

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



Documents

Document Sharing Hub

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:

¹Higher values for bend severity and lower values for temperature are subject to agreement between purchaser and supplier.

²Either 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 ft² [0.05 m²] per location and the maximum total grind area is 2 ft² [0.2 m²] 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 cm² [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 cm² [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 12³/₄", which may be on the outside surface or as agreed on between the applicator and the purchaser.