External Fusion Bonded Epoxy Coating of Line Pipe

API RECOMMENDED PRACTICE 5L9
FIRST EDITION, DECEMBER 2001

REAFFIRMED, MAY 2015

AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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External Fusion Bounded Epoxy Coating of Line Pipe

1 Scope

1.1 DESCRIPTION

This recommended practice provides external fusion bonded epoxy coating of line pipe for use in transportation pipelines. The Recommended Practice is limited to the application of external coatings on pipe prior to installation. There may exist differences in the surface condition of pipes produced by the various pipe making processes permitted under the latest editions of API standards. Surface conditions may preclude the coating of such pipe.

The applicator shall be responsible for assuring compliance with all of the provisions of this practice however, the Purchaser may make any investigation necessary to satisfy himself of compliance by the applicator.

1.2 DEFINITIONS

1.2.1 applicator: The organization responsible to the Purchaser for the application of the coating.

1.2.2 batch: The quantity of material produced during a continuous production run of not more than one calendar day.

1.2.3 coating: The film of coating as applied to the substrate.

1.2.4 coating material: The material prior to application to the substrate.

1.2.5 holiday: A discontinuity in a protective coating which exhibits electrical conductivity when exposed to a specific voltage.

1.2.6 inspector: An authorized agent of the purchaser.

1.2.7 may: "May" indicates that a provision is optional.

1.2.8 purchaser: The owner company or the authorized agency that buys the applied coating.

1.2.9 shall: "Shall" indicates that a provision is mandatory.

1.2.10 should: "Should" indicates that a provision is not mandatory, but recommended as good practice.

1.2.11 supplier: The manufacturer and/or distributor of the coating material and its authorized technician.

1.3 REFERENCED STANDARDS

1.3.1 General

This specification includes by reference, wither in total or in part, other API industry and government standards listed in Table 1.

1.3.2 Equivalent Standards

Other nationally or internationally recognized standards shall be submitted to and approved by API for inclusion in this recommended practice prior to their use as equivalent standards.

1.4 RETENTION OF RECORDS

Records of tests and inspections demonstrating compliance with this recommended practice shall be retained and shall be made available to the purchaser upon request for a 3-year period after the date of application.

2 Coating Material Requirements

2.1 PURPOSE

This section describes material properties of coating materials to be applied under the scope of this recommended practice. It is the supplier's responsibility to perform the tests referenced in Table 2. The purchaser or applicator may also perform any or all of the referenced tests as part of a quality assurance program.

2.2 COATING MATERIALS DESCRIPTION

The coating material shall consist of a one component, powdered, fusion-blended material consisting of epoxy resin(s), curing agent(s), pigment(s), fiber(s), catalyst(s), and flow-control agent(s) which, when applied to the preheated substrate, will melt, flow and subsequently cure to produce a coating complying with the requirements of API RP 5L9.

2.3 TRACEABILITY

The powder shall be delivered in clearly labeled containers identified up to the time of use with all the following:

a. manufacturer's name,
b. product description,
c. mass of material,
d. batch number,
e. location of manufacture
f. manufacturer's identification number,
g. date powder was manufactured.

Table 1—Referenced Standards

Standard	Titles	Edition
1. NACE No. 1/SSPC-SP5	*White Metal Blast Cleaning*	Latest Edition
2. NACE No. 2/SSPC-SP10	*Near-White Metal Blast Cleaning*	Latest Edition
3. SIS 05-59-00	*Pictorial Surface Preparation Standards for Painting Steel Surfaces*	Latest Edition
4. API RP 5LW	*Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*	Latest Edition
5. API RP 5L1	*Recommended Practice for Railroad Transportation of Line Pipe*	Latest Edition
6. NIST	*Film Thickness Standard*	(within 20% of specified coating thickness)
7. ASTM D4060	*Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*	Latest Edition

Table 2—Coating Material Physical Properties

Property	Value	Test Method
Specific Gravity	Per supplier's specification	Appendix A
Particle Size	0.1% Max. retained on 60 mesh [250 micron]	
Shelf Life	Per supplier's specification and conditions	
Gel Time	Per supplier's specification	Appendix B
Cure Cycle	Capable of cure at temperature below 500°F [260°C] for time specified by supplier[1]	
Glass Transition Temperature	Per supplier's specification	Appendix C
Potential Reaction Energy	Per supplier's specification	Appendix C
Moisture Content[2]	0.50% Maximum	Appendix D
Total Volatile Content[2]	0.60% Maximum	Appendix E

Notes:
1. Limitation imposed by some national regulations on heating of cold expanded pipe.
2. Either Moisture or Total Volatile Content may be determined at supplier's discretion.

2.4 COATING SUPPLIER INFORMATION

The Applicator shall furnish to the purchaser the following coating supplier information in written form upon request:

a. Specification of the basic physical properties and laboratory performance test results.
b. Directions for handling and storing of the coating materials.

2.5 CERTIFICATION OF PHYSICAL PROPERTIES

The coating material supplier shall furnish to the Purchaser and/or applicator the following information in a written form upon request:

a. Certification of the determined physical properties of each batch of material.
b. Specification of the basic physical properties and laboratory performance test results.

3 Coating Material Qualification

3.1 GENERAL

The coating material shall be qualified by testing laboratory-coated specimens and meeting the requirements for the tests outlined in 3.3. The coating shall be re-qualified when there is a change in coating material formulation.

3.2 PREPARATION OF LABORATORY COATED TEST SPECIMENS

Test panels shall be mild steel. Panel dimensions for each test are given in the referenced test method. Unless otherwise agreed upon, the surface shall be blast cleaned using steel grit (G40, HRC 55 or greater) to any of the following standards:

a. NACE No. 1 /SSPC-SP5 white metal finish.
b. Swedish Pictorial Standard SIS 05-59-00 SA3.

3.2.1 Surface Profile

The surface profile shall be 1.5 mils – 4.0 mils [38 microns – 100 microns], as measured using replicating tape or equivalent.

3.2.2 Coasting Application

Coating application and curing shall be in accordance with the supplier's recommendations.

Table 3—Performance of Laboratory Coated Steel Panels

Test	Value/Limits	Test Method
Abrasion	300 mg max.	Appendix F
Cathodic Disbondment[1]	0.31 in. [8 mm] maximum average radius	Appendix G
Chemical Resistance	90 days at 68°F + 5°F [20°C + 3°C] without blistering	Appendix H
Flexibility	3°/PD bend at 0°F [–18°C] with no cracking and no disbonding	Appendix I.1
Hot Water Soak	Maximum: Rating 3	Appendix L
Impact	15 in.-lb [1.70 J] minimum	Appendix J

Note: [1]This is included as an adhesion test, not a service simulation.

3.2.3 Thickness

Thickness of coating on the completed test panel shall be 14 + 2 mils [356 + 51 microns], measured using a calibrated coating thickness gauge.

3.3 EPOXY MATERIAL MECHANICAL PROPERTIES AND TESTS

Tests shall be performed on test panels which have been prepared and coated in accordance with 3.2. Tests shall be performed on duplicate panels. A coating shall be considered qualified when the results of both test panels meet the acceptance criterion for each test (see Table 3).

4 Applicator Practices

4.1 PLANT ACCESS

The inspector shall have free access, while work on the contract of the purchaser is being performed, to all parts of the applicator's plan concerned with the storage, application, testing, and handling of the epoxy powder and coating of the purchaser's pipe. All inspection shall be conducted so as not to interfere unnecessarily with the operation of the plant.

4.2 RECEIPT OF PIPE

Bare pipe shall be supplied to the applicator essentially free of salts, mill lacquer, oil, grease or other deleterious deposits that would prevent meeting the acceptance criteria of Table 4 when coated as required by this recommended practice. The applicator shall sufficiently remove any remaining deleterious deposits from the surface to be coated prior to coating application. Pipe received in damaged condition shall be reported to the purchaser.

4.3 HANDLING OF PIPE

Pipe shall be handled in a manner to prevent damage to pipe walls, beveled ends, and coating. Pipe that is damaged by the coating and/or handling operations shall be repaired in compliance with the latest editions of applicable API standards and purchaser's specification, or replaced by the applicator.

4.4 COATING OF MATERIAL SELECTION

Selection of coating materials shall be by agreement between the purchaser and the applicator.

4.5 HANDLING OF COATING MATERIALS

4.5.1 Storage

Coating materials shall be shipped and stored under cover and in such a manner that contamination or adverse effects on application or performance are avoided.

