

**External fusion bond epoxy
coating for steel pipe/
External polyethylene
coating for pipe**



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Preface

This is the fifth edition of CSA Z245.20, *External fusion bond epoxy coating for steel pipe*, and the fourth edition of CSA Z245.21, *External polyethylene coating for pipe*. They supersede the previous editions of CSA Z245.20 published in 2002, 1998, 1992, and 1986 and the previous editions of CSA Z245.21 published in 2002, 1998, and 1992.

CSA Z245.20 deals with the requirements for external fusion bond epoxy coating for steel pipe. The main differences from the previous edition are as follows:

- requirements for coating with a glass transition temperature higher than 110 °C have been added;
- requirements for two-layer and three-layer coating systems have been added;
- six different coating systems have been identified;
- requirements for residual magnetism have been added;
- the requirements for marking have been revised;
- the requirements for determining the thermal characteristics of the epoxy powder and coating have been revised;
- an optional test to determine the gouge resistance of the coating has been added;
- a requirement to determine the surface roughness of anti-slip overcoat systems has been added; and
- for coating with a glass transition temperature of 110 °C or lower, the following requirements have been revised:
 - qualification test requirements (Table 2);
 - laboratory coating test requirements (Table 3); and
 - production coating test requirements (Table 4).

CSA Z245.21 deals with the requirements for external polyethylene coating for pipe. The main differences from the previous edition are as follows:

- the definition of adhesive lot has been revised;
- a requirement to conduct the tests on the incoming raw material at the application facility, unless otherwise agreed by the purchaser, has been added;
- requirements for residual magnetism have been added;
- the acceptance criteria for holiday inspection have been revised;
- a test frequency has been specified for test rings on pipe that is stripped and recoated;
- the requirements for patching have been revised;
- the requirements for marking have been revised;
- the requirement to conduct a water absorption test on the adhesive has been deleted;
- an optional test to determine the gouge resistance of the coating has been added; and
- the requirements for testing the incoming powder primer have been revised (Table 7).

These Standards were prepared by the Subcommittee on Materials, 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.

December 2006

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 publication 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 publication.
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Z245.20-06

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 110 °C or less;
- (b) System 1B: single-layer FBE with a glass transition temperature greater than 110 °C;
- (c) System 2A: two-layer FBE with a corrosion coating and a protective overcoat;
- (d) System 2B: two-layer FBE with a corrosion coating and an abrasion-resistant overcoat;
- (e) System 2C: two-layer FBE with a corrosion coating and an anti-slip overcoat; and
- (f) System 3: three-layer FBE with an anti-slip overcoat applied over a corrosion coating and a protective overcoat.

1.3

In CSA Standards, “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; “may” is used to express an option or that which is permissible within the limits of the standard; and “can” is used to express possibility or capability. 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 edition listed below, unless the user finds it more appropriate to use newer or amended editions of such publications.

CSA (Canadian Standards Association)

CAN/CSA-ISO 9001-00 (R2005)

Quality management systems — Requirements

ASTM International (American Society for Testing and Materials)

E 29-06a

Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ISO (International Organization for Standardization)

9001:2000

*Quality management systems — Requirements***SSPC (The Society for Protective Coatings)**

SP 5 (2000)

White Metal Blast Cleaning

SP 10 (2000)

Near-White Blast Cleaning

3 Definitions

The following definitions apply in this Standard:

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

Anti-slip overcoat — a fusion bond epoxy 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 powder manufacturer or applicator that specifies that the powder or the product, whichever is applicable, is in compliance with the requirements or specific clauses of this Standard.

Coating — fusion bond epoxy coating.

Corrosion coating — a fusion bond epoxy coating applied directly on steel for the purpose of corrosion protection.

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.

High glass transition temperature — a glass transition temperature greater than 110 °C.

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.

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

Low glass transition temperature — a glass transition temperature of 110 °C or lower.

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

Protective overcoat — a fusion bond epoxy coating applied directly over an FBE 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.

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 (Z245.20-06);
- (b) pipe quantity, outside diameter, 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 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 12.11.3.1](#)).

4.1.2 Optional requirements

Where applicable, purchase orders shall include the following information:

- (a) additional surface treatments (see [Clause 6.2.2.6](#));
- (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 E 29.

4.3 Requirements for quality

The applicator shall comply with the requirements of CAN/CSA-ISO 9001 or ISO 9001.

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 Epoxy powders

5.2.1 General

The applicator shall use epoxy powders that are

- (a) certified by the 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](#);
- (b) identified with the following:
 - (i) 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 powder manufacturer's recommendations.

5.2.2 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. At least once per year, the epoxy powder manufacturer shall conduct tests and provide the applicator with a test report for 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.

5.2.3 Packaging

The 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) manufacturer;
- (b) coating formulation; and
- (c) location of manufacture.

6.1.2 Preparation of laboratory-coated test specimens

6.1.2.1

Test specimens shall be mild steel and shall have dimensions in accordance with the applicable test method (see [Clause 12](#)). Two samples shall be required for multi-layer FBE coating systems: one sample of the 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. The surface profile, measured from peak to trough, shall be 40 to 100 μm and in accordance with the powder manufacturer's recommendations.

6.1.2.3

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

6.1.2.4

The thickness of corrosion coating on the completed test specimen shall be $350 \pm 50 \mu\text{m}$, measured by a coating thickness gauge calibrated against a thickness standard that is within 20% of the specified nominal coating thickness of 350 μm . For multi-layer FBE coating systems, the thickness of the individual layers shall be as per manufacturer's specification, with the corrosion coating being at least 250 μm thick.

6.1.3 Corrosion 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](#). At least once per year, 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.

6.2 Production application practices and equipment

6.2.1 General

The coating to be applied during production shall have been qualified 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 oil and grease and any injurious contaminants prior to the application of the coating.

6.2.2.2

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.

6.2.2.3

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 specifications. The surface profile, measured from peak to trough, shall be 40 to 110 μm and in accordance with the powder 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, 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.

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

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 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 corrosion coating layer.

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

6.2.4 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 7.3.2.7.2](#), the minimum permissible thickness of the corrosion coating shall be 300 µm. The individual layer coating thickness for multi-layer coatings shall be in accordance with the manufacturer's recommendations or the purchaser's specification, with the corrosion coating being at least 250 µm thick.

6.2.5 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.

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 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 powder batch shall be accepted. Where one or both retests fail to conform to the specified requirements, the powder batch shall be rejected.

7.3.1.4

Prior to the use of the powder for production coating, laboratory-coated test specimens shall be prepared by the applicator at the proposed plant application temperature 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, if applicable, [Table 7](#) for Systems 2A, 2B, 2C, and 3. The epoxy powder shall meet the requirements of [Table 3](#) for Systems 1A and 1B and, if applicable, [Table 7](#) for Systems 2A, 2B, 2C, and 3, before its use for production coating. 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 powder batch shall be accepted. Where one or both retests fail to conform to the specified requirements, the 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 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

7.3.2.7.1.1

The total coating thickness shall be measured at three random locations along each pipe length using a coating thickness gauge that has been calibrated at least once every working shift (to a maximum of 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.

7.3.2.7.1.2

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 calibrated 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. Calibration of gauges shall be completed once per working shift (to a maximum of 12 h), and measured thickness values shall be recorded once every 4 h per shift. Areas where the overcoat has been removed shall be repaired in accordance with [Clause 8](#).

7.3.2.7.2

7.3.2.7.2.1

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.

7.3.2.7.2.2

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, and no individual measured thickness value for the total coating thickness, as well as the individual coating thickness, shall be less than 85% of the specified minimum.

7.3.2.7.3

Coated pipe that does not meet the requirements of [Clause 7.3.2.7.2](#) 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

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. The detector shall be calibrated at least once every working shift (to a maximum of 12 h).

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

No holidays shall be permitted in finished coating.

7.3.2.8.2.2

Coated pipe having holidays shall be repaired by patching in accordance with the requirements of [Clause 8.2](#), provided that the number of holidays does not exceed the following:

- (a) for pipe smaller than 355.6 mm OD: 1.0 per metre, 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 square metre, determined by dividing the total number of holidays by the total outside surface area for the individual pipe tested.

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 cm², the affected pipe shall be stripped and recoated in accordance with the requirements of [Clause 8.3](#).

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) *It can be appropriate for the coating applicator to 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 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.

7.3.2.9.3

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 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.

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 demagnetized and remeasured.

7.3.3 Production test rings

7.3.3.1 Facilities

The applicator shall have suitable facilities available at the application plant for the preparation, testing, and evaluation of test ring samples for Type A tests (see [Tables 4](#) and [5](#)).

7.3.3.2 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.

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 (to a maximum of 12 h). Where specified in the purchase order for Systems 2A, 2B, 2C, and 3, additional test rings shall be taken with only the corrosion coating. Such test rings shall be obtained

by turning off the overcoat 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 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](#).

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 powder application.*

8 Repair of coated pipe

8.1 General

Where required by [Clause 7](#) or [10](#), coated pipe shall be repaired by patching 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.

8.2 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) Areas 25 mm in diameter or smaller shall be patched with the powder manufacturer's recommended hot-melt patch stick or two-part epoxy, or a purchaser-approved equivalent.
- (e) Areas greater than 25 mm in diameter and less than 250 cm² in area shall be patched with the powder manufacturer's recommended two-part epoxy or a purchaser-approved equivalent.
- (f) The patching material shall be applied in accordance with the patching manufacturer's recommendations.
- (g) The minimum thickness of repaired coating shall be in accordance with the requirements of [Clause 6.2.4](#).
- (h) All patch repairs and patches 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.

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.

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 shall be permitted.

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

9.2 Required markings

The following markings shall be placed on the coating:

- (a) applicator's name or mark;
- (b) CSA Standard designation and year of publication (Z245.20-06);
- (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.

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 by patching 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.

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

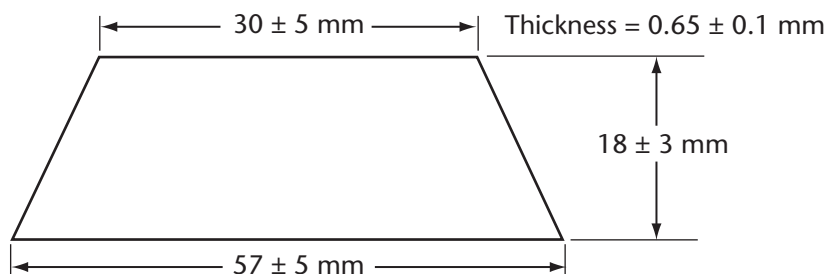
12.1 Cure time of the epoxy powder

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

12.1.2.1

Heat the metal plate to 232 ± 3 °C and maintain that temperature.

