

CSA Standard

Z245.21-02

External Polyethylene Coating for Pipe



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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 primarily intended 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; 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 references are 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

Z245.20-02

External Fusion Bond Epoxy Coating for Steel Pipe

ASTM* Standards

D 570-98

Standard Test Method for Water Absorption of Plastics

D 618-00

Standard Practice for Conditioning Plastics for Testing

D 638-01

Standard Test Method for Tensile Properties of Plastics

D 746-98e1

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 1238-01e1

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

D 1475-98

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

D 1505-98e1

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

D 1525-00

Standard Test Method for Vicat Softening Temperature of Plastics

D 1652-97

Standard Test Methods for Epoxy Content of Epoxy Resins

D 1693-01

Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

D 2083-92 (R1998)

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

D 2196-99

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

D 2240-02

Standard Test Method for Rubber Property — Durometer Hardness

D 3895-98

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

D 4703-00

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

E 28-99

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

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 6-1989

Commercial 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:

Adhesive —

- (a) For Systems A1 and A2, a material used to provide bonding between the bare steel and the polyethylene topcoat.
- (b) For Systems B1 and B2, a material used to provide bonding between the epoxy primer and the polyethylene topcoat.

Adhesive lot — an identifiable quantity of material made in continuous production, not in excess of 20 mg.

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

Certificate of compliance — a document provided by the product manufacturer or applicator, whichever is applicable, 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 — natural resin with ultraviolet stabilizer or colorant, 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 (Z245.21-02);
- (b) pipe quantity, outside diameter, wall thickness, and nominal length;
- (c) pipeline system maximum design temperature;
- (d) coating system (A1, A2, B1, or B2; see Clause 1.2);
- (e) bare pipe standard or specification designation (see Clause 5.1);
- (f) cutback length for both ends of pipe (see Clause 6.2.4);
- (g) cathodic disbondment radius at maximum design temperature (see Table 1); and
- (h) test temperature for the flexibility test (-30°C , -18°C , or 0°C ; see Clause 12.11.3.1 of CSA Standard 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) increased test ring length (see Clause 7.4.3.2);
- (c) increased test frequency (see Clauses 7.4.3.3 and 7.4.3.5);
- (d) additional markings (see Clause 9.1);
- (e) handling procedures (see Clause 10.1.1);
- (f) storage procedures (see Clause 10.2);
- (g) waiver of test reports (see Clause 11.1); and
- (h) 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 be 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 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 inclusive, and compatible with the requirements of Table 1 (this certification is 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 given in Table 4.

5.3.2 Powdered Primer

The powdered epoxy primer shall have properties that are in accordance with the requirements of Table 1 of CSA Standard Z245.20.

5.4 Adhesive

The adhesive properties shall be as given in Table 2.

5.5 Polyethylene

The virgin polyethylene resin properties shall be as given in Table 3. Where test plates are required, they shall be made in accordance with the requirements of ASTM Standard D 4703, Procedure C, and conditioned in accordance with the requirements of ASTM Standard 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 is not specifically marked for that product (eg, railway cars), 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, eg, 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 given in Table 1. For each such test, test specimens shall be obtained from each of 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 any 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 given 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 given in Table 5.

6.2 Production Application Practices and Equipment

6.2.1 General

The coating system 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 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 any 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 any blast cleaning and inspection.

6.2.2.3

The external pipe surface to be coated shall be blast cleaned at least to 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 inclusive and, where applicable, 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 given 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 recommendation. The minimum adhesive thickness shall be as given 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 given 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 from 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 may undergo growth or shrinkage following cutback due to temperature change.*

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

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 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.

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 given in Table 7.

7.3.4

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

7.3.5

The properties of the polyethylene shall be as given 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 7.4.2.2 inclusive shall be made 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 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 minimum recording frequency shall be at start-up and 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) and shall be recorded. Such tests shall be conducted on 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 a minimum frequency of once at start-up and once every 4 h of production. Such measured thickness values shall be recorded.

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.

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

Pipe having two or fewer holidays shall be repaired in accordance with the requirements of Clause 8.2. Any pipe having more than two holidays or a holiday having an axial length greater than 300 mm shall be stripped and recoated in accordance with the requirements of Clause 8.3.