4.5.2 Gel Time Testing

Gel tests shall be conducted routinely. The minimum testing frequency shall be one sample on every vehicle shipment of epoxy powder received and on each batch of coating material before use. Test conducted and the acceptance criterion shall be in accordance with Appendix B and Table 4.

4.5.3 Powder Samples

It shall be the right of the purchaser to procure a coating material batch sample prior to or during the job for the purpose of verification of conformance to coating material specifications.

4.5.4 Shelf Life

Any batch of coating material which has exceeded the supplier's recommended shelf life and/or storage temperature shall be subjected to material verification tests in accordance with Table 4, prior to usage.

4.6 DESIGNATED QUALITY CONTROL RESPONSIBILITY

Applicator shall have a designated representative for quality control.

4.7 INSPECTOR NOTIFICATION

When the inspector representing the purchaser desires to inspect the coated pipe or witness the tests, the applicator shall give reasonable notice of the time at which the application or tests are to be made.

Table 4—Performance of Coating Materials

Test	Acceptance Criterion	Test Method
Flexibility	3°/PD bend at 0°F [– 18°C][1]	Appendix I.1
Gel Time	Per Supplier's specification	Appendix B
Moisture Content	0.50% Maximum	Appendix D
Hot Water Soak	Maximum: Rating 3	Appendix L
Total Volatile Content[2]	0.60% Maximum	Appendix E

Notes:
[1]Higher values for bend severity and lower values for temperature are subject to agreement between purchaser and supplier.
[2]Either moisture or total volatile content may be determined at Supplier's discretion.

5 Application Procedures

5.1 PURPOSE

This section prescribes the equipment and practices used in the surface preparation of line pipe for external fusion bonded epoxy coating and the application of this coating on the prepared surface.

5.2 SURFACE PREPARATION

The cleaning must be of sufficient quality to ensure a surface that will permit proper adhesion of the coating to the pipe.

5.2.1 Contamination

All pipe, coating and conveying equipment surfaces shall be essentially free from deleterious deposits such as oil, grease, mud or other material which are detrimental to the coating.

5.2.2 Pre-heat

Pre-heat is required if pipe is not visually free of moisture or if pipe temperature is less than 5°F [3°C] above the dew point. The pipe shall be uniformly heated to at least 5°F [3°C] above the dew point before blast cleaning and inspection. The surface temperature shall not exceed 525°F [274°C].

5.2.3 Method and Degree of Cleanliness

The blast abrasive such as shot and/or grit shall be agreed upon by applicator and purchaser. The pipe surface shall be blast cleaned to a near-white #2 finish in accordance with the latest edition of NACE No. 2/SSPC-SP10 or equivalent [Sa2-1/2 per SIS 05-59-00], unless more stringent cleanliness requirements are agreed upon between purchaser and applicator.

5.2.4 Abrasive Cleanliness

The abrasive mix shall be cleaned of dust contaminants by continuous effective operation of blasting machine scalping and air wash separators.

5.2.5 Abrasive Removal

Residual products from blasting shall be removed from the interior surfaces of the pipe.

5.2.6 Surface Preparation Inspection

5.2.6.1 Surface Profile

The surface profile shall be 1.5 mils – 4.0 mils [38 microns – 100 microns]. At least twice per 8 hour shift, the external surface profile on two pipes shall be measured using replicating film or equivalent.

5.2.6.2 Surface Imperfections or Defects

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

5.2.6.3 Grind Area

The maximum grind area is $^1/_2$ ft^2 [0.05 m^2] per location and the maximum total grind area is 2 ft^2 [0.2 m^2] per joint of pipe. The disposition of any joint of pipe that exceeds these limits shall be subject to agreement between the applicator and purchaser.

5.2.7 Flash Rusting

The cleaned surface shall not be allowed to deteriorate prior to coating application. The coating operation should take place within four hours of the blast cleaning operation. Where flash rusting or surface contamination has occurred, the surface shall be reblasted, regardless of elapsed time.

5.2.8 End Caps

Bevel lands and pipe ends shall be protected from blast-cleaning and impact damage by caps when requested by purchaser.

5.2.9 Additional Surface Treatments

Where approved by the purchaser, additional surface treatments may be used prior to application of coating. When specified by the purchaser, additional surface treatments prior to application of coating shall be performed.

5.3 COATING APPLICATION

5.3.1 Coating Equipment

5.3.1.1 Compressed Air Requirements

A source of clean, dry air with instrumentation to monitor dryness is required. The dew point of air in the fluidized bed and powder feed lines shall be no higher than – 20°F [– 29°C].

5.3.1.2 Powder Filter

Adequate screens (60 mesh [250 micron] or finer) shall be present in the powder handling system to ensure that large particles or agglomerates are not carried to the application equipment.

5.3.1.3 Coating Apparatus

Coating material shall be maintained in a fluidized condition during application. The apparatus used to apply the coating to the surface shall do so in a uniform manner and to the specified thickness in a single pass.

5.3.2 Pipe Surface Heating

Pipe may be brought up to temperature by in-line furnace, soaking oven or induction coils, which have sufficient controls to preclude exceeding the maximum allowable pipe temperature, stipulated in 5.3.2.4.

5.3.2.1 Method of Measurement

Pipe temperature prior to coating shall be monitored by means of temperature indicating crayons or other suitable means as agreed between purchaser and applicator. Coated pipe temperature may be monitored by infrared pyrometer or other suitable instrument.

5.3.2.2 Frequency of Measurement

Pipe temperature immediately prior to coating shall be monitored every 10 minutes. More frequent measurements are necessary at start-up and when there is any change in process parameters.

5.3.2.3 Coating Application Temperature

The temperature of the pipe at time of application of the coating material shall be within the minimum and maximum limits recommended by the coating material supplier.

5.3.2.4 Maximum Pipe Temperature

Unless otherwise agreed upon, pipe surface temperature shall not exceed 525°F [274°C]. It should be recognized that elevated temperatures may have an effect on base material (steel pipe) properties such as strength, elongation and fracture toughness. Pipe which has exceeded the maximum temperature shall be set aside for further evaluation.

5.3.3 Powder Application

5.3.3.1 Thickness

The minimum coating thickness shall be 12 mils [305 microns], unless a greater minimum thickness is specified by the purchaser. Coating thickness should be checked on every pipe with an approved gauge. The gauge is to be calibrated daily, or upon purchaser's request.

5.3.3.2 Uniformity

Coating shall be applied in a uniform manner.

5.3.3.3 Time to Quench

The minimum elapsed time between application of coating material and quenching of the pipe shall be measured and used in conjunction with the temperature measurement in 5.3.2.1 to ensure compliance with the supplier's recommended cure schedule, for each combination of diameter and wall thickness of pipe. The time to quench shall be monitored by means of a stop watch at start-up and when line speed is changed.

5.3.3.4 Recycled Powder

The use of recycled powder may be permitted if adequate recovery and screening equipment is used and maintained. An adequate recycle system should continuously blend recycled powder with virgin powder into the delivery system. The amount of recycled powder used shall be by agreement between purchaser and applicator.

5.3.4 Coating Cutback

Suitable means shall be used to provide the bare steel cutback area specified by the purchaser.

6 Production Inspection and Documentation

6.1 PURPOSE

This section describes the methods of inspection, the acceptance criteria and the documentation for pipe externally coated with fusion bonded epoxy.

6.2 WORKING AREA

A safe working area that is suitable for the performance of their duties shall be provided by the applicator for the purchaser's inspectors. Inspection area(s) shall be arranged to permit adequate time for inspection without affecting production.

6.3 VISUAL INSPECTION

The applied coating shall be examined for uniformity in gloss and color and irregularities such as blisters, pinholes, fisheyes, sags, or "orange peel".

6.4 THICKNESS INSPECTION

Coating thickness shall be measured on every pipe using a suitable gauge.

6.4.1 Calibration

Calibration of the gauge shall be checked at least once each shift or upon purchaser's request on a National Institute Standards Technology non-magnetic coating standard with a thickness within 20% of the specified nominal thickness. Equivalent standards agreed upon by purchaser and applicator may also be used.

6.4.2 Coating Thickness

The coating thickness shall be measured at a minimum of five random locations along the pipe length. The minimum and maximum measured thicknesses shall be recorded. Pipe failing to meet the specified coating thickness requirements shall, at the purchaser's option, be accepted, repaired, or stripped and recoated.

