Specification for Fusion-Bonded Epoxy for External Pipeline Coating

Engineering Services, L.P. 832-418-9180
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1.0 SCOPE

1.1 General
This Specification covers the minimum material, application, and handling requirements for fusion-bonded epoxy (FBE) powders used for external pipeline coating.

1.2 Conflicting Requirements
Several testing and surface preparation standards are referenced in this Specification. The latest editions of these standards shall be considered a part of this Specification. In case of conflict, this Specification will take precedence over the referenced documents.

1.3 Industry Standards
Fusion-bonded epoxy shall conform to the following Specifications, except as supplemented in this Specification. The latest published industry standard shall be used.

1.3.1 Steel Structures Painting Council (SSPC)
SSPC SP1 Surface Preparation
SSPC SP10 Near-White Metal Blast
SSPC VIS-1 Pictorial Surface Preparation Standards for Painting Steel Surfaces

1.3.2 National Association of Corrosion Engineers (NACE)
RP-0490-90 Recommended Practice, Holiday Detection of External Fusion-Bonded Epoxy Pipeline Coatings 10 to 30 mil Thick

2.0 MATERIALS

2.1 Piping
Piping shall be supplied without varnish or mill lacquers.

2.2 Coating
Shop-applied external coating material shall be one of the following fusion-bonded epoxy powders:

2.2.1 For lines operating at temperatures up to 150°F
• 3M Scotchkote 206N
• International Interpon HD3005
• Nap-Guard Mark X
• Lilly Pipeclad
• Valspar D1003LD

2.2.2 For lines operating at temperature up to 230°F
• 3M Scotchkote 226N or equivalent

2.3 Batch Information
Each container of powdered coating materials used by the Applicator shall be marked with the following information:

2.3.1
• The manufacturer's name
• The material identification number
• The batch number
• Date of manufacture
• The shelf life and storage temperature limits

The fusion bond epoxy manufacturer shall supply the information listed below for each batch of powder. Standards for comparison shall also be provided for each item. This information will be used to check that no changes have been made in the epoxy formulation.

• Infrared scan of powder and typical powder scans for comparison.
• Gel time at recommended application temperature.
• Particle size distribution.

2.3.3 Coating powder shall be segregated by batch numbers during shipment, storage, and handling. Batches shall be used consecutively during coating application and shall not be mixed except when necessary to keep the coating process continuous.

2.3.4 No powder stored beyond the manufacturer's recommended shelf life shall be used for coating pipe.

2.4 Repair Materials

2.4.1 Materials for touch-up or repairs shall be the original powder, the manufacturer's two-part epoxy repair material, or other compatible material approved by the powder manufacturer.

2.4.2 Coating and repair materials shall be stored, handled, and applied in strict accordance with the manufacturer's Specifications or as directed by an authorized manufacturer's representative.

3.0 APPLICATION

3.1 General

3.1.1 The fusion-bonded epoxy coating shall be applied in accordance with the coating manufacturer's application procedures. The Applicator must have a copy of these procedures at the site where the coating is being applied. Any deviation from the coating manufacturer's application procedures shall be submitted to the Company for approval.

3.1.2 It shall be the Applicator's responsibility to stop the coating process at any time when conditions may exist that might adversely affect the coating quality. The Company inspector may reject any product not proven by the Applicator to be in compliance with this Specification.

Proper equipment for the handling, unloading, and temporary storage of bare pipe shall be used to avoid any damage to bare pipe and pipe ends, or obliteration of necessary pipe markings. The Applicator shall also take special care to avoid damage to any internal coatings during all phases of the external coating process.

The finished coating shall have a cutback at each end of the pipe. The length of the cutback shall be 1 inch minimum, 2 inches maximum, measured from the end of the pipe. If coating materials accumulate within these areas, the cutback areas shall be buffed free of coating material.

3.2 Surface Preparation

Prior to abrasive cleaning, all oil, grease, salts, and other deleterious materials shall be removed by solvent cleaning in accordance with SSPC SP1 or by detergent washing or steam cleaning. No residue that will affect adhesion shall be left on the surface.

