

CSA Standard

Z245.20-02

***External Fusion Bond
Epoxy Coating for Steel Pipe***



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ASSOCIATION**

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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 does not cover dual powder FBE coating systems or high temperature (a glass transition temperature higher than 110 °C) FBE coating systems.

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; and "may" is used to express an option or that which is permissible within the limits of the standard. Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material. Notes to tables and figures are considered part of the table or figure and may be written as requirements. Legends to equations and figures are considered requirements.

2. Reference Publications

This Standard refers to the following publications, and where such reference is made, it shall be to the editions listed below, unless the user finds it more appropriate to use newer or amended editions of such publications.

CSA Standards

CAN/CSA-ISO 9000-1-94 (R2000)

Quality Management and Quality Assurance Standards — Part 1: Guidelines for Selection and Use

CAN/CSA-ISO 9000-2-98

Quality Management and Quality Assurance Standards — Part 2: Generic Guidelines for the Application of ISO 9001, ISO 9002 and ISO 9003

CAN/CSA-ISO 9001-94 (R2000)

Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation and Servicing

CAN/CSA-ISO 9001-00

Quality Management Systems — Requirements

CAN/CSA-ISO 9002-94 (R2001)

Quality Systems — Model for Quality Assurance in Production, Installation and Servicing

CAN/CSA-ISO 9003-94 (R2001)

Quality Systems — Model for Quality Assurance in Final Inspection and Test

ASTM* Standard

E 29-93a (R1999)

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

ISO† Standards

9000-1:1994

Quality management and quality assurance standards — Part 1: Guidelines for selection and use

9000-2:1998

Quality management and quality assurance standards — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002 and ISO 9003

9001:1994

Quality systems — Model for quality assurance in design, development, production, installation and servicing

9001:2000

Quality management systems — Requirements

9002:1994

Quality systems — Model for quality assurance in production, installation and servicing

9003:1994

Quality systems — Model for quality assurance in final inspection and test

SSPC‡ Specifications

SP 5-2000

White Metal Blast Cleaning

SP 10-2000

Near-White Blast Cleaning

*American Society for Testing and Materials

†International Organization for Standardization

‡Steel Structures Painting Council

3. Definitions

The following definitions apply in this Standard:

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.

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.

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.

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

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 (Z245.20-02);
- (b) pipe quantity, outside diameter, wall thickness, and nominal length;
- (c) bare pipe standard or specification designation (see Clause 5.1);
- (d) nominal thickness and maximum permissible thickness of the coating (see Clause 6.2.4);
- (e) cutback length for both ends of pipe (see Clause 6.2.5); and
- (f) test temperature for the flexibility test (-30°C , -18°C , 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 for additional test rings (see Clause 7.3.3.2);
- (g) additional markings (see Clause 9.1);
- (h) handling procedures (see Clause 10.1.1);
- (i) storage procedures (see Clause 10.2);
- (j) waiver of test reports (see Clause 11.1); and
- (k) 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 Standard E 29.

4.3 Requirements for Quality

The applicator shall comply with the requirements of one of the CAN/CSA-ISO 9000 Standards or one of the ISO 9000 Standards.

4.4 Compliance

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

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 may not necessarily have a surface condition that is appropriate for the application of coating.

5.2 Epoxy Powder

5.2.1 General

The applicator shall use epoxy powder that is

- (a) certified by the powder manufacturer to be in accordance with the requirements of 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°C , -18°C , 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. 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 given in Table 1.

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).

6.1.2.2

The surface shall be blast cleaned using G40 steel grit in accordance with SSPC-SP 5. The surface profile, measured from peak to trough, shall be 40 to 100 μm inclusive and be 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 $^{\circ}\text{C}$.

6.1.2.4

The thickness of 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 .

6.1.3 Coating Qualification Test Requirements

The tests to be conducted, the number of test specimens, the test methods to be used, and the acceptance criteria shall be as given in Table 2. At least once per year, the epoxy powder manufacturer shall conduct tests and provide the applicator with a test report for the coating properties given in Table 2.

6.2 Production Application Practices and Equipment

6.2.1 General

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

6.2.2 Surface Preparation

6.2.2.1

The pipe external surfaces 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 specification. The surface profile, measured from peak to trough, shall be 40 to 110 µm inclusive 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.