7.4.3 Production Test Rings

7.4.3.1

The applicator shall have suitable facilities available at the application facility 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 a higher 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: The stated 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 given 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. 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, either

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

- (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 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.

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 (such as protrusions, inclusions of particles under the coating, sharp cuts, and indentations) that fail to meet the requirements of Clause 7.4.2 shall be cut out.

8.2.2

Where there has been damage to the primer or where there is missing primer, all such damaged areas shall be repaired with a primer that is compatible with the original coating system. The repair shall be completed by the application of a compatible adhesive-lined heat-shrink sleeve or patch material. The repair material shall overlap at least 75 mm over the undamaged coating.

8.2.3

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

8.2.4

All repairs shall be electrically 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 nonconformance to 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, it shall be permissible for coated pipe that fails to conform to the minimum adhesive thickness requirements to 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, it shall be permissible for coated pipe that fails to conform to the minimum polyethylene thickness requirements to 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 given in Table 10.

8.3.4

For Systems B1 and B2, where the requirements of Table 10 are met, but where only minimum adhesive and/or polyethylene thickness requirements of Table 6 are not met, it shall be permissible for the pipe to 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 given 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 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 required markings shall be as follows:

- (a) applicator's name or mark;
- (b) CSA Standard designation and year of publication (Z245.21-02);
- (c) markings required by the applicable pipe specification or standard;
- (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 "FOC" 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

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 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 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 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[®], Thermosel[®] adapter, and accessories or purchaser-approved equivalent; and
- (b) an oven controllable to within 3 °C.

12.1.2 Procedures

12.1.2.1

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

12.1.2.2

Preset the Thermosel[®] control to 150 °C.

12.1.2.3

Pour the adhesive into the cup to a level such 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 in Clauses 12.1.2.1 to 12.1.2.6 inclusive with temperatures set at 163 °C 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 Reports

Where 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; and
- (c) the temperature, spindle number, speed, and viscosity.

12.2 Flow Tests**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 Procedures**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 the 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 mould and cool to 20 ± 3 °C.

12.2.2.5

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

12.2.2.6

Condition the test specimens at 20 ± 3 °C for at least 0.5 h 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

Place immediately 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 report the average flow to the nearest millimetre.

12.2.3 Reports

Where 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 °C.

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 carbon electrode;
- (e) a 75 ± 3 mm ID plastic cylinder;
- (f) a 3% sodium chloride solution in distilled water;
- (g) a utility knife; and
- (h) needle-nose pliers.

12.3.2 Test Specimens**12.3.2.1**

Test specimens shall be either a full ring section of pipe approximately 100 mm in length or a panel cut from the full ring section, approximately 100 mm × 100 mm × the pipe wall thickness.

12.3.2.2

Use only test specimens that are confirmed to be holiday-free in accordance with the requirements of Clause 7.4.2.

12.3.3 Procedures

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 a minimum of 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 given 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 the completion of the test, dismantle the test cell and air cool the specimen to 20 ± 3 °C for up to 1 h. The cathodic disbondment characteristics of the test specimens shall be evaluated within 1 h from the end of the duration of the test.

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. Such cuts shall 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 Reports

Where 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 on which
 - (i) the rate of movement between the heads of the testing machine remains essentially constant under fluctuating loads;
 - (ii) the testing machine measures the load to within 1%; and
 - (iii) the testing machine and range are selected so that the maximum load on the specimen falls between 15% and 85% of the full-scale capacity; 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.

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 $\times$ the pipe wall thickness; and
- (b) plates: 150 mm $\times$ 150 mm $\times$ the 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 length of the peel strip shall be at least 75 mm.

12.4.3.4

The width of the peel strip shall be 25 ± 1 mm.

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 Procedures

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), then 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, the sample fails the test. If a small portion (less than 5%) of the total peeled length has a peeling load below the specified minimum value, accept the test as satisfactory; however, do not use the peeling load for that small portion 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 Calculations

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

$$P = L_p \times 9.81 \quad (1)$$

where

P = minimum peel strength, N

L_p = minimum peeling load, kg

12.4.6 Reports

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

- the lot number of each coating component;
- the date of testing;
- the test specimen type and length of strip peeled in millimetres; and
- the minimum peel strength in newtons.

