ANSI/AWWA C213-07
(Revision of ANSI/AWWA C213-01)

American Water Works Association

The Authoritative Resource on Safe Water®

AWWA Standard

Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

STANDARD
Since 1881

ANSI American National Standards Institute

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C530.

I. Introduction.

I.A. *Background.* Fusion-bonded epoxy coatings are one part dry-powder thermosetting coatings 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 coating technology, which was current at that time. The primer provision was deleted in the 1985 revision. The 2001 revision incorporated the latest technology and requirements at that time. This edition was approved on June 24, 2007.

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 American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (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 effects of products and drinking water additives from such products, state and local agencies may use various references, including

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1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.

2. Specific policies of the state or local agency.

3. Two standards developed under the direction of NSF, NSF*/ANSI† 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

4. 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 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 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 coatings to establish the characteristics desired for long-term corrosion protection. It is intended for interior and exterior coatings for steel water pipelines for underground and underwater installation under normal conditions.

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* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

† American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street, N.W., Washington, DC 20001.

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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 Coating for the Interior and Exterior of Steel Water Pipelines, of latest revision.
2. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.
3. Any exceptions to the standard.
4. Diameter, length, and location of pipeline.
5. Temperature of conveyed water (Sec. 1.1.2).
6. Details of other federal, state or provincial, and local requirements (Sec. 4.2).
7. Requirements for coating application at pipe ends (Sec. 4.4.3.2).
8. Requirement for coating thickness (Sec. 4.4.3.3).
9. Optional coating performance (Sec. 4.4.3.7, Sec. 5.3.3.4).
10. Requirements for field-welded joint coating (Sec. 4.4.5).
11. Coating requirements for thread systems, special connections, and appurtenances (Sec. 4.5.3.2).
12. Provision for pipe bedding and trench backfill (Sec. 4.6.3).
13. Requirements of inspection and laboratory testing (Sec. 5.1.1, 5.1.3, and Sec. 5.3).
14. Requirements for adhesion testing of coating (Sec. 5.3.3.2).
15. Requirements for outdoor storage and handling (Sec. 6.2).
16. 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. Sec. 5.3.2.5 Changed impact testing to ASTM G14.
2. 5.3.3.3 Added alternative method NACE RP0394.
3. 5.3.4.2 Added alternative method NACE RP0394.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at 303.794.7711,

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AWWA Standard

Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines

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SECTION 1: GENERAL

Sec. 1.1 Scope

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

1.1.1 *Minimum pipe diameter.* The minimum pipe diameter for application of an internal coating 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.

* 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.

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

Sec. 1.2 Purpose

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

Sec. 1.3 Application

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

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 Pipelines—Enamel and Tape—Hot Applied.

ANSI/AWWA C209—Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.

ANSI/AWWA C210—Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines.

ANSI/AWWA C214—Tape Coating Systems for the Exterior of Steel Water Pipelines.

ANSI/AWWA C216—Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.

ANSI/AWWA C217—Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried or Submerged Steel Water Pipelines.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

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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.

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 D1044—Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion.

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

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 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† RD-0188—Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

NACE RP0394—Application, Performance, and Quality Control of Plant-Applied, Fusion-Bonded Epoxy External Pipe Coating.

NACE RP0490—Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 Micrometers (10 to 30 Mils).

NSF‡/ANSI 60—Drinking Water Treatment Chemicals—Health Effects.

NSF/ANSI 61—Drinking Water System Components—Health Effects.

SSPC§-AB1—Mineral and Slag Abrasives.

SSPC-AB3—Ferrous Metallic Abrasive.

SSPC-SP1—Solvent Cleaning.

SSPC-SP10/NACE No. 2—Near-White Blast Cleaning.

SSPC-VIS 1-89-05—Visual Standard for Abrasive Blast Cleaned Steel.

* ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

† NACE International, 1440 South Creek Drive, Houston, TX 77084.

‡ NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

§ SSPC: The Society for Protective Coatings, 40 24th Street, Pittsburgh, PA 15222.