6.2.2.5

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 specified in the purchase order, it shall be permissible for the applicator to 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.

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 coating shall be 300 µm.

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

The inspector representing the purchaser shall have unrestricted entry at all times, while work on the contract of the purchaser is being performed, to all parts of the applicator's plant that relate to the

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7.2 Plant Access

The inspector representing the purchaser shall have unrestricted entry at all times, while work on the contract of the purchaser is being performed, 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 or 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, using suitable equipment at the application facility.

7.3.1.2

The minimum testing frequency shall be one sample on 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 given in Table 1. 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 given in Table 3. The epoxy powder shall meet the requirements of Table 3 before its use for production coating. Where a Table 3 test fails to conform to the specified requirements, the applicator shall have the option of repeating that specific test using two additional samples taken from the batch. 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 7.3.2.8 inclusive 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 if 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 minimum recording frequency shall be at start-up and once every hour 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 minimum recording frequency shall be at start-up and once every hour of production thereafter.

7.3.2.7 Coating Thickness

7.3.2.7.1

The 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.

7.3.2.7.2

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 .

7.3.2.7.3

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. 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.

7.3.3 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.

7.3.3.2 Test Rings

Test rings shall be approximately 500 mm long, unless otherwise specified in the purchase order and shall be obtained from locations at least 300 mm from a pipe end, unless an increased test-ring length is specified in the purchase order.

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).

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 given in Table 4.

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, either

- (a) the test (see Table 4, Column 2) 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 one or both of the retests fail to conform to the specified requirements, either

(a) all pipe coated after the previous acceptable test and prior to the next acceptable test shall be stripped and recoated in accordance with the requirements of 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 upon obtaining test results for both the first and last pipes in the portion that conform to the specified requirements. Pipe in those portions of the affected lot that are not acceptable shall be stripped and recoated in accordance with the requirements of Clause 8.3.

7.3.3.5 Retests — Type B Test Failures

Where a Type B test (see Table 4, Column 2) 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 may not need to 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, two-part epoxy, or 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 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 electrically tested in accordance with the requirements of Clause 7.3.2.8; and

(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 as desired by the applicator shall be permitted.

Note: Such additional markings may include bar code markings. It is recommended that any one-dimensional bar code marking be of the Code 39 type or Code 128 type, and any two-dimensional bar code marking 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 (Z245.20-02);
- (c) markings required by the applicable pipe specification or standard;
- (d) date of coating application; and
- (e) 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; such procedures shall include loading requirements where the applicator is responsible for loading.

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 specified in the purchase order that test reports are waived, the applicator shall furnish test reports to the purchaser for the tests required by Clauses 7.3 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 the results of the coating tests and other required tests have been found to conform to such requirements.

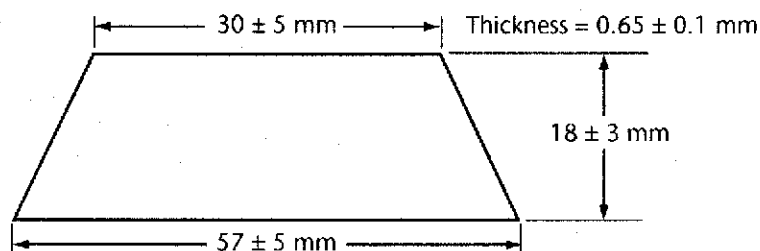
12. Test Procedures

12.1 Cure Time of the Epoxy Powder

12.1.1 Equipment

The equipment shall consist of the following:

- (a) a hotplate, controllable to within 3 °C;
- (b) a metal plate, approximately 25 × 150 × 150 mm;
- (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 dimensions as shown in the following sketch and an exposed cutting edge of 25 ± 5 mm.



12.1.2 Procedures

12.1.2.1

Heat and maintain the metal plate temperature at $232 \pm 3 \text{ }^{\circ}\text{C}$.

12.1.2.2

Use the draw-down tool to deposit a film of epoxy powder on the metal plate, aiming at a film thickness of 300 to 400 μm . Start the timing device at the instant of powder deposition on the hotplate 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 10 strips of coating.

12.1.2.4

Following 30 ± 3 s after the timing device has started, using the utility knife, 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 Reports

Where 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 hotplate controllable to within 3°C ;
- (b) a metal plate placed on top of the hotplate;
- (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 Procedures**12.2.2.1**

Conduct three tests and average the results.

