ANSI/AWWA C213-22

(Revision of ANSI/AWWA 213-15)

AWWA Standard

Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings

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American Water Works Association

Approved American National Standard ANSI

STANDARD Since 1881

AWWA Standard

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Committee Personnel

The Steel Water Pipe Manufacturers Technical Advisory Committee (SWPMTAC) Task Group for AWWA C213, which revised this standard, had the following personnel at the time:

Larry McKinney, *Chair*
David D'Ambrosio, *Vice-Chair*

J. Buratto, Seal for Life, Pflugerville, Tex.
A. Collins, JCM Industries, Nash, Tex.
D. D'Ambrosio, Polyguard Products, Houston, Tex.
A. Fletcher, Consultant representing Steel Mains PTY Ltd., Melbourne, Australia
G. Larsen, Smith-Blair Inc., Texarkana, Tex.
A. Lemke, Romac Industries, Bothell, Wash.
L. McKinney, Womble Company Inc., Houston, Tex.
C. Patton, Seal for Life, Houston, Tex.
S. Salehpour, Seal for Life, Toronto, Ont.
R.N. Satyarthi, Baker Coupling Company Inc., Los Angeles, Calif.
S. Serpe, Arkema, King of Prussia, Penn.
G. Sinkovich, Sherwin-Williams, Barrie, Ont.
C. Smith, Lone Star Specialty Products LLC, Lone Star, Tex.
A. Sterling, Mobile Pipe Lining and Coating, Adelanto, Calif.

The AWWA Standards Committee on Steel Pipe, which reviewed and approved this standard, had the following personnel at the time of approval:

John H. Bambei Jr., *Chair*
Bob J. Card, *Vice-Chair*
John Luka, *Secretary*

General Interest Members

S.A. Arnaout (*alternate*), Stantec, Dallas, Tex.
J.H. Bambei Jr., Bambei Engineering Services, Arvada, Colo.
R.J. Card, Lockwood, Andrews & Newnam Inc., Suwanee, Ga.
R.L. Coffey, Consultant, Bend, Ore.
M. Garcia (*liaison, nonvoting*), Standards Council Liaison, AECOM, Englewood, Colo.
R.L. Gibson, Freese and Nichols Inc., Fort Worth, Tex.

M.D. Gossett, HDR, Denver, Colo.
M.B. Horsley (*alternate*), Horsley Engineering LLC, Overland Park, Kans.
R. Issa, AECOM, McKinney, Tex.
C.H. Kirby (*alternate*), Lockwood, Andrews & Newnam Inc., Houston, Tex.
R.A. Kufaas, Norske Corrosion & Inspection Services Ltd., Abbotsford, B.C.
J.L. Mattson, Corrosion Control Technologies, Sandy, Utah
D.L. McPherson (*alternate*), HDR, Charlotte, N.C.
A. Murdock, Jacobs, Salt Lake City, Utah
R. Ortega, Aurora Technical Services, Houston, Tex.
E.S. Ralph (*liaison, nonvoting*), Standards Engineer Liaison, AWWA, Denver, Colo.
A.E. Romer (*alternate*), AECOM, Orange, Calif.
J.R. Snow, Stantec, Denver, Colo.
A.M. Stanton, Black & Veatch, Pasadena, Calif.
W.R. Whidden, Woolpert, Orlando, Fla.

Producer Members

H.H. Bardakjian, Consultant, Glendale, Calif.
D. Dechant, Dechant Infrastructure Service, Aurora, Colo.
D.W. Dunker, Thompson Pipe Group, Rialto, Calif.
B.D. Keil, Northwest Pipe Company, Draper, Utah
J.L. Luka, American SpiralWeld Pipe Company, Columbia, S.C.
R. Mielke (*alternate*), Northwest Pipe Company, Raleigh, N.C.
G.F. Ruchti (*alternate*), Consultant, Punta Gorda, Fla.
B.P. Simpson (*alternate*), American SpiralWeld Pipe Company, Birmingham, Ala.
C.C. Sundberg, Victaulic, Issaquah, Wash.
R. Wu (*alternate*), Thompson Pipe Group, Grand Prairie, Tex.

User Members

L. Adams, US Bureau of Reclamation, Denver, Colo.
G.A. Andersen, New York City Bureau of Water Supply, Little Neck, N.Y.
B. Cheng, Metro Vancouver, Burnaby, B.C.
B. Fountain, San Diego County Water Authority, San Diego, Calif.
J. Fox, Tampa Bay Water, Clearwater, Fla.

S. Hattan, Tarrant Regional Water District, Fort Worth, Tex.
M. Lobik, Springfield Water & Sewer, Springfield, Mass.
T. Peng, Metropolitan Water District, Los Angeles, Calif.
V. Scutelnicu, Los Angeles Department of Water and Power, Los Angeles, Calif.
M. Turney (*alternate*), Denver Water, Denver, Colo.

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C213.*

I. Introduction.

I.A. *Background.* Fusion-bonded epoxy coatings are one-part dry-powder thermosetting epoxies that, when heat activated, produce a chemical reaction to the steel pipe surface while maintaining the performance of its properties. The first known applications for corrosion protection in the United States occurred in 1960 on the external surfaces of small-diameter pipe for gas distribution. Since then, applications have expanded to larger pipe sizes as internal and external coatings for gas, oil, water, and wastewater applications. Custom application to accessory fittings, pumps, valves, couplers, flowmeters, and a variety of other parts is also possible. Materials are applied by electrostatic spray, air spray (flocking), or fluid bed, usually in a controlled plant environment. However, equipment is available that allows for internal or external application to pipe joints in the field.

