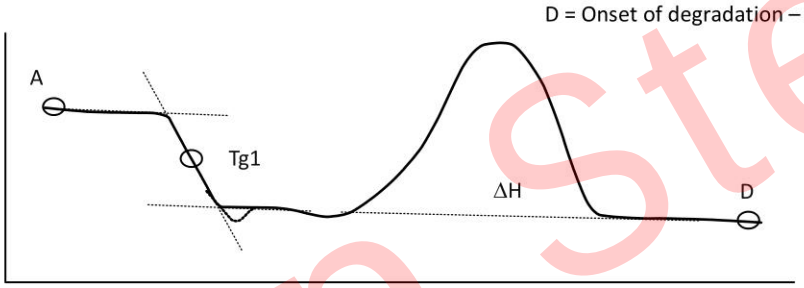


Run 2: Unknown cured powder run from 10 °C to 200 °C

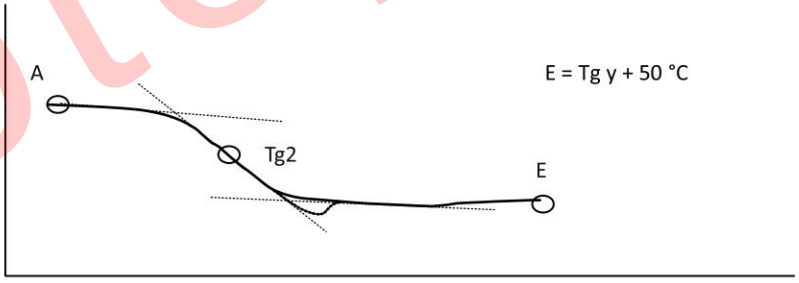
Figure 4
Thermal scans of epoxy powder
(See Clauses 12.7.3.2.1 and 12.7.3.3.1.)



Run 1: Enthalpic relaxation



Run 2: Determine Tg1 and completely cure FBE powder

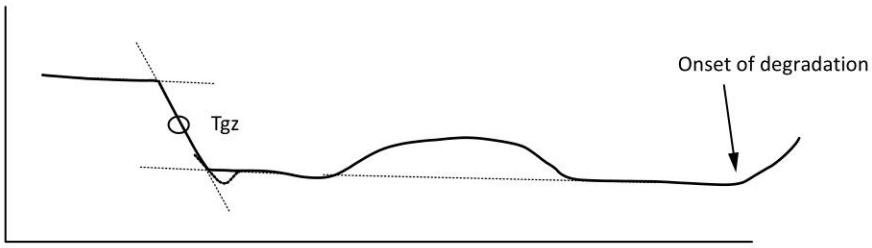


Run 3: Determine Tg2 of cured FBE

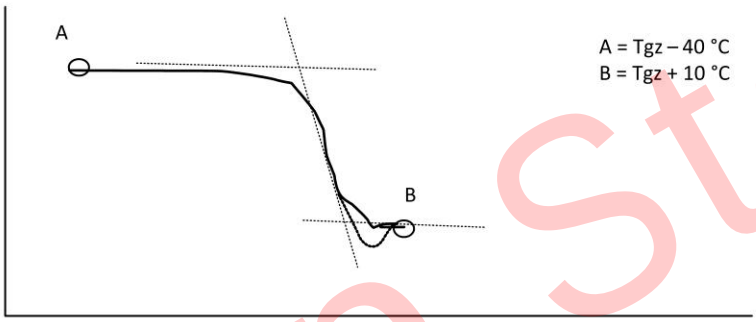
DSC method for epoxy powder:

1) Ramp at 20 °C/min from A to B, then immediately cool to A.
2) Ramp at 20 °C/min from A to D (D shall be after the completion of the exotherm and before the onset of degradation), then immediately cool to A.
3) Ramp at 20 °C/min from A to E.

Figure 5
Thermal scans of epoxy coating
(See Clauses 12.7.3.2.2 and 12.7.3.3.1.)



Unknown epoxy run from 25 °C to 285 °C



Run 1: Enthalpic relaxation

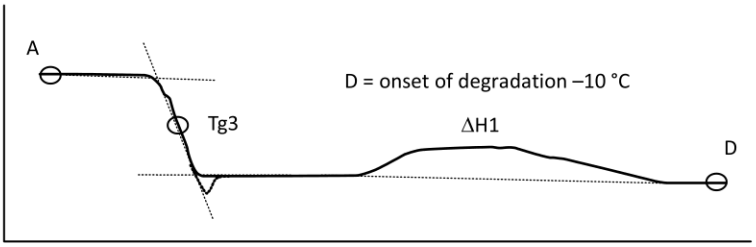
DSC method for coating:

a) Ramp at 20 °C/min from A to B, hold isothermally at B for 1.5 min, then immediately cool to A.
b) Ramp at 20 °C/min from A to D, then immediately cool to A.
c) Ramp at 20 °C/min from A to E.

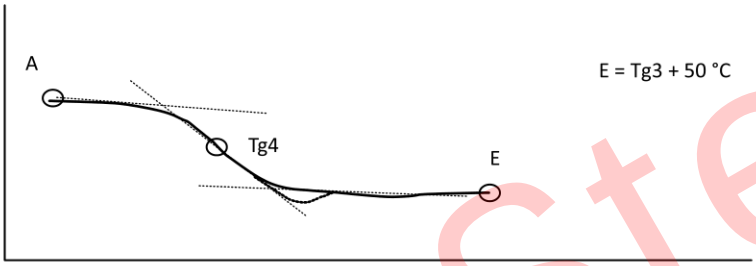
Note: *For convenience, A may be set to 25 °C.*

(Continued)

Figure 5 (Concluded)



Run 2: Determine Tg3 and complete reaction of uncured Epoxy



Run 3: Determine Tg4 of cured Epoxy

Note: *In the event that Run 2 showed significant degradation, and the value Tg3 is within 5 °C of the nominal Tg, the end point D could have been adjusted to a lower temperature. However, if Run 2 showed negligible residual ΔH and Tg3 is significantly lower than the nominal Tg, the coating could have been overcured.*

Figure 6
Interfacial contamination comparison chart
(See Clause 12.9.3.)

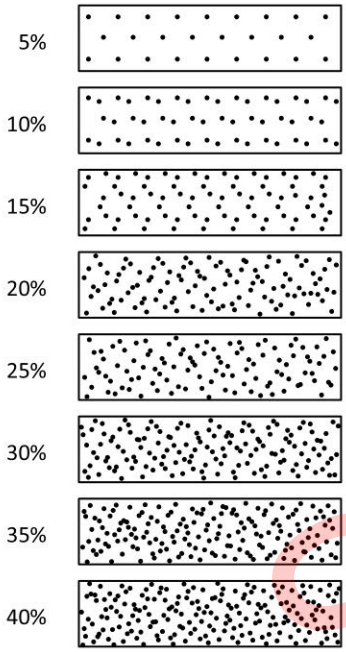


Figure 7
Examples of radial cuts through the coating
(See Clause 12.8.3.2.)

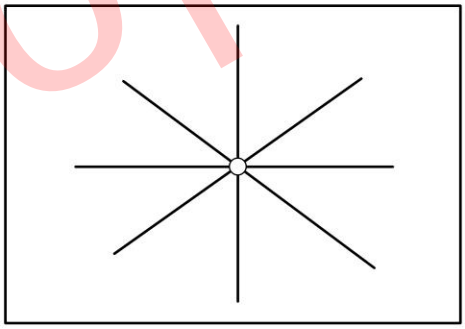


Figure 8
Examples of cross-section porosity
(See Clause 12.10.3.)

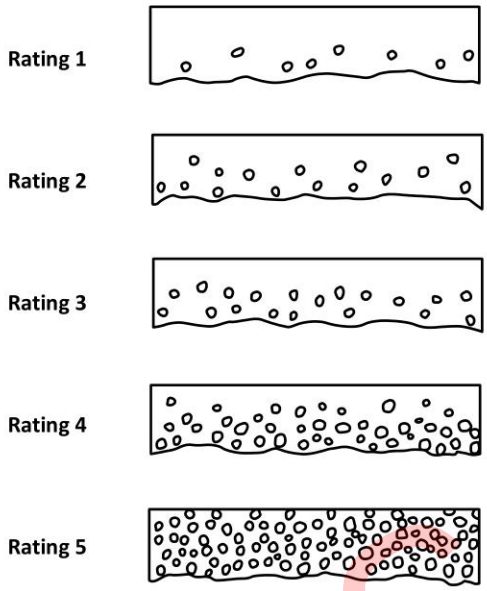


Figure 9
Examples of interface porosity
(See Clause 12.10.3.)

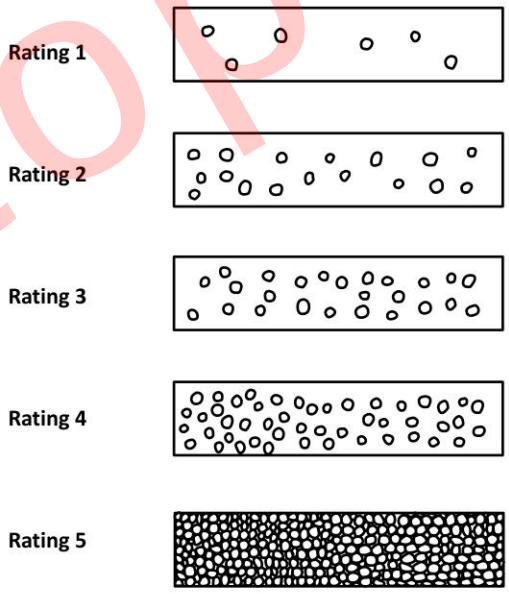


Figure 10
Determination of sample thickness flexibility test (end view)
(See Clause 12.11.3.)

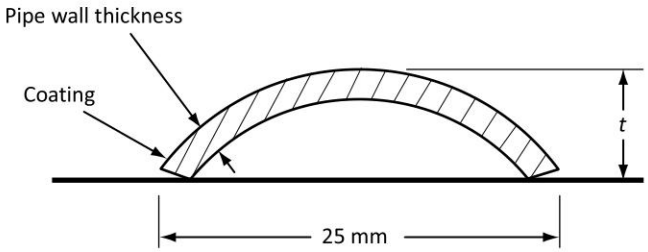
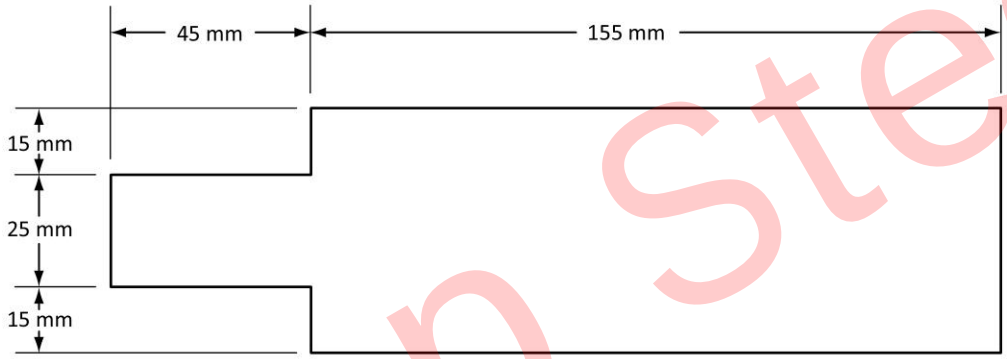
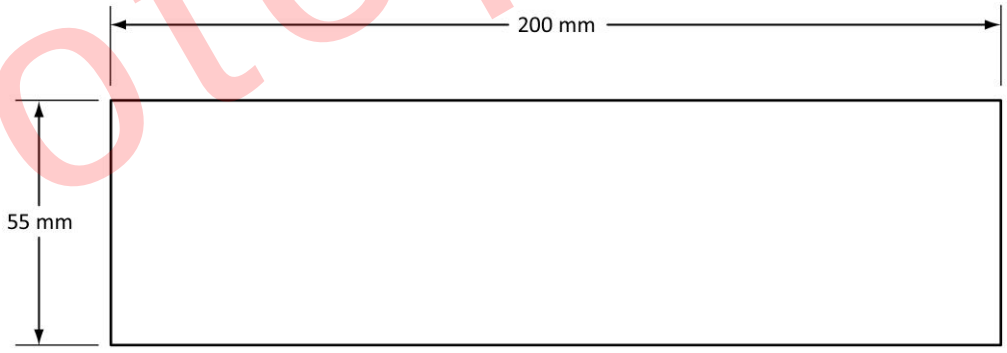


Figure 11
Test specimen — Cathodic disbondment of strained coating test
(See Clause 12.13.2.)



a) With notch



b) Without notch

CSA Z245.21:22

Plant-applied external polyethylene coating for steel pipe

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CSA Z245.21:22
Plant-applied external polyethylene coating for steel pipe

1 Scope

1.1
This Standard covers the qualification, application, inspection, testing, handling, and storage of materials required for plant-applied polyethylene coating applied externally to steel pipe, whereby an adhesive is interposed between a bare or epoxy-primed pipe and the polyethylene. The coated pipe is intended primarily for buried or submerged service for oil or gas pipeline systems.

1.2
This Standard covers the following coating systems:

a) System A: a coating that consists of an adhesive and a polyethylene outer sheath (see Table 1);
b) System B1: a coating that consists of a liquid or powdered epoxy primer, a polymeric adhesive, and a polyethylene outer sheath; and
c) System B2: a coating that consists of a powdered epoxy primer, a powdered copolymer adhesive, and a powdered polyethylene outer layer.

1.3
In this Standard, "shall" is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the Standard; "should" is used to express a recommendation or that which is advised but not required; and "may" is used to express an option or that which is permissible within the limits of the Standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the editions listed below.

Note: *In cases where the editions listed below are amended, replaced by new editions, or superseded by another standard during the life of this referencing Standard, it is the responsibility of the users of this Standard to investigate the possibility of applying those amendments, new editions, or superseding standards.*

CSA Group

CAN/CSA-ISO 9001:16 (R2020)
Quality management systems — Requirements

Z245.20:22
Plant-applied external fusion bond epoxy coating for steel pipe

Z245.30:22
Field-applied external coatings for steel pipeline systems

Z662:19
Oil and gas pipeline systems

ASTM International

D618-21
Standard Practice for Conditioning Plastics for Testing

D638-14
Standard Test Method for Tensile Properties of Plastics

D746-20
Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

D792-20
Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1238-20
Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

D1475-13(2020)
Standard Test Method for Density of Liquid Coatings, Inks, and Related Products

D1505-18
Standard Test Method for Density of Plastics by the Density-Gradient Technique

D1525-17e1
Standard Test Method for Vicat Softening Temperature of Plastics

D1652-11(2019)
Standard Test Method for Epoxy Content of Epoxy Resins

D1693-21
Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

D2083-92(1998) (withdrawn)
Standard Test Method for Calculation of Percent of Primary, Secondary, and Tertiary Amines in Fatty Amines

D2196-20
Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer

D2240-15(2021)
Standard Test Method for Rubber Property — Durometer Hardness

D3895-19
Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

D4703-16
Standard Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets

E28-18
Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus

E29-13(2019)
Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ISO (International Organization for Standardization)
9001:2015
Quality management systems — Requirements

SSPC (The Society for Protective Coatings)/NACE International
SP 6/NACE No. 3-2007
Commercial Blast Cleaning

SP 10/NACE No. 2-2007
Near-White Blast Cleaning

3 Definitions

The following definitions shall apply in this Standard:

Adhesive —
a) for System A, a material used to provide bonding between the bare steel and the polyethylene topcoat; and
b) for Systems B1 and B2, a material used to provide bonding between the epoxy primer and the polyethylene topcoat.

Adhesive lot —
a) for System A, an identifiable quantity of material, not exceeding 20 Mg, made in continuous production; and
b) for Systems B1 and B2, the entire quantity of material that is traceable to a period of continuous production of 24 h or less.

Applicator — the company responsible for the actual application of the coating.

Batch — a quantity of primer that is a continuous production of not more than 8 h.

Certificate of compliance — a document provided by the product manufacturer or coating applicator certifying that the product or the coating, as applicable, is in compliance with the requirements of this Standard.

Coating — the total coating system, consisting of compounded polyethylene applied over the previously applied adhesive, with or without a previously applied epoxy.

Compounded polyethylene — a natural resin with an ultraviolet stabilizer and a colourant.

Continuous production — the uninterrupted manufacture of materials.

Defect — an imperfection of sufficient magnitude to warrant rejection based on the requirements of this Standard.

Holiday — a discontinuity in the applied coating that exhibits electrical conductivity when exposed to a specific voltage.

Imperfection — a material discontinuity or irregularity that is detectable by inspection in accordance with the requirements of this Standard.

Polyethylene lot — a quantity that is a continuous production of not more than 24 h.

Test report — a document that provides the quantitative test results for tests conducted in accordance with the requirements of this Standard.

Test ring — a sample taken from production-coated pipe.

Working shift — a period of production, to a maximum of 12 h, at the application facility.

4 General requirements

4.1 Product ordering requirements

4.1.1 Standard requirements

The following information shall be included in purchase orders for coating for pipe:

a) CSA Standard designation and year of publication (CSA Z245.21:22);
b) pipe quantity, outside diameter (OD), wall thickness, and nominal length;
c) maximum design temperature;
d) pipeline system maximum design temperature;
e) coating system (A, B1, or B2)*;
f) bare pipe standard or specification designation (see Clause 5.1);
g) cutback length and tolerance for both ends of pipe (see Clause 6.2.4);
h) cathodic disbondment radius at maximum design temperature (see Table 1); and
i) test temperature for the flexibility test [–30, –18, or 0 °C; see Clause 12.11.3 b) of CSA Z245.20].

* *See Clause 1.2.*

4.1.2 Optional requirements

Where applicable, purchase orders shall include the following information:

a) plant inspection by the purchaser (see Clause 7.1);
b) location of laboratory testing (see Clause 7.3.1);
c) increased test ring length (see Clause 7.4.3.2);
d) increased test frequency (see Clauses 7.4.3.3 and 7.4.3.5);
e) additional markings (see Clause 9.1);
f) handling procedures (see Clause 10.1.1);

g) storage procedures (see Clause 10.2);
h) waiver of test reports (see Clause 11.1);
i) gouge test (see Clause 12.7); and
j) other special requirements.

4.2 Rounding procedure

Except as otherwise required by this Standard, 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 the rounding method of ASTM E29.

4.3 Requirements for quality

The applicator and polyethylene manufacturer shall comply with the requirements of a nationally or internationally recognized quality management system and the requirements of Clause 4.4.

Note: *CAN/CSA-ISO 9001 or ISO 9001 provides suitable quality management systems.*

4.4 Compliance

The applicator shall be responsible for complying with all of the applicable requirements of this Standard. The purchaser may make any investigation necessary in order to be assured of compliance by the applicator and to reject any material that does not comply.

5 Materials

5.1 Pipe

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

Note: *Pipe conforming to such standards or specifications will, in some cases, not have a surface condition that is appropriate for the application of coating.*

5.2 General

5.2.1

The applicator shall use materials that are

a) certified by the manufacturer to be in accordance with the applicable requirements of Clauses 5.3 to 5.5 and compatible with the requirements of Table 1. Test reports shall be supplied with each batch or lot of material;
b) identified with the following:
    i) manufacturer's name;
    ii) product description;
    iii) batch or lot number;
    iv) location of manufacture;
    v) date of manufacture; and
    vi) test date(s); and
c) handled, transported, and stored in accordance with the manufacturer's recommendations.

5.2.2
The date of tests performed by the epoxy powder manufacturer for the materials being applied shall not be more than 365 d prior to the date of application of the coating by the applicator.