12.2.2.2

Heat and maintain the temperature of the metal plate surface that will be in contact with the powder at a temperature of $205 \pm 3^\circ\text{C}$.

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.

Note: The target thickness of the cured film is 300 to 400 µm.

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 contacts the metal plate.

12.2.3 Reports

Where 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

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 syringe (Luer-Lok™); and
- (j) a spatula.

12.3.2 Reagents

The reagents required 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 Procedures

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 Reports

Where 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 apparatus used; and
- (d) the percentage of moisture content and average.

12.4 Moisture Content of the Epoxy Powder — Mass Loss

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 Procedures

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; repeat at intervals of $1 \text{ h} \pm 10 \text{ min}$ until two consecutive mass determinations are within 0.001 g.

12.4.1.2.3

Calculate the percentage of moisture using the following formula:

$$M = \frac{B - C}{B - A} \times 100 \quad (1)$$

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 Reports

Where 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 required shall consist of the following:

- (a) an air-jet sieving unit with vacuum cleaner attachment and 150 µm and 250 µm screens; and
- (b) a balance accurate to 0.01 g.

12.5.2 Procedures

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:

$$P = \frac{100}{M} (F - I) \quad (2)$$

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, using the other screen.

12.5.3 Reports

Where 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

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 Procedures

12.6.2.1 General

At the option of the applicator, the density of the epoxy powder shall be determined using the procedure described in either Clause 12.6.2.2 or 12.6.2.3. The test temperature shall be 20 ± 3 °C.

Note: The choice of procedure used is at the option of the applicator.

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 plus 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 walls of the flask with mineral spirits until they are free of powder and the flask is filled to the 100 mL level. Weigh the flask plus epoxy powder and mineral spirits to the nearest 0.01 g.

12.6.2.2.4

Empty the flask. Clean and dry the flask, add 100 mL of mineral spirits, and weigh the flask plus mineral spirits to the nearest 0.01 g.

12.6.2.2.5

Calculate the density of the mineral spirits using the following formula:

$$P_s = 10 (M_{FS} - M_F) \quad (3)$$

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:

$$P_p = \frac{M_{EP} - M_F}{0.1 - \frac{(M_{FPS} - M_{EP})}{P_s}} \quad (4)$$

where

P_p = density of epoxy powder, g/L

M_{EP} = 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 Reports

Where 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; and
- (e) the density of the epoxy powder, g/L.

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 Procedures

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 it with a dry, nonreactive 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 order stated:

- (a) heat the sample from 25 ± 5 °C to 70 ± 5 °C at a rate of 20 °C/min, then immediately cool the sample to 25 ± 5 °C;
- (b) heat the same sample from 25 ± 5 °C to 285 ± 10 °C at a rate of 20 °C/min, then immediately cool the sample to 25 ± 5 °C; and
- (c) heat the same sample from 25 ± 5 °C to 150 ± 10 °C 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 order stated:

- (a) heat the sample from 25 ± 5 °C 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;

- (b) heat the same sample from $25 \pm 5^\circ\text{C}$ to $285 \pm 10^\circ\text{C}$ at a rate of $20^\circ\text{C}/\text{min}$, then immediately cool the sample to $25 \pm 5^\circ\text{C}$; and
(c) heat the same sample from $25 \pm 5^\circ\text{C}$ to $150 \pm 10^\circ\text{C}$ at a rate of $20^\circ\text{C}/\text{min}$.

12.7.3.3 Calculations

12.7.3.3.1

For each of the thermal scans required by Clauses 12.7.3.2.1(b) and (c) and 12.7.3.2.2(b) and (c), determine the applicable T_g 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 $\Delta H1$ in Figures 3 and 4).

12.7.3.3.2

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

$$\Delta T_g = T_{g4} - T_{g3} \quad (5)$$

where

ΔT_g = change in T_g value, $^\circ\text{C}$

T_{g4} = T_g value for the thermal scan required by Clause 12.7.3.2.2(c), $^\circ\text{C}$

T_{g3} = T_g value for the thermal scan required by Clause 12.7.3.2.2(b), $^\circ\text{C}$

12.7.3.3.3

For coatings, determine the percentage conversion using the following formula:

$$C = \frac{\Delta H - \Delta H1}{\Delta H} \times 100 \quad (6)$$

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 Reports

Where 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, T_{g1} , T_{g2} , and ΔH ; and
- (e) for coating, T_{g3} , T_{g4} , ΔT_g , $\Delta H1$, 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 hotplate 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 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 be approximately $6.4 \times 100 \times 100$ mm. Specimens from test rings shall be approximately $100 \text{ mm} \times 100 \text{ mm} \times$ pipe wall thickness.