6.5 HOLIDAY INSPECTION

6.5.1 Procedure

The entire coated surface of each length of pipe shall be inspected with a holiday detector having a conductive rubber search electrode designed so that the entire coated surface is contacted during holiday inspection. The electrical potential shall be agreed upon by purchaser and applicator, but shall be at least 125 volts per mil [25.4 microns] of specified coating thickness. The unit shall have both visual and audible alarms to indicate holidays. The maximum number of holidays permitted shall be per 6.5.3. Pipe lengths with coating holidays that exceed 6.5.3 shall be stripped and recoated. Those with an acceptable number of holidays shall be repaired.

6.5.2 Calibration

Holiday detector voltage shall be checked at least twice per 8 hour shift with a calibrated D.C. voltmeter.

6.5.3 Maximum Number of Holidays

The maximum number of repaired holidays shall be equal to the pipe length in feet divided by 3, for pipe sizes smaller than 14 [355.6 mm] OR, the total surface area in square feet divided by 25 (or square meters divided by 2.32) for pipe sizes 14 [355.6 mm] and larger.

6.6 DOCUMENTATION

Applicator shall furnish the purchaser with an inspection report recording pipe size, nominal wall thickness, number of joints coated, each coating thickness measurement for each pipe, and the number of repairs on each joint coated for each shift.

7 Repair of Coating Defects

7.1 REPAIRS

All coating defects disclosed by the holiday detector and by visual inspection shall be repaired and holiday inspected by the applicator.

7.2 PREPARATION OF REPAIR AREA

Damaged areas and holidays shall be cleaned by removing all rust, scale, dirt or other foreign material and loose coating. The areas to be patched should be suitably roughened before patching. Dust generated by the cleaning shall be removed with a clean dry cloth or brush prior to patching.

7.3 PINHOLES AND SMALL AREA REPAIRS

Areas 1 in. [25 mm] in diameter and smaller shall be patched with the supplier's recommended hot melt patch stick, two-part epoxy or equivalent.

7.4 LARGE AREA REPAIRS

Areas greater than 1 in. [25 mm] in diameter and less than 260 cm^2 [40 $in.^2$] shall be patched with the powder supplier's recommended two-part epoxy or equivalent. The disposition of pipe requiring a repair area greater than 260 cm^2 [40 $in.^2$] shall be subject to agreement between the applicator and purchaser.

7.4.1 Application Procedure

Two-part epoxy shall be thoroughly mixed in accordance with the supplier's specification and may be applied by brush or spatula to damaged area and shall overlap the surrounding undamaged coating by a minimum of 1 in. [25 mm].

7.4.2 Minimum Thickness

Minimum film thickness of coating after repair shall be as specified by the supplier's recommendation or in accordance with the minimum coating thickness as specified in 5.3.3.1.

8 Production Acceptance Testing and Documentation

The applicator is responsible for the quality control production tests outlined in this section to ensure conformance with this recommended practice.

8.1 TESTING FREQUENCY

Test rings shall be cut once per shift unless otherwise agreed by the Purchaser and Applicator. Additional test rings for destructive testing may be cut upon agreement between purchaser and applicator.

8.2 PRODUCTION TEST RINGS

The usual width of the production test ring is 1.5 ft [0.45 m]. Rings shall be cut in such a manner that the cut end of the remaining pipe length has a bevel configuration similar to the original.

8.3 FLEXIBILITY TESTS

At least 3 flexibility tests shall be conducted with samples from each test ring in accordance with Appendix I and Table 5. Greater flexibility requirements or lower test temperatures shall be subject to agreement between purchaser and applicator.

8.4 CATHODIC DISBONDMENT TESTS

A cathodic disbondment test of 24 hour duration shall be performed on a sample from each test ring in accordance with Appendix L and Table 5.

8.5 HOT WATER SOAK TEST

A hot water soak test shall be performed and evaluated in accordance with Appendix L and Table 5.

8.6 MICROSCOPIC EXAMINATION

8.6.1 Interfacial and Cross-section Porosity

Samples shall be prepared and evaluated in accordance with Appendix K and Table 5.

8.6.2 Interfacial Contamination

Samples shall be prepared and evaluated in accordance with Appendix K and Table 5.

8.7 RETEST OF TYPE A OR TYPE B FAILURES

8.7.1 Retest of Type A Failures

Where a Type A test (See Table 5) fails to conform to the specified requirements, at the applicator's option, all coating applied after the previous acceptable test and prior to the next acceptable test shall be rejected, or the test that failed repeated using two additional samples taken from the same end of the affected pipe. The test samples shall be taken in accordance with 8.2. and Table 5.

8.7.1.1 Where both retests conform to the specified requirements, the lot of coated pipe shall be accepted. Except where allowed by 8.7.1.2, where one or both of the retests fail to conform to the specified requirements, all coating applied after the previous acceptable test and prior to the next acceptable test shall be rejected.

8.7.1.2 At the request of the applicator, the purchaser may consider a further retest program to determine whether any of the affected pipe meets the criteria for acceptance.

8.7.1.3 Rejected coated pipe shall be reworked in accordance with 8.8.

8.7.2 Retest of Type B Failures

Failure to meet the acceptance criteria for Type B tests shall be grounds for requiring changes to the application process parameters. The purchaser may require that the applicator limit the application process until the cause of the failure has been remedied.

8.7.2.1 When certain pretreatments are used on the surface of the pipe prior to powder application, it may be difficult to perform the interface contamination and interface porosity tests accurately and the process may not need to be adjusted.

8.8 STRIPPING AND RECOATING

The pipe surface shall be cleaned by a combination of heating to a temperature not to exceed 525°F [275°C], scraping, and abrasive blasting. All coating shall be removed prior to any recoating process. Recoating shall be performed in accordance with the requirements of Section 5.

9 Coating Stencil Requirements

9.1 LOCATION OF COATING STENCILS

Coating and stencil information in 9.2 shall be applied using permanent ink or paint and shall be applied either continuously along the length of each pipe or on both ends of each pipe. Markings applied only on the ends of the pipe shall be on the inside surface except for pipe sizes less than $12\frac{3}{4}$", which may be on the outside surface or as agreed on between the applicator and the purchaser.

Table 5—Production Test Ring Requirements

Test Type		Acceptance Criteria	No. of Specimens	Test Method
Cathodic Disbondment	A	Max. radius: 12 mm	1	Appendix G
Hot Water Soak	A	Rating of 1 – 2, inclusive	1	Appendix L
Flexibility	A	No cracking or disbonding at 32°F [0°C] at severity > 2.5°/PD temporary deflection	3	Appendix I.1
		— OR —		Appendix I.2
		No cracking or disbonding at 32°F [0°C] at severity > 2.0°/PD permanent deflection		
Total Interface Contamination	B	Maximum 30%	1	Appendix K
Interfacial Porosity	B	Rating of 1 – 4 inclusive	1	Appendix K
Cross-section Porosity	B	Rating of 1 – 3 inclusive	1	Appendix K

9.2 INFORMATION REQUIRED

The following identification markings shall be placed on each coated pipe:

a. Applicator's name or mark,
b. Pipe size, wall thickness, grade and pipe manufacturer,
c. Date of coating application,
d. Coating material identification, and
e. Additional markings as agreed to by the applicator and purchaser.

9.3 RESTENCILING

9.3.1 Coating Stencil

If a pipe requires rework which invalidates existing coating stencil information, then that pipe shall be restenciled when repairs are completed.

9.3.2 Pipe Mill Stencil

Where pipe mill stencil information is removed during coating operations, applicator shall maintain, in a manner acceptable to the purchaser, traceability of each joint of pipe. The required stencil information of length, grade, dimensions, heat number, joint number and/or other information specified by the purchaser shall be re-applied after coating.

10 Handling, Storage and Shipping of Coated Pipe

10.1 HANDLING

10.1.1 Cooling

After being externally coated and cured, the pipe shall be sufficiently cooled to permit handling.

10.1.2 Separators

Coated pipe shall be stacked in a manner and with materials of a type, thickness and width necessary to maintain a suitable spacing between each pipe and all adjacent coated pipe without damage to the coating.

10.1.3 Padding of Handling Equipment

Coated pipe shall be handled in such a way that damage to the pipe and/or coating is avoided. Equipment used in the handling and storage of coated pipe shall be appropriately padded.

10.1.4 Repair of Damaged Coating or Pipe

Pipe or coating that is damaged during handling shall be repaired in accordance with the requirements for the applicable pipe specification or standard or Section 7 of this recommended practice.

10.2 STORAGE

10.2.1 Coated Pipe Stored Off Ground

Pipe shall not be stored directly on the ground. Pipe racks shall be of sufficient height to prevent water from contaminating the interior of exterior of the pipe, and shall be constructed to allow water to drain from each joint of racked pipe. All rows shall be restrained to prevent joints from rolling.

