ANSI/AWWA **C203-20**

(Revision of ANSI/AWWA C203-15)

AWWA Standard

Coal-Tar Protective Coatings and Linings for Steel Water Pipe

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American Water Works Association

Approved American National Standard ANSI

STANDARD Since 1881

AWWA Standard

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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 C203.*

I. Introduction.

I.A. *Background.* Hot-applied coal-tar enamel has been used for corrosion protection of steel water pipe, both as an interior lining and as an exterior coating, since the mid-1930s. Internally, the coal-tar enamel is used without reinforcement or shielding. The hot enamel is spun into the pipe and provides a smooth internal lining having low hydraulic frictional resistance. When used as an external coating, the coal-tar enamel, when specified, is reinforced with glass fiber inner and outer wraps. These wraps have replaced the original fibrous material, such as asbestos felt, which was a standard wrap for many years until health concerns regarding asbestos surfaced. The glass fiber inner and outer wraps are now being specified as routine reinforcements for coal-tar enamel coatings.

I.B. *History.* The first AWWA standards for coal-tar enamel were approved Apr. 25, 1940, and were designated 7A.5, for steel water pipe in sizes 30 in. (750 mm) and larger, and 7A.6, for steel water pipe of sizes up to, but not including, 30 in. (750 mm). Revisions of these documents were approved on Oct. 3, 1949; June 21, 1950; May 1, 1951; and July 14, 1955.

In 1951, the designations of 7A.5 and 7A.6 were changed to AWWA C203 and AWWA C204, respectively.

On Mar. 27, 1957, a revision was approved that combined the two standards into one document designated as AWWA C203. Subsequent revisions were approved by the AWWA Board of Directors on Jan. 23, 1962; May 22, 1966; Jan. 29, 1973; June 25, 1978; Jan. 26, 1986; June 23, 1991; Feb. 1, 1998; Jan. 20, 2002, and June 7, 2015. This edition was approved on October 26, 2020.

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). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

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

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

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 C203 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 all 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 Product Application*. This standard defines coal-tar protective coatings and linings in terms of performance to establish the quality desired

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[†] Persons outside the United States should contact the appropriate authority having jurisdiction.

[‡] NSF International, P.O. Box 130140, 789 North Dixboro Road, Ann Arbor, MI 48105.

[§] Both publications available from The National Academies Press, 500 Fifth Street NW, Keck 360, Washington, DC 20001.

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

for long-term prevention of corrosion. The standard covers the external coating and internal lining of steel water pipelines for underground or underwater installation. If an extended period of aboveground storage of coated pipe is anticipated, consideration should be given to the ability of the coating to resist ultraviolet degradation and other atmospheric and environmental conditions.

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 information should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA C203, Coal-Tar Protective Coatings and Linings for Steel Water Pipe, of latest revision.
2. Any exceptions to the standard that may be required.
3. Operating temperature.
4. Location of coating application with reference to environmental considerations.
5. Diameter, length, and location of pipeline, including maps and drawings necessary to show all details of the pipeline.
6. Application and use of materials covered in this standard should conform to warnings and instructions provided by the manufacturers and conform to existing federal and local governmental regulations.
7. Requirements for outdoor storage (Sec. 1.1.1).
8. Details of federal, state, and local requirements (Sec. 4.2).
9. For applications other than potable water, whether compliance with NSF/ANSI/CAN 61 Drinking Water System Components—Health Effects, is required (Sec. 4.2.3).
10. If materials only are being purchased according to the requirements of Sec. 4.3 of this standard, the purchaser shall specify quantities for the following items: (1) primer by type (Sec. 4.3.2); (2) coal-tar enamel by type (Sec. 4.3.3.1 and Table 1); (3) outerwrap (Sec. 4.3.4); and (4) glass fiber inner mat (Sec. 4.3.5). The purchaser should also specify if an affidavit of compliance is required (Sec. 6.3).
11. Type of liquid adhesive (Sec. 4.3.2).
12. Type of coal-tar enamel (Sec. 4.3.3).
13. Type of outerwrap (Sec. 4.3.4).
14. Length of pipeline requiring internal protection (Sec. 4.4.1.1).