12.1.2.2

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. Start the timing device at the instant of powder deposition on the hot plate surface.

12.1.2.3

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.

12.1.2.4

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.

12.1.2.5

For each additional 30 ± 3 s of elapsed time, repeat the operation required by [Clause 12.1.2.4](#). Remove the coating strips in sequential order following the direction of film drawn, starting at the beginning of the draw.

12.1.2.6

Using the differential scanning calorimeter, determine the change in T_g value, ΔT_g , or the percentage conversion, C , in accordance with the requirements of [Clause 12.7.3.3.2](#) or [12.7.3.3.3](#), respectively.

12.1.2.7

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

12.1.3 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 powder batch number;
- (b) the date of testing; and
- (c) the time in seconds corresponding to a ΔT_g of 2 °C, or the time in seconds corresponding to a conversion of 99%.

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

12.2.2.1

Conduct three tests and average the results.

12.2.2.2

Heat the metal plate surface that will be in contact with the powder to 205 ± 3 °C and maintain that temperature.

12.2.2.3

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

12.2.2.4

In a smooth motion, deposit and draw the epoxy powder across the metal plate while holding the tool at an angle of approximately 45° to the metal plate, thereby creating a tongue of epoxy powder approximately 25 mm wide. The cured film should be 300 to 400 µm thick.

12.2.2.5

Start the timing device and deposition of epoxy powder on the metal plate surface simultaneously.

12.2.2.6

Applying light pressure on the draw-down tool, repeatedly draw the edge of the tool through the melted epoxy powder. 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 a report is required by [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 gel time in seconds.

12.3 Moisture content of the epoxy powder — Titration

Note: Moisture content is 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

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

12.3.4 Report

Where a report is required by [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 is 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; and
- (d) a sample container.

12.4.1.2 Procedure

12.4.1.2.1

Weigh the sample container to the nearest 0.001 g. Transfer approximately 10 g of epoxy powder into the sample container. Weigh the sample container and epoxy powder to the nearest 0.001 g.

12.4.1.2.2

Place the sample container with the epoxy powder into the oven for a maximum of 2 h at 105 ± 3 °C. Remove the container from the oven and place it in the desiccator to cool. Weigh the sample container when it has cooled to 20 ± 3 °C and then return it to the desiccator; weigh again at intervals of $1 \text{ h} \pm 10$ min until two consecutive mass determinations are within 0.001 g.

12.4.1.2.3

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 shall be determined using a machine that automatically determines moisture content by mass loss.

12.4.3 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 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**12.5.2.1**

Weigh the sieve and one screen to the nearest 0.01 g. Place approximately 20 g of epoxy powder onto the top of the screen, and record the weight of the powder to the nearest 0.01 g.

12.5.2.2

Place the sieve into the sieving unit, cover the unit, and secure it. Operate the sieving unit for 3 min ± 10 s and remove the cover.

12.5.2.3

Remove the sieve and weigh it to the nearest 0.01 g.

12.5.2.4

Calculate the percentage of epoxy powder retained on the screen using the following formula:

$$P = \frac{F - 1}{M} \times 100$$

where

P = percentage of epoxy powder retained

M = initial mass of powder placed on screen, g

F = final mass of sieve, screen, and retained powder, g

I = initial mass of sieve and screen, g

12.5.2.5

Repeat the procedure specified in [Clauses 12.5.2.1](#) to [12.5.2.4](#) using the other screen.

12.5.3 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 powder batch number;
- (b) the date of testing; and
- (c) the percentage of powder retained for each screen size.

12.6 Density of the epoxy powder

Note: *This test is optional at the discretion of the applicator.*

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 a procedure specified in [Clause 12.6.2.2](#) or [12.6.2.3](#). The choice of procedure shall be at the option of the applicator. The test temperature shall be 20 ± 3 °C.

12.6.2.2 Procedure A

12.6.2.2.1

Weigh the flask to the nearest 0.01 g.

12.6.2.2.2

Add approximately 20 g of epoxy powder to the flask and weigh the flask and the epoxy powder to the nearest 0.01 g.

12.6.2.2.3

Add sufficient mineral spirits to cover and wet the epoxy powder. Stopper the flask and agitate it for several minutes, ensuring that neither air pockets nor lumps of powder exist. Wash the stopper and the walls of the flask with mineral spirits until they are free of powder and the flask is filled to the 100 mL level. Weigh the flask and the epoxy powder and mineral spirits to the nearest 0.01 g.

12.6.2.2.4

Empty the flask. 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.

12.6.2.2.5

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

12.6.2.2.6

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 shall be determined using an air or helium pycnometer.

12.6.3 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 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 differential scanning calorimeter (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

Place a 10 ± 1 mg sample of epoxy powder or coating, whichever is applicable, into a preweighed aluminum pan, crimp the cover into place with the encapsulating press, and weigh them. Determine the sample mass to an accuracy of 0.1 mg.

12.7.3.1.2

Place the sample and a reference in the DSC cell and purge the cell with a dry non-reactive gas.

12.7.3.2 Calorimetry

12.7.3.2.1 Epoxy powder

For epoxy powder samples, obtain thermal scans (see [Figure 3](#)) for the following cycles in the following order:

- heat the sample from 25 ± 5 to 70 ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 ± 5 °C;
- heat the same sample from 25 ± 5 to 265 ± 10 °C at a rate of 20 °C/min, then immediately cool the sample to 25 ± 5 °C; and
- heat the same sample from 25 ± 5 to 30 ± 10 °C above the Tg_2 (as specified by the epoxy powder manufacturer) of the material at a rate of 20 °C/min.

12.7.3.2.2 Coating

For coating samples, obtain thermal scans (see [Figure 4](#)) for the following cycles in the following order:

- heat the sample from 25 ± 5 to 110 ± 5 °C at a rate of 20 °C/min, hold at 110 ± 5 °C for 1.5 min, then immediately cool the sample to 25 ± 5 °C;
- heat the same sample from 25 ± 5 to 265 ± 10 °C at a rate of 20 °C/min, then immediately cool the sample to 25 ± 5 °C; and
- heat the same sample from 25 ± 5 to 30 ± 10 °C above the Tg_4 (as specified by the epoxy powder manufacturer) of the material at a rate of 20 °C/min.

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 (b) and (c) of [Clause 12.7.3.2.2](#), determine the applicable Tg values (which are the points of intersection of the extrapolated baseline at the low temperature end and the tangents to the curve at the inflection point) and determine the applicable exothermic heats of reaction (see ΔH and ΔH_1 in [Figures 3](#) and [4](#)).

12.7.3.3.2

For coatings, determine the change in Tg value using the following formula:

$$\Delta Tg = Tg_4 - Tg_3$$

where

ΔTg = change in Tg value, °C

Tg_4 = Tg value for the thermal scan required by [Clause 12.7.3.2.2\(c\)](#), °C

Tg_3 = Tg value for the thermal scan required by [Clause 12.7.3.2.2\(b\)](#), °C

12.7.3.3.3

For coatings, determine the percentage conversion 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 a report is required by [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 differential scanning calorimeter;
- (d) for epoxy powder, $Tg1$, $Tg2$, and ΔH ; and
- (e) for coating, $Tg3$, $Tg4$, ΔTg , $\Delta H1$, and C.

12.8 Cathodic disbondment of the coating

12.8.1 Equipment

The equipment shall consist of the following:

- (a) a rectified 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 calomel reference electrode;
- (d) platinum wire or a carbon electrode;
- (e) a 75 ± 3 mm ID plastic cylinder;
- (f) a 3% sodium chloride solution in distilled water; and
- (g) a utility knife (see [Clause 12.1.1\(g\)](#)).

12.8.2 Test specimens

Laboratory-coated test specimens shall measure approximately 100 × 100 × 6.4 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 holiday detector set at a minimum of 1800 V shall be used.

12.8.3.2

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.

12.8.3.3

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

12.8.3.4

Add to the cylinder at least 300 mL of the sodium chloride solution that has been preheated to the test temperature. Mark the solution level on the cylinder. Insert the electrode into the solution and connect it to the positive wire from the dc power supply. Attach the negative wire from the dc power supply to a bare spot prepared on the test specimen.

12.8.3.5

Apply voltage (negative with respect to the calomel reference electrode) to the test specimen and maintain constant temperature under one or more of the following test conditions, as specified in [Tables 2 to 4](#) for Systems 1A and 1B and [Tables 6 to 8](#) for Systems 2A, 2B, 2C, and 3:

- (a) 1.5 V, 20 ± 3 °C, for a minimum of 28 d;
- (b) 3.5 V, 65 ± 3 °C, for a minimum of 24 h;
- (c) 1.5 V, 65 ± 3 °C, for a minimum of 28 d; and
- (d) 1.5 V, 95 ± 3 °C, for a minimum of 28 d.

Maintain the solution level by the addition of distilled water as required. For the test conditions specified in Items (c) and (d), the solution shall be replaced after 7, 14, and 21 d.

12.8.3.6

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.

12.8.3.7

Using the utility knife, make eight evenly spaced radial cuts through the coating to the substrate as shown in [Figure 5](#). Ensure that such cuts extend at least 20 mm from the centre of the holiday.

12.8.3.8

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

12.8.3.9

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 a report is required by [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 average disbondment value in millimetres.

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

12.9.3.1

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 12.10.3.1](#).

12.9.3.2

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

12.9.4 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 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 $25 \times 200 \times 6.4$ mm. Specimens from test rings shall measure approximately 25×200 mm $\times$ pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

12.10.3 Procedure

12.10.3.1

Cool the test specimen to -30 °C or lower and bend it approximately 180° in the bench vise or guided-bend jig.

12.10.3.2

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

12.10.3.3

Rate the porosity present in the coating in accordance with the rating scale shown in [Figures 6 and 7](#).

12.10.4 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 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.