The Contractor shall take measures to prevent visible and non-visible surface contamination of bare pipe during transport, handling, and storage. Prior to surface coating, the Applicator shall demonstrate by testing the abrasive blast material used to clean the pipe for the presence of water-soluble salts such as chlorides, sulfates, and nitrates. If salt contamination is detected, salts shall be removed by phosphoric acid (5 percent solution) and/or high pressure demineralized water-based treatment.
3.2.2 The pipe shall be preheated prior to blast cleaning to a temperature at least 5 degrees in excess of the dew point or higher if recommended by coating manufacturer or Applicator. All pipe shall be preheated in a uniform manner to avoid distortion of the pipe and/or damage to internal coatings.

3.2.3 All external surfaces to be coated shall be cleaned to a near-white metal finish in accordance with Specification SSPC SP10. Abrasive cleaning on steel pipe surface shall have a slightly angular pattern. Particle hardness and size distribution of the shot employed shall be continually controlled by screening to ensure that the surface profile after cleaning shall have a nominal height of 3.0 mil, with a minimum height of 2.5 mils, and a maximum height of 4.0 mil as measured by Testex Press-O-Film replication tape and SSPC-VIS-1. All cleaning shall be done in such a manner that beveled ends and any internal coating will not be damaged.

3.2.4 For consistent surface finish, a stabilized working mix shall be maintained by frequent small additions of new abrasive commensurate with consumption; infrequent large additions shall be avoided.

3.2.5 The working abrasive mix shall be maintained clean of contaminants by continuous effective operations of cleaning machine scalping and air wash separators.

3.2.6 After abrasive cleaning and before coating, the surface to be coated shall be carefully inspected for metal defects which may affect coating application, i.e., scabs, slivers, gouges, or laminations. The Applicator shall be responsible for the repair of any defects which can be repaired by filing or grinding of the repair and for restoring the anchor pattern at the locations of such repairs when the size of the repair exceeds 3 inches in any direction. The tools and manner employed to remove metal defects shall not contaminate the surface.

3.2.7 If the profile is destroyed over a single area greater than 25 in² or over a total area greater than 0.5% of a pipe joint, the pipe shall be reblasted at no expense to the Company.

3.2.8 Surface preparation shall not reduce the pipe wall thickness below the minimum required by the pipe Specification.

3.2.9 After surface preparation is complete and before heating the pipe, pressurized air or a vacuum shall be used to remove all loose abrasive, metal, or other contaminating particles. Both the exterior and interior of the pipe shall be cleaned. The air shall be properly filtered to be clean and dry so as not to contaminate the pipe.

3.2.10 Total elapsed time between cleaning and coating of the cleaned surface shall be kept to a minimum to avoid the formation of oxides on the surface. Oxidation of the steel prior to coating, in the form of “blooming” or other apparent oxide formation, is not acceptable. Visual formation of such oxides shall cause the entire pipe to be recleaned prior to coating. Any pipe not coated within three hours after cleaning shall be completely recleaned before coating at Applicator’s expense.

3.3 Heating

3.3.1 Before coating, the pipe shall be heated so that its temperature is within the application temperature range recommended by the coating
manufacturer when it reaches the coating application area. The temperature shall not exceed 500°F. Oxidation (bluing) of the steel is not acceptable. If such oxidation should occur, the pipe shall be allowed to cool and recleaned.

3.3.2 The furnace atmosphere shall be such that the clean pipe surfaces are not contaminated.

3.3.3 The temperature of the pipe shall be monitored continuously and recorded by means of thermometers and/or optical pyrometers.

3.3.4 For accurate control of pipe temperature, the pipe shall be periodically checked with "Tempilstik" heat-indicating crayons or other suitable devices, provided that the amount of material deposited and the length of marks will be limited to 1/8-inch wide by 1/2-inch long. The Tempilstik marks shall be wire brushed from the pipe surface before application of the coating.

3.3.5 Pipe heated above 500°F shall be scrapped and replaced by Applicator. The actual Company invoiced cost of scrapped pipe, including pipe, coating, and transportation, shall be deducted from the amount due the Applicator.