10.2.2 Separation of Orders, Grades, Wall Thicknesses, Etc.

Coated pipe of different specifications (i.e., size, wall, grade, manufacturer) shall be stored in such a manner as to be clearly identifiable at all times.

10.3 SHIPPING

10.3.1 Load Configuration

The load configuration shall be agreed on between applicator and purchaser.

10.3.2 Dunnage

The coated pipe shall be shipped using sufficient and proper dunnage and separators to adequately protect the pipe and coating.

10.3.3 Rail Shipment

Rail shipments shall be in accordance with API 5L1.

10.3.4 Barge Shipment

Barge shipments shall be in accordance with API 5LW.

10.3.5 Protected From Damage (Gravel or Debris)

Pipe shall be loaded in a manner to minimize damage from gravel or debris.

APPENDIX A—SPECIFIC GRAVITY DETERMINATION

A.1 Scope

To determine the specific gravity of a virgin powder coating material. Two methods shall be allowed for specific gravity determination; the procedure used shall be designated on the supplier's data sheet.

A.2 Liquid Displacement Test Method

This method covers the determination of the specific gravity of coating material by the liquid displacement method.

A.2.1 EQUIPMENT

Volumetric flask, 100 ml
Balance accurate to 0.1 gram
Mineral spirits

A.2.2 PROCEDURE

A.2.2.1 Accurately weigh the flask and record the weight, which shall be designated WP.

A.2.2.2 Add approximately 20 grams of coating material to the flask and weigh the flask with coating material. Record the weight, which shall be designated WFP.

A.2.2.3 Add sufficient mineral spirits to cover and wet out the coating material. Stopper the flask and agitate it for several minutes in order to ensure that there are no air pockets or lumps of dry coating material. Wash the stopper and walls of the flask down with mineral spirits until they are free of any coating materials and fill the flask to the 100 ml level. Weigh the flask, coating material and liquid together to obtain WFPL.

A.2.2.4 Clean and dry the flask, fill with mineral spirits to the 100 ml level, and weigh to determine the weight (WFL) of the mineral spirits used.

Density of Mineral Spirits DL = (WFL – WF)

A.2.2.5 Calculate the specific gravity of the coating material according to the following equation:

Specific Gravity of Coating Material

$$\text{S.G.} = \frac{(W_{FP} - W_P)}{100 - \left(\frac{W_{FPL} - W_{FP}}{D_L}\right)}$$

A.3 Air Pycnometer Test Method

Specific gravity of the coating material shall be conducted using an air comparison pycnometer or equivalent.

A.4 Report

A.4.1 Powder manufacturer.

A.4.2 Product type.

A.4.3 Batch number and date tested.

A.4.4 Specific gravity calculated and procedure used.

APPENDIX B—GET TIME DETERMINATION

B.1 Scope

To determine the gel time of a coating material. Two procedures are allowed for gel time determination; the procedure used shall be reported on the supplier's data sheet. Tests shall be made in triplicate and averaged.

B.2 Equipment

Hot plate
Stop Watch or Electric Timer: 0.1 second interval
Spatula or other stirring device
Draw down bar:
gap depth 0.012 – 0.014 in. [300 – 360 microns]
Thermocouple

B.3 Procedure

B.3.1 PROCEDURE A

B.3.1.1 Gel time shall be conducted by placing approximately 0.5 gram of coating material on a hot plate stabilized at 400°F + 5°F [204°C + 3°C]. Use a spatula to coat out at least one square inch [650 mm^2] to a uniform thickness. Start the timer as soon as the coating material becomes molten. Stir the coating with a stiff wire or spatula and stop the watch when the coating becomes an unstirrable gelatinous product. The elapsed time is the gel time.

B.3.2 PROCEDURE B

B.3.2.1 Adjust and stabilize the hot plate to 400°F + 5°F [204°C + 3°C] as measured by a thermocouple on the plate surface. Set the draw down bar at a right angle to the hot plate, quickly place a sample of coating material in front of the blade and draw a continuous film across the surface of the hot plate. Start the timer. Applying only light pressure on the spatula, draw it across the strip of melted powder at short intervals.

B.3.2.2 The gel time is the length of time from when the film is applied until the spatula rides up on the gelled surface.

B.4 Report

B.4.1 Powder manufacturer.

B.4.2 Product type.

B.4.3 Batch number and date tested.

B.4.4 Gel time in seconds and procedure used.

APPENDIX C—GLASS TRANSITION AND HEAT OF REACTION DETERMINATION FOR COATING MATERIALS (POWDERS)

C.1 Scope

This test determines the glass transition temperature [Tg] and the amount of exothermic heat of reaction [delta H] of a coating material.

C.2 Equipment

Differential scanning calorimeter (DSC)
Cooling accessory
Analytical balance accurate to 0.1 mg
Aluminum pans and covers
Device to measure areas on the charts produced
Straight pin or dental pick

C.3 Procedure

This procedure is specific to the use of the DSC in the analysis of fusion bonded epoxy (FBE). It does not include procedures for start up, shut down, calibration, or problem analysis.

The typical scan on FBE consists of several runs from ambient temperature to some elevated temperature. In all runs, use a programmed heating rate of 36°F [20°C] per minute.

C.3.1 SAMPLE ACQUISITION AND PREPARATION

The accepted analytical sampling techniques to obtain material representative of the batch being analyzed. Specimen size shall be 1.0 mg –10.0 mg.

Place the specimen in a preweighed aluminum pan. Obtain the specimen weight by subtracting the pan weight from the total weight. The powder should be in a symmetrical low mound in the center of the pan. Puncture the aluminum cover one to four times with the pin for ventilation. Put the cover in place, being careful not to allow the powder to contact the cover. Do not crimp the cover onto the pan.

Be sure that the temperature of the DSC cell is 77°F [25°C] or less. Place the specimen and reference in the DSC cell. Purge the cell continuously with an inert gas such as dry nitrogen.

C.3.2 POWDER CONDITIONING RUN

Heat the specimen to just beyond the Tg0 (typically 158°F [70°C]). It is not necessary to record this run or use it for calculations. Immediately after heating, cool the cell below 77° F [25°C]. This step may be omitted without affecting the heat of reaction or the peak in the exothermic region.

C.3.3 DELTA E RUN

Heat the specimen to a point about 77°F [25°C] beyond the end of the expected exothermic reaction region as determined from a previous powder scan. This temperature is typically 545°F [285°C] but may be as low as 437°F [225°C]. The curve will show a glass transition (Tg0) and a bell-shaped exothermic reaction region. Immediately after heating, cool the DSC cell below 77°F [25°C].

C.3.4 TG1 RUN

Heat the specimen to a point beyond the glass transition temperature (302°F + 18°F [150°C + 10°C]).

C.4 Calculations

The Tg is taken as the point of intersection of the extrapolated baseline at the low temperature end and the tangent to the curve at the inflection point.

Draw the lines to establish the temperature for this intersection for each recorded scan.

The first Tg measured is designated Tg0, that is, the initial glass transition temperature. The second Tg on the powder scan is Tg1.

Draw a straight line from a point on the baseline beyond the Tg0 just before the exothermic reaction occurs to the point where the curve returns to a nearly horizontal path beyond the exothermic reaction. (See Figures 1 and 2.) Measure the area under the curve in the exothermic reaction region and calculate the heat of reaction (delta H), following the instructions provided by the manufacturer of the DSC equipment. Record the temperature of the peak in the exothermic reaction region.

C.5 Report

C.5.1 Report the product and sample identification.

C.5.2 Report the batch number of material.

C.5.3 Report date of testing.

C.5.4 Report Tg0, delta H, Tg1 and the peak of the exothermic reaction region.

C.5.5 Report type of apparatus, method and parameters used.

C.6 Precision

C.6.1 Precision limits apply to two adjacent specimens taken from the same powder sample. The following limits should be used for judging acceptability of results.