5.3 Primer

5.3.1 Liquid primer
The liquid epoxy primer properties shall be as specified in Table 4.

5.3.2 Powdered primer
The powdered epoxy primer properties shall be as specified in Table 1 of CSA Z245.20.

5.4 Adhesive
The adhesive properties shall be as specified in Table 2.

5.5 Polyethylene
The virgin polyethylene resin properties shall be as specified in Table 3. Where test plates are required, they shall be made in accordance with the requirements of ASTM D4703, Procedure C, and conditioned in accordance with the requirements of ASTM D618.

5.6 Packaging

5.6.1
Except where allowed by Clause 5.6.2, the material shall be delivered in containers that are clearly labelled to identify the items specified in Clause 5.2.1 b).

5.6.2
For bulk shipments where the container (e.g., a railway car) is not specifically marked for the product in question, the manufacturer shall provide documentation to ensure traceability in accordance with the requirements of Clause 5.2.1 b).

6 Coating application

6.1 Coating qualification

6.1.1 General
The coating system shall be qualified for production by the applicator by testing specimens removed from pipe coated in the plant, except as required by Clause 6.1.4, for each applicable test and by meeting the acceptance criteria. The coating shall be requalified by the applicator where there is a change in one or more of the following:

a) manufacturer of any of the coating materials;
b) location of manufacturer of primer, adhesive, or polyethylene;
c) formulation of any of the coating materials; and
d) combination of coating components(e.g., substitution of liquid epoxy for a powdered epoxy).

6.1.2 Testing requirements for Systems A, B1, and B2

The tests to be conducted, the test methods to be used, and the acceptance criteria shall be as specified in Table 1. For each test, specimens shall be obtained from two production pipes.

6.1.3 Polyethylene evaluation for Systems A and B1

The sample of polyethylene to be evaluated shall be taken from the pipe, cut transverse to the pipe axis, and shall be free of primer and adhesive. The tests to be conducted, the test methods to be used, and the acceptance criteria shall be as specified in Table 5.

6.1.4 Polyethylene evaluation for System B2

The sample of polyethylene shall not be taken from the pipe but shall be made in accordance with the requirements of ASTM D4703, Procedure C, and conditioned in accordance with the requirements of ASTM D618. The tests to be conducted, the test methods to be used, and the acceptance criteria shall be as specified in Table 5.

6.2 Production application practices and equipment

6.2.1 General

The coating shall be qualified for production in accordance with the requirements of Clause 6.1.

6.2.2 Surface preparation

6.2.2.1

The external surfaces of the pipe shall be free of any injurious levels of contaminants such as oil, grease, and salts prior to the application of the coating.

6.2.2.2

Prior to blast cleaning and coating, the pipe shall be preheated to remove moisture. The pipe surface shall be maintained at a temperature at least 3 °C above the dew point, but less than 150 °C, during blast cleaning and inspection. During and after blast cleaning, the pipe surface shall be protected from contact with materials and equipment that might contaminate the pipe at the pipe surface's processing temperature.

6.2.2.3

The external pipe surface to be coated shall be blast cleaned to at least the following requirements:

a) for System A, SSPC SP 6/NACE No. 3; and
b) for Systems B1 and B2, SSPC SP 10/NACE No. 2.

The surface profile, measured from peak to trough, shall be 40 to 110 µm and, where applicable, be in accordance with the primer manufacturer's recommendations.

6.2.2.4

Residual blast products from the interior and exterior surfaces of the pipe shall be suitably removed.

6.2.2.5

Prior to the coating application for System B2, the cleaned pipe shall be inspected in accordance with

the requirements of Clause 7.4.1.2, and imperfections that might cause holidays in the coating shall be removed in a manner that gives a surface finish suitable for subsequent application of coating.

Notes:

1) *Disposition of pipe with imperfections that cannot be removed during the normal production cycle should be subject to agreement between the applicator and the purchaser.*
2) *Surface defects include, but are not limited to, gouges, grooves, arc burns, dents, and surface laminations. See Clause 6.3 of CSA Z662 for more information on pipe surface requirements applicable to steel piping.*

6.2.2.6

Unless otherwise specified in the purchase order, the applicator may use additional surface treatments prior to the application of the coating.

Note: *The purchaser should be satisfied that the applicator's quality control program for such treatments is acceptable.*

6.2.3 Application

6.2.3.1 Application of primer

The primer selected by the applicator shall be applied in accordance with the primer manufacturer's recommendations. The minimum thickness for Systems B1 and B2 primer shall be as specified in Table 6.

6.2.3.2 Application of adhesive

The adhesive selected by the applicator shall be applied in accordance with the adhesive manufacturer's recommendations. The minimum adhesive thickness shall be as specified in Table 6.

6.2.3.3 Application of polyethylene

6.2.3.3.1

The polyethylene selected by the applicator shall be applied immediately following the application of the adhesive to the pipe.

6.2.3.3.2

The minimum polyethylene thickness shall be as specified in Table 6.

6.2.3.3.3

The coating application shall be a continuous process in order to provide an outer sheath of uniform thickness free of pinholes, cracks, and visible defects.

6.2.4 End finish

The polyethylene cutback length and tolerance for both ends of pipe shall be as specified in the purchase order. The pipe surface shall be free of all coating for a length no less than 50 mm nor greater than the specified maximum cutback length, as applicable, as measured from the end of the pipe.

Note: *The polyethylene can undergo growth or shrinkage following cutback due to temperature changes.*

7 Production, inspection, and testing

7.1 Inspection notice

When it is specified in the purchase order that the inspector representing the purchaser intends to inspect the coating or witness the tests, the applicator shall give the purchaser reasonable notice of the production schedule.

7.2 Plant access

While work on the contract of the purchaser is being performed, the inspector representing the purchaser shall have unrestricted entry at all times to all parts of the applicator's plant that relate to the storage, application, testing, and handling of the pipe and coating. The applicator shall afford the inspector all reasonable facilities in order to be satisfied that the coating is being applied in accordance with the requirements of this Standard. 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, testing, or both.

7.3 Incoming raw materials testing

7.3.1

The applicator shall conduct the sample preparation, testing, and evaluation of the primer, adhesive, and polyethylene using suitable equipment at the application facility. Tests shall be done at the application facility unless otherwise agreed upon by the purchaser.

7.3.2

The minimum testing frequency shall be once per vehicle shipment for the primer, adhesive, and polyethylene. Gel time tests (see Clause 12.2 in CSA Z245.20) shall be conducted on each batch prior to use in production.

7.3.3

The properties of the primer shall be as specified in Table 7.

7.3.4

The properties of the adhesive shall be as specified in Table 8.

7.3.5

The properties of the polyethylene shall be as specified in Table 9.

7.4 Production tests

7.4.1 In-line inspection and measurement

7.4.1.1 General

The inspections and measurements required by Clauses 7.4.1.2 to 7.4.1.6 shall be performed and taken by the applicator.

7.4.1.2 Surface preparation

The blast-cleaned surface shall be monitored a minimum of every 2 h during production to determine compliance with the requirements of Clause 6.2.2.3. At least once every 4 h of production, the external surface profile on two pipes shall be measured using a profilometer, replicating film, or a purchaser-approved equivalent. The profile shall be in accordance with the requirements of Clause 6.2.2.3.

7.4.1.3 Application temperature

The surface temperature of the pipe immediately prior to coating application shall be monitored and controlled within the limits recommended by the material manufacturer. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

7.4.1.4 Coating thickness for Systems A and B1

7.4.1.4.1

For System A, the total thickness and the thickness of the individual components shall be measured at four locations around the pipe circumference using a coating thickness gauge that has been verified at least once every working shift.

7.4.1.4.2

For System B1, the total thickness and the thicknesses of the individual layers shall be measured using a suitable measurement technique.

7.4.1.4.3

The thickness shall be determined and the results recorded for each of the following, as applicable to the coating run length:

a) the first pipe coated in the run;
b) one pipe from the subsequent lot of 4 pipes sequentially coated in the run;
c) one pipe from the subsequent lot of 10 pipes sequentially coated in the run;
d) one pipe from the subsequent lot of 35 pipes sequentially coated in the run; and
e) one pipe from each subsequent lot of 50 pipes sequentially coated in the run.

7.4.1.5 Coating thickness for System B2

The total thickness shall be measured at four random locations along each pipe length using a coating thickness gauge that has been verified at least once every working shift. The thickness of the individual components shall be measured using a suitable measurement technique at start-up and at least once every 4 h of production thereafter. Such measured thickness values shall be recorded.

7.4.1.6 Residual magnetism

Notes:

1) *These requirements apply only to measurements made within the coating facility during final coating inspection. Measurements of residual magnetism made subsequent to shipment can be affected by procedures and conditions imposed on the coated pipe during and after shipment.*
2) *The coating applicator may check the residual magnetism of the incoming pipe.*

7.4.1.6.1

The longitudinal magnetic field shall be measured on the root face or square cut face of coated pipe.

7.4.1.6.2
Measurements shall be made using a Hall-effect magnetic flux density meter or another type of calibrated instrument; however, in case of dispute, measurements made with a Hall-effect magnetic flux meter shall govern. The magnetic flux meter shall be operated in accordance with the applicator's documented procedures that have been demonstrated by the coating applicator to produce accurate results.

7.4.1.6.3
Measurements shall be made on each end of a coated pipe, to be selected at least once every 4 h per operating shift.

7.4.1.6.4
Residual magnetism on the coated pipe shall be measured in the coating facility. For coated pipe handled with magnetic equipment after the measurement of residual magnetism, such handling shall be performed in a manner demonstrated not to cause residual magnetism in excess of the levels specified in Clause 7.4.1.6.5.

7.4.1.6.5
For coated pipe smaller than 168.3 mm OD, at least two readings shall be taken approximately 180° apart around the circumference of each end of the coated pipe. For coated pipe 168.3 mm OD or larger, at least four readings shall be taken approximately 90° apart around the circumference of each end of the coated pipe. The average of such readings shall not exceed an absolute value of 3.0 mT, and no individual reading shall exceed an absolute value of 3.5 mT.

Measurements made on coated pipe in stacks or bundles shall not be accepted.

7.4.1.6.6
Any coated pipe that fails to meet the requirements specified in Clause 7.4.1.6.5 shall be considered defective. In addition, except as allowed by Clause 7.4.1.6.7, all pipe coated between the defective coated pipe and the last acceptable coated pipe shall be individually measured.

7.4.1.6.7
If the coating sequence is documented, coated pipe may be measured in reverse sequence, beginning with the pipe coated immediately prior to the defective coated pipe, until at least three consecutively coated pipes meet the requirements. Pipe coated prior to the three acceptable coated pipes need not be measured.

7.4.1.6.8
Pipe coated after the defective coated pipe shall be measured individually until at least three consecutive coated pipes meet the specified requirements.

7.4.1.6.9
Defective coated pipe shall be segregated, demagnetized, and remeasured.

7.4.2 Holiday inspection

7.4.2.1 General

7.4.2.1.1
The entire coated surface of each length of pipe shall be inspected with a holiday detector. The inspection shall be the responsibility of the applicator.

7.4.2.1.2
The detector shall be
a) calibrated at least once in a 12-month period; and
b) verified and tested at the beginning of each day of use and not less than once every 12 h against a voltmeter that has been calibrated to recognized standards within the previous six months.

For inspection, the direct current potential of the detector shall be set to exceed 10 V for each micrometre of total coating thickness, up to a maximum of 15 000 V.

7.4.2.2 Acceptance criteria
Coated pipe shall be repaired in accordance with the requirements of Clause 8.2 and Table 11. Any pipe that exceeds the requirements of Table 11 shall be dispositioned in accordance with the requirements of Clause 8.3.

7.4.3 Production test rings

7.4.3.1
The applicator shall have suitable facilities available for the preparation, testing, and evaluation of the test rings.

7.4.3.2
Unless otherwise specified in the purchase order, test rings shall be no more than 400 mm long. The rings shall be obtained from locations at least 300 mm from a pipe end. Removal of pipe exceeding the specified lengths for test rings shall be by agreement between the applicator and the purchaser.

7.4.3.3
Unless an increased test frequency is specified in the purchase order, the minimum test frequency shall be as follows:
a) for System A, one test ring per coating system per working shift;
b) for System B1 peel adhesion and 24 h cathodic disbondment tests, one test ring per specified pipe diameter and wall thickness combination per working shift;
c) for System B1 tensile stress at yield and elongation at break tests, one test ring per specified pipe diameter and wall thickness combination per week; and
d) for System B2 24 h cathodic disbondment, 24 h adhesion, and 2.5° flexibility tests, one test ring per specified pipe diameter and wall thickness combination per working shift.

Note: *These frequencies are not affected by the number of purchase orders that are completed during the working shift.*

7.4.3.4
For each test ring, the tests to be conducted, the test methods to be used, and the acceptance criteria shall be as specified in Table 10.

7.4.3.5
For pipe that is stripped and recoated, at least one test ring of the stripped and recoated pipe shall be taken per working shift. Where specified in the purchase order, additional test rings shall be taken.

7.4.4 Retests

7.4.4.1
Where a test fails to conform to the specified requirements,

a) the test that failed shall be repeated using two additional samples (see Clause 7.4.3.2) 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 Clause 8.3.

7.4.4.2
Where both retests conform to the specified requirements, the lot of coated pipe shall be accepted. Where at least one retest fails to conform to the specified requirements,

a) all coating applied after the previous acceptable test and prior to the next acceptable test shall be repaired in accordance with the requirements of Clause 8.3; or
b) subject to the approval of the purchaser, the lot shall be subjected to further retesting to determine those portions of the affected lot that are acceptable, based on obtaining test results for both the first and last pipes in the portion that conforms to the specified requirements. Pipe in those portions of the affected lot that are not acceptable shall be stripped and recoated in accordance with the requirements of Clause 8.3.

8 Repair of coated pipe

8.1 General
Where required by Clause 7 or 10, coating holidays shall be repaired in accordance with the requirements of Clause 8.2 or by stripping and recoating in accordance with the requirements of Clause 8.3, as applicable.

8.2 Holiday repairs

8.2.1
Coating imperfections that fail to meet the requirements of Clause 7.4.2 (e.g., protrusions, particles under the coating, sharp cuts, and indentations) shall be removed. Underlying steel pipe surface imperfections shall be addressed in compliance with the applicable steel pipe standard.

8.2.2
Coating repair applicators shall be qualified in accordance with CSA Z245.30, Clause 6.1.2. The applicable repair materials shall be applied in accordance with the manufacturer's recommendations qualified application procedure (MQAP) and qualified in accordance with CSA Z245.30, Clause 5.

8.2.3
All repairs shall be holiday tested in accordance with the requirements of Clause 7.4.2.

8.3 Stripping and recoating

8.3.1
Unless treated in accordance with the requirements of Clauses 8.3.2 to 8.3.5 for non-compliance with Table 6 or 11, the pipe surface shall be stripped to bare metal and recoated in accordance with the requirements of Clauses 6.2 and 7. The temperature during the stripping operation shall not exceed 275 °C. The applicator shall record the identity of each stripped and recoated pipe.

Notes:

1) *Applying fusion bond epoxy to pipe previously coated with System A might negatively affect the adhesion of fusion bond epoxy.*
2) *Heat applied to pipe during coating application can have an aging effect on the mechanical properties of steel pipe.*

8.3.2
For System A, where the requirements of Table 10 are met, coated pipe that fails to conform to the requirements of Table 11 may be overcoated by applying adhesive and polyethylene over the existing coating in accordance with the requirements of Clauses 6.2.3, 6.2.4, and 7. The peel adhesion between the polyethylene layers shall be tested using the applicable method and acceptance criterion specified in Table 10.

8.3.3
For System A, where the requirements of Table 10 are met, coated pipe that fails to conform to the minimum adhesive thickness requirements may be recoated by removing the polyethylene and reapplying the adhesive and polyethylene in accordance with the requirements of Clauses 6.2.3, 6.2.4, and 7.

At least one production test ring shall be taken from pipe recoated during each working shift. The test rings shall be prepared and tested in accordance with the requirements of Clause 7.4.3.

8.3.4
For System A, where the requirements of Table 10 are met, coated pipe that fails to conform to the minimum polyethylene thickness requirements may be overcoated by applying adhesive and polyethylene over the existing coating in accordance with the requirements of Clauses 6.2.3, 6.2.4, and 7. The peel adhesion between the polyethylene layers shall be tested using the applicable method and acceptance criterion specified in Table 10.

8.3.5
For Systems B1 and B2, where the requirements of Table 10 are met but the minimum adhesive and/or polyethylene thickness requirements of Table 6 are not met, the pipe may be overcoated by applying adhesive and polyethylene. Such application of adhesive and polyethylene over the existing coating shall be in accordance with the requirements of Clauses 6.2.3, 6.2.4, and 7.

At least one production test ring shall be taken from the overcoated pipe during each working shift. The test rings shall be prepared and tested in accordance with the requirements of Clause 7.4.3. For System B1, the peel adhesion between the polyethylene layers shall be tested using the applicable method and acceptance criterion specified in Table 10.

8.4 Repair of pipe ends

When the applicator cuts the pipe, steel pipe ends shall be refinished in accordance with the original pipe manufacturing specification, or as agreed upon by the purchaser and the applicator.

9 Markings

9.1 General

Coated pipe shall be marked in accordance with the requirements of Clause 9.2 and with any additional markings specified in the purchase order. Additional markings desired by the applicator may be used.

Note: *Additional markings include barcode markings. One-dimensional barcode markings should be of the Code 39 type or Code 128 type. Two-dimensional barcode markings should be of the PDF417 type.*

9.2 Required markings

9.2.1

The following markings shall be placed on the polyethylene:

a) applicator's name or mark;
b) CSA Standard designation and year of publication (CSA Z245.21:22);
c) markings required by the applicable pipe specification or standard, whether or not such specification or standard requires such markings to be applied to the outside surface;
d) date of coating application;
e) coating system (A, B1, or B2); and
f) flexibility test temperature. The temperature shall be marked using the designation "FM30C" for the –30 °C test, "FM18C" for the –18 °C test, or "F0C" for the 0 °C test.

9.2.2

Required markings shall be at least 300 mm from the coating cutback unless otherwise specified in the purchase order.

10 Handling and storage

10.1 Handling

10.1.1

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

10.1.2

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

10.1.3
Coating that is damaged after holiday inspection (see Clause 7.4.2) shall be repaired in accordance with the requirements of Clause 8.2 or by stripping and recoating in accordance with the requirements of Clause 8.3.

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

11 Test reports and certificates of compliance

11.1
Unless the purchase order specifies that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses 6.1, 6.2.3, 7.3, and 7.4.

11.2
The applicator shall furnish certificates of compliance stating that the coating has been manufactured, applied, inspected, and tested in accordance with the requirements of this Standard and any other requirements specified in the purchase order, and that the results of the coating tests and other required tests have been found to conform to such requirements.

12 Test procedures

12.1 Viscosity

12.1.1 Equipment
The equipment shall consist of the following:

a) a Brookfield Viscometer®, a Thermosel® adapter, and their accessories (or purchaser-approved equivalents); and
b) an oven controllable to within 3 °C.