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SSPC Modified PA2—Paint Application Specification No. 2 Measurement of Dry Paint Thickness with Magnetic Gages.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Blast cleaning:* Blast cleaning with steel shot, grit, or both.
2. *Constructor:* The party that provides the work and materials for placement or installation.
3. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.
4. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

SECTION 4: REQUIREMENTS

Sec. 4.1 Equipment

The equipment for blast cleaning and coating shall be of the design, manufacture, and condition to comply with the procedures and obtain the results prescribed in this standard.

Sec. 4.2 Materials and Workmanship

Materials provided shall meet the provisions of this standard. The entire operation of applying the fusion-bonded epoxy coating shall be performed by workers trained in the application of fusion-bonded epoxy coating systems.

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal requirements.

Sec. 4.3 Material Properties and Laboratory Test Methods for Coating Qualification Only

4.3.1 *Material.* The epoxy powder shall consist of a one-component, fusion-bonded material comprised of 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. When stored in the original sealed container at or below

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80°F (27°C), the epoxy powder shall have a minimum shelf life of 12 months from the date of manufacture. Consult the manufacturer if the powder is stored beyond this period or at temperatures above 80°F (27°C) for determination of continued use.

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. 4.4.3.3.

4.3.2 *Material properties of epoxy powder and laboratory-applied epoxy coatings.* The material property limits for epoxy powder and the required test methods are stated in Table 1. The physical property criteria for laboratory-applied epoxy coating materials and required test methods are stated in Table 2.

4.3.3 *Material certification.* Material certification from the Fusion Bond Epoxy manufacturer shall meet the values shown in Tables 1 and 2.

Sec. 4.4 Pipe Coating Application

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

4.4.2 *Surface preparation.*

4.4.2.1 Surface condition. Surfaces to be coated shall be free from mud, mill lacquer, wax, coal tar, asphalt, oil, grease, chlorides, or any other foreign material. Prior to blast cleaning, surfaces shall be inspected and, if required, precleaned

Table 1. Properties of epoxy powder materials

		Minimum	Maximum	Method
1.	Specific gravity at 73°F (23°C)	1.2	1.8	Sec. 5.3.2.1
2.	Sieve analysis (percent retained on 100 mesh screen)	—	2.0	Sec. 5.3.2.2
3.	Gel time(s) at 400°F ± 5°F (204°C ± 2°C), sec			Sec. 5.3.2.3
	Internal coating	7	*	
	External coating	7	*	

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Table 2. Physical properties of laboratory-applied materials

	Minimum	Maximum	Method
1. Thickness			Sec. 5.3.3.3
Interior, mils (µm)	12 (305)	*	
Exterior, mils (µm)	12 (305)	*	
2. Impact, lbf in. (Nm)	100 (11.3)		Sec. 5.3.2.5
3. Appearance	Uniform color and gloss; free from blisters, fish eyes, and pinholes		Sec. 5.3.2.4
4. Bendability	Pass		Sec. 5.3.2.6
5. Shear adhesion, psi (kPa)	3,000 (20,685)		Sec. 5.3.2.7
6. Penetration at 140°F (60°C), percent	Less than 10		Sec. 5.3.2.8
7. Abrasion resistance, 5,000 cycles-gm loss		0.3	Sec. 5.3.2.9
8. Water soak test at 203°F (95°C)	1–3 Pass 4–5 Fail		Sec. 5.3.2.10
9. Volume resistivity	1.1×10^{15}		ASTM D257
10. Dielectric strength, V/mil (V/mm)	1,000 (39.4)		ASTM D149

*Per manufacturer recommendations

according to SSPC-SP1 to remove oil, grease, and loosely adhering deposits. 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 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.

4.4.2.2 Abrasive blast cleaning. Pipe surfaces shall be abrasive blast-cleaned with mineral abrasives, slag abrasives, steel shot or steel grit (reference SSPC-AB 1 Mineral and Slag Abrasives and SSPC-AB 3 Ferrous Metal Abrasive) in accordance with SSPC-SP10/NACE No. 2. The blast anchor pattern or profile depth shall be 1.5 mils to 4.0 mils (38 µm to 102 µm) measured in accordance with ASTM D4417.