12.8.3 Procedures

12.8.3.1

Use only test specimens that are confirmed to be holiday-free with a holiday detector set at a minimum of 1800 V.

12.8.3.2

Drill either 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 given in Tables 2, 3, and 4:

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

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

12.8.3.6

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 the removal from heat.

12.8.3.7

Using the utility knife, make radial cuts through the coating to the substrate, generally as shown in Figure 5. Such cuts shall 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 such measured values.

12.8.4 Reports

Where 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 be approximately 25 mm × 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 40× magnification. Estimate the percentage of interface contamination.

12.9.4 Reports

Where 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 be approximately 6.4 × 25 × 200 mm. Specimens from test rings shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

12.10.3 Procedures

12.10.3.1

Cool the test specimen to at least -30 °C 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 40× 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 Reports

Where 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 be approximately 6.4 × 25 × 200 mm. Specimens from test rings shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

12.11.3 Procedures**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 °C, -18 °C, 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, 3, and 4) by using the applicable formula from the following:

Required deflection	Application formula	
2.5°	$R = 22.42t$	(7)
3.0°	$R = 18.60t$	(8)

where

R = mandrel radius, mm

t = sample thickness, mm

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 Reports

Where 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 Procedures**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.

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 inclusive for the 28 d cathodic disbondment test.

12.13.3.3

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

12.13.4 Reports

Where 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 noncorroding water bath;
- (b) tap water;

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 Reports

Where 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 Procedures**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.

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 inclusive for the 28 d cathodic disbondment test.

12.13.3.3

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

12.13.4 Reports

Where 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 noncorroding 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 be approximately $6.4 \times 100 \times 100$ mm. Specimens from test rings shall be approximately $100 \text{ mm} \times 100 \text{ mm} \times$ pipe wall thickness.

12.14.3 Procedures

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 such preheated water. Submerge the test specimens for a minimum of 24 h at a water temperature of 75 ± 3 °C, and then remove them from the slow cooker or water bath.

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 after 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 Reports

Where 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.

Table 1
Epoxy Powder Properties
 (See Clauses 5.2.2 and 7.3.1.3.)

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	Clause 12.5
	0.2% maximum powder retained on 250 µm mesh	
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
Coating Qualification Test Requirements
 (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	6.5 mm maximum radius	3	Clause 12.8
28 d cathodic disbondment	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
3.0° flexibility	No cracking	5	Clause 12.11
1.5 J impact resistance	No holidays	3	Clause 12.12
Strained coating, 28 d cathodic disbondment	No cracking	3	Clause 12.13
24 h adhesion	Rating of 1-3	3	Clause 12.14

Table 3
Laboratory-Coating Test Requirements
 (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	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
2.5° flexibility	No cracking	3	Clause 12.11
24 h adhesion	Rating of 1–3	1	Clause 12.14

Table 4
Production Coating Test Requirements
 (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	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
2.5° flexibility	A	No cracking	3	Clause 12.11
1.5 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

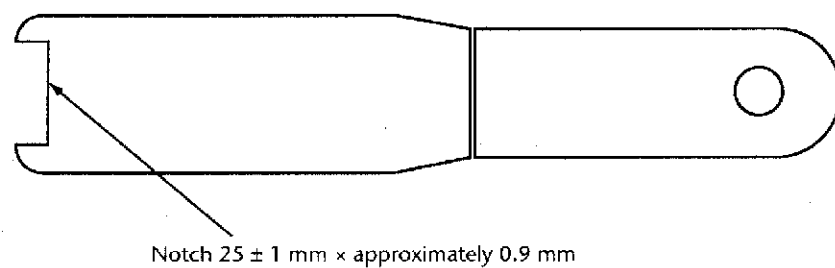


Figure 1
Draw-Down Tool
(See Clauses 12.1.1 and 12.2.1.)