15. Length of pipeline requiring: (1) normal exterior protection (Sec. 4.4.1.2) together with any preference regarding finish coat of whitewash, water-emulsion latex paint, or kraft paper; and (2) each type of additional exterior protection required for unusual underground or underwater conditions (Sec. 4.7).

16. Requirements for coating system thickness (Sec. 4.4.1.3 and 4.7).

17. Holdback of lining and coating at ends of pipe sections (Sec. 4.4.9)

18. Lining and coating of pipe ends (Sec. 4.4.10).

19. If materials only are being purchased according to the requirements of Sec. 4.6 of this standard, then, in addition to items 20 and 21, the purchaser should specify the following: (1) quantity of liquid adhesive (Sec. 4.6.5.1); (2) quantity of tape (Sec. 4.6.5.2); and (3) affidavit of compliance, if required (Sec. 6.3).

20. Additional materials or procedures (Sec. 4.6.2).

21. Thickness of tape (Table 4).

22. Adhesion tests (Sec. 4.6.8).

23. Additional exterior protection that may be required. Typically, the exterior coating includes a glass fiber innerwrap and outerwrap (Sec. 4.7).

24. Samples of materials, if required (Sec. 5.1.4).

25. Inspection, testing, and rejection (Sec. 5.1.4.1).

26. Testing frequency of coating thickness measurement (Sec. 5.3.1).

27. 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. Major revisions made to the standard in this edition include the following:

1. Section 2, References, was updated.

2. The definition for applicator was added and the definition for constructor was deleted in Section 3, Definitions, and the terms were switched out throughout the standard in order to clarify responsibilities.

3. The description for outerwraps was slightly revised in Sec. 4.3.4.1.

4. The title of Sec. 4.6 was changed.

5. Sec. 6.3 was modified to include affidavits from both the coal-tar 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

Coal-Tar Protective Coatings and Linings for Steel Water Pipe

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard provides the minimum requirements for coal-tar protective coatings and linings used in the water supply industry for buried steel water pipelines.

AWWA steel pipe coating and lining standards are written for and based on the service temperature of potable water. For operating temperatures higher than the normal temperature of potable water, consult the manufacturer for recommendations concerning temperature limitations for coal-tar protective coatings and linings.

1.1.1 *Storage conditions*. Because aboveground and environmental conditions vary, the purchaser should consult the manufacturer as to type of coating that is recommended for the specific anticipated storage conditions, including the necessity for ultraviolet-light protection.

1.1.2 *Safety and environmental considerations*. The components of the coal-tar system may contain skin irritants and may be flammable. Precautions should be taken to protect against these hazards and to comply with the manufacturer's recommendations concerning the use and handling of the components.

Sec. 1.2 Purpose

The purpose of this standard is to provide the requirements for coal-tar protective coatings and linings for steel water pipelines—enamel and tape—hot applied, including materials, application, verification, and delivery.

Sec. 1.3 Application

This standard can be referenced in purchase documents for hot-applied coal-tar protective coatings and linings of steel water pipelines. The stipulations of this standard apply when this document has been referenced and then only to protective coatings and linings of steel water pipelines with hot-applied coal-tar enamel systems and to hot-applied coal-tar tape on the exterior of special sections, connections, and fittings.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they 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 C205—Cement–Mortar Protective Lining and Coating for Steel Water Pipe—4 In. (100 mm) and Larger—Shop Applied.

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

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

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

ASTM† D5/D5M—Standard Test Method for Penetration of Bituminous Materials.

ASTM D36/D36M—Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus).

ASTM D71—Standard Test Method for Relative Density of Solid Pitch and Asphalt (Displacement Method).

ASTM D146/D146M—Standard Test Methods for Sampling and Testing Bitumen-Saturated Felts and Woven Fabrics for Roofing and Waterproofing.

ASTM D388—Standard Classification of Coals by Rank.

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

ASTM D546—Standard Test Method for Sieve Analysis of Mineral Filler for Asphalt Paving Mixtures.

ASTM D689—Standard Test Method for Internal Tearing Resistance of Paper.

ASTM D737—Standard Test Method for Air Permeability of Textile Fabrics.

ASTM D882/D882M—Standard Test Method for Tensile Properties of Thin Plastic Sheeting.

ASTM D2415—Standard Test Method for Ash in Coal Tar and Pitch.