12.1.2 Procedure
The test procedure to measure the viscosity of the adhesive material shall be as follows:

a) Heat the adhesive in an oven set at 150 °C until it begins to flow.
b) Preset the Thermosel® control to 150 °C.
c) Pour the adhesive into the cup to such a level that, when the spindle is inserted, the material reaches the immersion groove at the base of the shaft without overflowing the cup.
d) Insert the cup into the Thermosel®.
   Note: *The cup should not be able to revolve once it is inserted.*
e) With the speed set at its minimum value and the adhesive at the test temperature, start the spindle revolving.
f) Allow the temperature to stabilize.
g) Record the dial reading and speed. If the dial reading is above 85, lower the speed (where possible) or use another spindle.
h) Repeat the steps specified in Items a) to g) with temperatures set at 163 and 177 °C.

i) Using the instrument manufacturer's supplied chart, obtain the multiplication factor for the spindles and speeds used.
j) Multiply the viscometer reading by the applicable multiplication factor to obtain the viscosity in millipascal seconds (mPa·s).

12.1.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the adhesive lot number;
b) the date of testing;
c) the test temperatures in degrees Celsius;
d) the spindle number;
e) the test speeds; and
f) the viscosity obtained in each test, in millipascal seconds.

12.2 Flow

12.2.1 Equipment

The equipment shall consist of the following:
a) flow moulds [approximately 9.5 mm inside diameter (ID) and approximately 19 mm high];
b) silicone-treated release paper;
c) a corrugated brass plate with dimensions approximately as shown in Figure 1; and
d) an oven controllable to within 3 °C.

12.2.2 Procedure

The test procedure to measure the flow rate of adhesive shall be as follows:
a) Melt the adhesive slowly to prevent local overheating.
b) Line the moulds with treated paper projecting at least 15 mm over the top of each mould for easy removal of the specimen.
c) Preheat the moulds and the liner on a lined metal plate.
d) Pour the adhesive into the moulds and cool to 20 ± 3 °C.
e) Chill the test specimens to facilitate removal of the moulds, and cut the moulded adhesive into lengths of approximately 19 mm.
f) Condition the test specimens at 20 ± 3 °C for at least 30 min before starting the test.
g) Place the test specimens on the brass plate, aligning the 9.5 mm diameter of the test specimens with the inscribed line on the plate.
h) Immediately place the plate in the oven, maintained within 3 °C of the specified test temperature.
i) After 1 h ± 1 min, remove the plate and measure the distance of flow from the inscribed line to the bottom of the flow.
j) Average the flow of three test specimens, and record the average flow to the nearest millimetre.

12.2.3 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the adhesive lot number;
b) the date of testing;
c) the average flow in millimetres of the three test specimens; and
d) the test temperature in degrees Celsius.

12.3 Cathodic disbondment of the coating

12.3.1 Equipment

The equipment shall consist of the following:

a) a rectified DC power supply with controlled voltage output;
b) an oven controllable to within 3 °C;
c) a reference electrode, either calomel electrode with saturated KCl solution (≤80 °C), or silver/silver chloride with saturated KCl solution (all temperatures);
d) a platinum wire or a carbon electrode;
e) a 75 ± 3 mm ID plastic cylinder;
f) a 3% sodium chloride solution in purified water (such as distilled water or reverse osmosis-treated water);
g) a utility knife as specified in Clause 12.1.1 g) of CSA Z245.20; and
h) needle-nose pliers.

12.3.2 Test specimens

The test specimens shall be as follows:

a) Each test specimen shall be a full-ring section of pipe approximately 100 mm long or a panel that is cut from a full-ring section and measures approximately 100 × 100 mm × pipe wall thickness.
b) Only test specimens that are confirmed to be holiday-free in accordance with the requirements of Clause 7.4.2 shall be used.

12.3.3 Procedure

The test procedure to measure the resistance of the cooling to cathodic disbondment shall be as follows:

a) Drill a 6.4 mm diameter holiday through the coating to expose the steel substrate.
b) Centre the plastic cylinder over the holiday and apply a sealant to form a water-resistant seal.
c) Add to the cylinder at least 300 mL of the sodium chloride solution that has been preheated to the test temperature.
d) Mark the solution level on the cylinder.
e) Insert the electrode into the solution and connect it to the positive wire from the dc power supply.
f) Attach the negative wire from the dc power supply to a bare spot prepared on the test specimen.
g) Apply voltage (negative with respect to the reference electrode) to the test specimen and maintain constant temperature under one or more of the following test conditions, as specified in Tables 1 and 10:
    i) 1.5 V, 20 ± 3 °C, for a minimum of 28 d;
    ii) 1.5 V, maximum design temperature ± 3 °C, for a minimum of 28 d; and
    iii) 3.5 V, 65 ± 3 °C, for a minimum of 24 h.
h) Maintain the solution level by the addition of purified water (such as distilled or reverse osmosis-treated water) as required.
i) Upon test completion, dismantle the test cell, air cool the specimen to 20 ± 3 °C, and evaluate the cathodic disbondment characteristics of the test specimen within 1 h of removal of heat.
j) Using the utility knife, make eight evenly spaced radial cuts through the coating to the substrate as shown in Figure 2. Ensure that such cuts extend at least 25 mm from the centre of the holiday.
k) For System A, insert the tip of the blade of the utility knife under the coating at the holiday and lift the polyethylene. Using the pliers, peel the coating off for approximately 25 mm. Measure the disbonded distance from the edge of the original holiday along each radial cut and average such values. The disbonded areas shall be surfaces with no adhesive.

l) For Systems B1 and B2, insert the tip of the blade of the utility knife under the primer at the holiday. Using a levering action, lever off the primer. Continue until the primer demonstrates a definite resistance to the levering action. Measure the disbonded distance from the edge of the original holiday along each radial cut and average such values. The disbonded areas shall be surfaces with no primer.

12.3.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the lot number of each coating component;
b) the date of testing; and
c) the average disbondment value in millimetres.

12.4 Peel adhesion (constant rate of peel)

12.4.1 Equipment

The equipment shall consist of the following:

a) a tensile testing machine; and
b) a peeling apparatus, as shown in Figure 3 for pipe smaller than 200 mm OD and Figure 4 for pipe 200 mm OD or larger.

The rate of movement between the heads of the testing machine shall remain essentially constant under fluctuating loads, and the machine shall be capable of measuring the loads to within 1%. The machine and its range shall be selected so that the maximum load on the specimen falls between 15 and 85% of the full-scale capacity.

12.4.2 Test specimens

A full ring shall be used for pipe smaller than 200 mm OD and a plate shall be used for pipe 200 mm OD or larger. The test specimens shall have the following approximate dimensions:

a) full rings: 150 mm long × pipe wall thickness; and
b) plates: 150 × 150 mm × pipe wall thickness.

12.4.3 Test parameters

The test parameters shall be as follows:

a) The test temperature shall be 20 ± 3 °C.
b) The crosshead speed (peeling speed) shall be 10 ± 1 mm/min.
c) Except as allowed by Clause 12.4.4 g), the peel strip shall be at least 75 mm long.
d) The peel strip shall be 25 ± 1 mm wide.
e) The peel orientation shall be circumferential. The apparatus shown in Figure 3 shall be used for full rings, and the apparatus shown in Figure 4 shall be used for plates.

12.4.4 Procedure

The test procedure to measure peel adhesion strength of the coating by constant rate of peel method shall be as follows:

a) Condition the sample at 20 ± 3 °C for at least 1 h before starting the test.
b) Cut a strip to the required width and orientation through the coating to the steel substrate.
c) Make a cut at right angles to the strip and lift a portion of this strip to form a tab.
d) On the bonded strip, measure and mark the required test length.

e) Peel the strip at a rate of 10 ± 1 mm/min and record the load required to peel the coating.
Note: *The peel test should be continuously monitored by the operator. If the applied load drops momentarily (as indicated by the chart on the machine), the unbonded peel strip should be examined for elongation of the polyethylene or for voids between the substrate and the polyethylene.*
f) If more than 5% of the total peeled length has a peeling load below the specified minimum value calculated in accordance with Item h), the sample shall be considered to have failed the test. If a small portion (less than 5%) of the total peeled length has a peeling load below the specified minimum value, the test shall be considered satisfactory; however, the peeling load for that small portion shall not be used in the test calculations [see Item h)].
g) If the polyethylene breaks more than three times during the test, terminate the test even though the test sample has not been peeled the required 75 mm. Accept the test as satisfactory and use the test result in the test calculations [see Item h)].
h) Except as allowed by Item f), determine the minimum peeling load and calculate the minimum peel strength using the following formula:
$P = Lp \times 9.81$
where
P = minimum peel strength, N
Lp = minimum peeling load, kg

12.4.5 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:
a) the lot number of each coating component;
b) the date of testing;
c) the test specimen type;
d) the length of strip peeled in millimetres; and
e) the minimum peel strength in newtons.

12.5 Peel adhesion (hanging mass)

12.5.1 Equipment

The equipment shall consist of the following:
a) a mass of 1.0 kg (for System A) or 15.3 kg (for System B1);
b) an attaching device;
c) a utility knife as specified in Clause 12.1.1 g) of CSA Z245.20; and
d) a timing device.

12.5.2 Test specimens

Each test specimen shall consist of a complete pipe or test ring cut from a pipe. The test ring shall be approximately 150 mm long.

12.5.3 Test parameters

The test parameters shall be as follows:
a) The test temperature shall be 20 ± 3 °C.
b) The peel strip shall be 25 ± 1 mm wide.
c) The peel orientation shall be circumferential.

12.5.4 Procedure

The test procedure to measure the peel adhesion strength of the coating by hanging mass method shall be as follows:

a) Condition the sample at 20 ± 3 °C for at least 1 h before starting the test.
b) Make two cuts 25 ± 1 mm apart through the coating to the steel substrate with the utility knife from the 90° position to the 180° position.
c) Cut the coating at a right angle at the 90° position and peel it off down to the 135° position as shown in Figure 5.
d) Attach the appropriate mass to the free end of the peel strip as shown in Figure 5.
e) Measure the peeling time in minutes from the 135° position to the 180° position. Alternatively, terminate peeling when the test time calculated in accordance with the following formula has been exceeded:

$$T = \frac{0.125 \times \pi \times D}{10}$$

where
T = test time, min
D = specified pipe OD, mm

f) Measure the distance peeled in millimetres from the time the test was initiated until it was terminated.
g) Calculate the peeling speed using the following formula:
$PS = d/t$
where
PS = peeling speed, mm/min
d = distance peeled, mm
t = peeling time, min

If the peeling speed exceeds 10 mm/min at 20 ± 3 °C, the test shall be considered to have failed.

12.5.5 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the lot number of each coating component;
b) the date of testing;
c) the specified pipe OD in millimetres;
d) the mass in kilograms;
e) the distance peeled in millimetres;
f) the peeling time in minutes; and
g) the peeling speed in millimetres per minute.

12.6 Heat aging

12.6.1 Equipment

The equipment shall be as specified in ASTM D638, except that the circulating-air oven shall be controllable to within 3 °C.

12.6.2 Test specimens

The test specimens shall be as follows:

a) Three detached test specimens from which the primer and adhesive have been removed shall be prepared. The samples for heat aging shall measure approximately 50 × 150 mm × the polyethylene thickness.
b) The 150 mm length shall be cut transverse to the pipe axis.

12.6.3 Procedure

The test procedure to evaluate the effects of heat aging on the coating shall be as follows:

a) Three unheated test specimens shall be tested in accordance with the requirements of ASTM D638, except that a test temperature of 20 ± 3 °C shall be used. A Type IV sample with a crosshead speed of 50 mm/min shall be used. The results of these tests shall meet the acceptance criteria specified in Table 5.
b) Three other test specimens shall be placed in the oven at 100 ± 3 °C for 2400 ± 24 h. At the end of this heat-aging period, each specimen shall be removed from the oven and its temperature allowed to return to 20 ± 3 °C. This test shall be conducted in accordance with the requirements of Item a).
c) The tensile stress at yield after heat aging shall be not less than 65% of the original tensile stress at yield for the samples not heat aged.
d) The percentage of elongation at break after heat aging shall be not less than 150%.

12.6.4 Report

Where test reports are not waived as specified in Clause 11.1, the following information shall be reported to the purchaser by the applicator:

a) the polyethylene lot number and density, i.e., low density (LD), linear low density (LLD), medium density (MD), or high density (HD);
b) the date of testing;
c) for test specimens that were not heat aged, the tensile stress at yield in MPa;
d) for test specimens that were heat aged, the tensile stress at yield in MPa;
e) for test specimens that were not heat aged, the percentage elongation at break; and
f) for test specimens that were heat aged, the percentage elongation at break.

12.7 Gouge resistance

Where specified in the purchase order, the gouge resistance of the coating shall be determined. The test method and acceptance criteria shall be agreed on.

Table 1
Coating qualification test requirements
(See Clauses 1.2, 4.1.1, 5.2.1, 6.1.2, and 12.3.3.)

Test	Acceptance criteria	Test method	Number of test specimens
28 d cathodic disbondment at 20 °C	12 mm maximum radius	Clause 12.3	3
28 d cathodic disbondment at maximum design temperature	Meets purchaser's specification	Clause 12.3	3
Peel adhesion*		Clause 12.4 or 12.5	3
System A	10.0 N minimum		
System B1	150.0 N minimum		
Flexibility	No cracking of polyethylene	Clause 12.11 of CSA Z245.20; bend of 2.5°	5
Impact resistance	Minimum of 3.0 J/mm of actual total coating thickness	Clause 12.12 of CSA Z245.20, except that for each millimetre of thickness, the voltage setting for the dc holiday detector [see Clause 12.12.3 d) and e) of CSA Z245.20] shall be 10 V per micrometre of thickness, up to a maximum of 15 000 V	3
28 d adhesion (System B2 only)	Rating of 1–3	Clause 12.14 of CSA Z245.20; 28 d at 75 °C	3

* *Not applicable to System B2.*

Table 2
Adhesive requirements
(See Clause 5.4.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
System A				
Viscosity	mPa·s	Within 30% of manufacturer's specified nominal	Clause 12.1	1
Flow at maximum design temperature	mm	Not greater than 20% above the manufacturer's specified nominal	Clause 12.2	3*
Ring and ball softening point	°C	At least 20 °C above maximum design temperature	ASTM E28	2
Systems B1 and B2				
Flow rate	g/10 min	Within 20% of manufacturer's specified nominal	ASTM D1238; 190 °C/2.16 kg	3
Density	g/cm³	Within 1% of manufacturer's specified nominal	ASTM D792 or ASTM D1505	3†
Vicat softening point†	°C	At least 10 °C above maximum design temperature	ASTM D1525	3†
Brittleness temperature†	°C	–50 °C or lower (System B1 for F_{20}, System B2 for F_{40})	ASTM D746	10†

* *The number of specimens is also defined in the test method.*
† *This test is required at least every 12 months.*

Table 3
Virgin polyethylene resin requirements
(See Clause 5.5.)

		Acceptance criteria				
Test	Unit	LD and LLD	MD	HD	Test method	Number of test specimens
Density	g/cm³	<0.925	0.925–0.940	>0.940	ASTM D792 or ASTM D1505	3*
Elongation at break	%	600 minimum	600 minimum	600 minimum	ASTM D638; Type IV sample; crosshead speed, 50 mm/min	5*

(Continued)

Table 3 (Concluded)

Test	Unit	Acceptance criteria			Test method	Number of test specimens
		LD and LLD	MD	HD		
Flow rate†	g/10 min	LD: 0.15–0.6 LLD: 0.5–2.0	0.1–1.0	0.15–0.80	ASTM D1238; 190 °C/ 2.16 kg	3
Hardness	Shore D	45 minimum	50 minimum	60 minimum	ASTM D2240	5
Heat aging‡	MPa, %	At least 65% of original tensile stress at yield; minimum elongation of 150%	At least 65% of original tensile stress at yield; minimum elongation of 150%	At least 65% of original tensile stress at yield; minimum elongation of 150%	Clause 12.6	5*
Tensile stress at yield	MPa	9.7 minimum	12.4 minimum	18.5 minimum	ASTM D638; Type IV sample; crosshead speed, 50 mm/min	5*
Oxidative-induction time in oxygen at 220 °C, aluminum pan, no screen	min	10 minimum	10 minimum	10 minimum	ASTM D3895	3
Brittleness temperature†	°C	–70 or lower (for F_{20})	–70 or lower (for F_{20})	–70 or lower (for F_{20})	ASTM D746	10*
Environmental stress-cracking resistance condition†	h	300 minimum (for F50); Condition “C”	300 minimum (for F50); Condition “C”	300 minimum (for F50); Condition “B”	ASTM D1693; 100% Igepal®	10*
Vicat softening point‡	°C	90 minimum	110 minimum	120 minimum	ASTM D1525	3*

** The number of specimens is also defined in the test method.*
† The acceptance criteria are not applicable to System B2 or when bi-modal resin is used. The acceptance criteria for System B2 and bi-modal resin shall be within 20% of the manufacturer’s specified nominal.
‡ This test is required at least once every four years and whenever there is a change in one or more of the following:
a) manufacturer;
b) location of manufacture; and
c) catalyst type (e.g., chromium or Ziegler).

Table 4
Liquid epoxy primer requirements
(See Clause 5.3.1.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Base resin density	g/mL	Within 0.05 of manufacturer's specified nominal	ASTM D1475	3
Curing agent density	g/mL	Within 0.05 of manufacturer's specified nominal	ASTM D1475	3
Base resin viscosity	mPa·s	Within 15% of manufacturer's specified nominal	ASTM D2196	3
Curing agent viscosity	mPa·s	Within 15% of manufacturer's specified nominal	ASTM D2196	3
Epoxy equivalent weight	Weight percent epoxy (WPE)	Within 10% of manufacturer's specified nominal	ASTM D1652	3
Total amine value	mg KOH/g	Within 15% of manufacturer's specified nominal	ASTM D2083	3
Gel time (mixed components)	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20; thickness at 100 ± 25 µm; test temperature as recommended by manufacturer	3*

** The number of specimens is also defined in the test method.*

Table 5
Polyethylene qualification test requirements
(See Clauses 6.1.3, 6.1.4, and 12.6.3.)

Test	Acceptance criteria	Test method	Number of test specimens
Tensile stress at yield LD or LLD MD HD	8.5 MPa minimum 11.0 MPa minimum 17.0 MPa minimum	ASTM D638; Type IV sample; crosshead speed 50 mm/min	5*
Elongation at break	300% minimum	ASTM D638; Type IV sample; crosshead speed 50 mm/min	5*

* *The number of specimens is also defined in the test method.*

Table 6
Coating thickness requirements
(See Clauses 6.2.3.1, 6.2.3.2, 6.2.3.3.2, 8.3.1, and 8.3.5.)

	Minimum coating thickness, mm				
Specified pipe OD, mm	Primer thickness*	Adhesive thickness	Polyethylene thickness		
System A					
<75	—	0.15	0.55		
75–115	—	0.15	0.60		
>115–170	—	0.15	0.70		
>170–275	—	0.15	0.85		
>275	—	0.20	1.05		
System B1			**LD or LLD**	**MD**	**HD**
<100	0.12	0.10	1.80	1.00	0.85
100–250	0.12	0.10	2.00	1.15	1.00
>250–500	0.12	0.10	2.20	1.15	1.00
>500–800	0.12	0.10	2.50	1.15	1.00
>800	0.12	0.10	3.00	1.15	1.00
System B2			**LD or LLD**	**MD**	**HD**
All diameters	0.12	0.10	0.45	0.45	0.45

* *Not applicable to System A.*

Table 7
Primer requirements for incoming materials
(See Clause 7.3.3.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Liquid primer				
Base resin viscosity	mPa·s	Within 15% of manufacturer's specified nominal	ASTM D2196*	1
Curing agent viscosity	mPa·s	Within 15% of manufacturer's specified nominal	ASTM D2196*	1
Gel time (mixed components)	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20; thickness at 50–150 µm; test temperature as recommended by manufacturer	3†
Epoxy powder primer				
Gel time	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20	3†
24 h cathodic disbondment at 65 °C	mm	6.5 mm maximum radius	Clause 12.8 of CSA Z245.20‡	1
24 h adhesion at 75 °C	—	Rating of 1–3	Clause 12.14 of CSA Z245.20‡	1

* *Date of test and lot number shall also be included in the test report.*
† *The number of specimens is also defined in the test method.*
‡ *Sample shall be prepared in accordance with the requirements of Clause 6.1.2 of CSA Z245.20.*

Table 8
Adhesive requirements for incoming materials
(See Clause 7.3.4.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
System A				
Viscosity	mPa·s	Within 30% of manufacturer's specified nominal	Clause 12.1	1

(Continued)

Table 8 (Concluded)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Flow at 70 °C	mm	Not greater than 20% more than the manufacturer's specified nominal	Clause 12.2	3*
Ring and ball softening point	°C	At least 20 °C above maximum design temperature	ASTM E28†	2
Systems B1 and B2				
Flow rate	g/10 min	Within 20% of manufacturer's specified nominal	ASTM D1238;† 190 °C/2.16 kg	1

* *This number of specimens is also defined in the test method.*
† *Date of test and lot number shall also be included in the test report.*

Table 9
Polyethylene requirements for incoming materials
(See Clause 7.3.5.)