3.4 Surface Conditioning

Unless otherwise specifically deleted in the purchase order or request for quotation, after the appropriate surface cleanliness has been achieved, SSPC SP10, the pipe shall be treated as follows:

3.4.1 A solution of 1 part Oakite 31 or Foxbond 1099 to 9 parts clean water shall be applied by spray or gravity feed at the rate of 1 gallon per each 100 square feet of pipe surface (1 liter per each 2.5 square meters of pipe surface). Solution shall be agitated periodically or continuously as required to prevent setting of the mix.

3.4.2 A uniform pH of 1 or less shall be maintained over the entire surface of the treated area as checked with pH paper.

3.4.3 Treatment shall be for a minimum of 20 seconds with the pipe surface temperature between 110°F (66°C). With approval of Company, treatment time can be extended at the rate of 1 second for each degree below 110°F (2 seconds for each degree below 43°C).

3.4.4 Thorough, clean, high pressure water rinse at 500-1000 psi (35-670 bar) tip pressure must follow to remove any treatment residue. A minimum of 2-1/2 gallons of fresh water per 100 square foot of pipe surface must be used (4.0 liters/10 square meters). The wetted surface of the rinsed pipe shall have a pH of 6 or greater or not less than the original pH of the fresh rinse water if approved by the inspector. Water must be potable and have not more than 200 ppm total dissolved solids and 50 ppm chlorides.

3.4.5 The wash solution and rinse will result in a weak concentration of approximately 1.5% or less phosphoric acid. It shall be the responsibility of the Applicator in the proper handling and disposing of this waste including neutralizing if required, in a manner recommended by the manufacturer.

3.5 Coating Application

3.5.1 Prior to coating the surface shall be properly prepared according to the
coating manufacturer's requirements/recommendations. The pipe shall be coated while its surface temperature is within the manufacturer's recommended temperature limits.

3.5.2 The coating shall be applied to produce a uniform dry coating thickness of:

14 mil for lines operating at temperatures up to 150°F

12 mils minimum for lines operating at temperatures up to 230°F coated with 3M Scothkote 226N. (Minimum required thickness on equivalent high temperature coatings shall be according to manufacturer’s recommendation.)

Any coating area measured to be more than 2 mil thinner than the specified thickness will be cause for rejection of that joint.

3.5.3 Powder batches shall not be mixed together except as necessary to keep the coating process continuous. The Applicator shall record all batch numbers used along with other information necessary for the Company to relate the powder batches to the joints of pipe on which it was applied. No batch of powder shall be applied prior to the Company having in its possession all of the required batch information and having accepted the powder.

3.5.4 The use of recycled powder is permitted, provided that it has not been contaminated, has not been heat affected, and is continuously recovered and reprocessed through magnetic separators. It shall be uniformly mixed with new virgin powder up to a proportion of 30 percent.

3.5.5 Manufacturer’s recommendations for full curing shall be followed. The curing reaction of the coating must be completed prior to any forced cooling. Forced cooling of the pipe to facilitate inspection and repair may be conducted after the coating has completely cured.

3.5.6 The cured coating shall be of uniform color and gloss and shall be free of blisters, pinholes, fish eyes, sags or runs, and any other irregularities.

3.5.7 Any coating which, in Company's judgment, has not been applied in conformance with these Specifications shall be rejected.

4.0 INSPECTION

4.1 General

4.1.1 The Applicator shall perform all inspection necessary to ensure surface preparation and coating application comply with the requirements of this Specification. All work shall be subject to Company inspection.

4.1.2 The Applicator shall notify the Company not less than five days in advance of the start of each production run and shall provide him with a detailed time schedule to permit him to witness all processing and testing phases.

4.1.3 The Company's inspector shall be the final authority on the acceptability of surface preparation and coating application.
4.1.4 The Company's inspector shall have access to each part of the process and shall have the right and opportunity to witness any of the quality control tests and/or to perform such tests himself on a random sampling basis.

4.1.5 The Company shall have the right to halt the coating of pipe pending alterations or corrections to the process to correct all faults found in the work that result in failure of the work to conform to these Specifications.