I.B. *History.* The first edition of this standard was approved in 1979. The 1985 revision incorporated changes reflecting fusion-bonded epoxy technology, which was current at that time. The primer provision was deleted in the 1985 revision. The 2001 and 2007 revisions incorporated the latest technology and requirements at that time. The last edition was approved on Jan. 24, 2015. This edition was approved on Jan. 13, 2022.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International[†] (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). AWWA and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.[‡] Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.
‡ Persons outside the United States should contact the appropriate authority having jurisdiction.

effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. Specific policies of the state or local agency.

2. Two standards developed under the direction of NSF: NSF/ANSI/CAN[§] 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI/CAN 61, Drinking Water System Components—Health Effects.

3. Other references, including AWWA standards, *Food Chemicals Codex, Water Chemicals Codex*,[¶] and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI/CAN 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdictions. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI/CAN 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C213 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.

2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues.

II.A. *Advisory Information on Material Application.* This standard defines the quality of fusion-bonded epoxy to establish the characteristics desired for long-term corrosion protection. It is intended for interior linings and exterior coatings for steel water pipelines for underground and underwater installation under normal conditions.

[§] Standards Council of Canada, 55 Metcalfe Street, Suite 600, Ottawa, ON K1P 6L5 Canada.

[¶] Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be specified by the purchaser:

1. Standard used—that is, ANSI/AWWA C213, Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings, of latest revision.
2. Any exceptions to the standard.
3. Diameter, length, and location of pipeline.
4. Temperature of conveyed water (Sec. 1.1.2).
5. Details of federal, state provincial, territorial and local requirements (Sec. 4.2.1).
6. For applications other than potable water, whether compliance with NSF/ANSI/CAN 61, Drinking Water System Components—Health Effects, is required (Sec. 4.2.2).
7. Requirements for epoxy application at pipe ends (Sec. 4.5.2.2).
8. Optional epoxy performance testing (Sec. 4.5.2.7, Sec. 5.5.5).
9. Requirements for field-welded joint coating (Sec. 4.8).
10. Whether additional layers or thickness of material is required (Sec. 4.5.2.3).
11. Coating requirements for thread systems, special connections, and appurtenances (Sec. 4.6.3.2).
12. Requirements for cure of epoxy (Sec. 4.5.2.5 and Sec. 4.6.3.4).
13. Provision for field procedures (Sec. 4.9).
14. Requirements of inspection and laboratory testing (Section 5).
15. Requirements for adhesion testing of coating (Sec. 5.2.2.4 and Sec. 5.5.3).
16. Requirement for epoxy thickness (Sec. 5.5.4).
17. Additional optional epoxy testing (Sec. 5.5.5).
18. Rejection of pipe (Sec. 5.6).
19. Affidavit of compliance, if required (Sec. 6.3).

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. Revisions made to this standard in this edition include the following:

1. Section 2 References was updated.
2. The definition for applicator was added to Section 3 Definitions.

3. Section 4 was updated with standardized wording and headings to be consistent with other coating and lining standards.

4. Sec. 4.2.1 Materials was updated with the latest Standards Council approved language.

5. A new Sec. 4.2.3 Safety was added to be consistent with other AWWA steel pipe coating and lining standards.

6. Sec. 4.4 Surface Preparation was modified to be consistent with other coating and lining standards.

7. The tables were moved to the sections in which they are referenced.

8. The minimum blast profile was increased (Sec. 4.4.4.1).

9. The maximum preheat temperature was increased (Sec. 4.5.2.1).

10. The thicknesses related to electrical continuity inspection levels were further defined in Sec. 5.5.2.

11. The minimum adhesion to the pipe was further defined in Sec. 5.5.3 and Table 3.

12. Sec. 5.5.4 Thickness was revised for consistency with other coating and lining standards.

13. Sec. 5.6.3 and Sec. 5.6.4 were modified to be consistent with language from other coating and lining standards.

14. Sec. 6.3 was modified to include affidavits from both the epoxy manufacturer and the applicator.

V. Comments. If you have any comments or questions about this standard, please call AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email at standards@awwa.org

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American Water Works Association
Dedicated to the World's Most Important Resource®

AWWA Standard

Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes the material and application requirements for fusion-bonded epoxy coatings and linings for steel water pipe, special sections, welded joints, connections, fittings, and appurtenances for steel water pipelines installed underground or underwater. Fusion-bonded epoxies are heat-activated chemically cured systems.

1.1.1 *Minimum pipe diameter.* The minimum pipe diameter for application of epoxy lining that can be inspected and repaired by entering the pipe shall be 24 in. (600 mm).* Pipe diameters less than 24 in. (600 mm) that can be electrically inspected internally may be included, provided the work complies with applicable provisions of this standard.

1.1.2 *Maximum temperatures.* AWWA pipe coating standards are written for and based on the service temperature of potable water. Consult the epoxy manufacturer for conditions and limitations.

* Metric conversions given in this standard are direct conversions of US customary units and are not those specified in International Organization for Standardization (ISO) standards.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for fusion-bonded epoxy coatings and linings for steel water pipelines and fittings, including materials, application, and testing.

Sec. 1.3 Application

This standard can be referenced in documents for fusion-bonded epoxy coatings and linings for steel water pipelines and fittings. The stipulations of this standard apply when this document has been referenced and then only to fusion-bonded epoxy for the interior and exterior of steel water pipelines and fittings.