C.6.1.1 Repeatability

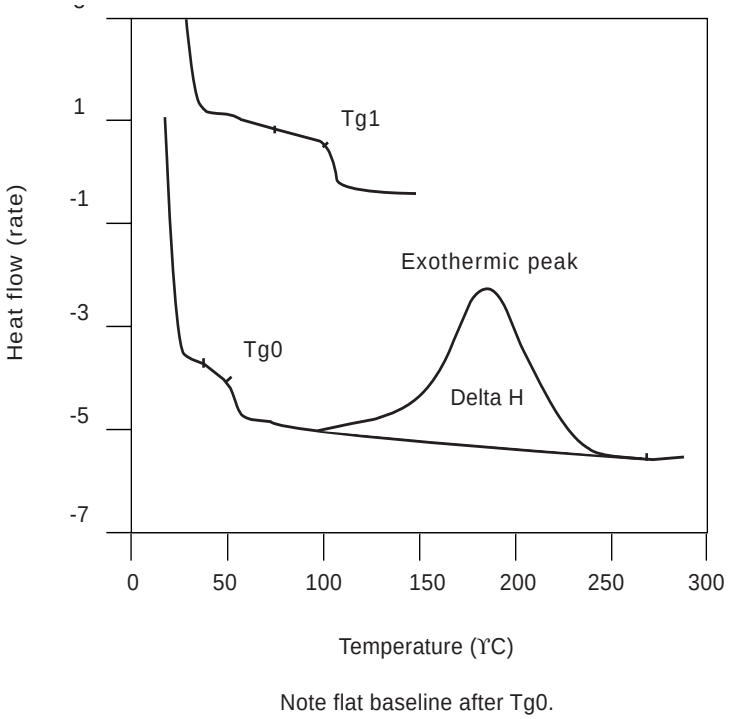
Duplicate results by the same worker should not be considered suspect unless they differ by more than:

C.6.1.1.1 Tg: 5°F [3°C]

C.6.1.1.2 Delta H: 20% of the larger value

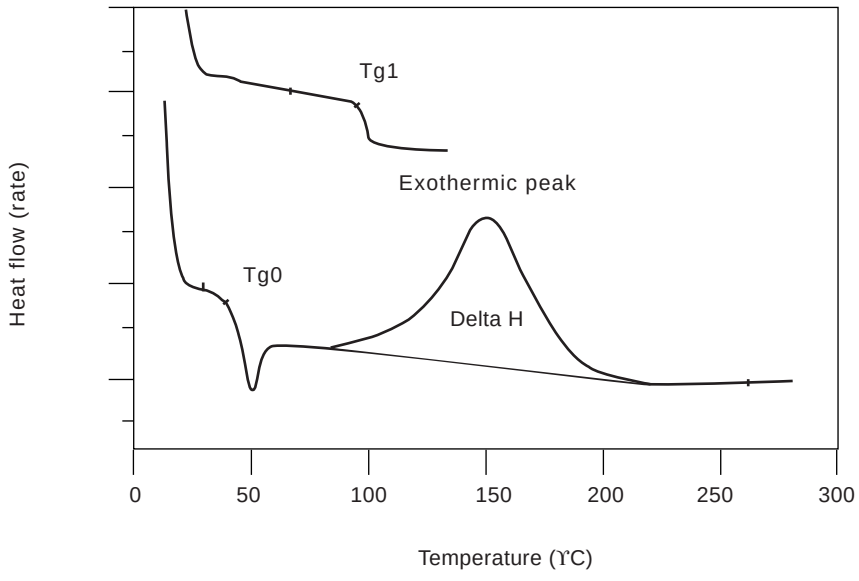
C.6.1.2 Reproducibility

Achieving comparable inter-laboratory results will require strict compliance with this test procedure followed by laboratory comparison testing.



Note flat baseline after Tg0.

Figure 1—DSC Scan on Coating Material with Conditioning Run



Note deep dip just after Tg0.

Figure 2—DSC Scan on Coating Material with No Conditioning Run

APPENDIX D—MOISTURE ANALYSIS DETERMINATION

D.1 Scope

To determine water content of coating materials by direct titration with Karl Fischer Reagent to an electrometric endpoint.

D.2 Equipment and Reagents

D.2.1 EQUIPMENT

Aquameter apparatus, Photovolt Aquatest IV or equivalent
Lab mill
Analytical balance
15 ml serum bottle and cap
Spatula
Metal pipetting holder—1 ml
1 ml syringe (Luer-Lok or equivalent)
4.5 in. (110 mm) hypodermic needle
Plastic syringe—10 ml
Automatic—50 ml

D.2.2 REAGENTS

Chloroform
Generator solution
Vessel solution (parts A and B)
Neutralizing solution

D.2.3 SAFETY PRECAUTIONS

Karl Fischer reagent is toxic. During handling of the solutions, limit breathing of the vapors and perform all operations in a well ventilated area.

D.3 Procedure

Run duplicate samples, following equipment manufacturer's instructions.

D.4 Report

D.4.1 Powder manufacturer.

D.4.2 Product type.

D.4.3 Batch number.

D.4.4 Date tested.

D.4.5 Record the two results and their average.

APPENDIX E—PERCENT TOTAL VOLATILE ANALYSIS BY MASS

E.1 Scope

Determine total volatile content in the coating material.

E.2 Equipment

Analytical balance having weight precision of 0.1 mg
Oven controllable within + 5°F [+ 3°C]
Sample container (laboratory aluminum dishes)
Desiccator

E.3 Procedure

E.3.1 Pre-heat oven to 300°F [150°C].

E.3.2 Weigh an aluminum weighing pan and record.

E.3.3 Place 2 + 0.2 grams of desired sample into the pan. Re-weight and record (run in duplicate).

E.3.4 Place the sample into the oven for two hours. Use the following formula to calculate percent volatile (%V).

X = Weight of empty pan
Y = Weight of sample plus pan
Z = Weight of sample ($Y - X = Z$)
A = Weight of pan and sample after heating and cooling off
B = Weight of sample after heating and cooling ($A - X = B$)
C = Weight lost in grams ($Z - B = C$)

% Total Volatile By Mass

$$\%V = \frac{100 \times C}{Z}$$

E.4 Report

E.4.1 Product code.

E.4.2 Batch number.

E.4.3 Date of test.

E.4.4 Percentage of total volatile by mass.

APPENDIX F—ABRASION TEST METHOD

F.1 Scope

The test method describes the evaluation of fusion bonded epoxy coatings for resistance to abrasion in the laboratory.

F.2 Equipment

Taber Abraser Model 503 or equivalent
Analytical balance, accurate to 0.1 mg.

F.3 Procedure Parameters

This test method follows ASTM D4060, "Abrasion Resistance of Organic Coatings by the Taber Abraser." Parameters are stipulated below. Refer to the ASTM Standard Test Method for full details on this procedure.

F.3.1 Duplicate specimens of each coating shall be tested.

F.3.2 Coating shall be applied to flat sheet steel panels 4 in. [100 mm] square and 0.032 in. [0.8 mm] thick. Coating shall be applied and cured according to the manufacturer's recommendations. For pipe coatings intended for application to preheated thick wall section surfaces, the flat sheet steel panels can be attached to thicker steel plate, which is then preheated, functioning as a heat reservoir for full coating cure. Thick section plates cannot be coated directly for use in this test, as the panel weight would be beyond the capacity of the typical analytical balance.

F.3.3 Coating shall be as applied with sufficient thickness so that the substrate is not exposed during testing.

F.3.4 The abrasive wheels shall be CS-17.

F.3.5 The load shall be 1000 grams on each wheel.

F.3.6 The test shall be run for at least 1000 cycles. If the coating wears through during the test, exposing the substrate, the test shall be stopped at that point, and wear cycles reported to the point where substrate exposure occurred. If appropriate, the test shall be repeated with a thicker coating.

F.4 Report

F.4.1 Powder manufacturer.

F.4.2 Product type.

F.4.3 Batch number and date tested.

F.4.4 Number or cycles and mass loss in milligrams per 1000 cycles.

APPENDIX G—24-HOUR CATHODIC DISBONDMENT TEST

G.1 Scope

This test provides an accelerated assessment of the coating adhesion for laboratory and production ring test samples.

G.2 Equipment

DC power supply unit

Platinum or platinum coated anode wire

Electrolyte solution consisting of 3% by weight sodium chloride (NaCl) in distilled water

Plastic tubes 3.5 in. [90 mm] diameter, 4 in. [100 mm] long

High resistance volt/amp meter

Hot plate or oven capable of maintaining a test cell at 150°F [66°C] within a range of 5°F [+ 3°C]

Calomel reference electrode

Utility knife

Felt tip marker

Thermometer capable of measuring 150°F [66°C]

Sealant

G.3 Sample Preparation Procedure

G.3.1 QUALIFICATION SAMPLE

The coating qualification test sample shall be 4 in. [100 mm] square by 0.25 in. [6 mm] thick, prepared and coated in accordance with 3.2 of the body of this recommended practice.

G.3.2 PRODUCTION TEST RING SAMPLE

The test ring sample shall be a segment of not less than 4 in. x 4 in. [100 mm x 100 mm] cut from the production test ring. If pipe is not large enough for such a sample size, a segment of pipe will be tested as shown in Figure 3.