4.4.2.3 Visual comparative standards. The constructor shall prepare a representative area of the abrasive blast cleaned surfaces on the actual work surface, as well as visual standards on panels that are a minimum of 6 in. × 6 in. × 0.25 in. (150 mm × 150 mm × 6 mm). On agreement between the purchaser and constructor that the visual standard meets the requirements of Sec. 4.4.2.2, the panels shall be wrapped in 4-mil to 6-mil (102-µm to 152-µm) plastic, sealed with tape, or otherwise protected from surface contamination and corrosion, and maintained as

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visual reference standards throughout the coating operation. Alternatively, other industry-accepted visual comparative standards, such as those provided by NACE or SSPC and agreed on by the purchaser and constructor, may be used.

4.4.2.4 Abrasive working mix. The abrasive working mix shall be maintained free of contaminants (oil, water, etc.). For consistent surface condition, an abrasive working mix shall be maintained in abrasive-recycling blasting machines by frequent small additions of new grit or shot commensurate with abrasive consumption; infrequent large additions shall be avoided. The abrasive working mix in abrasive-recycling blasting machines shall be maintained free of contaminants by continuous effective operation of blasting machine scalping and air-wash separators.

4.4.2.5 Surface profile. The cleaning abrasive shall be selected according to SSPC-SP10 to achieve a surface anchor pattern or profile of 1.5 mils to 4.0 mils (38 µm to 102 µm).

4.4.2.6 Surface inspection. The cleaned exterior and interior pipe surfaces shall be inspected for adequate surface preparation. Surface imperfections such as slivers, scabs, burrs, weld spatter, and gouges shall be removed by hand filing or grinding to prevent holidays in the applied coating.

4.4.2.7 Interior cleaning. If abrasives or other loose foreign matter have entered the interior of the pipe, then clean, dry, oil-free compressed air shall be used to remove the loose foreign matter in a manner that does not affect the surface of the pipe that is to be coated. Vacuum cleaning or other methods may be used in place of compressed-air cleaning.

4.4.2.8 Protection from moisture. Blast-cleaned surfaces shall be protected from conditions of high humidity, rainfall, or surface moisture. Surfaces shall not be allowed to flash rust before coating. If surface deterioration/contamination should occur, then surfaces shall be recleaned in accordance with Sec. 4.4.2.

4.4.3 *Coating application.*

4.4.3.1 Preheating. Pipe that has been cleaned in accordance with Sec. 4.4.2 shall be preheated in accordance with the coating manufacturer's recommendations but shall not exceed 500°F (260°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 hr of applicator operation to ensure accuracy. Oxidation caused by heating of the steel is not acceptable. If

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blueing occurs, the pipe shall be cooled to an ambient temperature and recleaned.

4.4.3.2 Pipe ends. When pipe sections are to be joined by field welding, coating shall be held back a minimum of 3 in., or as specified by the purchaser.

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

4.4.3.3 Thickness. The coating powder shall be applied to the preheated pipe at a uniform cured-film thickness of not less than 12 mils (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, rockshields, such as, but not limited to, cement–mortar overcoat, specially prepared backfill, or other methods or materials, may be necessary.

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

4.4.3.5 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.

4.4.3.6 Imperfections. On completion of the coating operation, the coating shall be visually inspected for blisters, bubbles, voids, or other discontinuities. The coatings shall also be electrically inspected for holidays in accordance with Sec. 5.3.4.1. 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. 4.4.4.

4.4.3.7 Optional coating performance testing. The purchaser may specify additional testing to establish coating 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.

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4.4.4 *Coating repair.*

4.4.4.1 Minor defects. Coating that requires repair caused by scars, slivers, coating imperfections, and other small defects as identified by the procedure in Sec. 5.3.3.1 shall be repaired using repair materials from the same manufacturer as the fusion-bonded epoxy or any other compatible material acceptable to the purchaser and coating manufacturer.

4.4.4.1.1 Minor defects shall be repaired in the shop. Surface grinders, files, or sanders shall be used to remove defective coating. Areas adjacent to the defective area shall be roughened by sanding or grinding. Dust shall be removed prior to the application of the repair material.