SECTION 2: REFERENCES

This standard references the following documents. In their current editions, these documents form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/AWWA C203—Coal-Tar Protective Coatings and Linings for Steel Water Pipe.

ANSI/AWWA C209—Tape Coatings for Steel Water Pipe and Fittings.

ANSI/AWWA C210—Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings.

ANSI/AWWA C216—Heat-Shrinkable Cross-Linked Polyolefin Coatings for Steel Water Pipe and Fittings.

ANSI/AWWA C217—Microcrystalline Wax and Petrolatum Tape Coating Systems for Steel Water Pipe and Fittings.

ANSI/AWWA C222—Polyurethane Coatings and Linings for Steel Water Pipe and Fittings.

ANSI/AWWA C604—Installation of Buried Steel Water Pipe—4 In. (100 mm) and Larger.

ASTM† D149—Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.

ASTM D153—Standard Test Methods for Specific Gravity of Pigments.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D257—Standard Test Methods for DC Resistance or Conductance of Insulating Materials.

ASTM D1002—Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal).

ASTM D1921—Standard Test Methods for Particle Size (Sieve Analysis) of Plastic Materials.

ASTM D4060—Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser.

ASTM D4417—Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel.

ASTM D6677—Standard Test Method for Evaluating Adhesion by Knife.

ASTM G8—Standard Test Methods for Cathodic Disbonding of Pipeline Coatings.

ASTM G14—Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test).

ASTM G17—Standard Test Method for Penetration Resistance of Pipeline Coatings (Blunt Rod).

NACE[‡] SP0188—Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

NACE SP0490—Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 Micrometers (10 to 30 Mils).

NSF/ANSI/CAN[§] 61—Drinking Water System Components—Health Effects.

SSPC[¶]-PA 2—Procedure for Determining Conformance to Dry Coating Thickness Requirements.

SSPC-SP 1—Solvent Cleaning.

SSPC-SP 10/NACE No. 2—Near-White Metal Blast Cleaning.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Applicator:* The party that provides the work for applying the coating and/or lining.

[‡] NACE International, 1440 South Creek Drive, Houston, TX 77084.
[§] Standards Council of Canada, 55 Metcalfe Street, Suite 600, Ottawa, ON K1P 6L5 Canada.
[¶] SSPC: The Society for Protective Coatings, 40 24th Street, Pittsburgh, PA 15222.

2. *Blast cleaning:* Blast cleaning with steel shot, grit, or both.

3. *Constructor:* The party that provides the work and materials for placement or installation.

4. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

5. *Potable water:* Water that is safe and satisfactory for drinking and cooking.

6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

SECTION 4: REQUIREMENTS

Sec. 4.1 Equipment

The applicator's equipment for surface preparation and epoxy application shall be of such design, manufacture, and condition to permit compliance with the procedures and obtain the results prescribed in this standard.

Sec. 4.2 Materials and Workmanship

4.2.1 *Materials.* Materials supplied shall meet the provisions of this standard. Materials shall comply with the requirements of the Safe Drinking Water Act and applicable federal, state, provincial, territorial, or other authoritative regulations for water systems. Material or workmanship that fails to conform to this standard may be rejected at any time before final acceptance.

4.2.2 *Certification.* When NSF compliance is required, materials in contact with potable water shall be certified to NSF/ANSI/CAN Standard 61.

4.2.3 Safety. Necessary precautions shall be taken to protect personnel and property from accidents caused by falls, hazardous materials, fire, explosion, and other dangers. The methods and practices prescribed by applicable federal, state, provincial, territorial, or other authoritative regulations shall be followed.

4.2.4 *Personnel.* The entire operation of applying the coating or lining system shall be performed by qualified personnel trained in the application of the epoxy system.

Sec. 4.3 Epoxy System

4.3.1 *Material.* The epoxy powder shall consist of a one-component fusion-bonded material comprising epoxy resin, curing agents, catalysts, fillers, colorants, flow-control agents, and ultraviolet-light-resistant agents that, when

applied to the preheated substrate, will uniformly coalesce and cure to produce a homogeneous film that complies with the requirements of this standard.

4.3.1.1 Shelf life. The epoxy powder shall be stored in the original sealed containers at or below the manufacturer's specified temperature and shall be used within the shelf life as specified by the manufacturer.

4.3.1.2 Application capability. When applied by electrostatic spray, fluidized bed, or air spray to the preheated article and subsequently cured, the epoxy powder shall produce a uniform protective coating at the thickness specified in Sec. 4.5.2.3.

Sec. 4.4 Surface Preparation

4.4.1 *Surface imperfections.* Surface imperfections, such as burrs, gouges, and weld spatter, shall be removed by filing or grinding, or otherwise corrected to prevent holidays in the applied coating.

4.4.2 *Surface condition.* Surfaces to be coated or lined, and internal surfaces of pipe that is to be only coated, shall be free from mud, mill lacquer, wax, coal tar, asphalt, oil, grease, chlorides, and any other foreign material or combustible contaminants that could ignite at the fusion-bond epoxy application temperatures. Visible oil and grease spots shall be removed by solvent wiping. Only solvents that meet prevailing codes and that do not leave a residue shall be used. Heating to remove water and ice may be used provided the pipe section, fitting, or special section is preheated in a uniform manner to avoid distortion. If chlorides or other inorganic contaminants are present after blast cleaning, removal by chemical pretreatment, water flushing, or other acceptable methods may be required.

4.4.3 *Solvent cleaning.* Before abrasive blast cleaning, surfaces to be coated or lined shall be inspected and, if required, cleaned in accordance with SSPC-SP 1. Only solvents that do not leave a residue shall be used for cleaning.