12.11.2 Test specimens

Laboratory-coated test specimens shall measure approximately $25 \times 200 \times 6.4$ mm. Specimens from test rings shall measure approximately 25×200 mm $\times$ pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

12.11.3 Procedure

12.11.3.1

Smooth the coating on the edge of the sample to remove any potential stress risers. Place the test specimen in the freezer, cool it to within 3°C of the powder manufacturer's certified minimum flexibility test temperature of -30 , -18 , or 0°C (see [Clause 5.2.1\(b\)\(viii\)](#)), and hold it within that temperature range for a minimum of 1 h.

12.11.3.2

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 8](#).

12.11.3.3

Determine the mandrel radius that corresponds to an angle of deflection of 2.5 or 3.0° 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 table:

Required deflection, degrees	Application formula
1.5	$R = 37.70t$
2.0	$R = 28.15t$
2.5	$R = 22.42t$
3.0	$R = 18.60t$

Legend:

R = mandrel radius, mm

t = sample thickness, mm

12.11.3.4

Bend the test specimen over a mandrel whose radius is not larger than that determined in accordance with the applicable requirements of [Clause 12.11.3.3](#). Bend the specimen such that the operation lasts not longer than 10 s and is completed within 30 s of the test specimen's having been removed from the freezer.

12.11.3.5

Warm the bent test specimen to $20 \pm 5^\circ\text{C}$ and hold it in within this temperature range for a minimum of 2 h. Within the next hour, visually inspect it for cracks.

12.11.4 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 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 wooden base measuring at least $600 \times 600 \times 600$ mm, with the top of the base being hardwood;
- (b) a dc holiday detector; and
- (c) a freezer.

12.12.2 Test specimens

Laboratory-coated test specimens shall measure approximately $25 \times 200 \times 6.4$ mm. Specimens from test rings shall measure approximately 25×200 mm $\times$ pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

12.12.3 Procedure

12.12.3.1

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

12.12.3.2

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.

12.12.3.3

Allow the sample to warm to 20 ± 5 °C. 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 a report is required by [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 6.4 ± 0.2 mm thick and cut approximately as shown in [Figure 9](#).

12.13.3 Procedure

12.13.3.1

Strain the test specimen at -30 ± 3 °C a minimum of 2.5° in accordance with the applicable requirements of [Clause 12.11.3](#). For multi-layer and high-temperature FBE systems, the angle of deflection should be reduced to 1.5° .

12.13.3.2

Test the strained specimen in accordance with the applicable requirements of [Clauses 12.8.3.1](#) to [12.8.3.6](#) for the 28 d cathodic disbondment test.

12.13.3.3

Within 24 h of dismantling the cell, visually inspect the tested portion of the specimen for cracks.

12.13.4 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 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 or non-corroding water bath;
- (b) tap water;
- (c) a thermometer; and
- (d) a utility knife (see [Clause 12.1.1\(g\)](#)).

12.14.2 Test specimens

Laboratory-coated test specimens shall measure approximately $100 \times 100 \times 6.4$ mm. Specimens from test rings shall measure approximately 100×100 mm $\times$ pipe wall thickness.

12.14.3 Procedure

12.14.3.1

For each test, use fresh tap water that has been heated to 75 ± 3 °C prior to immersion of the test specimens. Place the test specimens in the slow cooker or water bath and submerge them fully in the preheated water.

Submerge the test specimens for a minimum of 24 ± 0.5 h at a water temperature of 75 ± 3 °C and then remove them from the slow cooker or water bath. Qualification testing requires that this test shall be performed at the same temperature for $28 \text{ d} \pm 4 \text{ h}$.

12.14.3.2

While the test specimen is still warm, use the utility knife to scribe an approximately 30×15 mm rectangle through the coating to the substrate, then air cool the test specimen to 20 ± 3 °C. Within 1 h of removal from heat (see [Clause 12.14.3.1](#)), insert the tip of the utility knife under the coating at a corner of the scribed rectangle. Use a levering action to remove the coating. Continue inserting the tip of the knife and levering it under the coating until either all of the coating in the rectangle is removed or the coating demonstrates a definite resistance to the levering action.

12.14.3.3

Rate the adhesion of the coating within the rectangle as follows:

- (a) Rating 1: coating cannot be removed cleanly;
- (b) Rating 2: less than 50% of the coating can be removed;
- (c) Rating 3: more than 50% of the coating can be removed, but the coating demonstrates a definite resistance to the levering action;
- (d) Rating 4: the coating can be easily removed in strips or large chips; and
- (e) Rating 5: the coating can be completely removed as a single piece.

12.14.4 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 powder batch number;
- (b) the date of testing; and
- (c) the adhesion rating.

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. The test method and acceptance criteria shall be agreed on.

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;
 - (ii) an adjustable loading mechanism for the test beam or carbide tool, capable of applying at least a 50 kg load;
 - (iii) a smooth carbide tip (i.e., SL-1) or a carbide burr (i.e., R-33); and
 - (iv) steel shims in various thicknesses;
- (b) a coating thickness gauge; and
- (c) a gouge-depth dial gauge.

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.

12.15.4 Procedure

12.15.4.1

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

12.15.4.2

Use a calibrated coating thickness gauge to take at least six measurements on the surface of the test panel (ideally in the regions of the panel to be gouge tested) and report the average thickness.

12.15.4.3

Place the test specimen (coating side facing the gouge tip) on the fixture cart. Secure the specimen with the longitudinal direction parallel to the cart track movement direction. If necessary, use steel shims to level the specimen on the cart.

12.15.4.4

Install the appropriate test bit on the bit-holder of the fixture beam. Position the beam and test bit over the coating surface at a sufficient distance to allow a minimum gouge travel length of 75 mm. Ensure that the test beam is parallel to the coating surface and that the gouge bit is perpendicular to the surface to be tested.

12.15.4.5

Perform the following steps:

- (a) Adjust the materials test machine or drive mechanism to produce a travel speed of 25.4 cm/min.
- (b) Perform the gouge test on the coating at the first test location.
- (c) Remove or reposition the test sample to perform additional tests.

12.15.4.6

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 2.54 cm 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 gouge, shall act as measurement reference points.

12.15.4.7

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; instead, it should rest on either side of this area. Record the depth of the scratches at the area where the scratches are intersected by the marked lines.

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 powders;
- (d) the load used for testing (if different from 50 kg); and
- (e) the type of carbide tip used.

12.16 Surface roughness measurement

12.16.1 Equipment

The equipment shall consist of the following:

- (a) press-o-film tape;
- (b) a burnishing tool; and
- (c) a spring micrometer.

12.16.2 Procedure

12.16.2.1

Choose a place with anti-slip material on the coated exterior of the pipe to take the roughness measurement. Place the press-o-film tape over the selected area.

12.16.2.2

Rub the large end (flat end) of a burnishing tool over the found cut-out portion of the press-o-film tape to obtain an impression. Press-o-film tape will become darker when replicated, so ensure that the entire circle area has uniformly darkened.

12.16.2.3

Remove the tape from the pipe and place it between anvils on the spring micrometer. Ensure that the darkened area of the tape is centred for accurate micrometer reading. Release the spring and take the reading displayed on the micrometer. The gauge reading is the maximum peak-to-valley difference of the selected area in the coating surface profile.

12.16.3 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 powder batch numbers;
- (b) the date of testing;
- (c) the total and individual coating thickness of applied powders; and
- (d) the measured value of the surface profile.

Table 1
Epoxy powder properties for corrosion coating test requirements
(See [Clauses 5.2.2](#), [7.3.1.3](#), [12.3](#), and [12.4](#).)

Test	Acceptance criteria	Test method
Cure time	Meets manufacturer's specification	Clause 12.1
Gel time	Within 20% of manufacturer's specified nominal	Clause 12.2
Moisture content*	0.5% maximum	Clause 12.3
	0.6% maximum	Clause 12.4
Particle size	3.0% maximum powder retained on 150 µm mesh and 0.2% maximum powder retained on 250 µm mesh	Clause 12.5
Density	Meets manufacturer's specification within 50 g/L	Clause 12.6
Thermal characteristics	Meets manufacturer's specification	Clause 12.7

*The specific test method to be used shall be at the manufacturer's option.

Table 2
Qualification test requirements for Systems 1A and 1B
 (See [Clauses 6.1.3](#), [12.8.3.5](#), and [12.11.3.3](#).)

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
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	20 mm maximum radius	—	3	Clause 12.8
28 d cathodic disbondment at 95 °C	—	20 mm maximum radius	3	Clause 12.8
Cross-section porosity	Rating of 1–4	Rating of 1–4	3	Clause 12.10
Interface porosity	Rating of 1–4	Rating of 1–4	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	Rating of 1–3	Rating of 1–3	3	Clause 12.14
28 d adhesion	Rating of 1–3	Rating of 1–3	3	Clause 12.14
Cure — per cent conversion	95%	95%	1	Clause 12.7

Table 3
Laboratory coating test requirements for Systems 1A and 1B
 (See [Clauses 7.3.1.1, 7.3.1.4, 12.8.3.5, and 12.11.3.3.](#))

Test	Acceptance criteria		Number of test specimens	Test method
	System 1A	System 1B		
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 1–4	Rating of 1–4	1	Clause 12.10
Interface porosity	Rating of 1–4	Rating of 1–4	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	Rating of 1–3	Rating of 1–3	3	Clause 12.14
Cure — per cent conversion	95%	95%	1	Clause 12.7

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, 12.8.3.5, and 12.11.3.3.](#))

Test	Test type	Acceptance criteria		Number of test specimens	Test method
		System 1A	System 1B		
24 h cathodic disbondment at 65 °C	A	11.5 mm maximum	6.5 mm maximum radius	1	Clause 12.8
Cross-section porosity	B	Rating of 1–4	Rating of 1–4	1	Clause 12.10
Interface porosity	B	Rating of 1–4	Rating of 1–4	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	A	Rating of 1–3	Rating of 1–3	1	Clause 12.14
Interface contamination	B	30% maximum	30% maximum	1	Clause 12.9
Cure — per cent conversion	B	95%	95%	1	Clause 12.7

Table 5
Epoxy powder properties for Systems 2A, 2B, 2C, and 3
 (See [Clauses 5.2.2](#), [7.3.1.3](#), and [7.3.3.1](#).)