12.5 Peel Adhesion (Hanging Mass)

12.5.1 Equipment

The equipment shall consist of the following:

- masses of 0.3 kg, 2.0 kg, and 15.3 kg;
- an attaching device;
- a utility knife; and
- a timing device.

12.5.2 Test Specimens

The test specimens shall consist of a complete pipe or a test ring cut from the test 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 width of the peel strip shall be 25 ± 1 mm.

12.5.3.3

The peel orientation shall be circumferential.

12.5.4 Procedures**12.5.4.1**

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

12.5.4.2

Two cuts 25 ± 1 mm apart shall be made through the coating to the steel substrate with the utility knife from the 90° position to the 180° position. The coating shall be cut at a right angle at the 90° position and peeled off down to the 135° position, as shown in Figure 5.

12.5.4.3

The appropriate mass shall be attached to the free end of the peel strip as shown in Figure 5.

Mass:	System A1	0.3 kg
	System A2	2.0 kg
	System B1	15.3 kg

12.5.4.4

The peeling time in minutes from the 135° position terminating at the 180° position shall be measured. The peeling may also be terminated when the test time calculated by using the following formula has been exceeded:

$$T = \frac{0.125 \times 3.14 \times D}{10} \quad (2)$$

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:

$$PS = \frac{d}{t} \quad (3)$$

where

PS = peeling speed, mm/min

d = distance peeled, mm

t = peeling time, min

If the peeling speed is in excess of 10 mm/min at 20 ± 3 °C, the test shall be considered a failure.

12.5.5 Reports

Where 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 Standard 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 be approximately 50 mm wide × 150 mm long × the polyethylene thickness.

12.6.2.2

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

12.6.3 Procedures

12.6.3.1

Three unheated test specimens shall be tested in accordance with the requirements of ASTM Standard D 638, except that a test temperature of 20 ± 3 °C shall be used. Sample Type IV with a crosshead speed of 50 mm/min shall be utilized. The results of these tests shall meet the acceptance criteria given in Table 5.

12.6.3.2

Three other test specimens shall be placed in an oven at a temperature of 100 ± 3 °C for a period of 2400 ± 24 h. At the end of the heat aging period, each test specimen shall be removed from the oven and its temperature allowed to return to 20 ± 3 °C. The tests 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 Reports

Where 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 (LD, LLD, MD, or HD);
- (b) the date of testing;
- (c) the tensile stress at yield for test specimens that were not heat aged in MPa;
- (d) the tensile stress at yield for test specimens that were heat aged in MPa;
- (e) the percentage elongation at break for test specimens that were not heat aged; and
- (f) the percentage elongation at break for test specimens that were heat aged.

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	Purchaser's specification	Clause 12.3
Impact resistance	A minimum of 3.0 J/mm of actual total coating thickness	CSA Z245.20, Clause 12.12, except that for each µm of thickness, the voltage setting for the dc holiday detector (see Clause 12.12.3.3) shall be 10 V per micrometer of thickness, up to a maximum of 15 000 V
Flexibility	No cracking of polyethylene	CSA Z245.20, Clause 12.11; 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†		CSA Z245.20, Clause 12.14; 28 d at 75 °C
System B2	Rating 1–3	

*Not applicable for System B2.

†Applicable for System B2 only.

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 test at maximum design temperature	mm	No 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
Water absorption	wt %	0.1 maximum	ASTM D 570
Systems B1 and B2			
Flow rate	g/10 min	Within 20% of the 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 once 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) 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%			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	minute	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 for System B2. The acceptance criteria for System B2 shall be within 20% of the manufacturer's specified nominal.

†This test is required at least once 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	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	CSA Z245.20, Clause 12.2; 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	1.80	1.00	0.85
100–250	0.12	0.10	2.00	2.00	1.15	1.00
> 250–500	0.12	0.10	2.20	2.20	1.15	1.00
> 500–800	0.12	0.10	2.50	2.50	1.15	1.00
> 800	0.12	0.10	3.00	3.00	1.15	1.00
System B2						
				LD or LLD	MD	HD
All pipe diameters	0.12	0.1	0.45	0.45	0.45	0.45

*Not applicable for 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	CSA Z245.20, Clause 12.2; thickness at 50 to 150 µm; test temperature as recommended by manufacturer
Powder primer			
Gel time	s	Within 20% of manufacturer's specified nominal	CSA Z245.20, Clause 12.2

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

Table 8
Adhesive Requirements
 (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 test at 70 °C	mm	No 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 the 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
 (See Clause 7.3.5.)