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

ASTM D7091—Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals.

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

ISO[‡] 719—Glass—Hydrolytic Resistance of Glass Grains at 98°C, Method of Test and Classification.

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

SSPC[††]-SP 1—Solvent Cleaning.

SSPC-SP 2—Hand Tool Cleaning.

SSPC-SP 3—Power Tool Cleaning.

SSPC-SP 6/NACE[‡‡] No. 3—Commercial Blast Cleaning.

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

TAPPI[§§] T411—Thickness (Caliper) of Paper, Paperboard, and Combined Board.

TAPPI T414—Internal Tearing Resistance of Paper (Elmendorf-Type Method).

[‡] International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

[§] NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

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

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

[††] SSPC: The Society for Protective Coatings, 800 Trumbull Drive, Pittsburgh, PA 15205.

[‡‡] NACE International, 1440 South Creek Drive, Houston, TX 77084.

[§§] Technical Association of the Pulp and Paper Industry, 15 Technology Parkway South, Norcross, GA 30092.

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.

2. *Blasting:* Blasting shall refer to blasting with sand, steel shot, or grit.

3. *Centrifugal casting:* The process of applying coal-tar enamel to the inside surface of the pipe. Molten coal-tar enamel is introduced into the pipe, spread on the surface of the pipe, and held thereon by the centrifugal force developed by rotating the pipe about its longitudinal axis until the enamel has cooled, solidified, and become bonded to the pipe.

4. *Day:* A day is defined as a 24-hr period.

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

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

7. *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 blasting, priming, enameling, wrapping, and taping shall be designed, manufactured, and maintained in adequate condition so that the application procedure produces the results prescribed in this standard.

Sec. 4.2 Materials and Workmanship

4.2.1 *Personnel.* The entire operation of applying the coating and lining shall be performed by personnel trained in the application of the coal-tar system.

4.2.2 *Materials.* Materials shall comply with the requirements of the Safe Drinking Water Act and federal regulations for potable water, wastewater, and reclaimed water systems as applicable.

4.2.3 *Certification.* If the lining system is in contact with potable water, it shall be certified to NSF/ANSI/CAN 61.

Sec. 4.3 Materials for Hot Coal-Tar Enamel Systems

4.3.1 *General.* This section describes the composition and physical properties of materials to be used for liquid adhesives, coal-tar enamel, innerwraps, outerwraps, and finish coats intended for use in hot-applied coal-tar enamel linings and protective coating systems for steel water pipelines. The liquid adhesive and coal tar shall be provided by the same manufacturer.

4.3.2 *Liquid adhesive*. Type A (coal-tar), Type B (fast-drying, synthetic), and Type C (two-component heat-curable liquid epoxy) liquid adhesives are covered by this standard. Unless Type A liquid adhesive is specified by the purchaser, Type B or Type C liquid adhesive, which may be employed under all conditions when coal-tar enamel is specified, shall be used. At site locations where air emission regulations may restrict the use of Type A and Type B liquid adhesive, other resin-base liquid adhesives may be used as equivalent to the Type A, B, and C liquid adhesives covered in this standard, provided that when topcoated with the appropriate coal-tar enamel, they meet the performance requirements of Table 1 and are approved by the purchaser. Consult the manufacturer for specific alternative surface preparation and application systems.

4.3.2.1 Type A liquid adhesive. Coal-tar liquid adhesive shall consist only of processed coal-tar pitch and refined coal-tar oils, suitably blended to produce a liquid that may be applied cold by brushing or spraying and that will produce an effective bond between the metal and a subsequent coating of coal-tar enamel.

4.3.2.2 Type B liquid adhesive. Fast-drying synthetic liquid adhesive shall consist of chlorinated rubber, synthetic plasticizer, and solvents. These constituents shall be suitably compounded to produce a liquid that can be readily applied cold by brushing or spraying and that will produce a suitable and effective bond between the metal and a subsequent coating of coal-tar enamel.

4.3.2.3 Type C liquid adhesive. Rapid-curing two-component liquid epoxy system uses the latent heat of the hot enamel to cure the system. The constituents shall be suitably compounded to produce a liquid that can be readily applied at ambient temperatures by brushing or spraying and that will produce a suitable and effective bond between the metal and a subsequent coating of coal-tar enamel.