4.4.4.1.2 For internal coating repair, a two-part, 100-percent solids, liquid-epoxy patching compound compatible with the coating epoxy shall be applied on the prepared areas to a minimum thickness as stated in Sec. 4.4.3.3. The epoxy in the repaired area shall be applied and cured in accordance with the coating manufacturer's recommendations.

4.4.4.1.3 Minor defects on the exterior of the pipe shall be repaired in the shop using hot-applied tape, cold-applied tape, liquid epoxy, hot melt patch compound, or heat-shrinkable coatings in accordance with the requirements of ANSI/AWWA C203, ANSI/AWWA C209, ANSI/AWWA C210, ANSI/AWWA C214, or ANSI/AWWA C216.

4.4.4.1.4 Repaired areas shall be electrically inspected using a holiday detector in accordance with Sec. 5.3.3.1.

4.4.4.2 Major defects. Pipe sections with coating defects, such as partial coating, unbonded coating, or inadequate film thickness, shall be reprocessed starting with surface preparation procedures in Sec. 4.4.2.

4.4.5 *Field-welded joints.*

4.4.5.1 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-SP10/or NACE No. 2, as defined in Sec. 4.4.2.2. SSPC VIS 1-89-05 is a series of photographs of surface cleanliness. The adjacent fusion-bonded coating shall be roughened by sanding or grinding for a distance of 1 in. (25 mm) back from the edge of the cutback. When alternative joint coatings are used, surface preparation shall be in accordance with the applicable ANSI/AWWA standard.

4.4.5.2 Epoxy application. Fusion-bonded epoxy may be field-applied on the internal and external field joints using induction heat. The epoxy used on the

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joint shall be fully compatible with the material used on the pipe. The constructor shall consult the manufacturer of the coating material for the required minimum temperature of epoxy application. For determination of final cure, see Sec. 4.4.3.4, Sec. 4.4.3.5, and Sec. 4.4.3.7.

The weld area shall be heated to a temperature not to exceed 500°F (260°C) 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 pipe coating. See Sec. 4.4.3.1 regarding higher temperatures.

Immediately after heating, the weld shall be coated with a powder coating in accordance with this standard for the minimum thickness stated in Sec. 4.4.3.3. The welded-joint coating shall overlap the original pipe coating by no less than 1 in. (25 mm).

The joint coating 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. 4.4.3.4).

On completion of the coating operation, the joint coating shall be inspected for continuity as provided in Sec. 5.3.3.1. Holidays shall be repaired in accordance with Sec. 4.4.4. Inspection and repair may commence after the heat zone has cooled to 200°F (93°C) or below.

4.4.5.3 Alternative joint coatings. The exterior of field-welded joints may be coated with hot-applied tape, cold-applied tape, liquid epoxy, or heat-shrinkable coatings in accordance with the requirements of ANSI/AWWA C203, ANSI/AWWA C209, ANSI/AWWA C210, ANSI/AWWA C216, ANSI/AWWA C217, or as otherwise specified or agreed to by the purchaser.

Sec. 4.5 Coating Special Pipe Connections and Appurtenances

4.5.1 *General.* This section describes application of fusion-bonded epoxy coatings to mechanical couplings, flanges, and similar attachments for steel pipe fittings and specials, as well as nuts, bolts, and other appurtenances used in conjunction with connections and attachments. Coatings hereunder shall be applied in the shop or at the place of manufacture and shall meet the requirements of Sec. 4.3.

4.5.2 *Surface preparation.* Preparatory to coating, the article shall be blast-cleaned to near-white as defined in Sec. 4.4.2.2. 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. 4.4.2.5 may be used if acceptable to the purchaser and coating manufacturer.

4.5.3 *Coating application.*

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4.5.3.1 Preheating. Fusion-bonded coatings 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 coating 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 that the item to be coated can withstand the required preheating without damage. Blueing of the steel during preheating will not be acceptable. If blueing occurs, the pipe shall be cooled to room temperature and recleaned in accordance with Sec. 4.5.2.