The coating Applicator shall keep the records indicated in Table I below and submit these records to the Company daily for verification to the Company's satisfaction.

<table>
<thead>
<tr>
<th>Table I Required Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating/Inspect on Step</td>
</tr>
<tr>
<td>1. Surface Profile</td>
</tr>
<tr>
<td>Check three locations per joint:</td>
</tr>
<tr>
<td>a. At beginning of each eight-hour shift and every two hours throughout the shift.</td>
</tr>
<tr>
<td>b. Whenever any change in abrasive type or blast pressure is made (see Section 4.2).</td>
</tr>
<tr>
<td>2. Thickness</td>
</tr>
<tr>
<td>Five measurements per joint of pipe (see Section 4.4).</td>
</tr>
<tr>
<td>3. Repaired Holidays</td>
</tr>
<tr>
<td>100% inspected. Record number of repaired holidays per joint (see Section 4.5.5).</td>
</tr>
</tbody>
</table>

4.2 Surface Preparation

4.2.1 Surface cleanliness shall be judged against both written (NACE No. 2, SSPC-SP10) and visual (NACE TM-01, SSPC VIS-1) standards. Surface cleanliness must be inspected constantly.

4.2.2 The surface profile shall be checked at the beginning of every eight-hour shift and every two hours throughout the shift (see Paragraph 3.2.3). The anchor pattern shall be determined at three different places on the pipe joint. The readings shall be recorded. Anchor patterns shall also be checked if abrasive material or blast pressure is changed and after grinding of slivers.

4.3 Preheat Temperatures

Optical pyrometers and/or thermometers shall be used to assure correct pipe temperature (see Section 3.3). Tempilstiks may be used to check accuracy of the pyrometers and/ or thermometers, but their use must be minimized (see 3.3.4).

4.4 Thickness

4.4.1 The dry coating thickness of each joint shall be measured using a nondestructive magnetic or electronic thickness gauge. The gauge shall be calibrated twice per eight-hour shift using U.S. Department of Commerce Certified Coating Thickness Calibration Standards for Nonmagnetic Coating of Steel.

4.4.2 A minimum of five (5) measurements randomly distributed along the length and circumference of each joint of pipe shall be made and recorded, with notation of the minimum, maximum, and predominant thickness measured.

4.4.3 Any joint of pipe with a measured thickness less than that specified in this Specification shall be rejected. Refer to Section 5.0 for procedures to recoat rejected pipe.

4.5 Holiday Detection

4.5.1 All coated pipe shall be 100% inspected for holidays. Either a pulsating or a nonpulsating spiral coil or wet sponge detector is acceptable, provided it meets and is operated according to the requirements in NACE Recommended
4.5.3 The detector electrode shall be in direct contact with the entire surface of the coating being inspected. There shall be no gaps in the electrode or separations between the electrode and the surface of the coating, including the surfaces on either side of the longitudinal seam of the pipe.

4.5.4 The travel rate of the detector's electrode shall not exceed 1 foot/second and shall not be allowed to remain stationary while the power is on. Refer to NACE RP-0490-90 to determine rate of travel.

4.5.5 All holidays and other coating defects, including without limitation primer blisters, excess powder mounds, crazed coating, lifted and unfilled pipe scabs, etc., shall be marked with a nongrease marker and the number and nature of holidays and coating defects in each joint of pipe recorded, as per Section 4.1.6.

Pipe joints not meeting both the requirements below shall be rejected:

- The numbers of pinholes (defects less than 1 mm in diameter) shall be less than one per 25 ft² for any given joint.
- The number of larger holidays (to a maximum size of 3 in²) shall be less than three per joint. Any holiday greater than 3 in² is unacceptable.

Rejected pipe shall be handled as described in Paragraph 5.1. Nonrejected pipe joints that have defects shall be repaired as described in Paragraph 5.2.

5.0 COATING REPAIR

Each length of coated pipe leaving the Applicator's premises shall be completely free of holidays and visual coating defects.