4.3.2.4 Application properties. The Type A and Type B liquid adhesives shall dry to the touch in accordance with the manufacturer's recommendations. Type C liquid adhesive shall be applied according to the manufacturer's recommendations. Type C shall not be allowed to cure or dry prior to the application of hot enamel.

Table 1 Physical properties of coal-tar enamel

Test	Type I Enamel		Type II Enamel		Test Method
	Minimum	Maximum	Minimum	Maximum	
Softening point	220°F (104°C)	240°F (116°C)	220°F (104°C)	240°F (116°C)	ASTM D36
Filler (ash); percent by weight	25	35	25	35	ASTM D2415
Filler fineness through 200 mesh; percent by weight	90	—	90	—	ASTM D546
Specific gravity at 77°F (25°C)	1.4	1.6	1.4	1.6	ASTM D71
Penetration* at 77°F (25°C), 100-g weight for 5 sec; 0.1 mm	5	10	10	20	Sec. 5.4.2
Penetration at 115°F (46.1°C), 50-g weight for 5 sec; 0.1 mm	12	30	15	55	Sec. 5.4.2
High-temperature sag test at 160°F (71°C)	—	1⁄16 in. (1.6 mm)	—	1⁄16 in. (1.6 mm)	Sec. 5.4.4
Low-temperature cracking test at –10°F (–23.3°C)	—	none	N/A	N/A	Sec. 5.4.5
Low-temperature cracking test at –20°F (–28.9°C)	N/A	N/A	—	none	Sec. 5.4.5
Impact test at 77°F (25°C), 650-g ball, 8-ft drop;					Sec. 5.4.7
Direct impact, disbonded area	—	16 in.^{2} (10,323 mm^2)	—	10 in.^{2} (6,452 mm^2)	
Indirect impact, disbonded area		6 in.^{2} (3,871 mm^2)		2 in.^{2} (1,290 mm^2)	
Peel test†		no peeling		no peeling	Sec. 5.4.6
Cathodic disbondment		9 mm (0.35 in.)		9 mm (0.35 in.)	Sec. 5.4.15
Service temperature limitations‡					
Interior lining		90°F (32.2°C)		90°F (32.2°C)	
Exterior coating		160°F (71.1°C)		160°F (71.1°C)	

* For static conditions above 5°F (–15°C), use enamel with 5–10 penetration at 77°F (25°C); below 5°F (–15°C) and above –10°F (–23°C), use 10–15 penetration; and below –10°F (–23°C) and above –20°F (–29°C), use 15–20 penetration enamel. (Static conditions are those conditions under which the pipe is not being handled.)

† Type I enamel in the 5–10 penetration range at 77°F (25°C) shall be tested with liquid adhesive, Type B or Type C.

‡ It is not intended that each lot of coating be tested against this standard. However, the manufacturer's recommendations for use must be consistent with the requirement.

Type A liquid adhesive shall not be specified for either laboratory testing or field usage when the following conditions exist:

1. If the enamel will be applied less than 16 hr or more than 72 hr after application of the Type A adhesive.

2. If the temperature and humidity conditions are such that adequate drying of the liquid adhesive and bonding of enamel will not be obtained within 24 hr.

3. The pipe is to be coated with Type I enamel and will be handled at temperatures below 30°F (–1°C).

4.3.3 *Coal-tar enamels.*

4.3.3.1 Quality of enamel. Coal tar shall be produced from coal that has a minimum heating value of 13,000 Btu/lb (7.233×10^6 cal/kg) on a moisture- and mineral-free basis (ASTM D388) and that has been carbonized in a slot-type coke oven at a temperature of not less than 1,652°F (900°C). The coal-tar enamel shall be Type I or Type II enamel as specified by the purchaser. When tested in accordance with Sec. 5.4, the enamel shall have the physical properties shown in Table 1 and shall be composed of a specially processed coal-tar pitch and compatible oils combined with an inert mineral filler. The enamel shall contain no asphalt of either petroleum or natural base.