4.5.3.2 Application. The fusion-bonded epoxy coating shall be uniformly applied to the thickness specified in Sec. 4.4.3.3 by fluidized bed, electrostatic spray, or air spray according to the coating manufacturer's recommendations. Selection of the method of application depends on the size, shape, and configuration of the item to be coated. If not specified for coating by the purchaser, uncoated threaded areas shall be protected. The purchaser should specify the coating requirements for flange faces or other appurtenances.

4.5.3.3 Cure. If it is necessary to postcure the fusion-bonded coating, the coated surface shall be heated immediately after application of the coating according to the coating manufacturer's recommendations until total cure is achieved (Sec. 4.4.3.5).

4.5.3.4 Imperfections. Following completion of the coating operation, the coating shall be visually inspected for blisters, bubbles, voids, or other discontinuities. The coatings shall also be electrically inspected for holidays in accordance with Sec. 5.3.4. Inspection and repair may commence after the article has cooled to 200°F (93°C) or below.

4.5.3.5 Coating repair. Holidays and imperfections detected by electrical inspection or visually shall be repaired in accordance with Sec. 4.4.4.

4.5.3.5.1 Coating requiring repair caused by scars, slivers, coating imperfections, and other small defects as identified by the procedures in Sec. 5.3.4 shall be repaired using materials fully compatible with the fusion-bonded epoxy.

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

b. For internal 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 coating manufacturer's minimum suggested film thickness for coating repair, or the thickness stated in Sec. 4.4.3.3, whichever is greater. The

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epoxy in the repaired area shall be applied and cured in accordance with the coating manufacturer's recommendations.

c. Minor defects on the exterior of the pipe may be repaired with hot-applied tape, cold-applied tape, liquid epoxy, hot melt patch compound, or heat-shrinkable coatings in accordance with the requirements of ANSI/AWWA C203, ANSI/AWWA C209, ANSI/AWWA C210, or ANSI/AWWA C216. If a liquid epoxy coating is used, the freshly coated area shall be allowed to harden prior to handling and storage. Cure in accordance with Sec. 4.4.3.5.

d. Repaired areas shall be electrically inspected using a holiday detector in accordance with Sec. 5.3.4.

4.5.3.5.2 Major defects on connections and appurtenances such as partial coating, unbonding coating, or inadequate film thickness shall be reprocessed starting with Sec. 4.4.2.

Sec. 4.6 Field Procedures

During construction of the pipeline, the constructor shall use every precaution to prevent damage to the protective coating on the pipe. No metal tools or heavy objects shall be permitted to have contact with the finished coating. Workers shall not be permitted to walk on the pipe coating except when absolutely necessary, in which case they shall wear shoes with rubber or composition soles and heels or other suitable footwear that will not damage the coating. Damage to the pipe or the protective coating before final acceptance by the purchaser shall be repaired.

4.6.1 *Protection during welding.* A heat-resistant material with a minimum width of 18 in. (450 mm) shall be draped over the top half of the pipe on each side of the coating holdback during welding to avoid damage to the coating by hot weld spatter. If welding of the interior joint is required by the purchaser, appropriate means of protecting the coating shall be provided by the constructor.

4.6.2 *Hoisting.* Wide-belt slings shall be used to hoist coated pipes. The use of chains, cables, tongs, or other equipment likely to damage the epoxy coating shall not be permitted, nor shall the pipe be dragged or skidded. The constructor shall allow the coating on the underside of the coated pipes to be inspected while the pipes are suspended. Any coating damage shall be repaired according to Sec. 4.4.4.

4.6.3 *Pipe bedding and trench backfill.* Pipe bedding and backfill shall be installed so as to avoid abrasion or other damage to the coating. Unless otherwise specified by the purchaser, the following requirements shall be met.

4.6.3.1 Where the trench traverses rocky ground containing hard objects

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that could penetrate the protective coating, a layer of screened earth, sand, or gravel no less than 6 in. (150 mm) thick with a maximum particle size of 0.75 in. (20 mm) shall be placed in the bottom of the trench prior to the installation of pipe. Other suitable bedding materials may be used in place of earth, sand, or gravel if specified by the purchaser.