4.4.4 *Methods of cleaning.* Surfaces shall be cleaned using dry abrasive blast cleaning. If a greater degree of surface preparation is recommended by the manufacturer or is required for the coating to meet Sec. 4.4, that level of surface preparation shall be achieved.

4.4.4.1 Dry abrasive blast cleaning. When dry abrasive blast cleaning is performed, surfaces shall achieve a minimum surface preparation in accordance with SSPC-SP 10/NACE No. 2, unless otherwise specified by the purchaser. The blast profile shall be angular, and the depth shall be in accordance with the manufacturer's recommendations. If no recommendation is stated by the manufacturer, the profile

shall be within the range 2.0–4.0 mil (51–102 μm) measured in accordance with ASTM D4417.

4.4.4.2 Additional cleaning considerations. Cleaning shall be performed when the metal temperature is more than 5°F (3°C) above the dew point. Grounding of the equipment may be performed to mitigate the attraction of dust from static electricity. Preheating to remove moisture may be used.

4.4.5 *Air blowoff.* Contaminant-free compressed air shall be used to blow the dust, grit, or other foreign matter from the prepared substrate of the pipe in a manner that does not affect the cleaned surface, other cleaned pipe, or pipe to be coated or lined. Vacuum cleaning or other methods may be used in place of compressed air if approved by the purchaser.

4.4.6 *Protection from moisture and contaminants.* Cleaned pipe surfaces shall be protected from condensation, moisture, rainfall, frost, snow, and other contaminants. Flash rust or other contaminants shall be removed in accordance with SSPC-SP 1 or Sec 4.4.3, as applicable, before coating or lining application.

Sec. 4.5 Epoxy Application

4.5.1 *General.* When both a lining and coating are to be applied, it is preferable to preheat the pipe to the specified temperature and apply the lining first, immediately followed by the coating. Because elevated temperatures are required during processing, fusion-bonded epoxy must be applied before the application of other coatings or linings unless those coatings and linings are resistant to the processing heat.

4.5.2 *Epoxy application.*

4.5.2.1 Preheating. Pipe that has been cleaned in accordance with Sec. 4.4 shall be preheated in accordance with the epoxy manufacturer's recommendations but shall not exceed 525°F (274°C). Higher temperatures may alter the physical and toughness properties of the steel. The heat source shall not contaminate the pipe surface. Graduated, meltable temperature indicators shall be used to measure the temperature of the pipe surface. Optical pyrometers may be used in addition to, or in place of, meltable temperature indicators. The calibration of the optical pyrometer shall be checked every 4 h of applicator operation to ensure accuracy. Oxidation caused by heating of the steel is not acceptable. If blueing occurs and the pipe has not been heated beyond the 525°F (274°C) maximum allowable temperature, the pipe shall be cooled to an ambient temperature and recleaned in accordance with Sec. 4.4.

4.5.2.2 Pipe ends. When pipe sections are to be joined by field welding, epoxy shall be held back as specified by the purchaser.

This requirement applies to both the interior and exterior surfaces of the pipe. Epoxy material on the holdback, bevel, or root face is not acceptable. When rubber-gasketed joints or mechanical couplings are used, the epoxy shall extend to the ends of the pipe unless otherwise specified by the purchaser.

4.5.2.3 Thickness. The epoxy powder shall be applied to the preheated pipe at a uniform cured-film thickness of not less than 12 mil (305 μm) on the exterior or interior of the pipe surface, including the weld seam. The maximum thickness shall not exceed the manufacturer's recommendation. For difficult installation conditions, additional layers or thickness of material, such as but not limited to abrasion-resistant overcoats, rock shields, cement–mortar overcoats, specially prepared backfill, or other methods or materials, may be necessary as specified by the purchaser.

4.5.2.4 Cooling. After the epoxy has cured in accordance with the time/temperature requirements of the epoxy manufacturer, the epoxy may be cooled with air or water spray to a temperature below 200°F (93°C) to facilitate handling for inspection and repair.

4.5.2.5 Cure. If the purchaser requires testing to verify cure, a method such as differential scanning calorimeter (DSC) or bendability, agreed on by the purchaser and applicator, may be performed.

4.5.2.6 Imperfections. On completion of the epoxy application, the epoxy shall be visually inspected for blisters, bubbles, voids, or other discontinuities. The epoxies shall also be electrically inspected for holidays in accordance with Sec. 5.5.2. Inspection and repair may commence after the pipe has cooled to 200°F (93°C) or below. Holidays and imperfections detected by electrical inspection shall be repaired in accordance with Sec. 4.7.

4.5.2.7 Optional epoxy performance testing. The purchaser may specify additional testing to establish epoxy performance. The following test procedures, all of which shall be performed on production pipe test rings, may be specified:

1. Cross-section porosity.
2. Interface porosity.
3. Thermal analysis (DSC).
4. Permanent strain (bendability).
5. Water soak.
6. Impact.
7. Cathodic disbondment test.

Sec. 4.6 Coating Fittings, Special Sections, and Appurtenances

4.6.1 *General.* This section describes application of fusion-bonded epoxies to mechanical couplings, flanges, steel pipe fittings, specials, and other appurtenances used in conjunction with connections and attachments. Epoxies hereunder shall be applied in the shop or at the place of manufacture and shall meet the requirements of Sec. 5.2.

4.6.2 *Surface preparation.* Preparatory to application, the article shall be blast-cleaned as defined in Sec. 4.4.4.1. However, an alternate cleaning method that exposes clean parent metal; removes oxides, scales, oils, greases, and other deleterious contaminants; and imparts a profile in accordance with Sec. 4.4.4 may be used if acceptable to the purchaser and epoxy manufacturer.