		Acceptance criteria					
Test	Unit	LD	LLD	MD	HD	Test method	Number of test specimens
Flow rate*	g/10 min	0.15–0.6	0.5–2.0	0.15–1.0	0.15–0.8	ASTM D1238† 190 °C/ 2.16 kg	1

* *The acceptance criteria values are not applicable to System B2 or when bi-modal resin is used. The acceptance criteria for System B2 and bi-modal resin shall be within 20% of the manufacturer's specified nominal.*
† *Date of test and lot number shall also be included in the test report.*

Table 10
Production coating test requirements
(See Clauses 7.4.3.4, 8.3.2 to 8.3.5, and 12.3.3.)

Test	Acceptance criteria				Number of test specimens
	System A	System B1	System B2	Test method	
24 h cathodic disbondment	12 mm maximum radius	7 mm maximum radius	7 mm maximum radius	Clause 12.3	1
2.5° flexibility*	—	—	No cracking	Clause 12.11 of CSA Z245.20	3

(Continued)

Table 10 (Concluded)

Test	Acceptance criteria			Test method	Number of test specimens
	System A	System B1	System B2		
Peel adhesion†	10.0 N minimum	150.0 N minimum	—	Clause 12.4 or 12.5	1
Tensile stress at yield‡					
LD or LLD	—	8.5 MPa minimum	—	ASTM D638;	5§
MD	—	11.0 MPa minimum	—	Type IV sample;	
HD	—	17.0 MPa minimum	—	crosshead speed, 50 mm/min	
Elongation at break‡	—	300% minimum	—	ASTM D638; Type IV sample; crosshead speed, 50 mm/min	5§
24 h adhesion at 75 °C*	—	—	Rating of 1–2	Clause 12.14 of CSA Z245.20	1

* *Applicable to System B2 only.*
† *Not applicable to System B2.*
‡ *Applicable to System B1 only.*
§ *This number of specimens is also defined in the test method.*

Table 11
Polyethylene coating — Repair
(See Clauses 7.4.2.2, 8.3.1, and 8.3.2)

Coating system	Acceptance criteria	Holiday repair (Clause 8.2)	Strip and recoat (Clause 8.3)	Repair materials
A and B1	≤2.0 per 12 m pipe length and ≤300 mm length	X		Manufacturer's or applicator's recommendation
A and B1	>2.0 per 12 m pipe length or >300 mm length		X	N/A
B2	≤0.25/m², and <10 cm² area	X		Manufacturer's or applicator's recommendation

(Continued)

Table 11 (Concluded)

Coating system	Acceptance criteria	Holiday repair (Clause 8.2)	Strip and recoat (Clause 8.3)	Repair materials
B2	>0.25/m², and <10 cm² area		X	N/A
B2	≤0.25/m², and >10 cm² area		X	N/A
B2	>0.25/m², and >10 cm² area		X	N/A

Figure 1
Flow test apparatus
(See Clause 12.2.1.)

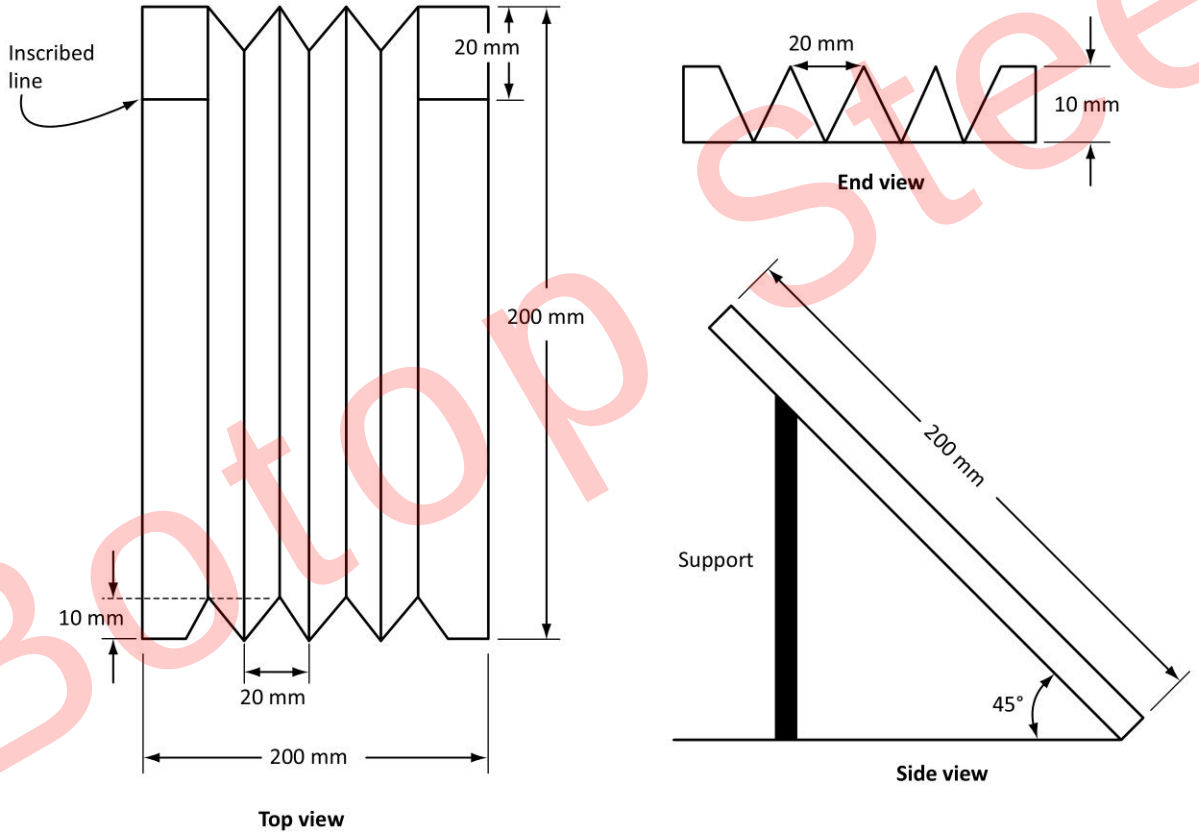


Figure 2
Examples of radial cuts through the coating
(See Clause 12.3.3.)

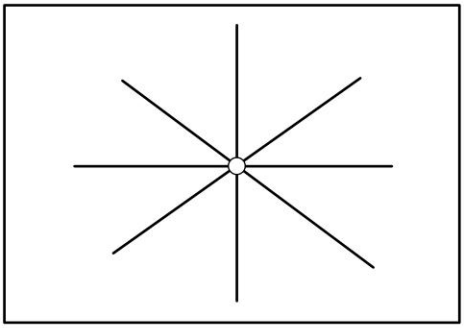


Figure 3
Peeling apparatus for pipe smaller than 200 mm OD
(See Clauses 12.4.1 and 12.4.3.)

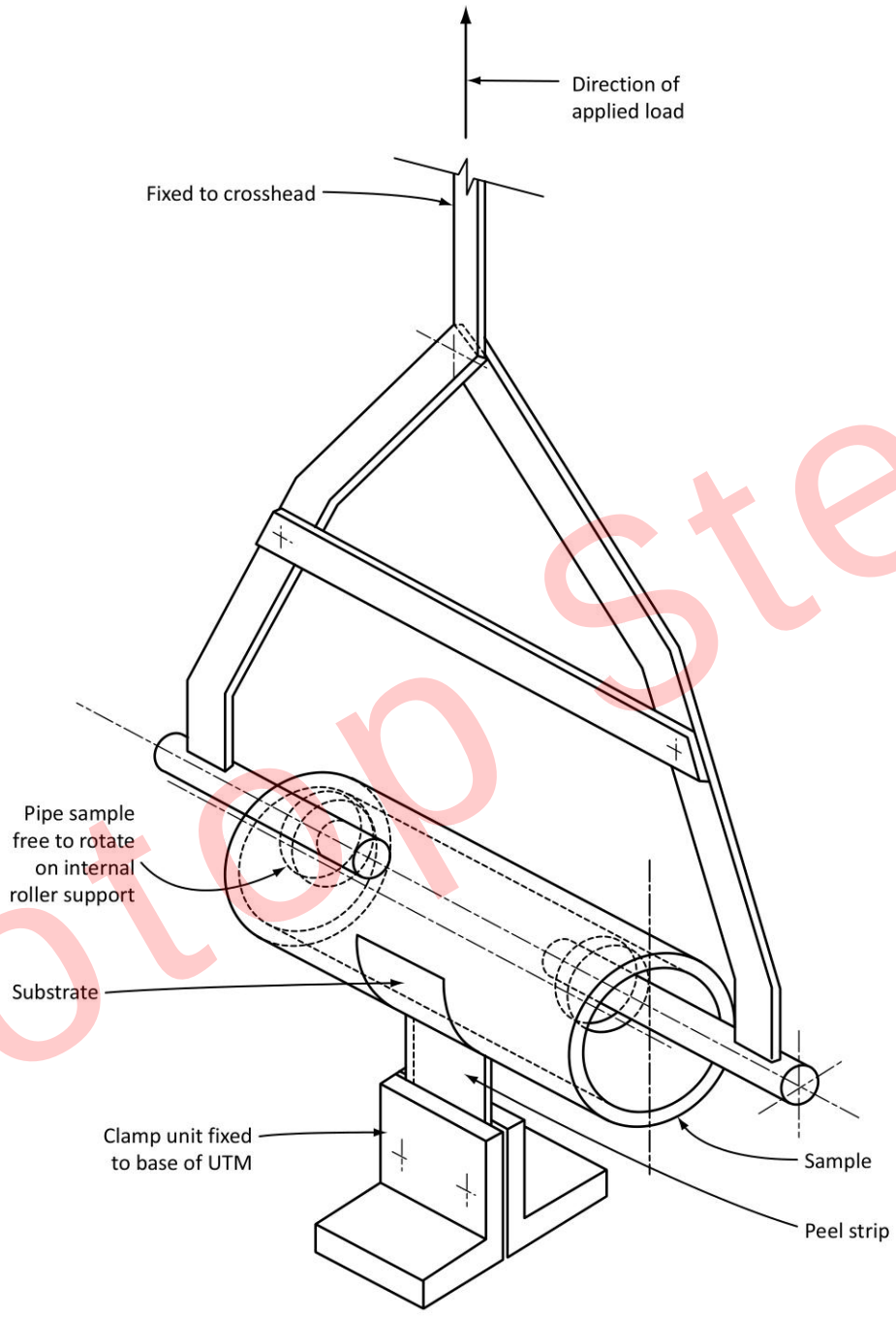


Figure 4
Peeling apparatus for pipe 200 mm OD or larger
(See Clauses 12.4.1 and 12.4.3.)

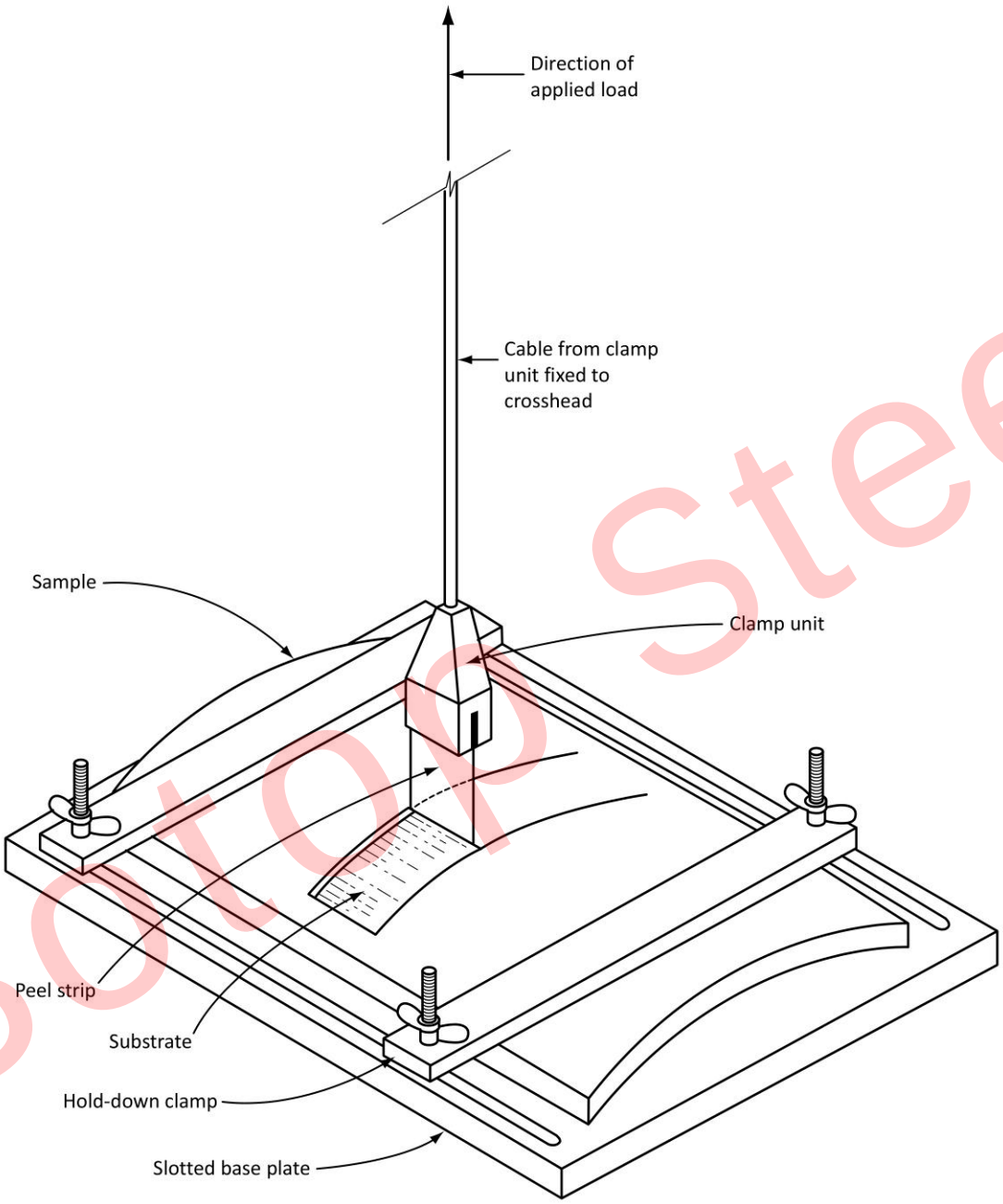
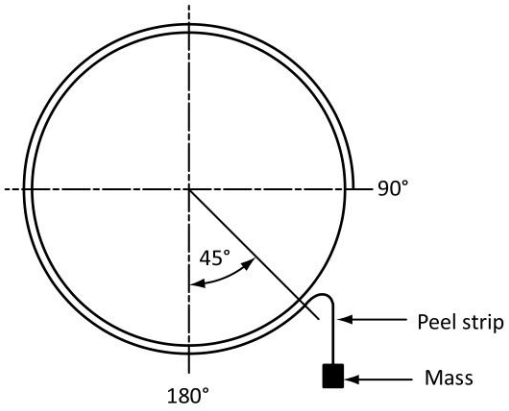


Figure 5
Hanging mass test set-up (end view)
(See Clause 12.5.4.)



CSA Z245.22:22

Plant-applied external polyurethane foam insulation coating for steel pipe

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CSA Z245.22:22
Plant-applied external polyurethane foam insulation coating for steel pipe

1 Scope

1.1
This Standard covers the qualification, application, inspection, testing, handling, and storage of materials required for plant-applied external polyurethane foam insulation coating to steel pipe. The coated pipe is intended primarily for buried or submerged service for oil or gas pipeline systems.

1.2
This Standard applies to foam insulation coating composed of

a) anti-corrosion coating layer, or a leak detection and monitoring system (LDMS), or a combination thereof;
b) polyurethane foam insulation; and
c) external polyethylene jacket.

1.3
This Standard covers spray-applied or moulded polyurethane foam insulation coating systems.

1.4
This Standard does not cover material requirements for steel pipe and cryogenic applications.

1.5
In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the Standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the Standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications

This Standard refers to the following publications, and where such reference is made, it shall be to the editions listed below.

Note: *In cases where the editions listed below are amended, replaced by new editions, or superseded by another standard during the life of this referencing Standard, it is the responsibility of the users of this Standard to investigate the possibility of applying those amendments, new editions, or superseding standards.*

CSA Group

CAN/CSA-ISO 9001:16 (R2020)
Quality management systems — Requirements

Z245.20:22
Plant-applied external fusion bond epoxy coating for steel pipe

Z245.21:22
Plant-applied external polyethylene coating for steel pipe

Z245.30:22
Field-applied external coatings for steel pipeline systems

Z662:19
Oil and gas pipeline systems

ASTM International

C518-21
Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

D638-14
Standard Test Method for Tensile Properties of Plastics

D792-20
Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1000-17
Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications

D1002-10(2019)
Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)

D1238-20
Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

D1259-06(2018)
Standard Test Methods for Nonvolatile Content of Resin Solutions

D1475-13(2020)
Standard Test Method for Density of Liquid Coatings, Inks and Related Products

D1505-18
Standard Test Method for Density of Plastics by the Density-Gradient Technique

D1525-17e1
Standard Test Method for Vicat Softening Temperature of Plastics

D1621-16
Standard Test Method for Compressive Properties of Rigid Cellular Plastics

D1622-20
Standard Test Method for Apparent Density of Rigid Cellular Plastics

D1693-21
Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

D2196-20
Standard Test Method for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer

D2842-19
Standard Test Method for Water Absorption of Rigid Cellular Plastics

D3289-17
Standard Test Method for Density of Semi-Solid and Solid Asphalt Materials (Nickel Crucible Method)

D3895-19
Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

D4878-15
Standard Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Polyols

D4889-21
Standard Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Crude or Modified Isocyanates

D5397-20
Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

D6226-21
Standard Test Method for Open Cell Content of Rigid Cellular Plastics

E28-18
Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus

E29-13(2019)
Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

AWWA (American Water Works Association)

C906-15
Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 63 In. (100 mm Through 1,600 mm), Waterworks

ISO (International Organization for Standardization)

179-1:2010
Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test

844:2021
Rigid cellular plastics — Determination of compression properties

9001:2015
Quality management systems — Requirements

SSPC (The Society for Protective Coatings)/NACE International

SP 5/NACE No. 1-2007
White Metal Blast Cleaning

SP 6/NACE No. 3-2007
Commercial Blast Cleaning

SP 10/NACE No. 2-2007
Near-White Blast Cleaning

3 Definitions

The following definitions shall apply in this Standard:

Anti-corrosion coating layer — a coating applied directly on steel for the purpose of corrosion protection.