Test	Unit	Acceptance criterion				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†					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
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	CSA Z245.20, Clause 12.14
2.5° flexibility‡	—	—	—	No cracking	CSA Z245.20, Clause 12.11

*Not applicable for System B2.

†Applicable for System B1 only.

‡Applicable for System B2 only.

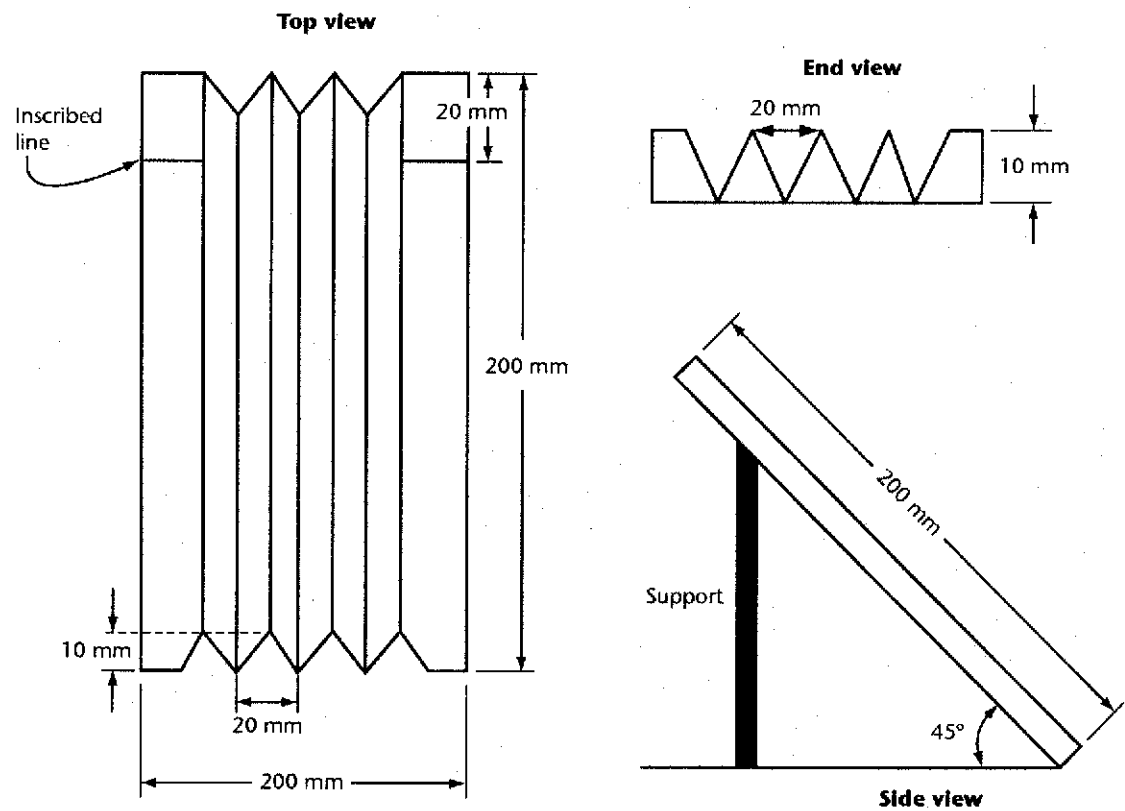


Figure 1
Flow Test Apparatus
(See Clause 12.2.1.)

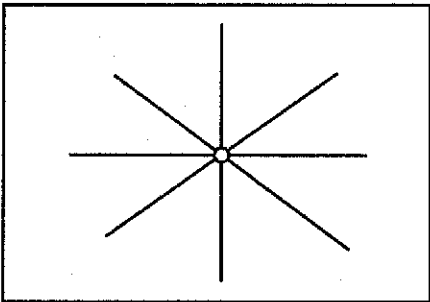


Figure 2
Example of Radial Cuts through the Coating
(See Clause 12.3.3.6.)