4.6.3 *Epoxy application.*

4.6.3.1 Preheating. Fusion-bonded epoxies can be applied to surfaces preheated to between 300°F and 475°F (149°C and 246°C). Preheat temperatures should be in accordance with the epoxy manufacturer's recommendation. The surfaces may be heated by any controllable means that does not contaminate the surface to be coated. Care should be exercised to ensure the item to be coated or lined can withstand the required preheating without damage. Blueing of the steel during preheating is not acceptable. If blueing occurs and the item has not been heated beyond the 525°F (274°C) maximum allowable temperature, the item shall be cooled to ambient temperature and recleaned in accordance with Sec. 4.4.

4.6.3.2 Application. The fusion-bonded epoxy shall be uniformly applied by fluidized bed, electrostatic spray, or air spray according to the epoxy manufacturer's recommendations. Selection of the method of application, including fluidized bed, electrostatic spray, and air spray, depends on the size, shape, and configuration of the item to be coated or lined. If not specified for application by the purchaser, uncoated threaded areas shall be protected. The purchaser should specify the requirements for application to flange faces or other appurtenances.

4.6.3.3 Thickness. The epoxy powder shall be applied to the preheated items at a uniform cured-film thickness of not less than 12 mil (305 μm). However, care shall be taken when this standard is used for coating or lining items other than pipe. The design configuration of these items may include areas with limited access, bolt-holes, irregular shapes, and areas where the Faraday cage effect is possible. The epoxy thickness in these areas may vary below the minimum cured-film thickness of 12 mil, but no area should be left uncoated unless specified or agreed

on by the purchaser. The maximum thickness shall not exceed the manufacturer's recommendation.

4.6.3.4 Cure. If it is necessary to postcure the fusion-bonded epoxy, the surface shall be heated immediately after application of the epoxy according to the epoxy manufacturer's recommendations until total cure is achieved. If the purchaser requires testing to verify cure, a method such as differential scanning calorimeter (DSC) or bendability, agreed on by the purchaser, may be performed.

4.6.3.5 Imperfections. Following completion of the application operation, the epoxy shall be visually inspected for blisters, bubbles, voids, or other discontinuities. When requested by the purchaser, the coatings or linings shall also be electrically inspected for holidays in accordance with Sec. 5.5.2. Inspection and repair may commence after the article has cooled to 200°F (93°C) or below.

Sec. 4.7 Epoxy Repair

4.7.1 *Epoxy repair.* Holidays and imperfections detected by electrical inspection or visually shall be repaired in accordance with the following:

4.7.1.1 Epoxy requiring repair caused by scars, slivers, surface imperfections, and other small defects as identified by the procedures in Sec. 5.5.2 shall be repaired using materials fully compatible with the fusion-bonded epoxy.

a. Areas on items requiring spot repairs shall be cleaned to remove dirt, scale, and damaged epoxy using surface grinders, files, or sanders. The adjacent epoxy shall be roughened and dust shall be removed.

b. For lining repair, a two-part, 100 percent solids, liquid-epoxy coating or a hot-melt patching compound shall be applied on the prepared areas in accordance with the lining manufacturer's minimum suggested film thickness for coating repair or the thickness stated in Sec. 4.6.3.3, whichever is greater. The epoxy in the repaired area shall be applied and cured in accordance with the epoxy manufacturer's recommendations.

c. Minor defects on the exterior of the item may be repaired with hot-applied tape, cold-applied tape, liquid epoxy, polyurethane, hot-melt patch compound, or heat-shrinkable coatings in accordance with the requirements of ANSI/AWWA C203 (tape only), ANSI/AWWA C209, ANSI/AWWA C210, ANSI/AWWA C216, or ANSI/AWWA C222.

d. Repaired areas shall be electrically inspected using a holiday detector in accordance with Sec. 5.5.2.

4.7.2 Major defects on connections and appurtenances such as partial coating or lining, unbonding epoxy, or inadequate film thickness shall be reprocessed starting with Sec. 4.6.2.

Sec. 4.8 Field Joints—Welded

4.8.1 *Preparation.* When fusion-bonded epoxy is used on field-welded joints, the welded joint shall be cleaned free of mud, oil, grease, and other foreign contaminants, and the exposed metal in the weld zone shall be blast-cleaned to comply with SSPC-SP 10/ NACE No. 2, as defined in Sec. 4.4. The adjacent fusion-bonded epoxy shall be roughened by sanding or grinding for a distance of 1 in. (25 mm) back from the edge of the cutback.

4.8.2 *Epoxy application.* Fusion-bonded epoxy may be field-applied on the internal and external field joints using induction heat. The epoxy used on the joint shall be fully compatible with the material used on the pipe. The constructor shall consult the manufacturer of the epoxy material for the required minimum temperature of epoxy application. For determination of final cure, see Sec. 4.5.2.4, Sec. 4.5.2.5, and Sec. 4.5.2.7.

The weld area shall be heated to application temperature as recommended by the manufacturer using a circumferential induction heating coil of sufficient size, width, and power to provide the required heat in the weld zone and 2 in. (50 mm) back under the fusion-bonded epoxy. See Sec. 4.5.2.1 regarding higher temperatures.

Immediately after heating, the weld shall be coated or lined with a powder coating in accordance with this standard for the minimum thickness stated in Sec. 4.5.2.3. The welded-joint coating or lining shall overlap the original pipe coating or lining by no less than 1 in. (25 mm).