G.3.3 A 1/8 in. [3.2 mm] diameter intentional holiday shall be drilled through the coating near the center of the specimen so that it will be in the center of the assembled cell. A full 1/8 in. [3.2 mm] diameter area of the substrate shall be exposed, but the hole shall not extend through the test sample.

G.3.4 The complete test cell shall be assembled, using a waterproof sealant, as shown in Figures 3 and 4.

G.3.5 When testing specimens cut from pipe, it is necessary to employ a heat transfer medium (e.g., steel shot or grit) in order to provide uniform heating of the specimen. Use of a metal pan partially filled with the heat transfer medium into which the specimen is implanted is preferable (see Figure 2).

G.4 Test Procedure

G.4.1 Pour approximately 350 ml of electrolyte into the completed test cell assembly. Using a hot plate or oven, maintain the electrolyte temperate at 150°F + 5°F [66°C + 3°C] for 24 hours, confirmed by measurements with an immersion thermometer.

G.4.2 Connect the negative lead from the power supply to the specimen and the positive lead to the anode as shown in Figure 1.

G.4.3 Apply a potential of negative 3.5 volts with respect to the calomel reference electrode to the test specimen.

G.4.4 Monitor the voltage, temperature, and electrolyte level as required to maintain consistent test conditions.

G.4.5 After 24 hours, drain the electrolyte, dismantle the cell, and cool the specimen to room temperature.

G.5 Evaluation

G.5.1 Insert the tip of a utility knife blade under the coating at the holiday. Use only a prying action in an attempt to remove the coating. Continue the removal of the adjacent coating until increased resistance is encountered. Do not thrust through the coating substrate to remove the coating.

G.5.2 The area of total disbondment will be indicated by the complete absence of coating remnants on the substrate as determined by visual examination without the aid of magnification.

G.5.3 Measure the disbondment radius from the edge of the holiday to the point that coating is not removed cleanly from the substrate.

G.6 Report

Report the maximum disbondment radius.

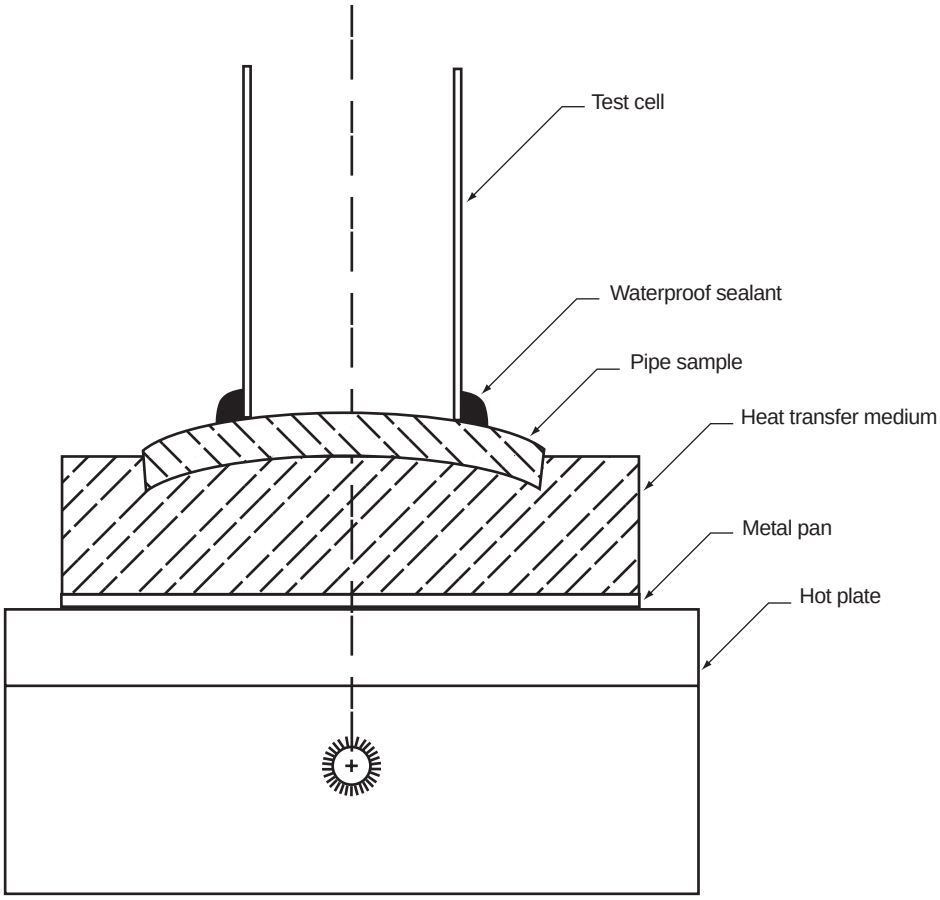


Figure 3—Cathodic Disbondment Test Set Up for Pipe Ring Samples

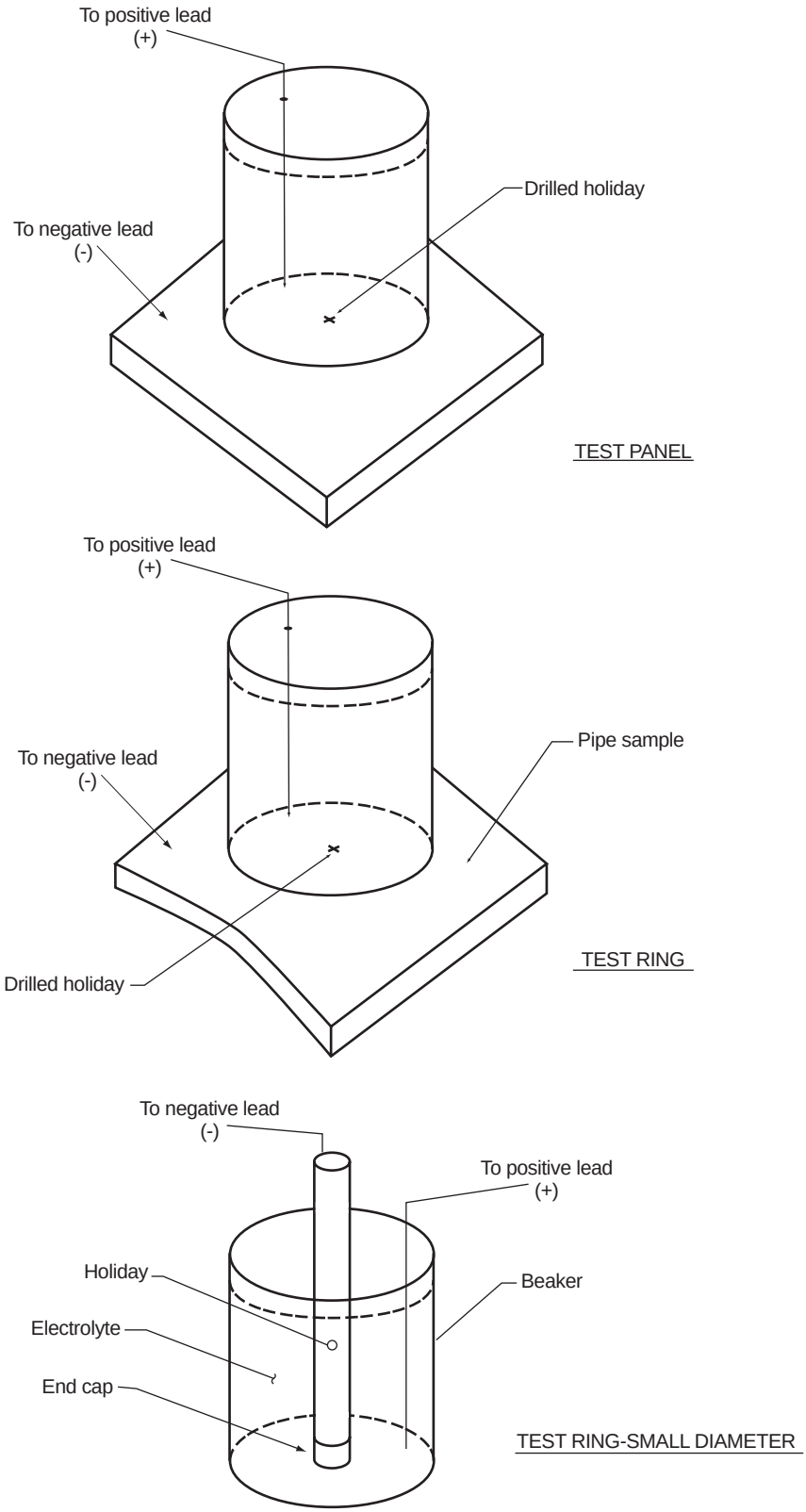


Figure 4—Schematic of Apparatus for Cathodic Disbondment Test

APPENDIX H—CHEMICAL RESISTANCE TEST

H.1 Scope

This test is intended for evaluating the resistance of pipe coating materials when exposed to various concentrations of reagents or suspected soil contaminants.