Test	Acceptance criteria	Test method
Cure time	Meets manufacturer's specification	Clause 12.1
Gel time	Meets manufacturer's specification	Clause 12.2
Moisture content*	Meets manufacturer's specification	Clauses 12.3 and 12.4
Particle size	Meets manufacturer's specification	Clause 12.5
Density	Meets manufacturer's specification within 50 g/L	Clause 12.6
Thermal characteristics	Meets manufacturer's specification	Clause 12.7

*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](#), [12.8.3.5](#), and [12.11.3.3](#).)

Test	Acceptance criteria	Number of test specimens	Test method
Thermal characteristics	Meets manufacturer's specification	3	Clause 12.7
24 h cathodic disbondment at 65 °C	6.5 mm maximum radius	3	Clause 12.8
28 d cathodic disbondment at 20 °C	8.5 mm maximum radius	3	Clause 12.8
Cross-section porosity*	Rating of 1–4	3	Clause 12.10
Interface porosity*	Rating of 1–4	3	Clause 12.10
2.0° flexibility	No cracking	5	Clause 12.11
3.0 J impact resistance†	No holidays	3	Clause 12.12
Surface roughness‡	> 50 µm peak to trough	3	Clause 12.16
24 h adhesion	Rating of 1–3	3	Clause 12.14
28 d adhesion	Rating of 1–3	3	Clause 12.14
1.5° strained coating, 28 d cathodic disbondment	No cracking	3	Clause 12.13
Cure — per cent conversion§	95%	3	Clause 12.7

*For individual layers of multi-layer coating systems except anti-slip overcoat.

†For all multi-layer coatings, except for corrosion coating with anti-slip overcoat, use 1.5 J.

‡Surface roughness for anti-slip overcoat systems only.

§Cure to be completed on inner layer of coating system.

Table 7
Laboratory coating test requirements for Systems 2A, 2B, 2C, and 3
 (See [Clauses 7.3.1.1, 7.3.1.4, 12.8.3.5, and 12.11.3.3.](#))

Test	Acceptance criteria	Number of test specimens	Test method
24 h cathodic disbondment at 65 °C	6.5 mm maximum radius	1	Clause 12.8
Cross-section porosity*	Rating of 1–4	1	Clause 12.10
Interface porosity*	Rating of 1–4	1	Clause 12.10
1.5° flexibility	No cracking	3	Clause 12.11
24 h adhesion	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 — per cent conversion§	95%	1	Clause 12.7

*For individual layers of multi-layer coating systems except anti-slip overcoat.

†For all multi-layer coatings, except for corrosion coating with anti-slip overcoat, use 1.5 J.

‡Surface roughness for anti-slip overcoat systems only.

§Cure to be completed on inner layer of coating system.

Table 8
Production coating test requirements for Systems 2A, 2B, 2C, and 3
 (See [Clauses 7.3.1.1, 7.3.3.3.3, 7.3.3.4.1, 7.3.3.5, 12.8.3.5, and 12.11.3.3.](#))

Test	Test type	Acceptance criteria	Number of test specimens	Test method
24 h cathodic disbondment at 65 °C	A	11.5 mm maximum	1	Clause 12.8
Cross-section porosity*	B	Rating of 1–4	1	Clause 12.10
Interface porosity*	B	Rating of 1–4	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	A	Rating of 1–3	1	Clause 12.14
Interface contamination	B	30% maximum	1	Clause 12.9
Cure — per cent conversion‡	B	95%	1	Clause 12.7
Surface roughness§		> 50 µm peak to trough	1	Clause 12.16

*For individual layers of multi-layer coating systems except anti-slip overcoat.

†For all multi-layer coatings, except for corrosion coating with anti-slip overcoat, use 1.5 J.

‡Cure to be completed on inner layer of coating system.

§Surface roughness for anti-slip overcoat systems only.

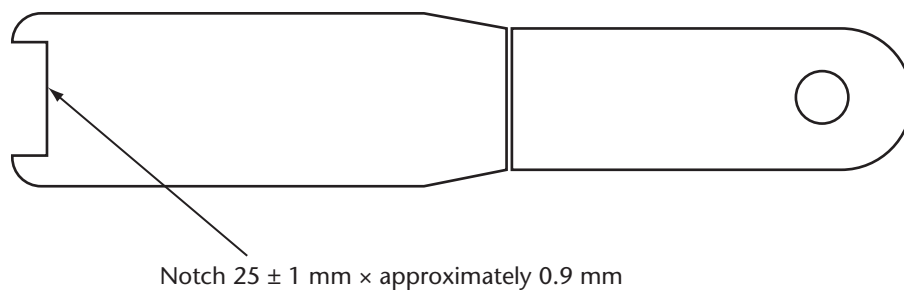


Figure 1
Draw-down tool
(See [Clauses 12.1.1](#) and [12.2.1](#).)

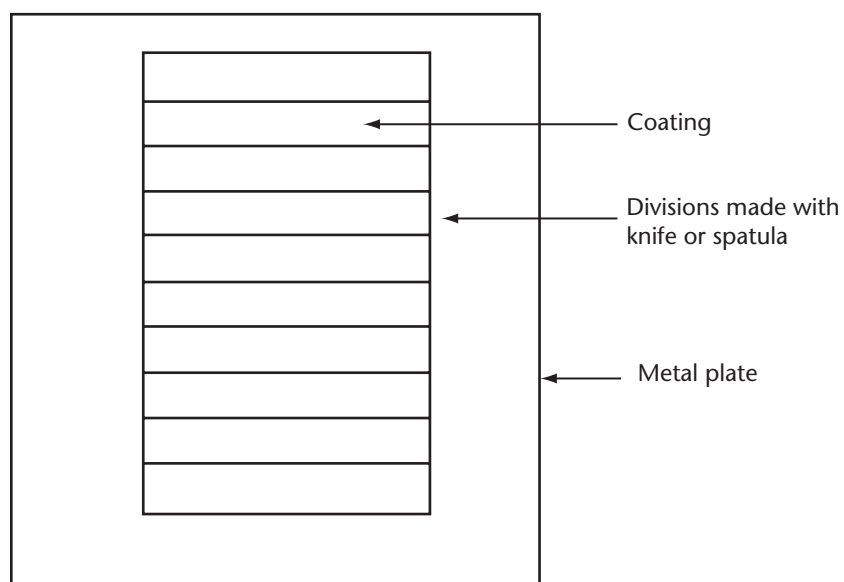


Figure 2
Coated plate configuration
(See [Clause 12.1.2.3](#).)

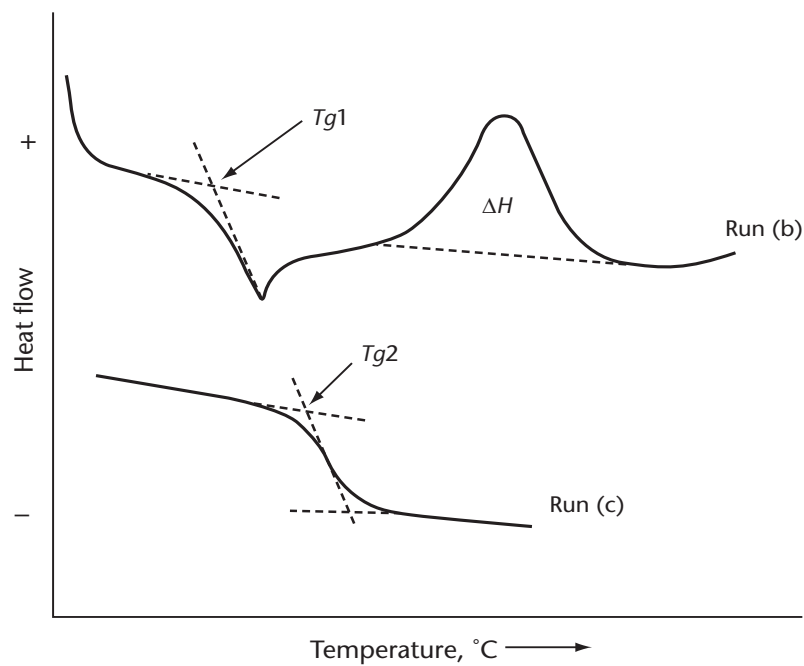


Figure 3
Examples of thermal scans on epoxy powder
(See [Clauses 12.7.3.2.1](#) and [12.7.3.3.1.](#))

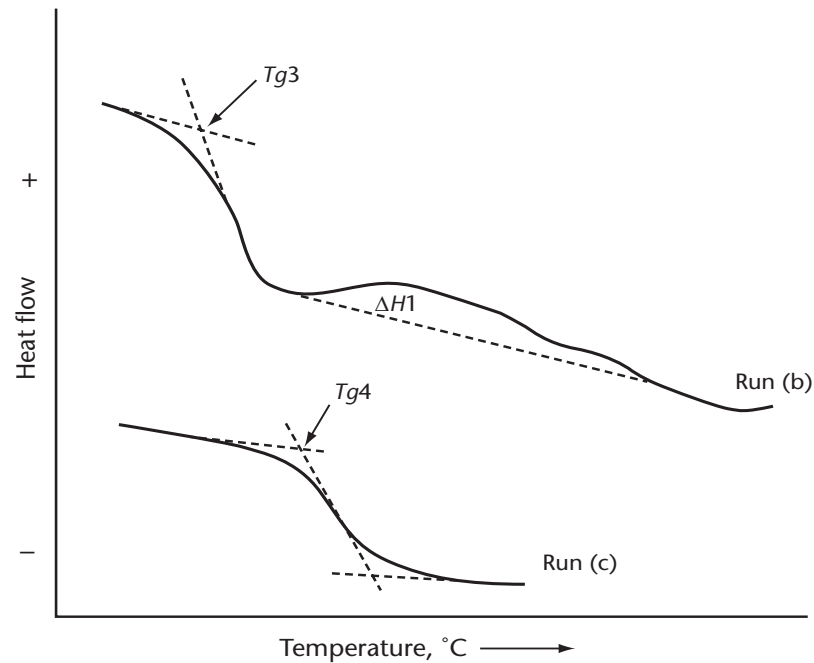


Figure 4
Examples of thermal scans on coating
(See [Clauses 12.7.3.2.2](#) and [12.7.3.3.1.](#))