The joint epoxy shall cure from the residual heat remaining in the heat zone. The heat zone shall be protected from adverse weather conditions such as rain or high winds that would cause rapid cooling (Sec. 4.5.2.4).

On completion of the epoxy application, the joint coating or lining shall be inspected for continuity as provided in Sec. 5.5.2. Holidays shall be repaired in accordance with Sec. 4.7. Inspection and repair may commence after the heat zone has cooled to 200°F (93°C) or below.

4.8.3 *Alternative joint coatings.* The exterior of field-welded joints may be coated with hot-applied tape (ANSI/AWWA C203, Tape only), cold-applied tape (ANSI/AWWA C209 or ANSI/AWWA C216), liquid epoxy (ANSI/AWWA C210), polyurethane (ANSI/AWWA C222), or heat-shrinkable coatings

(ANSI/AWWA C217) in accordance with the requirements of the applicable standard, or as otherwise specified or agreed to by the purchaser.

Sec. 4.9 Field Procedures

4.9.1 *General.* The methods and practices found in AWWA C604 shall be followed for the handling, shipping, storage, and installation of pipe coated or lined with this material. Special requirements associated with the field procedures of pipe coated or lined with this material can be found in Sec. 4.9.2.

4.9.2 *Special requirements.* No metal tools or heavy objects shall be permitted to come into contact with the finished coating or lining. Workers shall be permitted to walk on the pipe coating or lining only when necessary, in which case only shoes with rubber soles and heels shall be permitted. Coating and lining damaged during installation shall be repaired in accordance with Sec. 4.7.

4.9.2.1 Protection during welding. A heat-resistant material of sufficient width to prevent damage to the coating shall be placed on each side of the coating holdback during welding to avoid damage to the coating by hot weld spatter. No welding ground shall be made on the coated part of the article. Any coating or lining damage from welding, including burns from weld spatter, shall be repaired in accordance with Sec. 4.7.

SECTION 5: VERIFICATION

Sec. 5.1 Epoxy Materials Prequalification

Prequalification of the epoxy materials shall be the manufacturer's certified test reports or one of the following as specified by the purchaser: (1) the testing of samples of the epoxy materials submitted by the constructor with testing conducted at an independent, accredited laboratory, or (2) acceptance on another specified basis.

Sec. 5.2 Requirements of Epoxy System

5.2.1 *Properties of epoxy powder materials.* Before acceptance and application of the epoxy materials, samples of materials requested by the purchaser and submitted by the constructor may be tested by the purchaser in the purchaser's laboratory or in an independent commercial laboratory designated by the purchaser. If the values or conditions of the powder and coating systems determined from testing do not meet the values in Table 1 for the following items, they shall be subject to rejection.

Table 1 Physical properties of epoxy powder materials

	Requirement		
	Minimum	Maximum	Test Method
Specific gravity at 73°F (23°C)	1.2	1.8	Sec. 5.2.1.1
Sieve analysis (percent retained on 100-mesh screen)	—	2.0	Sec. 5.2.1.2
Gel time(s) at 400°F±5°F (204°C±2°C)			Sec. 5.2.1.3
Lining	7 s	*	
Coating	7 s	*	

* Per manufacturer recommendations.

5.2.1.1 Specific gravity. Specific gravity of the powder shall be determined using a Beckman Model 930 air comparison pycnometer (or equivalent) or by hexane displacement (method B of ASTM D153).

5.2.1.2 Sieve analysis. The sieve analysis of the powder shall be conducted in accordance with method D of ASTM D1921 using an Alpine sieve unit. Sample size shall be 25 g. Sieve size shall be US standard 100 mesh (150 µm). The percent of material retained on the 100-mesh (150-µm) sieve shall be reported.

5.2.1.3 Gel time. Gel time shall be determined by placing approximately 0.1 g of powder on a hot plate stabilized at 400°F±5°F (204°C±2°C). Use a wooden spatula to coat at least 1 $in.^2$ (650 mm^2) of the plate. Start a stopwatch as soon as the powder becomes molten. Continue to stir the molten epoxy material and stop the watch when the epoxy becomes so gelatinous that it can no longer be stirred. The gel time, in seconds, shall be reported.

5.2.2 *Prequalification requirements of epoxy system.*

5.2.2.1 Appearance. The coated impact panels shall be visually inspected for appearance. The cured epoxy shall be of uniform color and gloss and shall be free of blisters, pinholes, fish eyes, or other irregularities.

5.2.2.2 Impact resistance testing. Tests for impact resistance shall be conducted in accordance with ASTM G14 and at a thickness of 12–14 mil. The impacted epoxy shall not crack or disbond at the point of impact. Inspection for failure shall be performed using a wet-sponge 67.5-V holiday detector in accordance with NACE SP0188.

5.2.2.3 Bendability. Prepare one cold-rolled steel panel, 1 in. × 8 in. × 0.125 in. (25 mm × 203 mm × 3.2 mm), by blast cleaning one side in accordance with Sec. 4.4. Remove surface dust using a vacuum or a dry, oil-free blast of air. Preheat the plate in accordance with the epoxy manufacturer's instructions.

As soon as the plate has reached the required temperature, coat the blasted surface to a thickness of 14 mil±2 mil (356 μm±50 μm) using air or electrostatic spray and postcure as required. Epoxy application and curing shall be in accordance with the epoxy manufacturer's recommendations. Allow the plate to cool to room temperature before testing. Bend the cooled plate over a mandrel with a radius of 2.4 in. (61 mm). For fusion-bonded epoxies used solely on special pipe connections and appurtenances that are not bent after application, bend the coated plate over a mandrel with a radius of 6.25 in. (159 mm). The epoxy shall not crack or disbond in the bend area. Inspection for crack failure shall be performed using a wet-sponge 67.5-V holiday detector in accordance with NACE SP0188.