5.1 Rejected Coatings

All rejected coatings (those coated joints that fail to pass the criteria listed in Sections 4.0 and 6.0) shall be completely removed from the entire joint of pipe and the pipe surface reprepared and recoated in conformance with the foregoing sections at no additional expense to the Company.

5.2 Holiday Repair

All coating defects disclosed by visual or holiday detector inspection shall be repaired at no additional expense to Company. For all holiday repairs where repairs are approved by Company, the following procedure shall be followed:

5.2.1 Pinholes (defects less than 1 mm in diameter) need no more surface preparation. The pipe to be repaired shall be cleaned to remove all dirt and damaged or disbonded coating using approved means. The edges of the original coating shall be abraded around the area to be coated 1/2 - 1 inch out from the pinhole and all dust wiped off before applying the patch coating. Files shall not be used.
5.2.2 Large holidays (to a maximum size of 3 in) require surface preparation of the steel. Any exposed metal must be treated to remove contaminants such as corrosion products, salts, dirt, etc., using abrasive blast or other means approved by the Company. The FBE must also be abraded around the areas to be coated 1/2 - 1 inch out from the edge of the holiday and all dust removed before applying the patch coating. The patch coating shall be applied in accordance to Manufacturer’s recommendations to a minimum thickness of 25 mil and shall overlap the existing sound coating by a minimum of 1 inch.

5.2.3 The material for patching repairs in the mill shall be those listed in Section 2.4 of this Specification. No thermoplastic patchsticks shall be used.

5.2.4 The freshly patch-coated areas shall be allowed to cure fully according to the coating manufacturer’s specifications prior to handling those areas.

5.2.5 After curing, all patches shall be visually inspected and jeeped with a wand electrode of fine brass whiskers at a voltage of not less than 100 volts/mil and tested for adhesion by knife lifting. The use of a wet sponge detector set at the manufacturer’s recommended parameters is also acceptable. The patch shall be holiday-free and shall not disbond when lifted with a knife.

6.0 QUALITY CONTROL TESTS
The Applicator shall perform the tests listed in this section. The Company may be present during the tests. Test results must be made available within 72 hours of taking the sample. No pipe lot shall be accepted before the test results from the representative samples are known. If any test results do not meet the Specification, the Company will specify additional samples to be tested at Applicator's expense. Also, the Company reserves the right to test additional samples at Company's expense.

6.1 Sample Frequency
From the joints listed below, the Applicator shall cut an 18-inch long strap from the pipe for coating tests. The cut pipe ends shall be rebevelled and all burnt coating removed.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>From Joint No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>Etc.</td>
</tr>
<tr>
<td></td>
<td>Every 500 joints hereafter</td>
</tr>
<tr>
<td></td>
<td>The last joint.</td>
</tr>
<tr>
<td>Plus</td>
<td>One random, from each day’s production</td>
</tr>
</tbody>
</table>

6.2 Bend Test
The Applicator shall perform bend tests per Appendix I on each sample listed in Section 1.

6.3 Differential Scanning Calorimeter Analysis
The Applicator shall perform a differential scanning calorimeter (DSC) analysis on each coating sample listed in 6.1. Delta Tg shall be less than 5°F for the coating to be considered fully cured.

If analysis shows any sample to be partially cured, it must be determined which pipes of the lot were not properly cured. Those joints not properly cured will be rejected and repaired per Paragraph 5.1.

6.4 Adhesion Test
At production start-up, after production interruptions, at the start of using a new
batch of powder, and once every hour or 20 pipe lengths (whichever is more frequent), the adhesion of the coating will be determined at one location on the pipe. If three tests have been successful, the frequency may be reduced to once every two hours or 50 pipe lengths (whichever is more frequent) until an unsuccessful test.

6.4.1 With a sharp knife of narrow width blade, two approximately 0.5-in long incisions shall be made through to the metal substrate to form an X with an angle of intersection of approximately 30°.

6.4.2 At the intersection of the X, an attempt shall be made to force the coating from the steel substrate with the knife point. Refusal of the coating to peel constitutes a pass. Partial or complete adhesion failure between the coating and the metal substrate constitutes a failure.