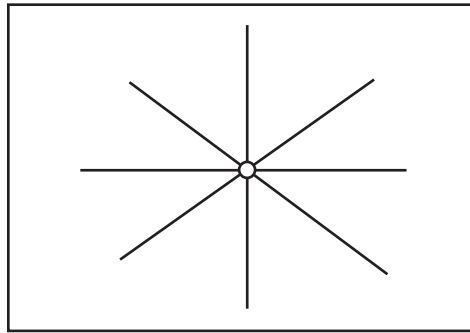


Figure 5
Examples of radial cuts through the coating
(See [Clause 12.8.3.7.](#))

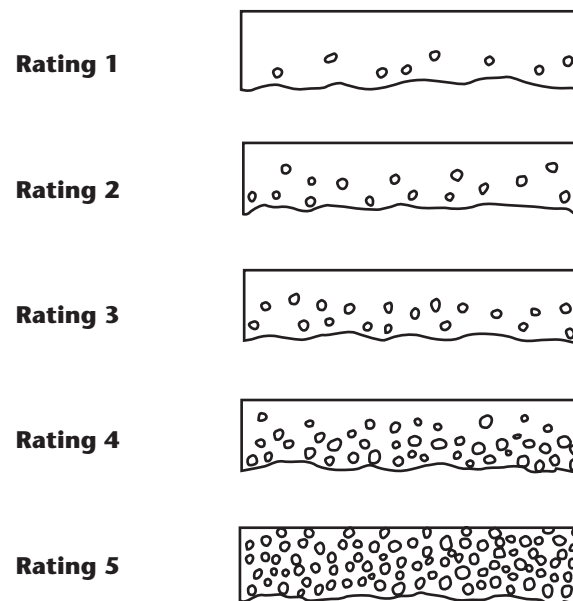


Figure 6
Examples of cross-section porosity
(See [Clause 12.10.3.3.](#))

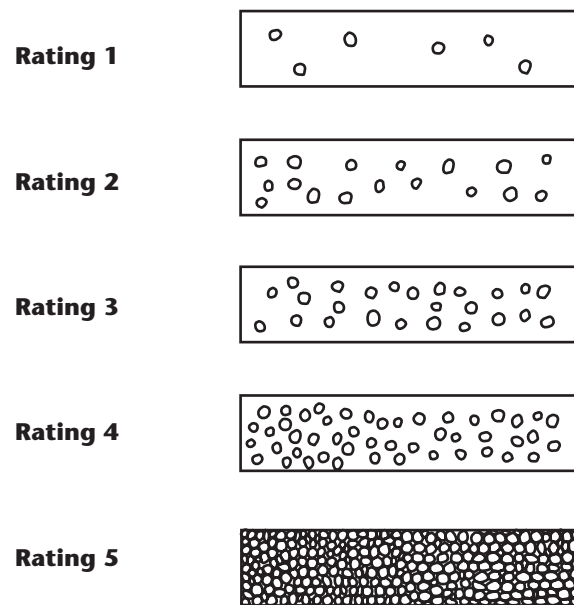


Figure 7
Examples of interface porosity
(See [Clause 12.10.3.3.](#))

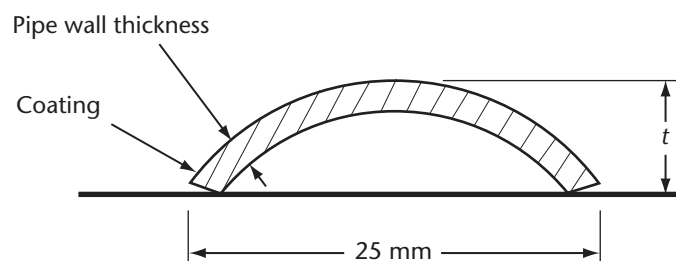


Figure 8
Determination of sample thickness flexibility test
(end view)
(See [Clause 12.11.3.2.](#))

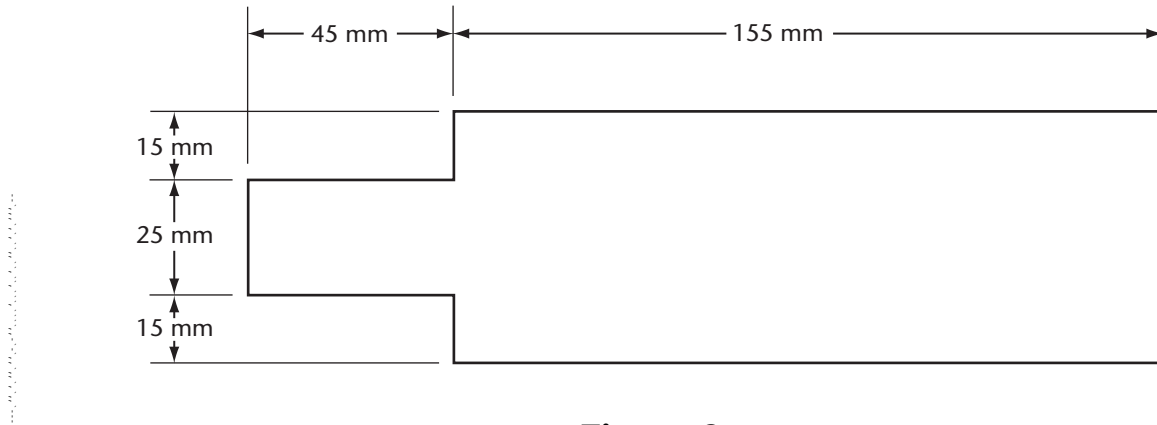


Figure 9
Test specimen — Cathodic disbondment of strained coating test
(See [Clause 12.13.2.](#))

CSA Standard

Z245.21-06

External polyethylene coating for pipe



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Z245.21-06

External polyethylene coating for 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 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 A1: a coating that consists of an adhesive and a polyethylene outer sheath;
- (b) System A2: a coating that consists of an adhesive and a polyethylene outer sheath that has more stringent peel adhesion requirements than those for System A1 (see [Table 1](#));
- (c) System B1: a coating that consists of a liquid or powdered epoxy primer, a polymeric adhesive, and a polyethylene outer sheath; and
- (d) System B2: a coating that consists of a powdered epoxy primer, a powdered copolymer adhesive, and a powdered polyethylene outer layer.

1.3

In CSA Standards, “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; “may” is used to express an option or that which is permissible within the limits of the standard; and “can” is used to express possibility or capability. 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 edition listed below, unless the user finds it more appropriate to use newer or amended editions of such publications.

CSA (Canadian Standards Association)

CAN/CSA-ISO 9001-00

Quality management systems — Requirements

Z245.20-06

External fusion bond epoxy coating for steel pipe

ASTM International (American Society for Testing and Materials)

D 618-05

Standard Practice for Conditioning Plastics for Testing

D 638-03

Standard Test Method for Tensile Properties of Plastics

D 746-04

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

D 792-00

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

D 1238-04c

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

D 1475-98 (2003)

Standard Test Method for Density of Liquid Coatings, Inks, and Related Products

D 1505-03

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

D 1525-06

Standard Test Method for Vicat Softening Temperature of Plastics

D 1652-04

Standard Test Method for Epoxy Content of Epoxy Resins

D 1693-05

Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

D 2083-92 (1998)

Standard Test Method for Calculation of Percent of Primary, Secondary, and Tertiary Amines in Fatty Amines

D 2196-05

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

D 2240-05

Standard Test Method for Rubber Property — Durometer Hardness

D 3895-04

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

D 4703-03

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

E 28-99 (2004)

Standard Test Methods for Softening Point of Resins Derived from Naval Stores by Ring-and-Ball Apparatus

E 29-06a

Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ISO (International Organization for Standardization)

9001:2000

*Quality management systems — Requirements***SSPC (The Society for Protective Coatings)**

SP 6 (2000)

Commercial Blast Cleaning

SP 10 (2000)

Near-White Blast Cleaning

3 Definitions

The following definitions apply in this Standard:

Adhesive —

- (a) for Systems A1 and A2, 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 Systems A1 and A2, 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.

Certificate of compliance — a document provided by the product manufacturer or applicator that specifies that the product is in compliance with the requirements or specific clauses 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, a colourant, or both.

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 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.

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

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

Primer lot — a quantity that is a continuous production of not more than 8 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.

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 (Z245.21-06);
- (b) pipe quantity, outside diameter, wall thickness, and nominal length;
- (c) maximum design temperature;
- (d) pipeline system maximum design temperature;
- (e) coating system (A1, A2, B1, or B2; see [Clause 1.2](#));
- (f) bare pipe standard or specification designation (see [Clause 5.1](#));
- (g) cutback length for both ends of pipe (see [Clause 6.2.4](#));
- (h) cathodic disbondment radius at maximum design temperature (see [Table 1](#));
- (i) gouge test (see [Clause 12.7](#)); and
- (j) test temperature for the flexibility test (–30, –18, or 0 °C; see [Clause 12.11.3.1](#) of CSA Z245.20).

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](#)); and
- (i) 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 E 29.

4.3 Requirements for quality

The applicator shall comply with the requirements of CAN/CSA-ISO 9001 or ISO 9001.

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 Manufacturer's documentation

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](#). (This certification shall be required for each lot of material. Except as allowed by [Tables 2 and 3](#), the testing frequency shall be one sample from each lot and the manufacturer's documentation shall include a test report for each lot.);
- (b) identified with the following:
 - (i) manufacturer's name;
 - (ii) product description;
 - (iii) lot number;
 - (iv) location of manufacture; and
 - (v) date of manufacture; and
- (c) handled and stored in the applicator's plant in accordance with the manufacturer's documented recommendations.

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 D 4703, Procedure C, and conditioned in accordance with the requirements of ASTM D 618.

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\(b\)](#).

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\(b\)](#).

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 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) formulation of any of the coating materials; and
- (c) combination of coating components, e.g., substitution of liquid epoxy for a powdered epoxy.

6.1.2 Testing requirements

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

6.1.3 Polyethylene evaluation for Systems A1, A2, and B1

The sample of polyethylene to be evaluated shall be free of primer and adhesive and shall be cut transverse to the pipe axis. 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

Samples of polyethylene shall be made in accordance with the requirements of ASTM D 4703, Procedure C, and conditioned in accordance with the requirements of ASTM D 618. 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 to be applied during production shall have been qualified 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 oil and grease and any injurious contaminants 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.