5.2.2.4 Shear adhesion. The test panels shall be 1-in. × 6-in. × 0.125-in. (25-mm × 152-mm × 3.2-mm) cold-rolled steel cleaned in accordance with Sec. 4.4. The panels shall be heated to the application temperature recommended by the coating manufacturer. Remove the panels and place sufficient powder coating on one end of the panels to cover a space approximately 0.75 in. (19 mm) long. Immediately assemble the panels and hold them rigidly so that the length of the overlap is 0.5 in.±0.01 in. (12.7 mm±0.25 mm) and the thickness of the glue line is 11–14 mil (280–356 μm). Return the assembled panels to the oven and cure as recommended by the epoxy manufacturer. Allow the assembled panels to cool to 73°F (23°C) before testing. Shear adhesion shall be determined in accordance with ASTM D1002. At least 10 assembled panels shall be tested and the average value reported. An average value below the limit stated in Table 2 shall constitute failure to meet the requirement.

Table 2 Prequalification requirements of epoxy system

	Requirement		
	Minimum	Maximum	Test Method
Appearance	Uniform color and gloss; free from blisters, fish eyes, and pinholes		Sec. 5.2.2.1
Impact	100 lbf in. (11.3 N·m)		Sec. 5.2.2.2
Bendability	Pass		Sec. 5.2.2.3
Shear adhesion	3,000 psi (20,685 kPa)		Sec. 5.2.2.4
Penetration at 140°F (60°C)		10%	Sec. 5.2.2.5
Abrasion resistance, 5,000 cycles-loss		300 mg	Sec. 5.2.2.6
Water soak test at 203°F (95°C)	1–3 Pass		Sec. 5.2.2.7
Dielectric strength	1,000 V/mil (39.4k V/mm)		Sec. 5.2.2.8
Volume resistivity	$1.1 \times 10^{15}\ \Omega \cdot cm^2$		Sec. 5.2.2.9
Cathodic disbondment		15 mm	Sec. 5.2.2.10

5.2.2.5 Penetration. Penetration resistance shall be conducted in accordance with ASTM G17 at a temperature of 140°F (60°C). An average value above the limit stated in Table 2 shall constitute failure to meet the requirement.

5.2.2.6 Abrasion resistance. Abrasion resistance shall be conducted in accordance with ASTM D4060 with a CS-17 abrasive wheel, or equivalent, and 1,000-g loading. An average value above the limit stated in Table 2 shall constitute failure to meet the requirement.

5.2.2.7 Water soak. Prepare two test panels approximately 4-in. (100-mm) square by 0.25-in. (6-mm) thick according to Sec. 4.4. Heat tap water in a slow cooker to 203°F±3°F (95°C±3°C). Immerse test specimens fully for a minimum of 24 h and remove. While the specimen is still hot, use a utility knife to scribe a rectangle approximately 0.5 in. (13 mm) by 1 in. (25 mm) through the epoxy to the substrate, then air cool the specimen to 73°F (23°C). Within 2 h after removal from heat, insert the tip of a utility knife under the epoxy at the corner of the scribed rectangle. Use a levering action to remove the epoxy. Continue inserting the tip of the knife and levering under the epoxy until either all the epoxy in the rectangle is removed or the epoxy demonstrates a definite resistance to the levering action. An adhesion rating greater than 3 shall constitute failure of the test in accordance with the criteria provided in Table 4.

5.2.2.8 Dielectric strength. The epoxy shall be tested for dielectric breakdown according to ASTM D149 using a 1-in. (25-mm) diameter electrode and 500-V/s voltage rise. An average value below the limit in Table 2 shall constitute failure to meet the requirement.

5.2.2.9 Volume resistivity. The epoxy shall be tested for volume resistivity according to ASTM D257. An average value below the limit in Table 2 shall constitute failure to meet the requirement.

Table 3 Quality control requirements of applied epoxy system

	Requirement		
	Minimum	Maximum	Test Method
Electrical continuity testing		No defects	Sec. 5.5.2
Adhesion	Rating of 1–3 in Table 4		Sec. 5.5.3
Thickness			Sec. 5.5.4
Interior	12 mil (305 µm)	*	
Exterior	12 mil (305 µm)	*	

* Per manufacturer recommendations.

Table 4 Adhesion rating criteria for epoxy system tests

Rating	Criteria
1	Epoxy cannot be removed cleanly.
2	Less than 50% of the epoxy can be removed.
3	More than 50% of the epoxy can be removed, but the epoxy demonstrates a definite resistance to the levering action.
4	The epoxy can be easily removed in strips or large chips.
5	The epoxy can be completely removed as a single piece.

5.2.2.10 Cathodic disbondment. The cathodic disbondment of the coating system shall be determined in accordance with ASTM G8. The test shall run for 30 days. Each specimen shall be a laboratory-coated steel panel with minimum dimensions of 4 in. × 6 in. × 0.25 in. (100 mm × 150 mm × 6 mm) prepared per Sec. 4.4. A single intentional holiday 0.25 in. (6.35 mm) in diameter shall be made in each specimen. The disbondment shall be measured from the edge of the initial holiday along each radial cut. The average of these measurements shall be the result for each specimen. Three specimens shall be tested and the results averaged. An average value above the limit stated in Table 2 shall constitute failure to meet the requirement.