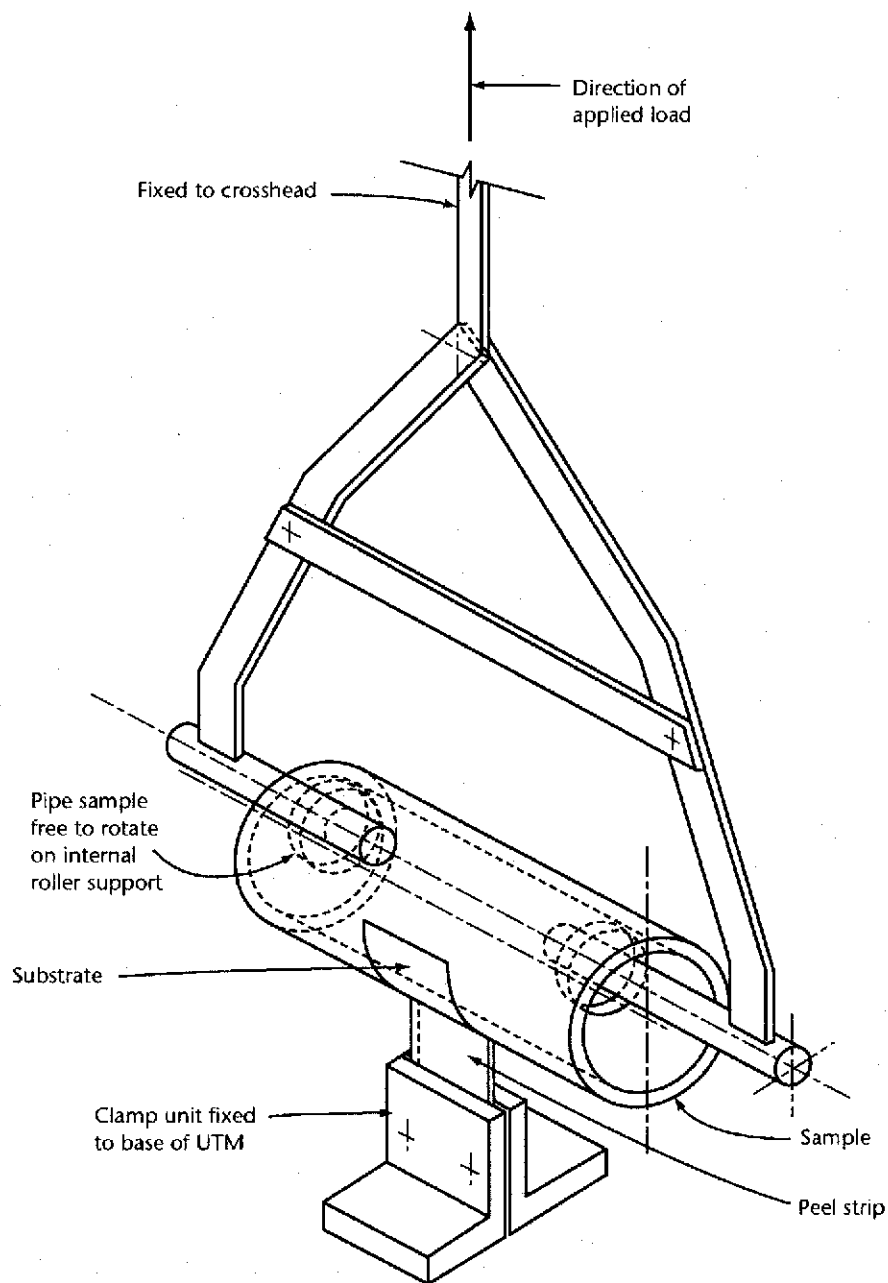


Figure 3
Peeling Apparatus for Pipe
Smaller than 200 mm OD
 (See Clauses 12.4.1 and 12.4.3.5.)