6.2.2.3

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

- (a) for Systems A1 and A2, SSPC SP 6; and
- (b) for Systems B1 and B2, SSPC SP 10.

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

6.2.2.4

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

6.2.3 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 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 of at least 50 mm, 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 by the purchaser.

7.3.2

The minimum testing frequency shall be once per lot for the primer, adhesive, and polyethylene.

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 hour of production thereafter.

7.4.1.4 Coating thickness for Systems A1, A2, and B1

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 calibrated at least once every working shift (to a maximum of 12 h). 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 calibrated at least once every working shift (to a maximum of 12 h). 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) *It can be appropriate for the coating applicator to 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 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 valid.

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 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

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. The detector shall be calibrated at least once every working shift (to a maximum of 12 h).

7.4.2.2 Acceptance criteria

Coated pipe having holidays less than 10 cm² shall be repaired by patching in accordance with the requirements of [Clause 8.3](#), provided that the number of holidays does not exceed the greater of

- (a) 0.25 per square metre, determined by dividing the total number of holidays by the total outside surface area for the individual pipe tested; or
- (b) 2 per pipe length.

7.4.3 Production test rings

7.4.3.1

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

7.4.3.2

The test ring length shall be approximately 400 mm or as specified in the purchase order.

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 Systems A1 and A2, one test ring per coating system per working shift (to a maximum of 12 h);
- (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 (to a maximum of 12 h);
- (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 (to a maximum of 12 h).

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 (to a maximum of 12 h). 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](#), coated pipe shall be repaired by patching 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.

8.2 Patching

8.2.1

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 cut out.

8.2.2

The primer, heat-shrink sleeve, patch stick, or patch material shall be applied in accordance with the manufacturer's recommendations.

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 [8.3.4](#) for non-compliance with [Table 6](#), the pipe surface shall be stripped to bare metal and new coating applied 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.

8.3.2

For Systems A1 and A2, 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 12 h working shift. The test rings shall be prepared and tested in accordance with the requirements of [Clause 7.4.3](#).

8.3.3

For Systems A1 and A2, 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.

8.3.4

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 12 h working shift. The test rings shall be prepared and tested in accordance with the requirements of Clause 7.4.3. The peel adhesion between the polyethylene layers shall be tested using the applicable method and acceptance criterion specified in Table 10.

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 shall be permitted.

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

9.2 Required markings

The required markings shall be as follows:

- (a) applicator's name or mark;
- (b) CSA Standard designation and year of publication (Z245.21-06);
- (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 (A1, A2, 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.

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

Coated pipe that is damaged after holiday inspection (see [Clause 7.4.2](#)) shall be repaired by patching 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

12.1.2.1

Heat the adhesive in an oven set at 150 °C until it begins to flow.

12.1.2.2

Pre-set the Thermosel® control to 150 °C.

12.1.2.3

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.

12.1.2.4

Insert the cup into the Thermosel®.

Note: The cup should not be able to revolve once it is inserted.

12.1.2.5

With the speed set at its minimum value and the adhesive at the test temperature, start the spindle revolving.

12.1.2.6

Allow the temperature to stabilize. Record the dial reading and speed. If the dial reading is above 85, lower the speed (where possible) or use another spindle.

12.1.2.7

Repeat the steps specified in [Clauses 12.1.2.1 to 12.1.2.6](#) with temperatures set at 163 and 177 °C.

12.1.2.8

Using the instrument manufacturer's supplied chart, obtain the multiplication factor for the spindle and speed used. Multiply the dial reading by the applicable multiplication factor to obtain the viscosity in millipascal seconds (mPa•s).

12.1.3 Report

Where a report is required by [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 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**12.2.2.1**

Melt the adhesive slowly to prevent local overheating.

12.2.2.2

Line the moulds with treated paper projecting at least 15 mm over the top of each mould for easy removal of the specimen.

12.2.2.3

Preheat the moulds and the liner on a lined metal plate.

12.2.2.4

Pour the adhesive into the moulds and cool to 20 ± 3 °C.

12.2.2.5

Chill the test specimens to facilitate removal of the moulds and cut the moulded adhesive into lengths of approximately 19 mm.

12.2.2.6

Condition the test specimens at 20 ± 3 °C for at least 30 min before starting the test.

12.2.2.7

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.

12.2.2.8

Immediately place the plate in the oven, maintained within 3 °C of the specified test temperature.

12.2.2.9

After $1 \text{ h} \pm 1 \text{ min}$, remove the plate and measure the distance of flow from the inscribed line to the bottom of the flow.

12.2.2.10

Average the flow of three test specimens and record the average flow to the nearest millimetre.

12.2.3 Report

Where a report is required by [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 calomel reference electrode;
- (d) a platinum wire or a carbon electrode;
- (e) a 75 ± 3 mm ID plastic cylinder;
- (f) a 3% sodium chloride solution in distilled 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**12.3.2.1**

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 $\times$ pipe wall thickness.

12.3.2.2

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

12.3.3.1

Drill a 6.4 mm diameter holiday through the coating to expose the steel substrate.

12.3.3.2

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

12.3.3.3

Add to the cylinder at least 300 mL of the sodium chloride solution that has been preheated to the test temperature. Mark the solution level on the cylinder. Insert the electrode into the solution and connect it to the positive wire from the dc power supply. Attach the negative wire from the dc power supply to a bare spot prepared on the test specimen.

12.3.3.4

Apply voltage (negative with respect to the calomel reference electrode) to the test specimen and maintain constant temperature under one or more of the following test conditions, as specified in [Tables 1](#) and [10](#):

- (a) 1.5 V, 20 ± 3 °C, for a minimum of 28 d;
- (b) 1.5 V, maximum design temperature ± 3 °C, for a minimum of 28 d; and
- (c) 3.5 V, 65 ± 3 °C, for a minimum of 24 h.

Maintain the solution level by the addition of distilled water as required.

12.3.3.5

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.

12.3.3.6

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.

12.3.3.7

For Systems A1 and A2, 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.

12.3.3.8

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 a report is required by [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 $\times$ pipe wall thickness; and
- (b) plates: 150 $\times$ 150 mm $\times$ pipe wall thickness.

12.4.3 Test parameters

12.4.3.1

The test temperature shall be 20 ± 3 °C.

12.4.3.2

The crosshead speed (peeling speed) shall be 10 ± 1 mm/min.

12.4.3.3

Except as allowed by [Clause 12.4.4.7](#), the peel strip shall be at least 75 mm long.

12.4.3.4

The peel strip shall be 25 ± 1 mm wide.

12.4.3.5

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

12.4.4.1

Condition the sample at 20 ± 3 °C for at least 1 h before starting the test.

12.4.4.2

Cut a strip to the required width and orientation through the coating to the steel substrate.

12.4.4.3

Make a cut at right angles to the strip and lift a portion of this strip to form a tab.

12.4.4.4

On the bonded strip, measure and mark the required test length.

12.4.4.5

Peel the strip at a rate of 10 ± 1 mm/min and record the load required to peel the coating.

Note: It is important that the peel test 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.

12.4.4.6

If more than 5% of the total peeled length has a peeling load below the specified minimum value calculated in accordance with [Clause 12.4.5](#), 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 [Clause 12.4.5](#)).

12.4.4.7

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 [Clause 12.4.5](#)).

12.4.5 Calculation

Except as allowed by [Clause 12.4.4.6](#), determine the minimum peeling load and calculate the minimum peel strength using the following formula:

$$P = L_p \times 9.81$$

where

P = minimum peel strength, N

L_p = minimum peeling load, kg

12.4.6 Report

Where a report is required by [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 0.3 kg (for System A1), 2.0 kg (for System A2), 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

12.5.3.1

The test temperature shall be 20 ± 3 °C.

12.5.3.2

The peel strip shall be 25 ± 1 mm wide.

12.5.3.3

The peel orientation shall be circumferential.

12.5.4 Procedure

12.5.4.1

Condition the sample at 20 ± 3 °C for at least 1 h before starting the test.

12.5.4.2

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. 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](#).

12.5.4.3

Attach the appropriate mass to the free end of the peel strip as shown in [Figure 5](#).

12.5.4.4

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:

$$T = \frac{0.125 \times 3.14 \times D}{10}$$

where

T = test time, min

D = specified pipe outside diameter, mm

12.5.4.5

Measure the distance peeled in millimetres from the time the test was initiated until it was terminated.

12.5.4.6

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 a report is required by [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 outside diameter 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 D 638, except that the circulating-air oven shall be controllable to within 3 °C.

12.6.2 Test specimens

12.6.2.1

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.

12.6.2.2

The 150 mm length shall be cut transverse to the pipe axis.

12.6.3 Procedure

12.6.3.1

Three unheated test specimens shall be tested in accordance with the requirements of ASTM D 638, 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](#).

12.6.3.2

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 [Clause 12.6.3.1](#).

12.6.3.3

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.

12.6.3.4

The percentage of elongation at break after heat aging shall be not less than 150%.

12.6.4 Report

Where a report is required by [Clause 11.1](#), the following information shall be reported to the purchaser by the applicator:

- (a) the lot number and density of polyethylene, 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, 6.1.2, and 12.3.3.4.](#))

Test	Acceptance criteria	Test method
28 d cathodic disbondment at 20 °C	12 mm maximum radius	Clause 12.3
28 d cathodic disbondment at maximum design temperature	Meets purchaser's specification	Clause 12.3
Impact resistance	Minimum of 3.0 J/mm of actual total coating thickness	Clause 12.12 of CSA Z245.20, except that for each µm of thickness, the voltage setting for the dc holiday detector (see Clause 12.12.3.3 of CSA Z245.20) shall be 10 V per micrometre of thickness, up to a maximum of 15 000 V
Flexibility	No cracking of polyethylene	Clause 12.11 of CSA Z245.20; bend of 2.5°
Peel adhesion*		Clause 12.4 or 12.5
System A1	3.0 N minimum	
System A2	19.6 N minimum	
System B1	150.0 N minimum	
28 d adhesion (System B2 only)	Rating of 1–3	Clause 12.14 of CSA Z245.20; 28 d at 75 °C

*Not applicable to System B2.

Table 2
Adhesive requirements
 (See [Clauses 5.2](#) and [5.4](#).)