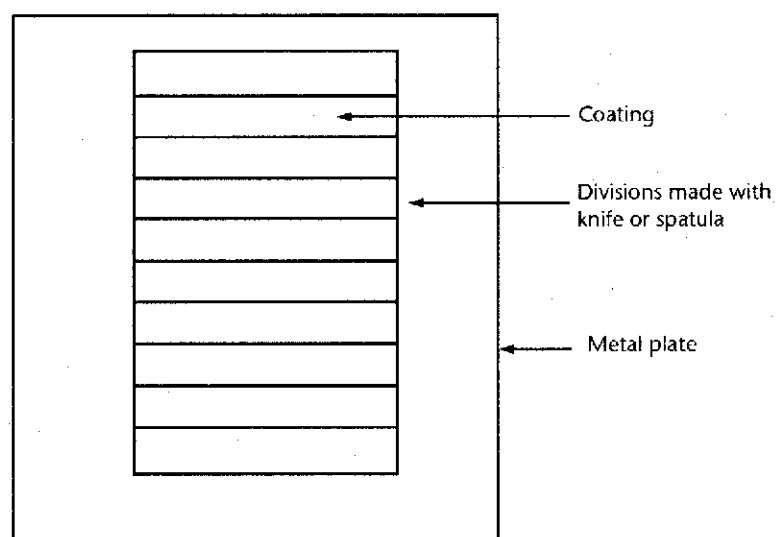


Figure 2
Coated Plate Configuration
(See Clause 12.1.2.3.)

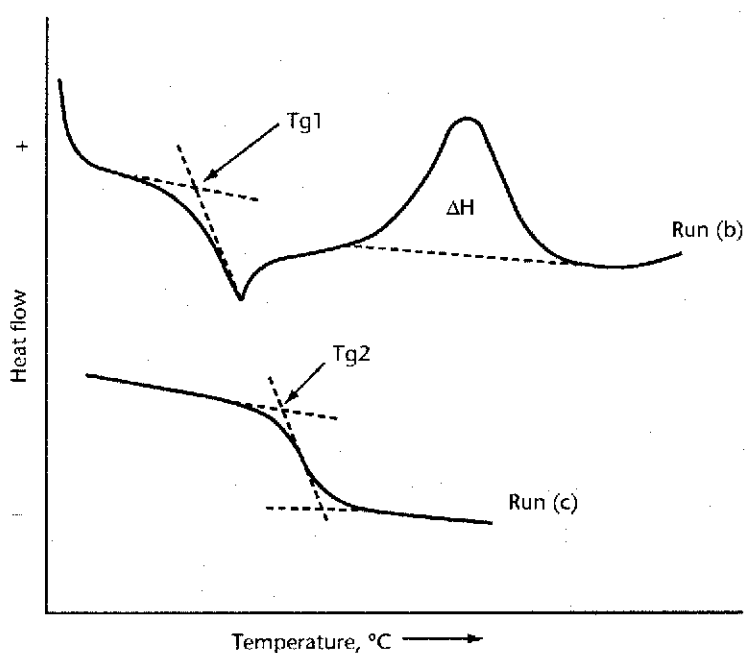


Figure 3
Examples of Thermal Scans on Epoxy Powder
(See Clauses 12.7.3.2.1 and 12.7.3.3.1.)