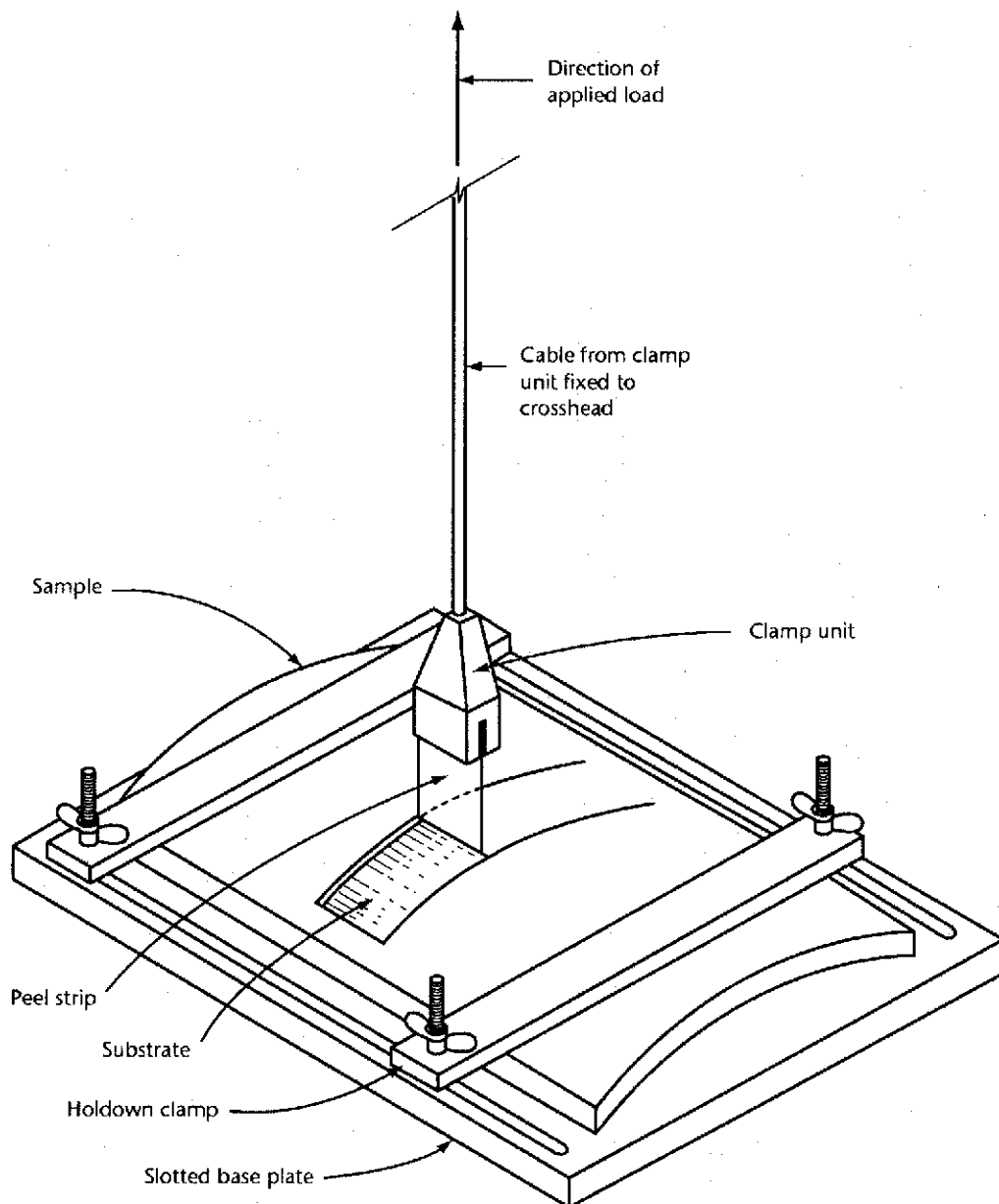


Figure 4
Peeling Apparatus for Pipe
200 mm OD or Larger
(See Clauses 12.4.1 and 12.4.3.5.)

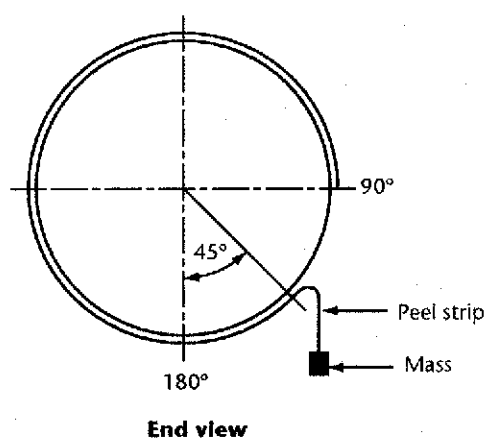


Figure 5
Hanging Mass Test Set-up
(See Clauses 12.5.4.2 and 12.5.4.3.)