4.3.4 *Outerwraps.*

4.3.4.1 Description. The outerwrap shall be a Type 1, 2, or 3 glass fiber mat base (as described in Table 2) or a Type 1, 2, or 3 glass fiber mat that has been uniformly impregnated and heavily coated with a coal-tar saturant produced from coal tar meeting the requirements of Sec. 4.3.3.1 that is compatible with the coal-tar enamel coating. The outerwrap shall have a uniform porosity that allows the air and fumes to escape and the hot coating to bleed through the outerwrap, ensuring it is fused into the outer surface.

4.3.4.2 Quality of outerwrap. The outerwrap shall be Type 1, 2, or 3 as specified by the purchaser. When tested in accordance with Sec. 5.4, the outerwrap shall have the physical properties shown in Table 2.

4.3.4.3 Appearance. When tested in accordance with ASTM D146, finished outerwrap shall have a uniform surface free from holes, slits, and other visible defects. Where applicable, the reinforcement yarns shall be spaced evenly over the width. Fine mineral matter (surfacing material) may be applied to the surface to prevent sticking between layers of the packaged outerwrap prior to its application. Before packaging, loose or unbonded surfacing material shall be removed from the surface of the wrap by brushing or other suitable means. When unrolled at temperatures between 32°F and 100°F (0°C and 38°C), the outerwrap shall not stick to itself to such an extent as to cause tearing of the outerwrap.

4.3.5 *Glass fiber innerwrap (inner mat).*

4.3.5.1 Description. The glass fiber innerwrap shall be a thin, flexible, uniform mat, composed of glass fibers in an open, porous structure, bonded with a suitable resin. The innerwrap may be of the reinforced or nonreinforced type.

Table 2 Physical properties of base glass and outerwraps

Test	Unit	Type 1	Type 2	Type 3	Test Method
Base Glass					
Type of glass fiber mat base		nonwoven glass fiber issue, reinforced or nonreinforced	woven glass fiber	lock-welded glass fiber scrim, laminated to a glass fiber tissue	
Mass per unit area of base glass before impregnation, minimum	lb/100 ft^2 (g/m^2)	1.7 (83)	3.5 (170)	1.8 (90)	ASTM D146
Outerwrap					
Mass per unit area, minimum/maximum	lb/100 ft^2 (g/m^2)	12–15 (580–732)	4.2–15 (204–732)	12–17 (580–828)	ASTM D146
Thickness, minimum	mil (mm)	30 (0.76)	30 (0.76)	30 (0.76)	TAPPI T411 modified Sec. 5.4.11
Breaking strength, average minimum –longitudinal, min	lbf/in. (N/m)	35 (6,130)	90 (15,760)	90 (15,760)	ASTM D882 modified Sec. 5.4.12
–transverse, min	lbf/in. (N/m)	27 (4,730)	90 (15,760)	90 (15,760)	
Pliability 1 in. diameter mandrel, 77°F (25°C), 2 sec	—	no cracking	no cracking	no cracking	ASTM D146 modified Sec. 5.4.9
Weight loss on heating, maximum 2 hr, 180°F (82°C)	% by weight	2	2	2	Sec. 5.4.10

The innerwrap shall be compatible with the hot coal-tar enamel coating with which it is used and shall have a texture such that it may be embedded completely within the coating material.

4.3.5.2 Quality of the innerwrap. The innerwrap shall comply with the requirements of Table 3. The glass shall be of Hydrolytic Class 3 quality as a minimum when tested in accordance with ISO 719.

4.3.5.3 Appearance. The innerwrap shall have a uniform surface and be free from holes, tears, and other visible defects.

Table 3 Physical properties of innerwrap

Test	Unit	Requirement	Test Method
Mass per unit area, minimum	lb/100 ft^2 (g/m^2)	0.91 (45)	ASTM D146
Thickness, minimum	mil (mm)	13 (0.33)	ASTM D146
Elmendorf tear strength, minimum			
–longitudinal	lb (g)	0.22 (100)	TAPPI T414 in Sec. 5.4.14.1
–transverse	lb (g)	0.22 (100)	
Breaking strength, minimum			
–longitudinal	lbf/in. (N/m)	13 (reinforced) 4 (nonreinforced) (2,280)(reinforced) (700)(nonreinforced)	ASTM D146 as modified in Sec. 5.4.14.2
–transverse	lbf/in. (N/m)	4 (700)	
Pliability ¼ in. diameter mandrel, 73°F (23°C), 2 sec	—	no cracking	ASTM D146 as modified in Sec. 5.4.14.3
Porosity, minimum/ maximum	in. of water (mm of water)	0.022–0.076 (0.6–1.9)	ASTM D737 as modified in Sec. 5.4.14.4

4.3.6 *Kraft paper*. Kraft paper shall be smooth 60-lb (27.2-kg), wet-strength, water-repellent type (Quilon additive or equivalent). It may be imprinted at intervals with the name of the manufacturer.