Applicator — the company responsible for the actual application of the coating.

Batch — specified quantity of material produced under the same uniform conditions during a continuous production run by one manufacturer.

Certificate of compliance — a document provided by the manufacturer or applicator certifying that the raw materials, products, or coatings, as applicable, are in compliance with the requirements of this Standard.

Creep — slow, progressive deformation under the influence of stress.

Defect — an imperfection of sufficient magnitude to warrant rejection based on the requirements of this Standard.

Foam insulation — polyurethane foam insulation material.

Holiday — a discontinuity that exhibits electrical conductivity when exposed to a specific voltage.

Imperfection — a material discontinuity or irregularity that is detectable by inspection in accordance with the requirements of this Standard.

Leak detection and monitoring system (LDMS) — a means of detecting and locating the presence of water and/or hydrocarbon in the polyurethane foam insulation.

Start-up — the first production run after
a) a break in production of 2 h or more; or
b) a change in pipe diameter or coating material.

Test report — a document that provides the quantitative test results for tests conducted in accordance with the requirements of this Standard.

Test ring — a sample taken from production-coated pipe.

4 General requirements

4.1 Product ordering requirements

4.1.1 Standard requirements

The following information shall be included in purchase orders for coating for pipe:
a) CSA Standard designation and year of publication (CSA Z245.22:22);
b) pipe quantity, outside diameter (OD), wall thickness, and nominal length;
c) bare pipe standard or specification designation (see Clause 5.1);
d) design temperature for the coating system;
e) anti-corrosion coating layer, where applicable (see Table 1);
f) LDMS, where applicable;
g) insulation system;
h) nominal thickness and permissible tolerance of the
   i) insulation coating system; and
   ii) individual layers, where applicable (see Clause 6.2);
i) cutback length for anti-corrosion coating and foam insulation (see Clause 6.2.5.1); and
j) requirements on end-sealant application on exposed polyurethane foam (see Clause 6.2.5.2).

4.1.2 Optional requirements

Where applicable, purchase orders shall include the following information:
a) plant inspection by the purchaser (see Clauses 7.1 and 7.2);
b) test sample location (see Clause 7.5.2);
c) test frequency (see Clause 7.5.4);
d) additional markings (see Clause 9.1);
e) handling procedures (see Clause 10.1.1);
f) storage procedures (see Clause 10.2);
g) waiver of test reports (see Clause 11.1);
h) number of permissible repairs;
i) deviations from acceptance criteria allowed in Table 2; and
j) other special requirements.

4.2 Rounding procedure

Except as otherwise required by this Standard, 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 the rounding method of ASTM E29.

4.3 Requirements for quality

The applicator and polyurethane manufacturer shall comply with the requirements of a nationally or internationally recognized quality management system and Clause 4.4.

Note: *CAN/CSA-ISO 9001 or ISO 9001 provides suitable quality management systems.*

4.4 Compliance

The applicator shall be responsible for complying with all of the applicable requirements of this Standard. The purchaser may make any investigation necessary in order to be assured of compliance by the applicator and to reject any material that does not comply.

5 Materials

5.1 Pipe

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

Note: *Pipe conforming to such standards or specifications will, in some cases, not have a surface condition that is appropriate for the application of coating.*

5.2 General

The applicator shall use materials that are

a) certified by the manufacturer to be in accordance with the requirements of Clauses 5.4, 5.5, 5.6, 5.8, and 6.1.2, and compatible with the requirements of Clause 7.3.1. Test reports shall be supplied with each batch of materials, if applicable;
b) identified with the following:
   i) manufacturer's name;
   ii) product description;
   iii) batch number;
   iv) location of manufacture;
   v) date of manufacture; and
   vi) temperature requirements for transportation and storage; and
c) handled, transported, and stored prior to use in accordance with the manufacturer's recommendations.

5.3 Anti-corrosion coating systems

5.3.1

Except where allowed by Clause 5.3.2, an anti-corrosion coating system shall conform to the applicable coating Standard or Annex specified in Table 1.

5.3.2

Where anti-corrosion coating standards or specifications other than the ones in Table 1 are specified, the anti-corrosion coating shall be qualified and applied in accordance with the applicable standard or specification.

5.4 Polyurethane foam system

The applicator shall use polyurethane foam systems conforming to Table 2.

5.5 Wrap tape over foam insulation

Where required as a processing aid during spray foam application, the applicator shall use wrap tape as specified in Table 3.

5.6 Adhesive over foam insulation

Where required, the applicator shall use adhesive having properties specified in Table 4 directly over foam insulation or over wrap tape over foam insulation.

5.7 External polyethylene jacket

The properties of the polyethylene resin used for the external jacket shall be as specified in Table 5.

5.8 Packaging

5.8.1

Except where allowed by Clause 5.8.2, material shall be delivered in containers that are clearly labelled to identify the items specified in Clause 5.2 b).

5.8.2

For bulk shipments where the container (e.g., a railway car) is not specifically marked for the product in question, the manufacturer shall provide documentation to ensure traceability in accordance with the requirements of Clause 5.2 b).

5.9 Leak detection and monitoring system (LDMS)

The LDMS shall be in accordance with the specifications of the LDMS manufacturer and any additional requirements specified by the purchaser.

6 Coating application

6.1 Qualification

6.1.1 General

The foam insulation coating system shall be qualified by the applicator by testing specimens removed from a pipe coated in the plant on each coating line used for production and for each applicable test (see Clause 6.1.2) and by meeting the acceptance criteria. The insulation coating system shall be requalified where there is a change in any of the following:

a) manufacturer;
b) formulation of polyol or isocyanate;
c) chemical type of the blowing agent; or
d) amount of blowing agent resulting in change of foam density greater than ±10% of qualified value as given in Table 2.

Where there is a change in the material to which the polyurethane foam is bonded, the only test in Table 2 required to requalify the insulated pipe assembly is the axial shear test before aging. The polyurethane foam system and external polyethylene jacket do not require requalification.

6.1.2 Qualification test requirements

The foam insulation and insulated pipe assembly shall be evaluated in accordance with Table 2. For each property, the test shall be conducted on specimens from production pipes. Qualification may be conducted with or without wrap tape.

6.1.3 Anti-corrosion coating with applied foam insulation qualification test requirement

At the option of the purchaser, the anti-corrosion coating layers specified in Table 1 shall be tested in accordance with the production coating tests for the associated reference Standard to ensure the application of the foam insulation has not adversely affected the properties and the performance of the anti-corrosion coating layer.

6.2 Production application practices and equipment

6.2.1 General

6.2.1.1

The foam insulation to be applied during production shall have been previously qualified in accordance with the requirements of Clause 6.1.

6.2.1.2

The anti-corrosion coating layer shall be applied in accordance with the referenced Standards or Annexes in Table 1 or specification identified in the purchase order.

Notes:

1) *In the event where the anti-corrosion coated pipe has been in storage for more than two years, stripping and recoating should be considered.*
2) *The purchaser may make any investigation necessary in order to be assured the properties of the anti-corrosion coating layer have not been adversely affected.*

6.2.2 Surface preparation

6.2.2.1

All surfaces shall be free of oil and grease and any injurious contaminants prior to the application of the insulation coating.

6.2.2.2

When an LDMS is used in lieu of an anti-corrosion coating layer, the external pipe surface to be coated shall be blast cleaned to at least the SSPC SP 6/NACE No. 3 specifications. The surface profile, measured from peak to trough, shall be 40 to 110 µm.

6.2.2.3

The anti-corrosion coating shall be inspected inside the plant for holidays and repaired in accordance with the referenced Standard or Annex in Table 1 or purchaser-specified specifications.

6.2.2.4

For liquid anti-corrosion coatings applied in line with the foam application, the coating thickness measurement and holiday inspection shall be carried out on coated pipe using calibrated instruments without foam application at start-up and every 4 h of production.

6.2.2.5
Surface treatment such as flame oxidation, corona treatment, or mechanical abrading of the anti-corrosion coating may be carried out to enhance the bond strength of the insulation to the anti-corrosion coating.

6.2.3 Foam insulation coating application

6.2.3.1
The foam insulation shall be applied in accordance with
a) the applicator's procedure that has been qualified in accordance with Table 2; and
b) the requirements specified by the purchase order. The foam insulation thickness shall be no more than 10 mm over the specified thickness and no more than 3 mm below the specified thickness.

6.2.3.2
At the option of the applicator, a wrap tape may be applied directly onto the foam insulation.

6.2.3.3
Prior to application of the foam insulation, the coated pipe shall be preheated to a temperature at least 3 °C above the dew point.

Note: *Care should be taken during preheating so as not to damage the anti-corrosion coating layer.*

6.2.4 External polyethylene jacket application

6.2.4.1
Where required, adhesive shall be applied over the insulation (or wrap tape where applicable) in accordance with the manufacturer's procedure and shall provide complete coverage. Polyethylene jacket shall be extruded over the insulation immediately following adhesive application.

6.2.4.2
The minimum polyethylene jacket thickness for systems with an anti-corrosion coating layer shall be as specified in Table 6.

6.2.4.3
The minimum polyethylene jacket thickness for systems without an anti-corrosion coating layer shall be as specified in Table 7.

6.2.4.4
The polyethylene jacket shall be compatible with the intended field joint coating LDMS connections.

System A adhesives in accordance with CSA Z245.21 shall not be used between the polyethylene layers for pipe intended to be used with electro-fusion welded field joints or repairs of the outer jacket using electro-fusion methods.

Note: *For field joint coatings that require electro-fusion polyethylene welding, increased polyethylene thickness might be required.*

6.2.4.5
The polyethylene jacket shall be free of pinholes, cracks, and visible defects. Defects shall be repaired in accordance with Clause 7.4.4.

6.2.4.6
The polyethylene jacket may be a separately pre-manufactured polyethylene pipe or be applied onto the insulation by extrusion.

6.2.5 End finish

6.2.5.1
The cutback length of the foam insulation, wrap tape where applicable, and external jacket for both ends of the pipe shall be as specified in the purchase order. The anti-corrosion coating layer shall extend beyond the foam insulation cutback as specified in the purchase order. The LDMS components shall be easily accessible in the cutback area. Care shall be exercised to prevent damage to the anti-corrosion coating layer or the LDMS components and to ensure the cutback length of the foam insulation is compatible with the intended field joint coating and LDMS connections. The cutback lengths for both the foam insulation and the anti-corrosion coating shall be measured from the end of the pipe and the pipe surface shall be free of all coating within the anti-corrosion cutback length.

6.2.5.2
The purchaser may choose to select an end treatment to protect the polyurethane foam insulation during storage and transportation. Where specified in the purchase order, an end sealant shall be applied to the exposed foam insulation surface. If used, the end sealant shall not impede or compromise the integrity of the LDMS.

7 Inspection and testing

7.1 Inspection notice
When it is specified in the purchase order that the inspector representing the purchaser intends to inspect the coating or witness the tests, the applicator shall give the purchaser reasonable notice of the production schedule.

7.2 Plant access
While work on the contract of the purchaser is being performed, the inspector representing the purchaser shall have unrestricted entry at all times to all parts of the applicator's plant that relate to the storage, application, testing, and handling of the pipe and coating. The applicator shall afford the inspector all reasonable facilities in order to be satisfied that the coating is being applied in accordance with the requirements of this Standard. 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, testing, or both.

7.3 Incoming raw materials testing

7.3.1
Sample preparation, testing, and evaluation of the polyurethane foam system (resin and isocyanate), adhesive, and polyethylene resin using suitable equipment shall be conducted by the applicator or manufacturer.

7.3.2
The minimum testing frequency shall be once per batch of the foam resin, isocyanate, adhesive, and polyethylene.

7.3.3
The viscosity of the foam resin and isocyanate at 25 ± 3 °C shall be determined in accordance with ASTM D4878 and ASTM D4889, respectively, and shall be provided with each batch of material. The acceptance criteria shall be within ±10% of the manufacturer's specified value.

7.3.4
The properties of the adhesive shall be as specified in Table 8.

7.3.5
The properties of the polyethylene shall be as specified in Table 9.

7.4 In-line inspection and measurement for production tests

7.4.1 General
The inspections and measurements required by Clauses 7.4.2 and 7.4.3 shall be made by the applicator.

7.4.2 Application temperature
The surface temperature of the anti-corrosion coating immediately prior to foam application shall be monitored and controlled within the limits established by the applicator and raw material manufacturer. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

7.4.3 Insulation coating thickness

7.4.3.1
The foam insulation thickness shall be
a) calculated from the circumference measured using a flexible tape wrapped around the coated pipe; or
b) measured at a minimum of four locations, equally spaced (e.g., 12, 3, 6, and 9 o'clock positions), around the circumference at both ends of the coated pipe. The method of measurement shall be at the applicator's option.

The thickness of the polyethylene jacket shall be measured at the two pipe ends. Measurements shall be made at a minimum of four locations, equally spaced (e.g., 12, 3, 6, and 9 o'clock positions), around the circumference.

The thicknesses of the foam insulation and polyethylene jackets shall be recorded within the first 1 h of production and every 1 h thereafter.

7.4.3.2
The average thickness of the foam insulation shall be no more than 10 mm over the specified thickness and no more than 3 mm below the specified thickness. Where the average thickness is more than 10 mm greater than the specified value, the thickness shall be reworked to bring the thickness within specification. Where the average is more than 3 mm less than the specified thickness, the pipe shall be treated in accordance with Clause 8.4.

7.4.4 External polyethylene jacket thickness

7.4.4.1

Where individual measured thickness values of the polyethylene jacket are less than the specified value in Table 6, the pipe shall be overcoated with an additional layer of polyethylene in accordance with the applicator's recommendations. The peel adhesion between the polyethylene layers shall be tested using the applicable method and acceptance criteria specified for System A in Table 10 of CSA Z245.21.

7.4.4.2

Where individual measured thickness values of the polyethylene jacket are less than the specified value in Table 7, the pipe shall be overcoated with an additional layer of polyethylene in accordance with the applicator's recommendations as approved by the purchaser. The lap shear between the polyethylene layers shall be tested using the applicable method and acceptance criteria specified for electrofusion in Table 4 of CSA Z245.30.

7.5 Finished product inspection and testing

7.5.1 Facilities

The applicator shall have suitable facilities available for the preparation, testing, and evaluation of finished product to the requirements of Table 10.

7.5.2 Test samples — Foam insulation and polyethylene jacket

Unless otherwise specified in the purchase order, test samples shall be approximately 150 mm long, and shall be obtained from locations at least 50 mm from a pipe end. Test samples may be taken from the cutback area.

Note: *Test samples should be taken after the insulated pipe has cooled to ambient temperature.*

7.5.3 Other tests

The leak detection components shall be tested in accordance with the leak detection manufacturer's recommended practices to ensure each component is in proper working order.

7.5.4 Testing requirements

7.5.4.1 Minimum test frequency

The minimum test frequencies shall be as specified in Table 10.

7.5.4.2 Retest procedures

7.5.4.2.1

Where the test results for compressive strength or impact resistance do not meet the acceptance criteria in Table 10, retesting shall be conducted as specified in Clauses 7.5.4.2.2 to 7.5.4.2.5.

7.5.4.2.2

The pipe in question shall be retested for the properties that do not meet the applicable requirements of Table 10. Two such tests shall be conducted for each failed property using test samples taken from the originally tested end of the affected pipe. If both of these retests pass, no further testing will be required, and the batch of pipe shall be accepted.

7.5.4.2.3
If either of the retests of the properties specified in Clause 7.5.4.2.2 fails, the pipe in question shall not be accepted. Subject to the approval of the purchaser, further testing shall be conducted to isolate the unacceptable pipes. This shall be done by sampling two additional pipes: one coated immediately prior to, and one coated immediately after the pipe in question. These additional pipes shall be tested only for the property out of specification.

7.5.4.2.4
If the results of the tests specified in Clause 7.5.4.2.3 meet the applicable requirements of Table 10, the unacceptable pipe, excluding the pipe coated between the retest pipes, shall be accepted without further testing.

7.5.4.2.5
If the results of the additional retest fail to meet the applicable requirements of Table 10, the unacceptable pipe shall be rejected. Further sequential testing as specified in Clause 7.5.4.2.3 shall be carried out to isolate the defective pipes.

7.5.4.3 Rejection

7.5.4.3.1
All pipes found to be out of specification when tested in accordance with Clause 7.5.4.2 shall be rejected.

7.5.4.3.2
All rejected pipe shall be stripped and recoated in accordance with Clause 8.4.

8 Repair of coated pipe

8.1 Anti-corrosion coating
Damage to the anti-corrosion coating shall be repaired according to the applicable coating Standards or Annexes listed in Table 1.

8.2 Foam insulation

8.2.1
Coating repair applicators shall be qualified in accordance with CSA Z245.30, Clause 6.1.2. The applicable repair materials shall be applied in accordance with the manufacturer's qualified application procedure (MQAP) and qualified in accordance with CSA Z245.30, Clause 5.

8.2.2
Voids or damage of applied insulation shall be repaired using the techniques detailed in Clauses 8.2.3 to 8.2.5, depending upon defect length. The maximum number of repairs shall be two per 12 m pipe length, regardless of technique.

8.2.3

Voids or damage under a maximum of 300 mm in axial length of the applied insulation shall be

a) repaired by mould or spray foam application of compatible material; or
b) repaired using pre-formed shells.

The maximum number of repairs shall be two per 12 m pipe length.

8.2.4

Voids or damage greater than 300 mm and up to a maximum of 1 m in axial length of the applied insulation shall be repaired by mould or spray application of compatible material.

8.2.5

Voids or damage greater than 1 m and up to a maximum of 3 m in axial length of the applied insulation shall be repaired by the same application technique and material equivalent to that originally used in production.

8.2.6

Where repair is performed by mould or spray, the surface of the repair area shall be roughened prior to application to promote adhesion of the repair material. The surface of the repair shall be cut or filed even to conform to the contour of the adjacent insulation.

8.2.7

Where leak detection monitoring is used, pre-formed shells shall not be used.

8.3 External polyethylene jacket

8.3.1

Coating repair applicators shall be qualified in accordance with CSA Z245.30, Clause 6.1.2. The applicable repair materials shall be applied in accordance with the MQAP and qualified in accordance with CSA Z245.30, Clause 5.

8.3.2

Where the external polyethylene jacket is damaged, the repair shall be carried out using either a heat-shrink sleeve or electro-fusion welded casing compatible with the parent coating. Sleeves or electro-fusion welded casings shall be installed in accordance with the MQAP. The maximum allowable numbers of repairs per joint shall be two, and the maximum axial length of the damage area shall be 300 mm.

If the maximum number of repairs or size of the damage area is exceeded, the pipe shall be recoated in accordance with Clause 7.4.4 or an alternative method approved by the purchaser.

8.3.3

The applicator shall ensure that repairs to the external polyethylene jacket at the cutback shall be compatible with the field joint coating system to be used.

8.4 Stripping and recoating

8.4.1

Unless treated in accordance with the requirements of Clause 7.4.3.2 for non-compliance of the foam insulation thickness, the coated pipe shall be stripped to either the anti-corrosion coating or bare metal and recoated in accordance with the requirements of Clause 6.2.3. The temperature during the stripping operation shall not exceed 275 °C. The applicator shall record the identity of each stripped and recoated pipe.

Note: *Heat applied to pipe during coating application can have an aging effect on the mechanical properties of steel pipe.*

8.4.2

Where the adhesive application fails to conform to the requirements of Clause 6.2.4.1, the pipe shall be recoated by removing the external polyethylene jacket and reapplying the adhesive and polyethylene in accordance with the requirements of Clause 6.2.4.1.