4.6.3.2 Placement of backfill around the exterior of the coated pipe shall be performed as specified by the purchaser after final inspection of the exterior coating. Rocks, concrete chunks, or other hard objects shall not be placed within 6 in. (150 mm) of the top of the pipe. If hard objects occur in the backfill along any section of the pipeline, a minimum of 6 in. (150 mm) of screened material shall be placed around and above the coated pipe before backfilling the remainder of the trench.

4.6.3.3 Compaction of bedding and backfill in the trench shall be specified by the purchaser. Compaction with metal rods or other metal tools that could come into contact with the pipe coating shall not be permitted.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection by the Purchaser

5.1.1 *Optional Inspection.* At the purchaser's option, the entire procedure of applying the protective coating material as described in this standard may be inspected from the time of surface preparation to completion of coating. This inspection shall not relieve the constructor of responsibility to provide material and perform work in accordance with this standard.

5.1.2 *Access for inspection.* The purchaser shall have access to the construction site and those parts of plants that are concerned with the performance of work according to this standard.

5.1.3 *Facilities for inspection.* Facilities and space for the inspection, testing, and acquisition of information regarding the material used, the application process, the progress and manner of the work, and the results obtained shall be as specified by the purchaser.

Sec. 5.2 Notice of Nonconformance

5.2.1 *Surface.* The purchaser may reject items to be coated if the surface condition does not comply with the requirements of Sec. 4.4.2. Items rejected because of inadequate cleaning shall be recleaned and reinspected.

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5.2.2 *Coating work.* The purchaser may reject coated items if at any time it is determined that the procedure of applying the protective coating material is not in accordance with this standard. Items rejected may be recoated and reinspected.

Sec. 5.3 Laboratory Tests

5.3.1 *Coating materials tests.* Prior to acceptance and application of the coating 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.

5.3.2 *Powder and coating systems tests.* If the values or conditions of the powder and coating systems determined from testing do not meet the values in Sec. 4.3.2 for the following items, the coating is subject to rejection.

5.3.2.1 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).

5.3.2.2 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.

5.3.2.3 Gel time—hot steel plate. 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 coating material and stop the watch when the coating material becomes so gelatinous that it can no longer be stirred. The gel time, in seconds, shall be reported.

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

5.3.2.5 Impact resistance testing. Tests for impact resistance shall be conducted in accordance with ASTM G14. The impacted coating 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 RP0188.

5.3.2.6 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. 4.4.2.2. Remove surface dust using a vacuum or a dry, oil-free blast of air. Preheat the plate in accordance with the coating manufacturer's instructions. As

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soon as the plate has reached the required temperature, coat the blasted surface to a thickness of 0.014 in. ± 0.002 in. (356 µm ± 50 µm) using air or electrostatic spray and postcure as required. Coating application and curing shall be in accordance with the coating 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 epoxy coatings used solely on special pipe connections and appurtenances that are not bent after coating, bend the coated plate over a mandrel with a radius of 6.25 in. (159 mm). The coating 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 RP0188.

5.3.2.7 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. 4.4.2.2. 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 mils–14 mils (280 µm–356 µm). Return the assembled panels to the oven and cure as recommended by the coating 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.

5.3.2.8 Penetration. Penetration resistance shall be conducted in accordance with ASTM G17 at a temperature of 140°F (60°C).

5.3.2.9 Abrasion resistance. Abrasion resistance shall be conducted in accordance with ASTM D1044 with a Tabor CS17 wheel, or equivalent, and 1,000-g loading.

5.3.2.10 Water soak. Prepare two test panels approximately 4-in. (100-mm) square by 0.25-in. (6-mm) thick according to Sec. 5.3.2.5. 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 hr 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 coating to the substrate, then air cool the specimen to 73°F (23°C). Within 2 hr after removal from heat, insert the tip of a utility knife under the coating at the corner of the scribed rectangle. Use a levering action to remove the coating. Continue inserting the tip of the knife and levering under the coating until either

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all of the coating in the rectangle is removed or the coating demonstrates a definite resistance to the levering action. An adhesion rating greater than three shall constitute failure of the test in accordance with the criteria provided in Table 3.