H.2 Equipment

pH meter—Capable of measuring pH of aqueous solutions with glass electrode

Thickness gauge—Capable of measuring the coating thickness

Glass jars—Large enough to provide adequate exposure to both the liquid and vapor states of reagent.

H.2.1 VARIOUS TEST REAGENTS

Hydrochloric acid in distilled water, 2.5 – 3.0 pH

10% sodium chloride and sulfuric acid in distilled water, 2.5 – 3.0 pH

10% sodium chloride in distilled water

Distilled water

5% sodium hydroxide in distilled water, 12 – 14 pH

Saturated solution mixture of equal parts by mass of magnesium carbonate and calcium carbonate in distilled water

H.3 Procedure

H.3.1 Place a single specimen in a vertical position in each container.

H.3.2 Fill the jar with the selected reagent so that the liquid level covers one half of the coated specimen.

H.3.3 Cover the jar, hold it at 68°F + 5°F [20°C + 3°C] for 90 days and maintain the initial reagent level by addition when applicable.

H.3.4 After 90 days immersion, examine the test specimen for bleaching, swelling, softening, cracks, and blisters.

H.4 Report

H.4.1 Epoxy powder product and batch number.

H.4.2 Date of start and end.

H.4.3 Condition of the coating after 90 days.

H.4.4 Temperature of test.

H.4.5 Duration of test.

H.4.6 Initial thickness of coating.

H.4.7 Method of preparing test specimen.

H.4.8 Each test reagent used.

APPENDIX I—FLEXIBILITY TEST

I.1 Mandrel Method

I.1.1 SCOPE

To assure the coating has adequate flexibility for field bending or reeling.

I.1.2 EQUIPMENT

Hydraulic press
Bending mandrels of fixed radii
Ice bath
Freezer
Microscope

I.1.3 TEST SPECIMEN

I.1.3.1 Qualification Specimen

Each specimen shall be 1 in. [25 mm] by 8 in. [200 mm] by 0.25 in. [16 mm] thick.

I.1.3.2 Test Ring Specimen

Each specimen shall be 1 in. [25 mm] by 8 in. [200 mm] by pipe wall thickness, with the 8 in. [200 mm] dimension parallel to the axis of the pipe.

I.1.4 PROCEDURE

I.1.4.1 Qualification Specimen

I.1.4.1.1 Place three test specimens into the freezer for a minimum of one hour and allow to cool to 0°F [– 18°C].

I.1.4.1.2 Bend the specimens over a mandrel with a radius that will insure a deflection of at least 3°/PD, completing the bend in approximately 30 seconds.

I.1.4.1.3 After specimens achieve room temperature, visually inspect the specimens under 40 power magnification for cracking and disbonding. Specimens shall be evaluated within 4 hours.

I.1.4.2 Test Ring Specimen

I.1.4.2.1 Place the specimen into the ice bath, a mixture of ice and water, for one hour so as to allow them to cool to 32°F [0°C]. Alternately, a freezer may be used to chill the specimen to the required temperature.

I.1.4.2.2 Calculate the required mandrel radius with the following formula:

R = Mandrel radius

t = Specimen thickness or [for test rings] effective strap thickness (see Figure 5).

s = 2.5°/PD (Strain or deflection expressed in degrees per pipe diameter).

I.1.4.2.3 Where a mandrel of the calculated radius is not available, the mandrel of next smaller radius shall be used.

I.1.4.2.4 Bend the test specimens over the radius, completing the bend in approximately 30 seconds.

I.1.4.2.5 Visually inspect the specimens under 40 power magnification for cracking and disbonding.

I.1.5 REPORT

I.1.5.1 Specimen thickness, effective strap thickness (for test rings) and mandrel radius.

I.1.5.2 Whether the specimen has any cracks, or disbondment of the coating, which exposes the substrate; the presence of any such defect within 1/8 in. (3 mm) of the strap edge or stress marks does not constitute a failure.

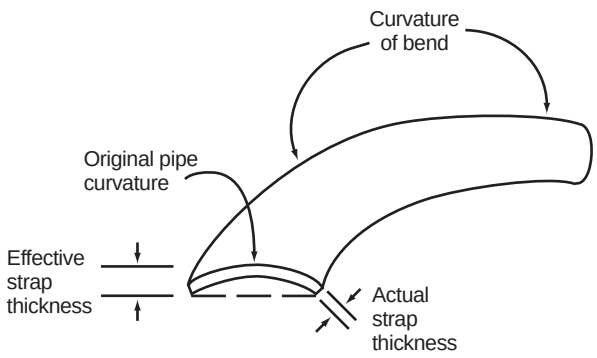


Figure 5—Effective Strap Thickness

I.2 Four Point Bend Method

I.2.1 SCOPE

To assure that the coating has adequate flexibility for field bending or reeling.

I.2.2 EQUIPMENT

Four point bend apparatus
Ice bath
Freezer
Microscope
Light
Chart with "arcs of known radii"

I.2.3 PRODUCTION TEST RING SAMPLE

Each specimen shall be 1 in. [25 mm] by 8 in. [200 mm] by the pipe wall thickness, with the 8 in. [200 mm] dimension parallel to the axis of the pipe (see Figure 5 of Appendix I.1).

I.2.4 PROCEDURE

I.2.4.1 Place three test samples into the ice bath, a mixture of ice and water, for one hour, so as to allow the samples to cool to 32°F [0°C]. Alternately, a freezer may be used to chill the samples to the required temperature.

I.2.4.2 Position the test samples in the bending apparatus and complete the bend in approximately 30 seconds (see Figure 6).

I.2.4.3 As the bend proceeds, visually look for cracks in the coating. Ignore those within 1/8 in. [3.2 mm] of the strap edge which may be caused by stress risers. Also ignore those within 1/4 in. [6.4 mm] of the pin contact points because of overbend due to bar breakover.

I.2.4.4 All three specimens shall be bent to achieve a minimum permanent deflection of 2.0°/PD.

I.2.4.5 Match the external curved portion of the strap to one of the arcs of known radius, keeping the external curved surface perpendicular to the template of drawn arcs.

I.2.4.6 Calculate the permanent strain with the following formula:

$$\text{Degrees/PD} = \frac{57.3t}{R - \frac{t}{2}}$$

t = effective strap thickness (see Figure 5 of Appendix I.1).

R_t = bend radius of outer curve of test specimen

I.2.4.7 Visually inspect the specimens under 40 power magnification for cracking and disbonding.

I.2.5 REPORT

I.2.5.1 Effective strap thickness, bend radius of outer curve of test specimen, results in degrees per pipe diameter, and whether the specimen passes or fails.

I.2.5.2 The presence of any defect within 1/8 in. [3 mm] of the strap edge and/or within 1/4 in. [6 mm] of the pin contact points, or stress marks do not constitute a failure (a stress mark is defined as a discoloration but not an open fissure in the coating resulting from the bending operation).

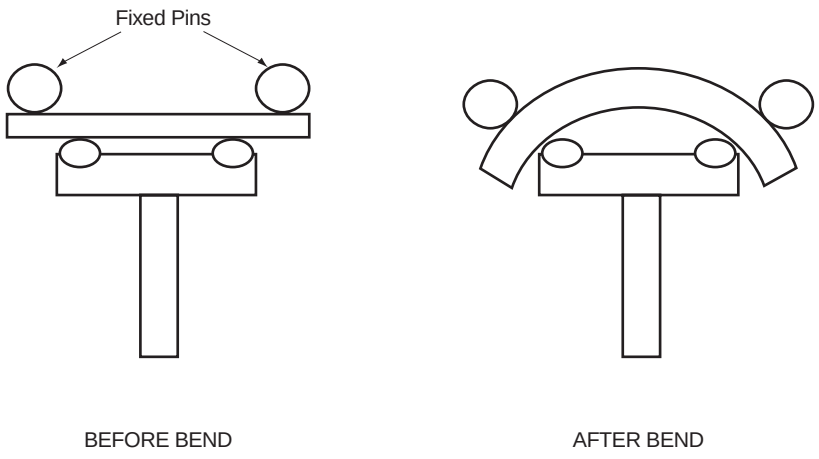


Figure 6—Four Point Bend

APPENDIX J—IMPACT TESTING

J.1 Scope

To provide a method for assessing coating resistance to damage.