8.4.3

Where the polyethylene thickness fails to conform to the requirements of Table 6 or 7, the external polyethylene jacket shall be repaired in accordance with the requirements of Clause 7.4.4.

8.5 Repair of pipe ends

When the applicator cuts the pipe, steel pipe ends shall be refinished in accordance with the original pipe manufacturing specification, or as agreed upon by the purchaser and the applicator.

9 Markings

9.1 General

Coated pipe shall be marked in accordance with the requirements of Clause 9.2 and with any additional markings specified in the purchase order. Additional markings desired by the applicator may be used.

Note: *Such additional markings include barcode markings or other technology.*

9.2 Required markings

9.2.1

The following markings shall be placed on the outer jacket of the coating:

a) applicator's name or mark;
b) CSA Standard designation and year of publication (CSA Z245.22:22);
c) markings required by the applicable pipe specification or standard, whether or not such specification or standard requires such markings to be applied to the outside surface;
d) anti-corrosion system, standard designation, and year of publication;
e) date of coating application;
f) type of foam insulation system; and
g) design temperature of coating.

9.2.2

Required markings shall be at least 300 mm from the coating cutback unless otherwise specified in the purchase order.

10 Handling and storage

10.1 Handling

10.1.1
Coated pipe shall be handled in a manner that avoids damage to the pipe and coating. Where 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.

10.1.2
Pipe that is damaged during handling shall be repaired in accordance with the requirements of the applicable pipe specification or standard.

10.2 Storage

10.2.1
Where specified in the purchase order, the applicator shall submit details of the facilities and the methods to be used for yard storage.

10.2.2
Coated pipe that is damaged in storage shall be repaired in accordance with Clauses 8.2 and 8.3 or stripped and recoated in accordance with Clause 8.4.

11 Test reports and certificates of compliance

11.1
Unless specified in the purchase order that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses 7.3 to 7.5.4.

11.2
The applicator shall furnish certificates of compliance stating that the coating has been manufactured, applied, inspected, and tested in accordance with the requirements of this Standard and any other requirements specified in the purchase order, and the results of the coating tests and other required tests have been found to conform to such requirements.

12 Test procedures

12.1 Heat aging

12.1.1 Equipment
The equipment shall consist of the following:
a) a temperature controller;
b) a heating device such as a silicone heating mat or other suitable heating device; and
c) insulation material.

12.1.2 Test specimen

A 3 m section of insulated pipe, preferably with an OD of 60.3 to 114.3 mm and a minimum thickness of 50 mm polyurethane foam, shall be prepared.

12.1.3 Procedure

The test procedure to evaluate the effects of heat aging on the coating shall be as follows:

a) Drill 3 mm holes through the insulation into the substrate (approximately 50% of pipe wall thickness) at the 1 m and 2 m position. Install thermocouples and ensure very good contact with the pipe.
b) Install a heating device on the inside wall of the pipe. Exposed foam at the ends shall be sealed with aluminum foil and silicone sealant.
c) Seal both ends of the pipe with fibreglass or ceramic insulation. The completed assembly is illustrated in Figure 1.
d) Heat the pipe (steel) and maintain at the maximum design temperature ±3 °C.
e) Carry out the heat aging for 100 d.
f) Use the middle 1 m of insulated pipe for performance evaluation.

12.2 Creep at maximum design temperature

12.2.1 Equipment

The equipment shall consist of the following:

a) a temperature controller;
b) a silicone heating mat or other suitable heating device; and
c) a micrometer depth gauge or a linear variable displacement transducer (LVDT) with recorder.

12.2.2 Test specimen

The test specimens shall be as follows:

a) Three sections of 200 mm long insulated pipe, preferably with an OD of 60.3 to 114.3 mm and 50 to 75 mm thick polyurethane foam and polyethylene jacket, shall be prepared.
b) The test arrangement shall be as shown in Figure 2. The test portion of the specimen shall be the central 100 mm, with the two 50 mm long portions at each end separated by cutting through the polyethylene (PE) jacket and foam to the steel pipe. The 50 mm length of insulation at both ends of the specimen shall be removed.

12.2.3 Procedure

The test procedure to measure creep at maximum design temperature shall be as follows:

a) Drill suitably sized holes through the insulation into the substrate (approximately 50% of pipe wall thickness) adjacent to the test part. Install thermocouples and ensure very good contact with the pipe.
b) Install a silicone heating mat on the inside wall of the pipe to cover the circumference [or other suitable heating device in the inside diameter (ID) of pipe]. The length of the mat shall be a minimum of 100 mm and shall be located in the test area of the pipe.
c) Seal the exposed foam at the ends with suitable insulation material (e.g., fibreglass or ceramic insulation).
d) Support the test specimen on non-insulated regions.
e) Measure and record the thickness of the foam at a temperature of 20 ± 3 °C before heating of the pipe is started.
f) Heat the pipe (steel) and maintain the temperature at the maximum design temperature ±3 °C.

g) Maintain the temperature for one week. Set the depth gauge or LVDT to zero, and apply a load to result in 0.1 MPa (load in kilograms equals pipe OD in millimetres times test sample length in millimetres times 0.1 MPa divided by 9.81 m/s^2).
h) Plot displacement versus time on double logarithmic diagram and extrapolate to 30 years.

12.2.4 Report

The average recorded radial displacement shall be reported at 100, 250, 500, 750, and 1000 h, and the extrapolated value at 30 years expressed as a percentage of foam thickness and the double logarithmic diagram of the radial displacement.

12.3 Insulation axial shear strength

12.3.1 Equipment

The equipment shall consist of the following:
a) a tensile or compression tester capable of indicating loads with an accuracy of ±1% and maintaining a crosshead speed of 5 mm/min ± 10%; and
b) a temperature controller and heating device such as a silicone heating mat.

12.3.2 Specimen

A section of insulated pipe with length equal to twice the thickness of the foam and a minimum length of 100 mm shall be prepared. See Figure 3 or 4.

The number of test specimens shall be three per test temperature.

12.3.3 Procedure

12.3.3.1

The test procedure to measure the axial shear strength of the applied insulation bond shall be as follows:
a) For determination of axial shear strength at 23 °C, the load shall be applied at a crosshead speed of 5 mm/min ± 10%.
b) For determination of axial shear strength at maximum design temperature, a heater, such as a silicone mat heater, shall be installed on the internal surface of the test specimen. The steel pipe shall reach the required test temperature within 30 min, and the temperature shall be maintained for 30 min before load application. The load shall be applied at a crosshead speed of 5 mm/min ± 10%.

12.3.3.2

The axial shear strength shall be calculated as follows:

$$\tau = \frac{F}{L \times D_s \times \pi}$$

where
τ = axial shear strength, MPa
F = maximum applied load, N
L = length, mm
D_s = OD of steel pipe plus anti-corrosion coating layer (if applicable), mm

12.3.4 Report
The average axial shear strength of the three specimens tested shall be reported.

12.4 External polyethylene jacket bend back

12.4.1 Equipment

12.4.1.1
For sample preparation, equipment such as a band saw, jigsaw, or router shall be used.

12.4.1.2
A vise with a minimum of 51 × 51 mm flat parallel plates that is capable of at least 76 mm of travel shall be used.

12.4.2 Specimen
A ring or section of external polyethylene jacket with a minimum width of 32 ± 5 mm shall be cut from the outer jacket.

If the test specimen has a wall thickness greater than 9.5 mm, material shall be removed from the outside surface, while maintaining an undisturbed inside surface, to produce a ring with 9.5 mm wall thickness.

12.4.3 Specimen conditioning — Temperature
The test shall be performed at 20 ± 3 °C, unless otherwise specified by the purchaser. Test specimens shall be conditioned to the specified temperature before testing.

12.4.4 Procedure
The following procedure shall be followed for each test with the complete procedure performed within a time period of 5 min.

a) The specimen shall be bent by hand and placed in the vise or apparatus so that when the vise is closed, the specimen shall protrude above the top of the vise a distance of 12.5 ± 2.5 mm to allow the strained area to be visually examined.
b) The vise shall be closed slowly until the surfaces or the outside of the jacket come into contact.
c) The bent inside surface of the jacket shall be examined for signs of cracking.

12.4.5 Report
The report shall state if any signs of cracking of the external polyethylene jacket material were observed.

Table 1
Anti-corrosion coating layer
(See Clauses 4.1.1, 5.3.1, 5.3.2, 6.1.3, 6.2.1.2, 6.2.2.3, and 8.1.)

Anti-corrosion coating system	Reference Standard/Annex
External fusion bond epoxy coating for steel pipe	CSA Z245.20
External polyethylene coating for pipe — 2LPE	CSA Z245.21
External polyethylene coating for pipe — 3LPE	CSA Z245.21
Polymer tape coatings	Annex A
Liquid coatings	Annex B

Table 2
Coating system qualification tests
(See Clauses 4.1.2, 5.4, 6.1.1, 6.1.2, and 6.2.3.1 and Table 10.)

Test	Unit	Accept-ance criteria	Test method	Number of test specimens
Polyurethane foam system				
Compressive strength (before aging) at 20 ± 3 °C	MPa	≥0.3	ASTM D1621 or ISO 844	5*
Density	kg/m³	Record value	ASTM D1622	3*
Open cell content	Volume %	≤12	ASTM D6226	3
Water absorption	Volume %	Record value	ASTM D2842	3*
k-factor	W/mK		ASTM C518	1
Initial		≤0.03†		
After aging (Clause 12.1) at maximum design temperature ±3 °C for 100 d		≤0.03†		
Insulated pipe assembly				
Creep at maximum design temperature ±3 °C	Radial displace-ment	Record value†	Clause 12.2	3*
Axial shear strength (before aging)			Clause 12.3	3*
Test temperature 20 ± 3 °C for foam applied directly to steel, FBE or 3LPE	MPa	≥0.12		
Test at maximum design temperature ±3 °C for foam applied directly to steel, FBE or 3LPE	MPa	≥0.08		

(Continued)

Table 2 (Concluded)

Test	Unit	Accept-ance criteria	Test method	Number of test specimens
Test temperature at 20 ± 3 °C for 2LPE and tape anti-corrosion coating layer	MPa	Record value‡		
Test at maximum design temperature ± 3 °C for 2LPE and tape anti-corrosion coating layer	MPa	Record value‡		
Axial shear strength (after aging) (Clause 12.1) 100 d at maximum design temperature ±3 °C			Clause 12.3	3*
Test temperature 20 ± 3 °C for foam applied directly to steel, FBE or 3LPE	MPa	≥0.12		
Test at maximum design temperature ±3 °C for foam applied directly to steel, FBE or 3LPE	MPa	≥0.08		
Test temperature at 20 ± 3 °C for 2LPE and tape anti-corrosion coating layer	MPa	Record value‡		
Test at maximum design temperature ±3 °C for 2LPE and tape anti-corrosion coating layer	MPa	Record value‡		
Impact energy at –30 ± 3 °C	J/mm thickness	≥3, no cracks or through penetration in PE jacket	Clause 12.12 of CSA Z245.20	3

* *The number of specimens is also defined in the test method.*
† *Unless otherwise specified in the purchase order.*
‡ *The shear value limiting factor is assumed to be the anti-corrosion coating layer.*

Table 3
Wrap tape
(See Clause 5.5.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Tensile strength at yield	kg/cm width	≥3.5	ASTM D1000	5

Table 4
Adhesive over foam insulation
(See Clause 5.6.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Softening point (R&B)	°C	≥55	ASTM E28	2
Viscosity at 150 °C ± 3 °C	mPa·s	Manufacturer's value ± 30%	Clause 12.1 of CSA Z245.21	1
Peel strength	N/2.54 cm	≥19.6	Clause 12.4 of CSA Z245.21	3
Lap shear	MPa	≥0.2	ASTM D1002 modified; 2.54 cm/min	5*

* *The number of specimens is also defined in the test method.*

Table 5
Polyethylene resin
(See Clause 5.7.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Stress crack resistance (4 MPa, 50 ± 3 °C)	h	≥500	ASTM D5397	5*
Impact resistance — Charpy at −40 ± 3 °C	kJ/m²	≥3.0	ISO 179-1	10
Flow rate†	g/10 min	0.15–0.80	ASTM D1238 190 °C/2.16 kg	3
Environmental stress cracking resistance (F50)	h	≥1000	ASTM D1693 condition "B", 100% Igepal® CO-630	10*
Tensile yield (50 mm/min) at 23 ± 3 °C	MPa		ASTM D638 Type IV specimen	5*
High density polyethylene (HDPE)		≥18.5		
Medium density polyethylene (MDPE)		≥12.4		

(Continued)

Table 5 (Concluded)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Tensile elongation at break (50 mm/min) at 23 ± 3 °C	%	≥600	ASTM D638 Type IV specimen	5*
Oxidative stability	min	≥10	ASTM D3895 at 220 °C (not copper-induced)	3

* *The number of specimens is also defined in the test method.*
† *The acceptance criteria values are not applicable when bi-modal resin is used. The acceptance criteria for bi-modal resin shall be within 20% of the manufacturer's specified nominal.*

Table 6
Polyethylene jacket thickness with anti-corrosion coating layer
(See Clauses 6.2.4.2, 7.4.4.1, 8.4.3 and Figure 3.)

Specified pipe diameter OD, mm	Minimum jacket thickness (mm)
≤275	1.0
>275 and ≤510	1.5
>510	2.0

Table 7
Polyethylene jacket thickness with LDMS
(See Clauses 6.2.4.3, 7.4.4.2, and 8.4.3, Table 10, and Figure 4.)

Nominal OD of pipe and foam insulation, mm	Minimum jacket thickness (mm)
75–180	3.0
≤200	3.2
≤225	3.4
≤250	3.6
≤280	3.9
≤315	4.1
≤355	4.5
≤400	4.8
≤450	5.2
≤500	5.6
≤560	6.0

(Continued)

Table 7 (Concluded)

Nominal OD of pipe and foam insulation, mm	Minimum jacket thickness (mm)
≤630	6.6
≤710	7.2
≤800	7.9
≤900	8.7
≤1000	9.4
≤1100	10.2
≤1200	11.0
≤1400	12.5

Table 8
Adhesive requirement for incoming materials
(See Clause 7.3.4.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Softening point (R&B)	°C	≥55	ASTM E28	2
Viscosity at 150 ± 3 °C	mPa·s	Manufacturer's value ±30%	Clause 12.1 of CSA Z245.21	1

Table 9
Polyethylene resin requirement for incoming materials
(See Clause 7.3.5.)

Test	Unit	Acceptance criteria	Test method	Number of test specimens
Flow rate	g/10 min	Within 20% of the manufacturer's specified nominal	ASTM D1238 190 °C/2.16 kg	1

Table 10
Production coating test requirements
(See Clauses 7.5.1, 7.5.4.1, 7.5.4.2.1, 7.5.4.2.2, 7.5.4.2.4, and 7.5.4.2.5.)

Test	Unit	Acceptance criteria	Frequency	Test method	Number of test specimens
Compressive strength of foam at 20 ± 3 °C	MPa	≥0.3	1 per shift, minimum of 1 every 12 h	ASTM D1621	5*
Density of foam	kg/m³	±10% of qualified value in Table 2	1 per shift, minimum of 1 every 12 h	ASTM D1622	3*
Bend back of polyethylene jacket for polyethylene thickness in accordance with Table 7		No cracking†	1 per shift, minimum of 1 every 12 h	Clause 12.4	1
Impact energy at –30 ± 3 °C on polyethylene jacket layer only	J	≥1.5	1 per shift, minimum of 1 every 12 h	Clause 12.12 of CSA Z245.20	1

* *The number of specimens is also defined in the test method.*
† *Cracking as defined by AWWA C906: a split or separation of material that is exhibited as a surface discontinuity.*

Figure 1
Typical heating aging test configuration
(See Clause 12.1.3.)

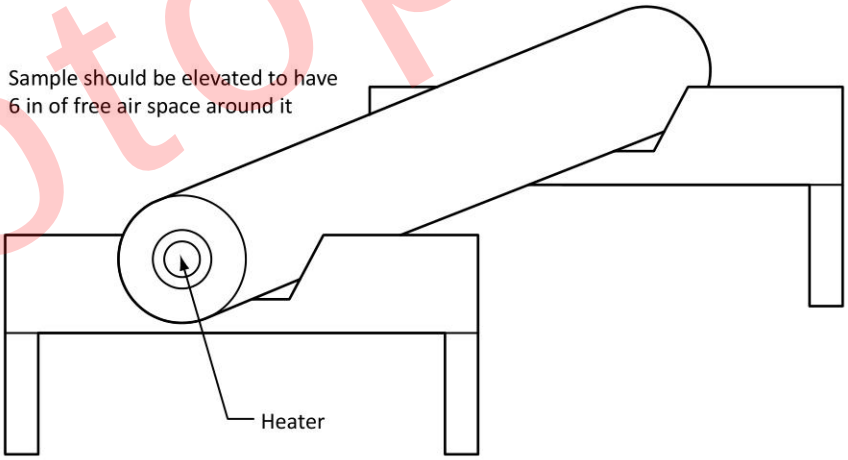
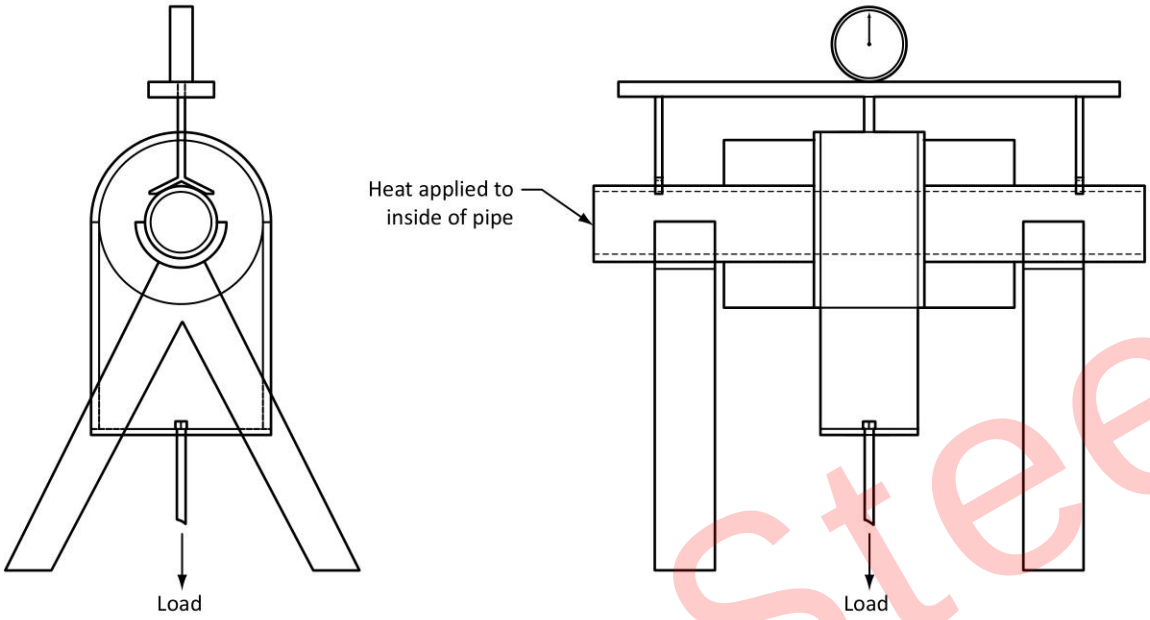
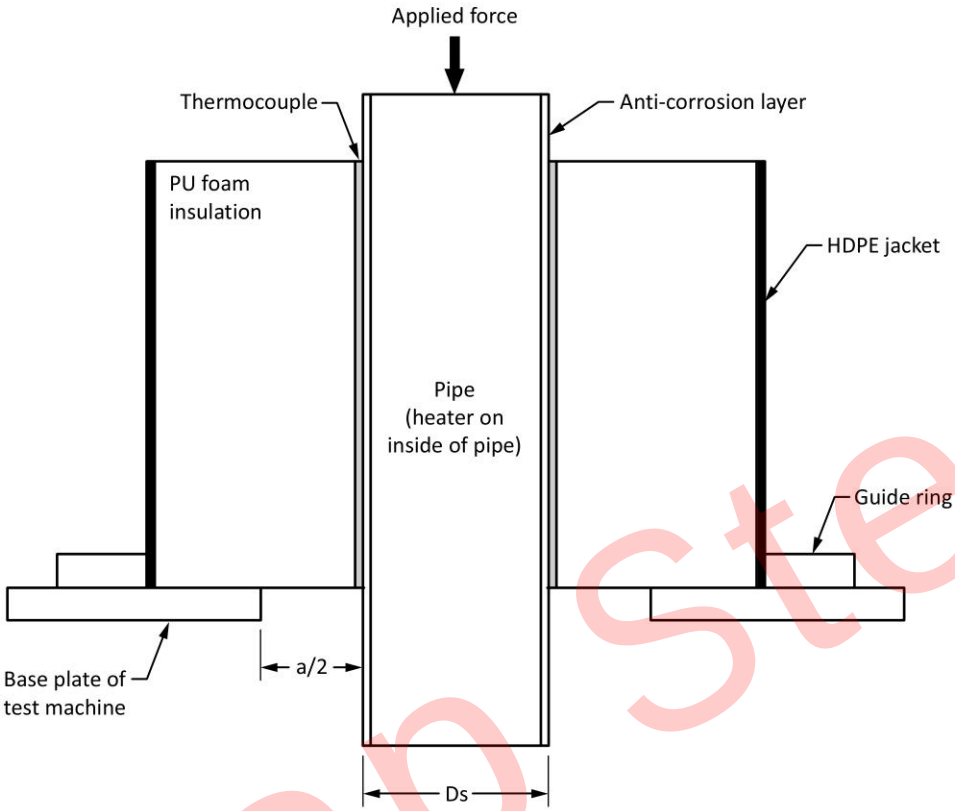


Figure 2
Typical creep test configuration
(See Clause 12.2.2.)