5.3.3 *Production coated-pipe tests.*

5.3.3.1 Electrical inspection for continuity. On completion of the coating operation but prior to storage, the exterior coating shall be inspected for continuity in accordance with NACE Standard RP0490. For interior coating, a low-voltage holiday detector set at a maximum of 75 V shall be used. 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. 4.4.4.

5.3.3.2 Adhesion. At the option of the purchaser, the adhesion of the cured coating to the surface of the pipe may be checked by pushing a sharp knife blade through the coating to the surface of the pipe and, using a plowing motion, attempting to remove the coating from the surface. The coating shall be fully adhered to the pipe and shall firmly resist the plowing action without brittle chipping. 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. 4.4.4.1.2.

5.3.3.3 Thickness. The coating thickness shall be in accordance with Sec. 4.4.3.3, or greater if specified by the purchaser. The thickness of the coating system shall be checked in accordance with the method described in SSPC Modified PA2 or an alternate method as described in NACE RP0394. The method shall be agreed on by the purchaser and constructor. The frequency shall be agreed on by the purchaser and constructor, but no less than once per pipe appurtenance.

5.3.3.4 Optional coating performance testing of coated pipe. The purchaser may specify additional testing to establish coating 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.

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Table 3. Adhesion rating criteria for coating system tests

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

A description of the above tests are available in NACE Standard RP0394 (Section 2).

5.3.4 *Coated connection and appurtenance test.* Electrical inspection for continuity and thickness testing may begin after the article has cooled to 200°F (93°C) or below.

5.3.4.1 Electrical inspection for continuity. On completion of the coating operation but prior to storage, the interior and exterior coating shall be inspected for continuity using a full-wave rectified, direct-current output detector set at a voltage computed by V (volts) = $525(t)^{1/2}$ (mils) where t is the coating thickness, to check for holidays, pinholes, and discontinuities. In areas where surface configurations preclude the use of a dry detector, the coating shall be checked for continuity with a low-voltage wet-sponge detector. Holidays shall be repaired in accordance with Sec. 4.4.4.

5.3.4.2 Thickness. The thickness of the coating system shall be checked in accordance with the method described in SSPC Modified PA2 or an alternate method as described in NACE RP0394. The method shall be agreed on by the purchaser and constructor. The frequency shall be agreed on by the purchaser and constructor, but no less than once per pipe appurtenance.

SECTION 6: DELIVERY

Sec. 6.1 Packaging and Marking

The coating 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.

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Sec. 6.2 Handling, Storage, and Shipping

Pipe shall be handled and stored so as to minimize damage to pipe, appurtenances, and the coating system. Damaged pipe, appurtenances, and coatings shall be repaired. Damaged coating shall be repaired in accordance with Sec. 4.4.4.

6.2.1 *Stacking.* Stacking shall be in accordance with appropriate safety practices and purchaser's instructions. Spacers or padding shall be used to prevent damage to the pipe and coating.

6.2.2 *Shipping.* Pipe shall be transported from the coating yard to the jobsite as recommended by the manufacturer and agreed to by the purchaser. Pipe shall be shipped using shoring or dunnage, padding, and banding to protect the pipe and its coating.

6.2.3 *Loading.* Pipe shall be loaded for shipping in compliance with existing shipping standards.

6.2.4 *Trench-side placement.* Pipe placed alongside the trench shall be supported off the ground to avoid damage to the coating.

6.2.5 *Outdoor storage.* The purchaser should consult with the manufacturer and the constructor regarding the specific weather conditions (e.g., temperature, humidity, ultraviolet exposure) to which coated steel articles, especially pipes coated on the exterior, will be subjected during storage prior to installation. From this consultation, any decisions concerning any protective measures shall be made.

Sec. 6.3 Affidavit of Compliance

The purchaser may require the constructor to provide an affidavit that all materials and work performed comply with the applicable requirements of this standard.

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ANSI/AWWA C213, "Standard for AWWA, Epoxy Coating, Fusion-Bonded for the Interior & Exterior of Steel Water Pipelines," was adopted on 24-DEC-86 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Commander, Defense Supply Center Philadelphia, 700 Robbins Avenue, Philadelphia, PA 19111-5096. DoD activities may obtain copies of this standard from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111. The private sector and other Government agencies may purchase copies from the American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

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