Test	Unit	Acceptance criteria	Test method
Systems A1 and A2			
Viscosity	mPa•s	Within 30% of manufacturer's specified nominal	Clause 12.1
Flow at maximum design temperature	mm	Not greater than 20% above the manufacturer's specified nominal	Clause 12.2
Ring and ball softening point	°C	At least 20 °C above maximum design temperature	ASTM E 28
Systems B1 and B2			
Flow rate	g/10 min	Within 20% of manufacturer's specified nominal	ASTM D 1238; 190 °C/2.16 kg
Density	g/cm ³	Within 1% of manufacturer's specified nominal	ASTM D 792 or ASTM D 1505
Vicat softening point*	°C	At least 10 °C above maximum design temperature	ASTM D 1525
Brittleness temperature*	°C	–50 °C or lower (System B1 for F ₂₀ , System B2 for F ₄₀)	ASTM D 746

*This test is required at least every 12 months.

Table 3
Virgin polyethylene resin requirements
 (See [Clauses 5.2](#) and [5.5](#).)

Test	Unit	Acceptance criteria			Test method
		Low density (LD) and linear low density (LLD)	Medium density (MD)	High density (HD)	
Density	g/cm ³	< 0.925	0.925–0.940	> 0.940	ASTM D 792 or ASTM D 1505
Elongation at break	%	600 minimum	600 minimum	600 minimum	ASTM D 638; Type IV sample; crosshead speed 50 mm/min
Flow rate*	g/10 min	LD: 0.15–0.6 LLD: 0.5–2.0	0.1–1.0	0.15–0.80	ASTM D 1238; 190 °C/2.16 kg
Hardness	Shore D	45 minimum	50 minimum	60 minimum	ASTM D 2240
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
Tensile stress at yield	MPa	9.7 minimum	12.4 minimum	18.5 minimum	ASTM D 638; Type IV sample; crosshead speed 50 mm/min
Oxidative-induction time in oxygen at 220 °C, aluminum pan, no screen	min	10 minimum	10 minimum	10 minimum	ASTM D 3895
Brittleness temperature†	°C	–70 or lower (for F ₂₀)	–70 or lower (for F ₂₀)	–70 or lower (for F ₂₀)	ASTM D 746
Environmental stress-cracking resistance condition†	h	300 minimum (for F ₅₀); Condition “C”	300 minimum (for F ₅₀); Condition “C”	300 minimum (for F ₅₀); Condition “B”	ASTM D 1693; 100% Igepal®
Vicat softening point†	°C	90 minimum	110 minimum	120 minimum	ASTM D 1525

*The acceptance criteria are not applicable to System B2. The acceptance criteria for System B2 shall be within 20% of the manufacturer's specified nominal.

†This test is required at least every 12 months.

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

Test	Unit	Acceptance criteria	Test method
Base resin density	g/mL	Within 0.05 of manufacturer's specified nominal	ASTM D 1475
Curing agent density	g/mL	Within 0.05 of manufacturer's specified nominal	ASTM D 1475
Base resin viscosity	mPa•s	Within 15% of manufacturer's specified nominal	ASTM D 2196
Curing agent viscosity	mPa•s	Within 15% of manufacturer's specified nominal	ASTM D 2196
Epoxy equivalent weight	Weight per cent epoxy (WPE)	Within 10% of manufacturer's specified nominal	ASTM D 1652
Total amine value	mg KOH/g	Within 15% of manufacturer's specified nominal	ASTM D 2083
Gel time (mixed components)	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20; thickness at $100 \pm 25 \mu\text{m}$; test temperature as recommended by manufacturer

Table 5
Polyethylene qualification test requirements
 (See [Clauses 6.1.3](#), [6.1.4](#), and [12.6.3.1.](#))

Test	Acceptance criteria	Test method
Tensile stress at yield		ASTM D 638;
LD or LLD	8.5 MPa minimum	Type IV sample;
MD	11.0 MPa minimum	crosshead speed
HD	17.0 MPa minimum	50 mm/min
Elongation at break	300% minimum	ASTM D 638;
		Type IV sample;
		crosshead speed
		50 mm/min

Table 6
Coating thickness requirements
 (See [Clauses 6.2.3.1](#), [6.2.3.2](#), [6.2.3.3.2](#), [8.3.1](#), and [8.3.4](#).)

Specified pipe OD, mm	Minimum coating thickness, mm					
	Primer thickness*	Adhesive thickness	Polyethylene thickness			
Systems A1 and A2						
< 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 Systems A1 and A2.

Table 7
Primer requirements
 (See [Clause 7.3.3.](#))

Test	Unit	Acceptance criteria	Test method
Liquid primer			
Base resin viscosity	mPa•s	Within 15% of manufacturer's specified nominal	ASTM D 2196*
Curing agent viscosity	mPa•s	Within 15% of manufacturer's specified nominal	ASTM D 2196*
Gel time (mixed components)	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20; thickness at 50 to 150 µm; test temperature as recommended by manufacturer
Powder primer			
Gel time	s	Within 20% of manufacturer's specified nominal	Clause 12.2 of CSA Z245.20
24 h cathodic disbondment at 65 °C	mm	6.5 mm maximum radius	Clause 12.8 of CSA Z245.20†
24 h adhesion	—	Rating of 1–3	Clause 12.14 of CSA Z245.20†

*Date of test and lot number shall also be included in the test report.

†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
Systems A1 and A2			
Viscosity	mPa•s	Within 30% of manufacturer's specified nominal	Clause 12.1
Flow at 70 °C	mm	Not greater than 20% more than the manufacturer's specified nominal	Clause 12.2
Ring and ball softening point	°C	At least 20 °C above maximum design temperature	ASTM E 28*
Systems B1 and B2			
Flow rate	g/10 min	Within 20% of manufacturer's specified nominal	ASTM D 1238*; 190 °C/2.16 kg

*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.](#))

Test	Unit	Acceptance criteria				Test method
		LD	LLD	MD	HD	
Flow rate*	g/10 min	0.15–0.6	0.5–2.0	0.15–1.0	0.15–0.8	ASTM D 1238†; 190 °C/2.16 kg

*The acceptance criteria values are not applicable to System B2. The acceptance criteria for System B2 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, 8.3.2–8.3.4, and 12.3.3.4.](#))

Test	Acceptance criteria				Test method
	System A1	System A2	System B1	System B2	
Peel adhesion*	3.0 N minimum	19.6 N minimum	150.0 N minimum	—	Clause 12.4 or 12.5
Tensile stress at yield†					
LD or LLD	—	—	8.5 MPa minimum	—	ASTM D 638; Type IV sample; crosshead speed 50 mm/min
MD	—	—	11.0 MPa minimum	—	
HD	—	—	17.0 MPa minimum	—	
Elongation at break†	—	—	300% minimum	—	ASTM D 638; Type IV sample; crosshead speed 50 mm/min
24 h cathodic disbondment	12 mm maximum radius	12 mm maximum radius	7 mm maximum radius	7 mm maximum radius	Clause 12.3
24 h adhesion‡	—	—	—	Rating of 1–2	Clause 12.14 of CSA Z245.20
2.5° flexibility‡	—	—	—	No cracking	Clause 12.11 of CSA Z245.20

*Not applicable to System B2.

†Applicable to System B1 only.

‡Applicable to System B2 only.

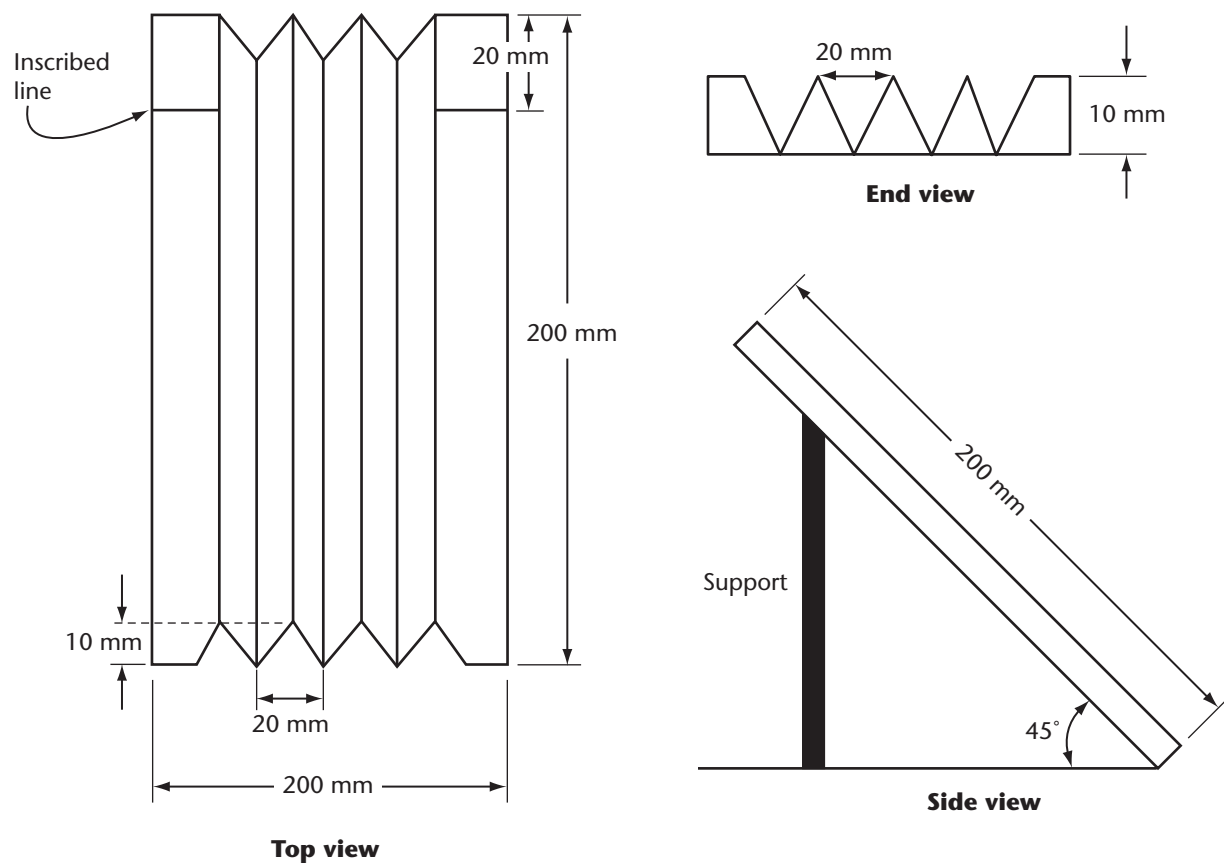


Figure 1
Flow test apparatus
(See [Clause 12.2.1.](#))