Sec. 5.3 Quality Assurance and Records

The constructor shall use a quality assurance program or system to ensure that the quality controls are followed. Completed records of inspection work shall be made available upon the purchaser's request.

Sec. 5.4 Inspection and Testing by the Purchaser

5.4.1. *Inspection.* The entire procedure of applying the epoxy materials as described in this standard may be inspected by the purchaser from surface preparation to the completion of application. Such inspection shall not relieve the constructor of responsibility to provide materials and perform work in accordance with this standard.

5.4.2. *Access of purchaser.* The purchaser shall have access to all areas used to perform the work according to the provisions of this standard.

5.4.3. *Facilities for purchaser.* In accordance with conditions agreed to by the purchaser and the constructor, the purchaser shall be provided with facilities and space for inspection, testing, and information-gathering purposes.

Sec. 5.5 Quality Control Requirements of Applied Epoxy System

5.5.1 *Appearance.* All coated or lined pipe shall be visually inspected. The epoxy shall be generally smooth. Cosmetic imperfections, such as sags, dimpling, scuffing, curtaining, overspray, and/or orange-peel, shall not be considered cause for rejection or repair. The epoxy shall have no blisters, cracks, bubbles, delamination, or other visible defects. All noncosmetic imperfections shall be identified and repaired according to Sec. 4.7.

5.5.2 *Electrical inspection for continuity.* On completion of the coating or lining operation but before storage, the coating shall be inspected for continuity in accordance with NACE SP0490. Electrical inspection for continuity and thickness testing may begin after the article has cooled to 200°F (93°C) or below. For linings with a thickness of 20 mils (508 µm) or less, a low-voltage holiday detector set at a maximum of 75 V shall be used in accordance with NACE SP0188. At the option of the purchaser, if the number of holidays exceeds one per 3 ft (1 m) of pipe length for pipe smaller than 14-in. (360-mm) outside diameter (OD) or one per 25 ft^2 (2.3 m^2) of surface area for pipe 14-in. (360-mm) OD and larger, the pipe shall be reprocessed. Unless reprocessed, defects disclosed by the holiday detector shall be repaired in the shop according to Sec. 4.7.

5.5.3 *Adhesion.* At the option of the purchaser, the adhesion of the cured epoxy to the surface of the pipe may be checked by pushing a sharp knife blade through the epoxy to the surface of the pipe and, using a plowing motion, attempting to remove the epoxy from the surface. The epoxy shall be fully adhered to the pipe and shall firmly resist the plowing action without brittle chipping and have a rating of 1–3 in Table 4. As an alternative, ASTM D6677 may be used. No more than one test per length of pipe or appurtenance shall be required by the purchaser. The tested area shall be repaired in accordance with Sec. 4.7.

5.5.4 *Thickness.* The epoxy thickness shall be in accordance with Sec. 4.5.2.3, or greater if specified by the purchaser. The thickness of the coating system shall be checked in accordance with the method described in SSPC PA2 Level 2. The method shall be agreed on by the purchaser and applicator. The frequency shall be agreed on by the purchaser and applicator, but no less than once per pipe appurtenance.

5.5.5 *Optional epoxy performance testing of completed pipe.* The purchaser may specify additional testing to establish epoxy performance. The following test

procedures, all of which shall be performed on production pipe test rings, may be specified for this purpose:

1. Cross-section porosity.
2. Interface porosity.
3. Thermal analysis (DSC).
4. Permanent strain (bendability).
5. Interfacial (backside) contamination.
6. Cathodic disbondment test.

Sec. 5.6 Rejection

5.6.1. *Surface preparation*. The purchaser may reject any pipe or fitting if the surface condition does not comply with the requirements of Sec. 4.4. Pipe or fittings rejected because of inadequate cleaning shall be recleaned.

5.6.2. *Epoxy materials*. If any sample of epoxy material does not comply with this standard, the epoxy materials represented by the sample shall be rejected.

5.6.3. *Epoxy application*. Application of the epoxy shall be performed by qualified applicators trained in the application of epoxies. If, at any time, it is determined that the procedure of applying the epoxy material is not according to this standard, the epoxy shall be rejected on the affected pipe and fittings.

5.6.4. *Coated or lined pipe and fittings*. Coated or lined pipe or fittings not meeting the minimum requirements of this standard shall be repaired or rejected.

SECTION 6: DELIVERY

Sec. 6.1 Marking

Containers shall be plainly marked with the name of the manufacturer, type of material, batch or lot number, date of manufacture, storage conditions, and information as required by federal, state, or provincial laws.

Sec. 6.2 Packaging and Storage

6.2.1 *Packaging.* Materials purchased or used according to this standard shall be packaged in containers that ensure acceptance and safe delivery to their destination.

6.2.2 *Shipping, Handling, and Storage.* Materials shall be stored and protected from the elements as required by current applicable federal, state or provincial, and local regulations. Temperature ranges in the storage area shall be maintained within the limits recommended by the manufacturer.

Sec. 6.3 Affidavit of Compliance

6.3.1 *Materials Affidavit.* The purchaser may require an affidavit from the epoxy manufacturer that the materials and work furnished comply with the applicable requirements of this standard.

6.3.2 *Workmanship Affidavit.* The purchaser may require an affidavit from the applicator that the work furnished complies with applicable requirements of this standard.

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American Water Works Association

6666 West Quincy Avenue
Denver, CO 80235-3098
T 800.926.7337
www.awwa.org

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