6.5 Foam Structure Test
The Applicator shall ensure excessive foaming does not take place. A cross-section examination of the coating under a 40-power magnification shall be within the 2-5 grade range per the attached Appendix II. The test shall be performed on coating chipped from the first joint coated each day and once per shift thereafter and on chips from the bend test specimens.

6.6 Cathodic Disbondment Test
The following cathodic disbondment test, shall be conducted on the samples listed in Section 6.1.

A 4 inch x 4 inch plate is cut from the production coated sample. A 1/8-inch holiday is drilled through the coating to the steel. A 3-inch diameter PVC cell is centered over the intentional holiday and fixed to the coated surface with silicone. The cell is filled with 3% NaCl electrolyte and a platinum wire anode is inserted below the electrolyte level. A 3.5 DC voltage (reference saturated calomel) is impressed and the entire test plate and apparatus are maintained at 150°F for 24 hours.

At test completion, a 30 degree "V" cut is made through the coating originating at the intentional holiday. The amount of coating disbonded in the "V" is evaluated and expressed in millimeters radius (mmr), as measured from the holiday edge to where well bonded coating exists.

The maximum disbondment allowed is 8 mmr.

7.0 HANDLING AND STORAGE PROCEDURES

7.1 The Applicator shall be solely responsible for the condition of the pipe from the time it is received until after it has been loaded for shipment.

7.2 All booms, hooks, clamps, forks, supports, and skids used in handling or storing coated pipe shall be designed and maintained in such a manner as to prevent any damage to the pipe or to the coating and shall be approved by Company.

7.3 All pipes shall be stored on padded elevated racks or polyethylene-sheathed sand berms until time for delivery. Noncompressible rubber pads 0.5-inch thick or hoops of 5/8-inch nylon rope, three per 40-foot length, shall be used to separate the pipe for yard transportation and storage.

7.4 The Company will have authority to stop
any storage procedure or means of transport from the yard if in his opinion there is a possibility of damage to the coating because of improper procedures.

7.5 Any pipe damaged by Applicator shall be repaired in accordance with Company's pipe Specifications and applicable API Standards at Applicator's expense. Pipe damaged beyond permissible repair shall become the property of Applicator. The actual Company invoiced cost of scrapped pipe, including pipe, coating, and transportation, shall be deducted from the amount due the Applicator.
APPENDIX I
BEND TEST PROCEDURE

Scope

This procedure checks degree of cure and adhesion of FBE-coated pipe.

Equipment

Four-point bend apparatus

Procedure

1. Cut a minimum of four 8-in (longitudinal) x 1-in (circumferential) x thickness (pipe + coating) straps out of the coated pipe. File all edges smooth.

2. Using a four-point bend apparatus, bend each strap until failure, which is the point where cracks begin to be visible in the coating when viewed with no magnification.

3. Measure the strap thickness (pipe + coating), t, and the deflected angle, A, as shown in Figure:

4. Calculate the amount of bend in degrees/pipe diameter.

\[
\text{degrees/pipe diameter} = \frac{(A \cdot t)}{d} \quad \text{(Eq. 1)}
\]

where

- A = deflection angle in degrees
- d = distance between two center points in bend test rig (where strain is constant), usually 2 inches.
- t = pipe wall + coating thickness.

5. To pass, the average of the values from Equation 1 for the four (or more) samples must be greater than 2.9 degrees/pipe diameter. Any single value must be at least 2.3 degrees/pipe diameter. Also, the coating shall show full adhesion to the steel in the bend, with no splitting, cracking, or flaking occurring before a bend of 2.9 degrees/pipe diameter is obtained.
APPENDIX II

FOAM STRUCTURE TEST PROCEDURE

Scope

This procedure covers the test method to determine the degree of foaming experienced by the coating during application.

Equipment

Sharp knife.

40-power magnifier (or microscope).

Procedure

Use the knife to "snap" off coating from surface and examine cross-sections under magnification. Rate the presence of voids according to the examples in Figure:

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![Diagram of foam structure test procedure](image)