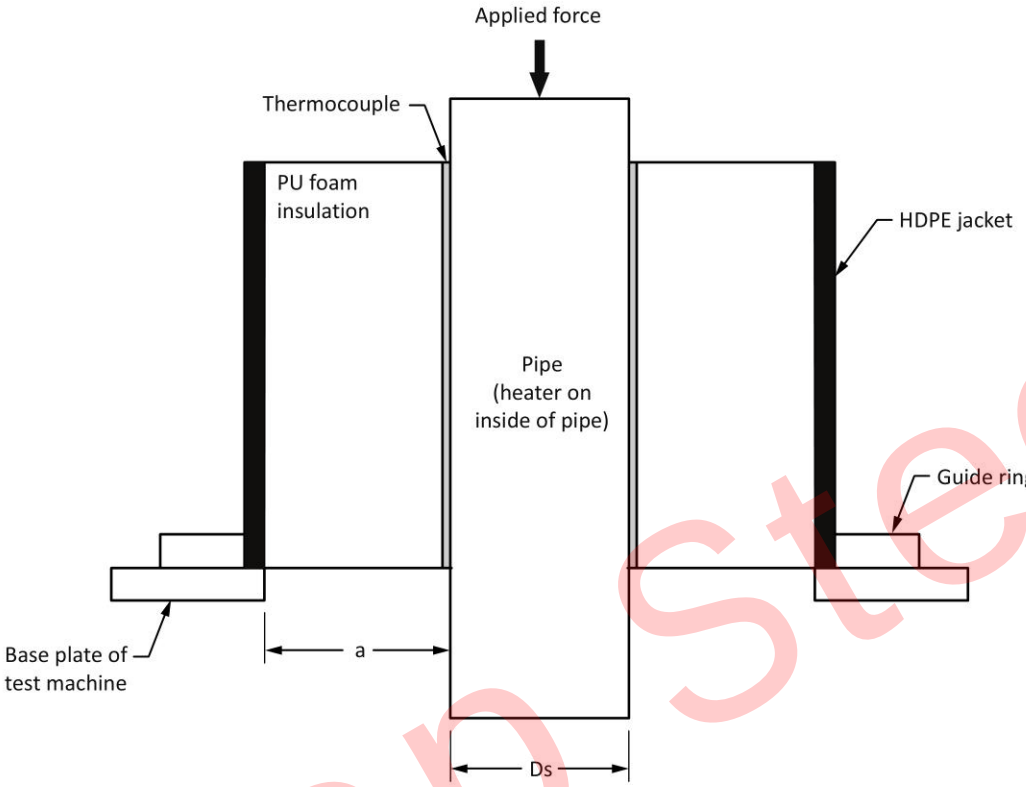
Measuring arrangement for radial displacement

Figure 3
Axial shear test for Table 6 insulation configuration
(See Clause 12.3.2.)



Legend:
a = foam thickness
D_s = OD of steel pipe plus anti-corrosion coating layer (if applicable), mm

Figure 4
Axial shear test arrangement for Table 7 insulation configuration
(See Clause 12.3.2.)



Legend:
a = foam thickness
D_s = OD of steel pipe plus anti-corrosion coating layer (if applicable), mm

Annex A (normative)
Polyolefin tape coatings

Note: *This Annex is a mandatory part of this Standard.*

A.1 Scope

This Annex covers plant-applied tape coating that consists of a polyolefin backing applied over a primer, to be used exclusively in conjunction with insulation. Tape coating in accordance with this Annex shall not be used as a stand-alone anti-corrosion coating.

A.2 Materials — Tape coating system

A.2.1 General

The applicator shall use tapes and primers that are

a) certified by the manufacturer to be in accordance with the requirements of Clauses A.2.2 and A.3.1, and compatible with the requirements of Clause A.4.1;
b) identified with the following:
   i) manufacturer's name;
   ii) product description;
   iii) batch number;
   iv) location of manufacture;
   v) date of manufacture; and
   vi) temperature requirements for transportation and storage; and
c) handled, transported, and stored prior to use in accordance with the manufacturer's recommendations.

A.2.2 Properties

The primer properties shall be in accordance with the requirements in Table A.1. The polyolefin tape properties shall be in accordance with the requirements in Table A.2.

A.2.3 Packaging

The primer and tape shall be delivered in containers clearly labelled to identify the items specified in Clause A.2.1 b).

A.3 Coating application

A.3.1 Coating qualification

A.3.1.1 General

The tape coating system shall be qualified for production by the applicator by testing specimens removed from pipe coated in the plant for each applicable test in accordance with Table A.3 and by meeting the acceptance criteria. The tape coating shall be requalified where there is a change in one or more of the following:

a) manufacturer; and
b) tape formulation.

A.3.1.2 Testing requirements

The tests to be conducted, the test methods to be used, and the acceptance criteria shall be as specified in Table A.3. For each test, specimens shall be obtained from two production pipes.

A.3.2 Production application practices and equipment

A.3.2.1 General

The coating shall be qualified for production in accordance with the requirements of Clause A.3.1.

A.3.2.2 Surface preparation

A.3.2.2.1

The external surfaces of the pipe shall be free of oil and grease and any injurious contaminants prior to the application of the coating.

A.3.2.2.2

Prior to blast cleaning, the pipe shall be preheated to remove moisture. The pipe surface shall be maintained at a temperature at least 3 °C above the dew point, but less than 150 °C, during blast cleaning and inspection.

A.3.2.2.3

The external pipe surface to be coated shall be blast cleaned to at least the requirements of SSPC SP 6/NACE No. 3. The surface profile, measured from peak to trough, shall be 40 to 110 µm and in accordance with the tape manufacturer's recommendations.

A.3.2.2.4

Residual blast products shall be suitably removed from the interior and exterior surfaces of the pipe.

A.3.2.2.5

Except as otherwise agreed to by the purchaser, the cleaned pipe shall be inspected prior to the coating application. Inspections shall be in accordance with the requirements of Clause A.4.2, and detected imperfections that might cause holidays in the coating shall be removed in a manner that gives a surface finish suitable for subsequent application of coating.

Note: *Disposition of pipe with imperfections that cannot be removed during the normal production cycle should be subject to agreement between the applicator and the purchaser.*

A.3.2.2.6

Unless otherwise specified in the purchase order, the applicator may use additional surface treatment prior to the application of the coating.

Note: *The purchaser should be satisfied that the applicator's quality control program for such treatments is acceptable.*

A.3.2.3 Application

A.3.2.3.1 Application temperature

The application temperature of the external pipe surface shall

a) be as selected by the applicator;

b) be in accordance with the tape manufacturer's recommendations; and
c) not exceed 275 °C.

A.3.2.3.2 Application of primer

The liquid primer shall be applied to the entire external pipe surface that will be coated with tape. The manufacturer's application specifications shall be consulted for primer thickness.

A.3.2.3.3 Application of tape coating

A.3.2.3.3.1

The preformed polyolefin tape thickness (adhesive plus backing) that is applied to the pipe shall be as specified in the purchase order.

A.3.2.3.3.2

The polyolefin tape that is applied shall be free of wrinkles, pinholes, and cracks.

A.3.2.3.3.3

The preformed polyolefin tape shall have an overlap of a minimum of 20 mm.

A.3.2.4 End finish

The cutback length for both ends of the pipe shall be as specified in the purchase order. The cutback area shall be free of coating.

A.4 Tests

A.4.1 Incoming raw materials testing

A.4.1.1

The manufacturer shall conduct the sample preparation, testing, and evaluation of the preformed polyolefin tape using suitable equipment.

A.4.1.2

The minimum testing frequency shall be one sample taken from every shipment of preformed tape.

A.4.1.3

The properties of the primer shall be as specified in Table A.4.

A.4.1.4

The properties of the preformed tape shall be as specified in Table A.5.

A.4.2 In-line inspection and measurement

A.4.2.1 General

The inspections and measurements required by Clauses A.4.2.2 to A.4.2.7 shall be made by the applicator.

A.4.2.2 Surface finish

The surface finish shall be monitored and recorded at start-up and at least every 2 h during production to determine whether the cleanliness is in accordance with the requirements of Clause A.3.2.2.3.

A.4.2.3 Surface profile

At start-up and at least once every 4 h of production, the external surface profile on two pipes shall be measured and recorded using replicating film or purchaser-approved equivalent. The profile shall be in accordance with the requirements of Clause A.3.2.2.3.

A.4.2.4 Application temperature

The surface temperature of the pipe immediately prior to the tape application shall be monitored and controlled within the limits recommended by the tape manufacturer. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

A.4.2.5 Application of primer

The primer shall be applied to the entire surface of the pipe to provide complete coverage of the pipe surface to be tape coated. The coverage of the primer shall be examined and recorded within the first 1 h of production and every 1 h thereafter.

A.4.2.6 Application of polyolefin tape

The thickness of the polyolefin tape shall be measured at two locations around the pipe circumference using a coating thickness gauge that has been verified at least once every working shift and a minimum of once every 12 h. Where tape is applied in-line with the spray foam process, the measurements may be taken at the ends (cutback). The thickness shall be determined, and the results shall be recorded within the first 1 h of production and every 1 h thereafter.

A.4.2.7 Holiday inspection

A.4.2.7.1 General

A.4.2.7.1.1

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.

A.4.2.7.1.2

The detector shall be

a) calibrated at least once in a 12 month period; and
b) verified and tested at the beginning of each day of use and not less than once every 12 h against a voltmeter that has been calibrated to recognized standards within the previous six months.

For inspection, the direct current potential of the detector shall be set to exceed 10 V for each micrometre of nominal applied tape thickness, to a maximum of 15 000 V.

A.4.2.7.1.3

Inspection shall be performed after application and prior to application of the insulation coating.

A.4.2.7.2 Acceptance criteria

A.4.2.7.2.1
There shall be no holidays in finished tape coating.

A.4.2.7.2.2
Tape-coated pipe having a holiday regardless of size shall be repaired by patching in accordance with the requirements of Clause A.5.2, provided that the number of holidays does not exceed two per pipe length.

A.4.2.7.2.3
Where the number of holidays exceeds two per pipe length, the affected pipe shall be stripped and recoated in accordance with the requirements of Clause A.5.3.

A.4.3 Production test rings

A.4.3.1 Facilities
The applicator shall have suitable facilities available at the application plant for the preparation, testing, and evaluation of test ring samples for tests of Table A.6.

A.4.3.2 Test rings
Unless otherwise specified in the purchase order, test rings shall be approximately 500 mm long. The rings shall be obtained from locations at least 300 mm from a pipe end.

A.4.3.3 Testing requirements

A.4.3.3.1
The minimum test frequency shall be one test ring per pipe diameter and specified wall thickness every working shift, with a minimum of once every 12 h. The testing methods and test results shall comply with all the requirements of Table A.6.

A.4.3.3.2
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. Where specified in the purchase order, additional test rings shall be taken.

A.4.3.4 Retests

A.4.3.4.1
Where a test fails to conform to the specified requirements of Table A.6,

a) the test that failed shall be repeated using two additional test samples (see Clause A.4.3.2) 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 Clause A.5.3.

A.4.3.4.2

Where both retests conform to the specified requirements, the batch of coated pipe shall be accepted. Where at least one retest fails to conform to the specified requirements,

a) all pipe coated after the previous acceptable test and prior to the next acceptable test shall be stripped and recoated in accordance with Clause A.5.3; or
b) subject to the approval of the purchaser, the lot shall be retested further to determine those portions of the affected lot that are acceptable, based on obtaining test results for both the first and last pipes in the portion that conforms to the specified requirements. Pipe in those portions of the affected lot that are not acceptable shall be stripped and recoated in accordance with Clause A.5.3.

A.5 Repair of tape-coated pipe

A.5.1 General

Where required by Clause A.4 or A.6.1.3, coated pipe shall be repaired by patching in accordance with Clause A.5.2 or by stripping and recoating in accordance with Clause A.5.3, whichever is applicable.

A.5.2 Patching

The repair of holidays by patching shall conform to the following requirements:

a) The patching material shall be applied in accordance with the tape or heat-shrink sleeve manufacturer's recommendations.
b) All patch repairs shall be holiday inspected in accordance with the requirements of Clause A.4.2.7.
c) The number of repairs per length of pipe shall be recorded.

A.5.3 Stripping and recoating

The pipe surface shall be cleaned by a combination of heating to a temperature not to exceed 275 °C, scraping, and abrasive blasting. All coating shall be removed prior to the recoating process. Recoating shall be performed in accordance with Clauses A.3.2 and A.4. The identity of each stripped and recoated pipe shall be recorded.

A.6 Handling and storage

A.6.1 Handling

A.6.1.1

Tape-coated pipe shall be handled in a manner that avoids damage to the pipe and coating. Where specified in the purchase order, the applicator shall submit details of the handling procedures. Where the applicator is responsible for loading, such procedures shall include loading requirements.

A.6.1.2

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

A.6.1.3

Coating that is damaged after the holiday inspection (see Clause A.4.2.7) shall be repaired by patching in accordance with Clause A.5.2 or by stripping and recoating in accordance with Clause A.5.3.

A.6.2 Storage

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

A.7 Test reports and certificates of compliance

A.7.1

Unless the purchase order specifies that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses A.4 and A.5.

A.7.2

The applicator shall furnish certificates of compliance stating that the coating has been manufactured, applied, inspected, and tested in accordance with the requirements of this Standard and any other requirements specified in the purchase order, and that the results of the coating tests and other required tests have been found to conform to such requirements.

Table A.1
Primer
(See Clause A.2.2.)

Test	Unit	Acceptance criteria	Test method
Total solids	%	Manufacturer's specified value ±5%	ASTM D1259
Viscosity at 23 ± 3 °C	mPa·s	Manufacturer's specified value ±30%	ASTM D2196

Table A.2
Polyolefin tape
(See Clause A.2.2.)

Test	Unit	Acceptance criteria	Test method
Preformed tapes			
Width	cm	Specified value ±5%	Measurement
Backing thickness	µm	200 minimum	Measurement
Adhesive thickness	µm	125 minimum	Measurement
Tensile strength (50 mm/min) at 23 ± 3 °C	MPa	≥80% of manufacturer's specified value	ASTM D1000 or ASTM D638 Type IV specimen
Tensile elongation at break (50 mm/min) at 23 ± 3 °C	%	200 minimum	ASTM D1000 or ASTM D638 Type IV specimen
Extrusion applied tapes			
Flow rate	g/10 min	Manufacturer's specified nominal value ±20%	ASTM D1238, 190 °C/2.16 kg
Density	g/cm³	Manufacturer's specified nominal value ±1%	ASTM D792 or D1505
Vicat softening point	°C	At least 10 °C above maximum design temperature	ASTM D1525

Table A.3
Tape coating requirements
(See Clauses A.3.1.1 and A.3.1.2.)

Test	Unit	Acceptance criteria	Test method
28 d cathodic disbondment at 20 ± 3 °C	mm	25 maximum	Clause 12.3 of CSA Z245.21
Peel adhesion	N/2.54 mm	≥90% of manufacturer's specified value	Clause 12.4 or 12.5 of CSA Z245.21

Table A.4
Liquid primer requirement for incoming material
(See Clause A.4.1.3.)

Test	Unit	Acceptance criteria	Test method
Viscosity at 23 ± 3 °C	mPa·s	Manufacturer's specified value ±30%	ASTM D2196

Note: *FBE primer shall meet the requirements in Table 7 of CSA Z245.20.*

Table A.5
Polyolefin tape requirement for incoming material
(See Clause A.4.1.4.)

Test	Unit	Acceptance criteria	Test method
Preformed tapes			
Width	cm	Specified value ±5%	Measurement
Backing thickness	µm	200 minimum	Measurement
Adhesive thickness	µm	125 minimum	Measurement
Tensile strength (50 mm/min) at 23 ± 3 °C	MPa	≥80% of manufacturer's specified value	ASTM D1000 or ASTM D638 Type IV specimen
Tensile elongation at break (50 mm/min) at 23 ± 3 °C	%	200 minimum	ASTM D1000 or ASTM D638 Type IV specimen
Resin for extrusion tapes			
Flow rate	g/10 min	Manufacturer's specified nominal ±20%	ASTM D1238, 190 °C/2.16 kg

Table A.6
Production coating test requirements
(See Clause A.4.3.1, A.4.3.3.1, and A.4.3.4.1.)

Test	Unit	Acceptance criteria	Test method
Peel adhesion	N/2.54 mm	≥90% of manufacturer's specified value	Clause 12.4 or 12.5 of CSA Z245.21

Annex B (normative)
Liquid coating

Note: *This Annex is a mandatory part of this Standard.*

B.1 Scope

This Annex covers the qualification, application, inspection, testing, handling, and storage of materials required for plant-applied liquid coating applied externally to bare steel pipe that is to be used exclusively in conjunction with insulation. Liquid coating according to this Annex is not intended to be a stand-alone coating.

B.2 General requirements

B.2.1 Product ordering requirements

B.2.1.1 Standard requirements

The following information shall be included in purchase orders for coatings for pipe:

a) CSA Standard designation and year of publication (CSA Z245.22:22 Annex B);
b) pipe quantity, OD, wall thickness, and nominal length;
c) bare pipe standard or specification designation (see Clause B.3.1);
d) nominal thickness and permissible tolerance of the anti-corrosion coating; and
e) cutback length for both ends of pipe.