J.2 Equipment

Gardner impact tester or equivalent
Holiday detector

J.3 Test Specimen

Each test specimen shall be 4 in. [100 mm] square by 0.25 in. [6 mm] thick. Specimens shall be prepared and coated in accordance with 3.2 of the body of this recommended practice.

J.4 Procedure

J.4.1 The Gardner Impact tester shall be modified as follows:

J.4.1.1 The tup used shall accommodate a 0.625 in. [15.9 mm] diameter ball bearing. The tup shall have a hardness of Rockwell C (HRC) 50-55.

J.4.2 The modified impact tester shall be screwed to a block of laminated wood. The wood block should measure approximately 24 in. [610 mm] on each side and have a top facing of hardwood.

J.4.3 Impact test shall be carried out with 2.2 lb [1 Kgf] weight in a 39 in. [1 m] graduated slotted tube. The ball bearing shall be rotated every 10 impacts to a new location and replaced after 200 impacts.

J.4.4 Allow the weight to fall into the tup and ensure the point of impact is supported on a base which does not permit the metal substrate to deform or bend. If a specimen has undergone any form of substrate deformation, then the result obtained from that specimen is invalid.

J.4.5 Check each impact indentation on the test specimen for substrate exposure with a holiday detector. The detector shall have a wet sponge search electrode set at 67.5 volts.

J.5 Report

The maximum amount of energy the coating may absorb without substrate exposure in in.- lb. or J.

APPENDIX K—MICROSCOPIC EXAMINATION FOR POROSITY AND VISIBLE INTERFACIAL CONTAMINATION UNDER FUSION-BONDED EPOXY PIPELINE COATINGS

K.1 Scope

This method provides a numerical value for the level of porosity in a coating applied in powder form to a heated metal substrate. It also provides an indication of the amount of visible residue left on the metallic substrate after the abrasive cleaning process.

K.2 Equipment

Microscope 40 power

Bend equipment

Freezer, dry ice, or other chilling media

K.3 Test Specimen

Cut a coupon with dimensions of approximately 1 in. x 8 in. [2.5 cm x 20 cm] with the long side parallel to the axis of the pipe. Rapidly bend the chilled specimen over a short radius mandrel to cause the coating to crack. Remove a coating chip for evaluation.

K.3.1 CROSS-SECTIONAL POROSITY

Compare the magnified image of the cross section of the coating to the pictorial chart in Figure 7 and estimate the level of porosity.

K.3.2 INTERFACIAL POROSITY

At areas of cohesive failure of the coating near the substrate, estimate the interfacial porosity level using the pictorial chart in Figure 8.

K.3.3 PERCENTAGE OF TOTAL INTERFACE CONTAMINATION

At areas of adhesive failure, examine the backside (substrate side of the delaminated coating chip) under magnification and compare Figure 9 to estimate the percentage of total interface contamination.

K.4 Report

K.4.1 Product and/or sample identification.

K.4.2 Date of testing.

K.4.3 Cross-sectional porosity rating.

K.4.4 Interfacial porosity rating.

K.4.5 Percent of total interfacial contamination.

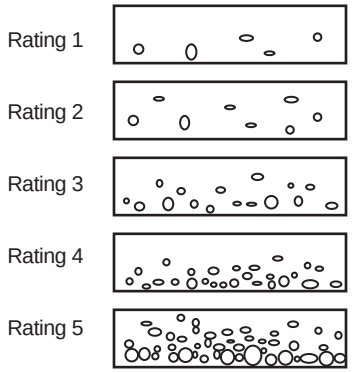


Figure 7—Examples of Cross-section Porosity

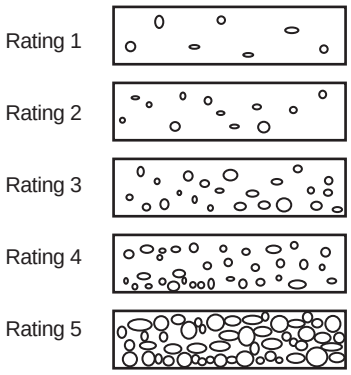


Figure 8—Examples of Interface Porosity

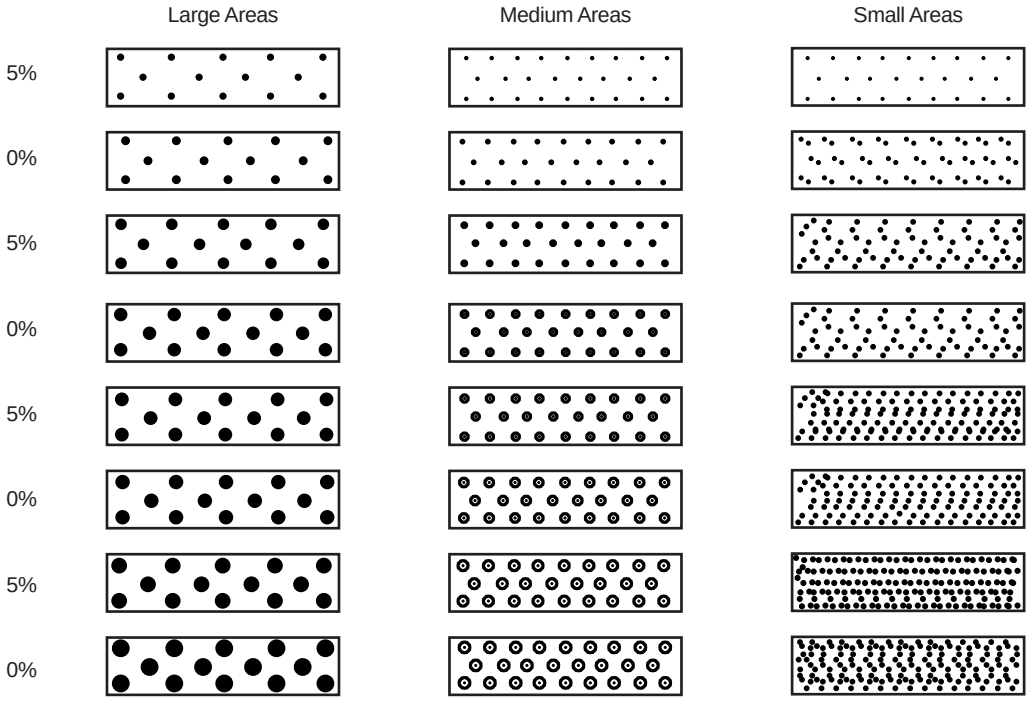


Figure 9—Interfacial Contamination Comparison Charts

APPENDIX L—HOT WATER SOAK TEST

L.1 Scope

This test provides an accelerated assessment of the coating quality and verification of the coating system process control.

L.2 Equipment

The equipment required shall be as follows:
Slow cooker (crock pot)
Temperature controller
Thermometer
Utility knife
Tap water
Test cell
Hot plate
Heat transfer medium

L.3 Test Specimen

L.3.1 QUALIFICATION SAMPLE

The coating qualification test sample shall be 4 in. x 0.250 in. [100 mm x 6.4 mm] thick and coated in accordance with 3.2 of the body of this recommended practice.

L.3.2 PRODUCTION TEST RING SAMPLE

The test ring sample shall be a segment of not less than 4 in. [100 mm] square by pipe wall thickness cut from the production test ring.

L.4 Test Procedure

L.4.1 Fill the slow cooker with sufficient tap water to submerge the specimen and preheat to 203°F + 5°F [95°C + 3°C]. Once the water has reached the desired temperature, place the specimen in the slow cooker for a minimum of 24 hours.

L.4.2 Remove the test specimen after the minimum time period and while the specimen is still warm, scribe a rectangle, approximately 1.25 in. x 0.75 in. [30 mm x 15 mm] through the coating to the substrate, using the utility knife. Air cool the specimen to 68°F + 5°F [20°C + 3°]. Within 1 hour of removal from heat, insert the tip of the utility knife under the coating at a corner of the scribed rectangle. Use a levering or lifting action to remove the coating. Continue inserting the tip of the knife under the coating until either all the coating is removed or the coating demonstrates a definite resistance to the levering action. Do not plow through the coating substrate to remove the coating.

L.5 Evaluation

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

L.6 Report

The following information shall be reported to the purchaser by the applicator:

a. Epoxy powder batch number,
b. Date of testing, and
c. Adhesion rating.

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