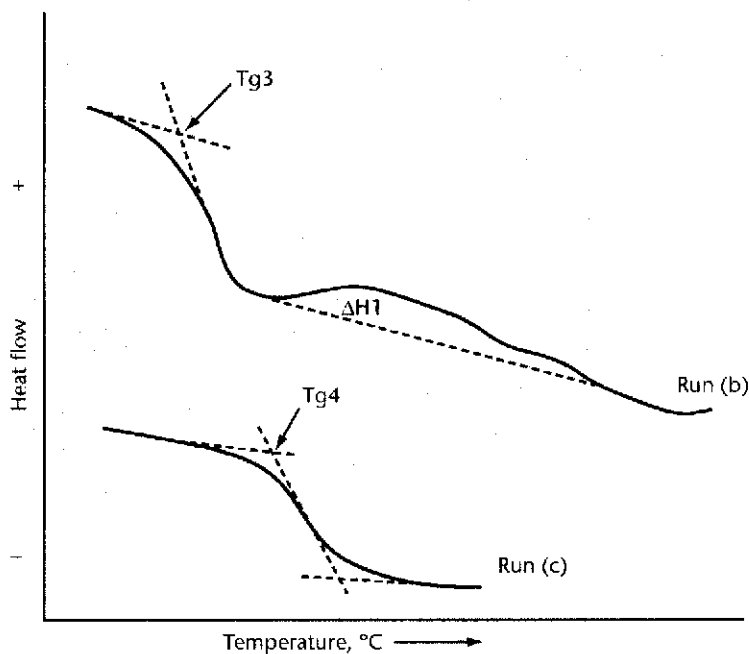


Figure 4
Examples of Thermal Scans on Coating
(See Clauses 12.7.3.2.2 and 12.7.3.3.1.)

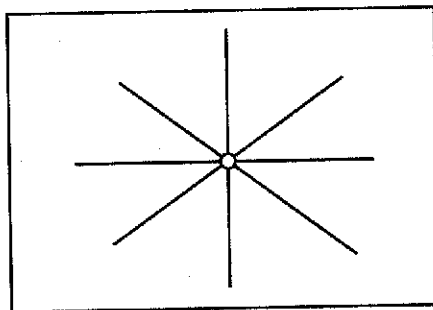
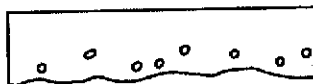
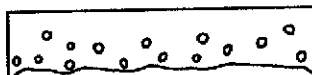


Figure 5
Examples of Radial Cuts through the Coating
(See Clause 12.8.3.7.)

Rating 1



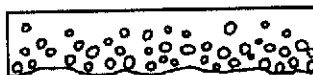
Rating 2



Rating 3



Rating 4



Rating 5



Figure 6
Examples of Cross-Section Porosity
(See Clause 12.10.3.3.)

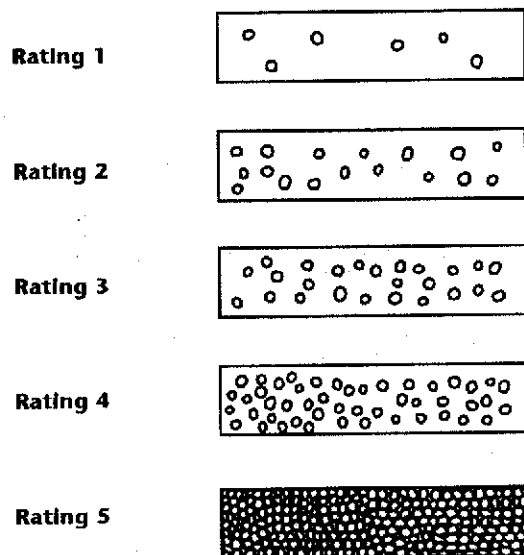


Figure 7
Examples of Interface Porosity
(See Clause 12.10.3.3.)

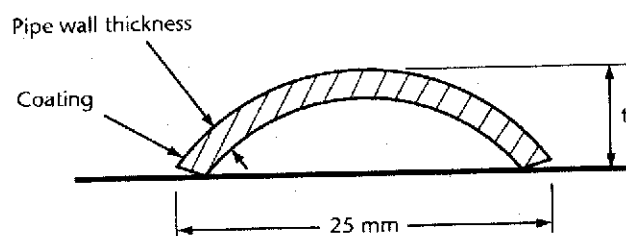


Figure 8
Determination of Sample Thickness Flexibility Test
(End View)
(See Clause 12.11.3.2.)

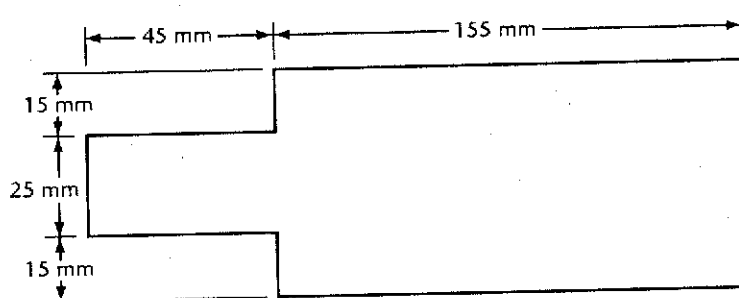


Figure 9
Test Specimen
Cathodic Disbondment of Strained Coating Test
(See Clause 12.13.2.)