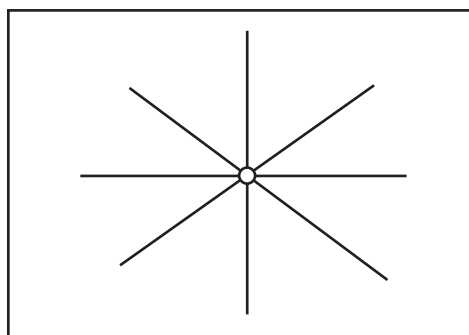


Figure 2
Examples of radial cuts through the coating
(See [Clause 12.3.3.6.](#))

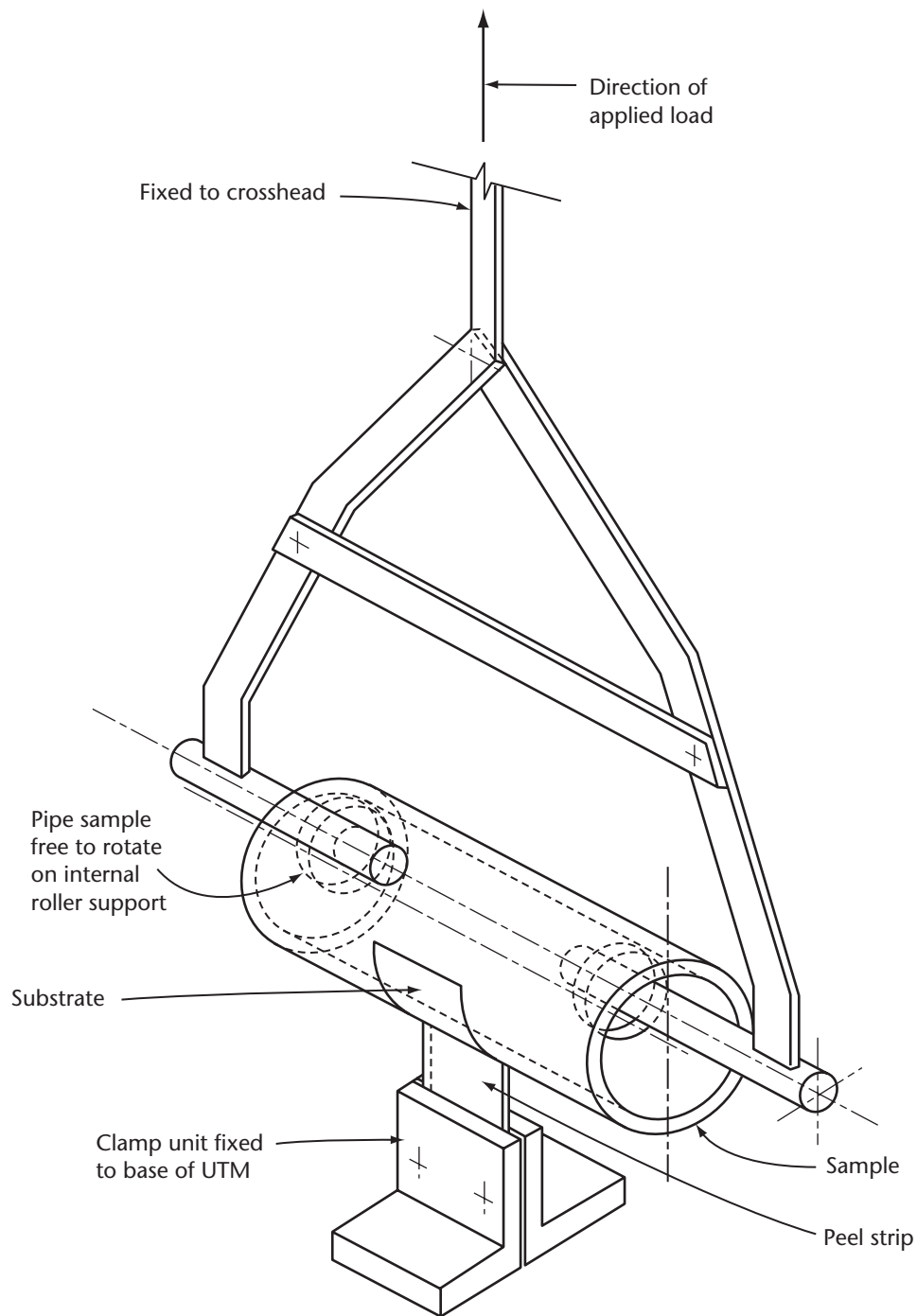


Figure 3
Peeling apparatus for pipe smaller than 200 mm OD
(See [Clauses 12.4.1](#) and [12.4.3.5.](#))

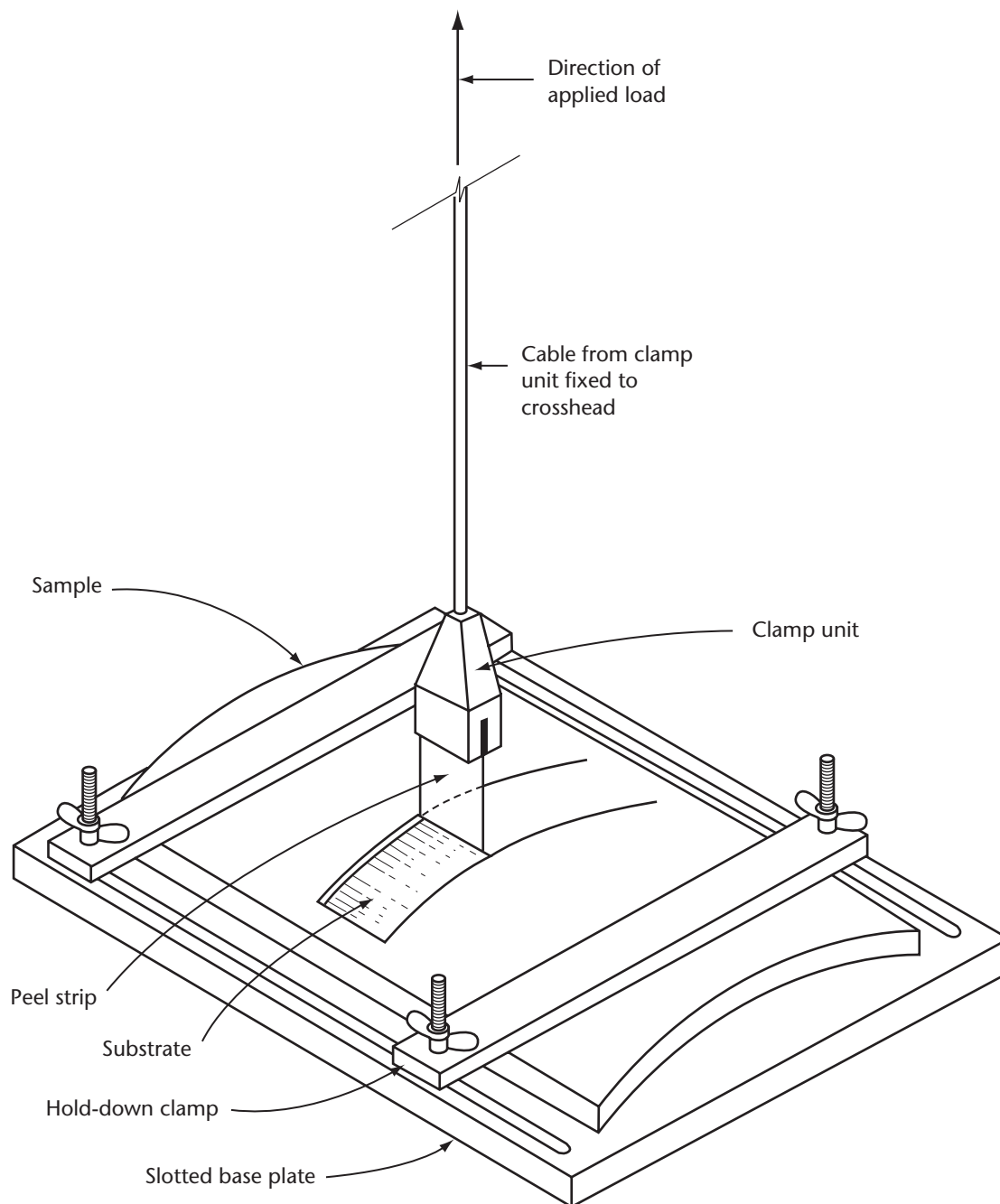


Figure 4
Peeling apparatus for pipe 200 mm OD or larger
(See [Clauses 12.4.1](#) and [12.4.3.5.](#))

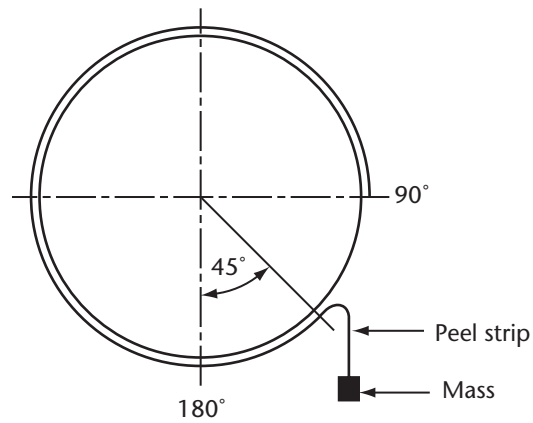


Figure 5
Hanging mass test set-up (end view)
(See [Clauses 12.5.4.2](#) and [12.5.4.3](#).)

Proposition de modification

N'hésitez pas à nous faire part de vos suggestions et de vos commentaires. Au moment de soumettre des propositions de modification aux normes CSA et autres publications CSA prière de fournir les renseignements demandés ci-dessous et de formuler les propositions sur une feuille volante. Il est recommandé d'inclure

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- le numéro de l'article, du tableau ou de la figure visé
- la formulation proposée
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- relevant Clause, Table, and/or Figure number(s)
- wording of the proposed change
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