B.2.1.2 Optional requirements

Where applicable, purchase orders shall include the following information:

a) plant inspection by the purchaser (see Clauses B.5.1 and B.5.2);
b) test sample location (see Clause B.5.3.3.2);
c) test frequency (see Clause B.5.3.3.3.1);
d) handling procedures (see Clause B.7.1.1);
e) storage procedures (see Clause B.7.2);
f) waiver of test reports (see Clause B.8.1); and
g) other special requirements.

B.2.2 Rounding procedure

See Clause 4.2.

B.2.3 Quality requirements

See Clause 4.3.

B.2.4 Compliance

See Clause 4.4.

B.3 Materials

B.3.1 Pipe

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

Note: *Pipe conforming to such standards or specifications might not necessarily have a surface condition that is appropriate for the application of coating.*

B.3.2 Liquid coatings

B.3.2.1 General

The applicator shall use liquid coatings that are

a) certified by the manufacturer to be in accordance with the requirements of Clauses B.3.2.2 and B.4.1.3, and compatible with the requirements of Clause B.5.3.1;
b) identified with the following:
   i) manufacturer's name;
   ii) product description;
   iii) batch number;
   iv) location of manufacture;
   v) date of manufacture; and
   vi) temperature requirements for transportation and storage; and
c) handled, transported, and stored prior to use in accordance with the manufacturer's recommendations.

B.3.2.2 Properties

The liquid coating properties shall be in accordance with Table B.1. At least once per year, the liquid manufacturer shall conduct tests and provide the applicator with a test report for the properties specified in Table B.1.

B.3.2.3 Packaging

The liquid coating shall be delivered in containers clearly labelled to identify the items specified in Clause B.3.2.1 b).

B.4 Coating application

B.4.1 Coating qualification

B.4.1.1 General

The liquid coating system shall be qualified for production by the applicator by testing specimens removed from pipe coated in the plant for each applicable test in accordance with Table B.2 and by meeting the acceptance criteria. The liquid coating shall be requalified where there is a change in one or more of the following:

a) manufacturer; and
b) coating formulation.

B.4.1.2 Preparation of laboratory-coated test specimens

B.4.1.2.1
Test specimens shall be mild steel and shall have dimensions in accordance with the applicable test method (either panels or bars).

B.4.1.2.2
The surface shall be blast cleaned using an acceptable steel grit in accordance with SSPC SP 5/NACE No. 1. The surface profile, measured from peak to trough, shall be 40 to 110 µm and in accordance with the liquid manufacturer's recommendations.

B.4.1.2.3
Coating application and curing temperatures shall be in accordance with the liquid manufacturer's recommendations and shall not exceed 100 °C.

B.4.1.2.4
The thickness of anti-corrosion coating on the completed test specimen shall be 425 ± 75 µm, measured by a coating thickness gauge verified at least once every working shift (a minimum of once every 12 h) against a thickness standard that is within 20% of the specified nominal coating thickness of 425 µm.

B.4.1.3 Anti-corrosion coating qualification test requirements
The liquid coating system shall be evaluated in accordance with Table B.2. The tests to be conducted, the number of test specimens, the test methods to be used, and the acceptance criteria shall be as specified in Table B.2. At least once per year, the liquid coating manufacturer shall conduct tests and provide the applicator with a test report for the coating properties specified in Table B.2.

B.4.2 Production application practices and equipment

B.4.2.1 General
The coating shall be qualified for production in accordance with the requirements of Clause B.4.1.

B.4.2.2 Surface preparation

B.4.2.2.1
The external surfaces of the pipe shall be free of oil and grease and any injurious contaminants prior to the application of the coating.

B.4.2.2.2
Prior to blast cleaning, the pipe shall be preheated to remove moisture. The pipe surface shall be maintained at a temperature at least 3 °C above the dew point, but less than 150 °C, during blast cleaning and inspection.

B.4.2.2.3
The external pipe surface to be coated shall be blast cleaned to at least SSPC SP 10/NACE No. 2 specifications. The surface profile, measured from peak to trough, shall be 40 to 110 µm and in accordance with the liquid coating manufacturer's recommendations.

B.4.2.2.4
Residual blast products from the interior and exterior surfaces of the pipe shall be suitably removed.

B.4.2.2.5
Except as otherwise agreed upon by the purchaser, the cleaned pipe shall be inspected prior to the coating application. Inspections shall be in accordance with the requirements of Clause B.5.3.2, and detected imperfections that might cause holidays in the coating shall be removed in a manner that gives a surface finish suitable for subsequent application of coating.

Note: *Disposition of pipe with imperfections that cannot be removed during the normal production cycle should be subject to agreement between the applicator and the purchaser.*

B.4.2.2.6
Unless otherwise specified in the purchase order, the applicator may use additional surface treatments prior to the application of the coating.

Note: *The purchaser should be satisfied that the applicator's quality control program for such treatments is acceptable.*

B.4.2.3 Application

B.4.2.3.1 Application and curing temperatures
The application temperature of the external pipe surface shall be as selected by the applicator. The temperature shall be in accordance with the liquid coating manufacturer's recommendations and shall not exceed 100 °C.

B.4.2.3.2 Coating thickness
The nominal thickness of the coating and the maximum permissible thickness of the coating shall be as specified in the purchase order. Except as allowed by Clause B.5.3.2.7.3, the minimum permissible thickness of the anti-corrosion coating shall be 350 µm.

B.4.2.4 End finish
The cutback length for both ends of the pipe shall be as specified in the purchase order. The cutback area shall be free of coating.

B.5 Production, inspection, and testing

B.5.1 Inspection notice
When it is specified in the purchase order that the inspector representing the purchaser intends to inspect the coating or witness the tests, the applicator shall give the purchaser reasonable notice of the production schedule.

B.5.2 Plant access
While work on the contract of the purchaser is being performed, the inspector representing the purchaser shall have unrestricted entry at all times to all parts of the applicator's plant that relate to the storage, application, testing, and handling of the pipe and coating. The applicator shall afford the inspector all reasonable facilities in order to be satisfied that the coating is being applied in accordance with the requirements of this Standard. 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, testing, or both.

B.5.3 Tests

B.5.3.1 Incoming raw materials testing

B.5.3.1.1
The applicator shall conduct the sample preparation, testing, and evaluation of the liquid coating using suitable equipment. Tests shall be done at the application facility unless otherwise agreed upon by the purchaser.

B.5.3.1.2
The minimum testing frequency shall be one sample taken from every batch of liquid resin received. The acceptance criteria and the tests to be conducted shall be in accordance with the requirements of Clause B.5.3.1.3.

B.5.3.1.3
Prior to the use of the liquid for production coating, laboratory-coated test specimens shall be prepared by the applicator at the proposed plant application temperature in accordance with the requirements of Clause B.4.1.3. The tests to be conducted, the number of test specimens to be used, the test methods to be used, and the acceptance criteria shall be as specified in Table B.3. The liquid coating shall meet the requirements of Table B.3 before its use for production coating. Where a 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. Where both retests conform to the specified test requirements, the liquid batch shall be accepted. Where one or both retests fail to conform to the specified requirements, the liquid batch shall be rejected.

B.5.3.2 In-line inspection and measurement

B.5.3.2.1 General
The inspections and measurements required by Clauses B.5.3.2.2 to B.5.3.2.9 shall be made by the applicator.

B.5.3.2.2 Surface finish
The surface finish shall be monitored and recorded at start-up and a minimum of once every 2 h during production to determine whether the cleanliness is in accordance with the requirements of Clause B.4.2.2.3.

B.5.3.2.3 Surface profile
At start-up and a minimum of 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 Clause B.4.2.2.3.

B.5.3.2.4 Visual inspection
Except as otherwise agreed upon by the purchaser, each pipe shall be inspected after cleaning for surface defects and surface imperfections that might cause holidays in the coating. Such detected surface imperfections shall be removed by grinding, provided that the remaining wall thickness is within

specified limits. Pipe found to be containing surface defects shall be rejected or repaired at the purchaser's option.

Note: *Surface defects include, but are not limited to, gouges, grooves, arc burns, dents, and surface laminations. See CSA Z662, Clause 6.3, for more information on pipe surface requirements applicable to steel piping.*

B.5.3.2.5 Application temperature

The surface temperature of the pipe immediately prior to the liquid coating application shall be monitored and controlled within the limits recommended by the liquid coating manufacturer. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

B.5.3.2.6 Curing

The post-application temperature and the time interval between application and quenching, if required, shall be measured, recorded, and controlled to ensure that the coating is being adequately cured. The temperature shall be recorded at start-up and at least once every 1 h of production thereafter.

B.5.3.2.7 Coating thickness

B.5.3.2.7.1

The total coating thickness shall be measured at three random locations along each pipe length using a coating thickness gauge that has been verified at least once every working shift and a minimum of once every 12 h against a thickness standard that is within 20% of the nominal coating thickness specified in the purchase order. Such measured thickness values shall be recorded once every 4 h per working shift.

B.5.3.2.7.2

For liquid anti-corrosion coatings applied in line with the foam application, the coating thickness measurement shall be carried out on coated pipe using calibrated instruments without foam application at start-up and every 4 h of production.

B.5.3.2.7.3

Where 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 300 µm, and no individual value shall be less than 250 µm.

B.5.3.2.7.4

Coated pipe that does not meet the requirements of Clause B.5.3.2.7.3 shall be stripped and recoated in accordance with the requirements of Clause B.6.3.

B.5.3.2.8 Holiday inspection

B.5.3.2.8.1 General

B.5.3.2.8.1.1

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.

B.5.3.2.8.1.2

The detector shall be

a) calibrated at least once in a 12 month period.; and
b) verified and tested at the beginning of each day of use and not less than once every 12 h against a voltmeter that has been calibrated to recognized standards within the previous six months.

For inspection, the direct current potential of the detector shall be set to exceed 5 V for each micrometer of nominal coating thickness, to a maximum of 5000 V.

B.5.3.2.8.1.3

Inspection shall be performed after application and prior to application of foam insulation coating.

B.5.3.2.8.2 Acceptance criteria

B.5.3.2.8.2.1

There shall be no holidays in finished liquid coating.

B.5.3.2.8.2.2

Coated pipe having holidays shall be repaired by patching in accordance with the requirements of Clause B.6.2, provided that the number of holidays does not exceed the following:

a) for pipe smaller than 355.6 mm OD: 1.0 per m, determined by dividing the total number of holidays by the total pipe length for the individual pipe tested; or
b) for pipe 355.6 mm OD or larger: 0.7 per m^2, determined by dividing the total number of holidays by the total outside surface area for the individual pipe tested.

B.5.3.2.8.2.3

Where the quantity of holidays exceeds the applicable limit specified in Clause B.5.3.2.8.2.2, or where 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 Clause B.6.3.

B.5.3.2.9 Residual magnetism

Notes:

1) *These requirements apply only to measurements made within the coating facility during final coating inspection. Measurements of residual magnetism made subsequent to shipment can be affected by procedures and conditions imposed on the coated pipe during and after shipment.*
2) *The coating applicator may check the residual magnetism of the incoming pipe.*

B.5.3.2.9.1

The longitudinal magnetic field shall be measured on the root face or square cut face of coated pipe.

B.5.3.2.9.2

Measurements shall be made using a Hall-effect magnetic flux density meter or another type of calibrated instrument; however, in case of dispute, measurements made with a Hall-effect magnetic flux meter shall govern. The magnetic flux meter shall be operated in accordance with the applicator's documented procedures that have been demonstrated by the coating applicator to produce accurate results.

B.5.3.2.9.3
Measurements shall be conducted and recorded on each end of a coated pipe, at start-up and a minimum of once every 4 h of production thereafter.

B.5.3.2.9.4
Residual magnetism on the coated pipe shall be measured in the coating facility. For coated pipe handled with magnetic equipment after the measurement of residual magnetism, such handling shall be performed in a manner demonstrated not to cause residual magnetism in excess of the levels specified in Clause B.5.3.2.9.5.

B.5.3.2.9.5
For coated pipe smaller than 168.3 mm OD, at least two readings shall be taken approximately 180° apart around the circumference of each end of the coated pipe. For coated pipe 168.3 mm OD or larger, at least four readings shall be taken approximately 90° apart around the circumference of each end of the coated pipe. The average of such readings shall not exceed 3.0 mT, and no individual reading shall exceed 3.5 mT.

Note: *Measurements made on coated pipe in stacks or bundles are not considered to be valid.*

B.5.3.2.9.6
Any coated pipe that fails to meet the requirements specified in Clause B.5.3.2.9.5 shall be considered defective. In addition, except as allowed by Clause B.5.3.2.9.7, all pipe coated between the defective coated pipe and the last acceptable coated pipe shall be individually measured.

B.5.3.2.9.7
If the coating sequence is documented, coated pipe may be measured in reverse sequence, beginning with the pipe coated immediately prior to the defective coated pipe, until at least three consecutively coated pipes meet the requirements; pipe coated prior to the three acceptable coated pipes need not be measured.

B.5.3.2.9.8
Pipe coated after the defective coated pipe shall be measured individually until at least three consecutive coated pipes meet the specified requirements.

B.5.3.2.9.9
Defective coated pipe shall be demagnetized and remeasured.

B.5.3.3 Production test rings

B.5.3.3.1 Facilities
The applicator shall have suitable facilities for the preparation, testing, and evaluation of test ring samples for tests required in Table B.4.

B.5.3.3.2 Test rings
Unless otherwise specified in the purchase order, test rings shall be approximately 500 mm long. The rings shall be obtained from locations at least 300 mm from a pipe end.

B.5.3.3.3 Testing requirements

B.5.3.3.3.1

The minimum test frequency shall be one test ring per pipe diameter and specified wall thickness every working shift and a minimum of once every 12 h. The testing methods and test results shall comply with the requirements of Table B.4.

B.5.3.3.3.2

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. Where specified in the purchase order, additional test rings shall be taken.

B.5.3.3.4 Retests

B.5.3.3.4.1

Where a test fails to conform to the specified requirements of Table B.4,

a) the test that failed shall be repeated using two additional test samples (see Clause B.5.3.3.2) 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 Clause B.6.3.

B.5.3.3.4.2

Where both retests conform to the specified requirements, the batch of coated pipe shall be accepted. Where at least one retest fails to conform to the specified requirements,

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 Clause B.6.3; or
b) subject to the approval of the purchaser, the batch shall be subjected to further retesting to determine those portions of the affected batch that are acceptable, based on obtaining test results for both the first and last pipes in the portion that conforms to the specified requirements. Pipe in those portions of the affected lot that are not acceptable shall be stripped and recoated in accordance with the requirements of Clause B.6.3.

B.6 Repair of coated pipe

B.6.1 General

Where required by Clause B.5 or B.8, coated pipe shall be repaired by patching in accordance with the requirements of Clause B.6.2 or by stripping and recoating in accordance with the requirements of Clause B.6.3, whichever is applicable.

B.6.2 Patching

The repair of holidays by patching shall conform to the following requirements:

a) Holidays shall be cleaned by removing all rust, scale, dirt, other foreign material, and loose coating.
b) The areas shall be suitably roughened in accordance with the patching manufacturer's recommendations.
c) Dust shall be removed with a clean, dry cloth or brush.
d) The patching material shall be applied in accordance with the patching manufacturer's recommendations.
e) The minimum thickness of repaired coating shall be in accordance with the requirements of Clause B.4.2.3.2.

f) All patch repairs shall be holiday tested in accordance with the requirements of Clause B.5.3.2.8.
g) The number of patch repairs per length of pipe shall be recorded.

B.6.3 Stripping and recoating

The pipe surface shall be cleaned by a combination of heating to a temperature not to exceed 275 °C, scraping, and abrasive blasting. All coating shall be removed prior to the recoating process. Recoating shall be performed in accordance with the requirements of Clauses B.4.2 and B.5. The identity of each stripped and recoated pipe shall be recorded.

B.7 Handling and storage

B.7.1 Handling

B.7.1.1

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

B.7.1.2

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

B.7.1.3

Coating that is damaged after the holiday inspection (see Clause B.5.3.2.8) shall be repaired by patching in accordance with the requirements of Clause B.6.2 or by stripping and recoating in accordance with the requirements of Clause B.6.3.

B.7.1.4

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.

B.7.2 Storage

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

B.8 Test reports and certificates of compliance

B.8.1

Unless the purchase order specifies that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses B.5.3 and B.6.

B.8.2

The applicator shall furnish certificates of compliance stating that the coating has been manufactured, applied, inspected, and tested in accordance with the requirements of this Standard and any other requirements specified in the purchase order, and that the results of the coating tests and other required tests have been found to conform to such requirements.

Table B.1
Liquid properties
(See Clause B.3.2.2.)

Test	Unit	Acceptance criteria	Test method
Viscosity of base at 23 ± 3 °C	mPa·s	Manufacturer's specified value ±30%	ASTM D2196
Viscosity of cure at 23 ± 3 °C	mPa·s	Manufacturer's specified value ±30%	ASTM D2196
Specific gravity mixed	—	Manufacturer's specified value ±0.05	ASTM D3289
Gel time	min	Manufacturer's specified value ±20%	Gardner Gel-timer model GT-S or manufacturer-specified procedure

Table B.2
Coating qualification requirements
(See Clauses B.4.1.1 and B.4.1.3.)

Test	Unit	Acceptance criteria	Test method
28 d cathodic disbondment at 20 ± 3 °C	mm	8.5 maximum radius	Clause 12.8 of CSA Z245.20
28 d cathodic disbondment at maximum design temperature	mm	20 maximum radius	Clause 12.8 of CSA Z245.20
24 h cathodic disbondment at 65 ± 3 °C	mm	6.5 maximum radius	Clause 12.8 of CSA Z245.20
Adhesion, 24 h	Rating	1–3	Clause 12.14 of CSA Z245.20
Adhesion, 28 d	Rating	1–3	Clause 12.14 of CSA Z245.20
Impact resistance at 0 °C, –18 °C, or –30 °C	J	≥1.5	Clause 12.12 of CSA Z245.20, modified
2.0° flexibility at 0 °C, –18 °C, or –30 °C		No cracking at manufacturer-specified test temperature	Clause 12.11 of CSA Z245.20
Cure	% conversion	≥95	Clause 12.7 of CSA Z245.20

Table B.3
Requirement for incoming material
(See Clause B.5.3.1.3.)

Test	Unit	Acceptance criteria	Test method
Viscosity of base at 23 ± 3 °C	Pa·s	Manufacturer's specified value ±30%	ASTM D2196
Viscosity of cure at 23 ± 3 °C	Pa·s	Manufacturer's specified value ±30%	ASTM D2196
Specific gravity mixed	—	Manufacturer's specified value ±0.05	ASTM D1475 or ASTM D3289
Gel time	min	Manufacturer's specified value ±20%	Gardner Gel-timer model GT-S or manufacturer-specified procedure

Table B.4
Laboratory and production coating requirements
(See Clauses B.5.3.3.1, B.5.3.3.3.1, and B.5.3.3.4.1.)

Test	Unit	Acceptance criteria	Test method
24 h cathodic disbondment at 65 ± 3 °C	mm	6.5 maximum radius	Clause 12.8 of CSA Z245.20
Adhesion, 24 h	Rating	1–3	Clause 12.14 of CSA Z245.20
Impact resistance	J	≥1.5	Clause 12.12 of CSA Z245.20
1.5 flexibility at 23 °C, 10 °C, 0 °C, or –30 °C		No cracking at test temperature	Clause 12.11 of CSA Z245.20
Cure	% conversion	≥95	Clause 12.7 of CSA Z245.20

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