NOTE: The 60-lb (27.2-kg) designation is the weight of 500 sheets of paper measuring 24 in. × 36 in. (610 mm × 914 mm) in size.

4.3.7 *Whitewash.* Whitewash used shall be formulated from water, boiled linseed oil, processed quicklime, and salt in the following proportions:

Ingredient	Quantity
Water	50 gal (189 L)
Boiled linseed oil	1 gal (3.86 L)
Quicklime	150 lb (68 kg)
Salt	10 lb (4.5 kg)

To prepare the whitewash, the sequence of operations shall be to first combine the salt and water, followed by the slow, simultaneous addition of the linseed oil and quicklime. The combined ingredients shall be thoroughly mixed, and the mixture then allowed to stand for not less than three days before it is used.

4.3.8 *Water-emulsion latex paint.* Water-emulsion latex paint used shall be stabilized, pigmented dispersion of water-insoluble, film-forming, high-molecular-weight (100,000 and higher) synthetic polymeric materials in water. After application and drying, the paint shall produce a film that adheres to the coal-tar enamel and is white in color, water-resistant, and able to withstand exterior exposure without degradation for a minimum of 90 days. Discoloration of this paint's film by the coal-tar enamel is not a cause for rejection.

The paint shall not be applied to wet surfaces or to surfaces that will be exposed to rain before the paint is dry. Neither shall it be applied when the relative humidity is greater than 80 percent, nor shall it be applied when either the ambient air temperature or the substrate temperature is below 40°F (4°C).

4.3.9 *Shelf life.* The coal-tar enamel system materials shall show no product instability when stored in their original, unopened containers at temperatures not greater than 100°F (38°C) for the length of time stated by the manufacturer.

Sec. 4.4 Application of Hot Coal-Tar Enamel Systems

4.4.1 *General.* The applicator shall provide labor, equipment, and material required; shall prepare surfaces to be coated or lined; and shall apply liquid adhesive and coal-tar enamel to surfaces to be coated or lined. Except as otherwise provided in Sec. 4.5 for specials, fittings, field joints, and repairs, lining and coating of straight sections of pipe shall be applied in the shop by mechanical means as stated in this standard.

4.4.1.1 Pipe linings. The inside of pipe shall receive a coat of liquid adhesive, followed by a hot coat of coal-tar enamel. Pipe smaller than 24 in. (600 mm) in diameter should be joined in a manner that eliminates the need for entering the pipe to complete or repair the coal-tar lining at the joints. Pipe 24 in. (600 mm) or larger in diameter may be joined as specified by the purchaser.

4.4.1.2 Pipe coatings. A minimum requirement is for one coat of liquid adhesive followed by a hot coat of coal-tar enamel on which a single layer of specified outerwrap shall be applied. The coating shall then be finished with either one coat of water-resistant whitewash or water-emulsion latex paint, or a single wrap of kraft paper. Unless the purchaser specifies the type of finish coat to be provided, the choice of finish coat shall be at the option of the applicator. For additional external protection coating system, see Sec. 4.7.

4.4.1.3 System thickness. The thickness of the liquid adhesive and coal-tar enamel when used as a lining shall be 3⁄32±1⁄32 in. (2.4±0.8 mm) and measured at the barrel of the pipe. The resulting construction of the coating system shall consist of liquid adhesive and coal-tar enamel 3⁄32±1⁄32 in. (2.4±0.8 mm) thick, outerwrap, and finish coat. Thicker systems may be specified by the purchaser.

4.4.2 *Surface preparation*.

4.4.2.1 Cleaning and blasting. Before the metal is blasted, clean the surface of oil and grease according to SSPC-SP 1 solvent cleaning. After solvent cleaning, metal surfaces shall be cleaned by blasting. The pipe surface shall be abrasive blast cleaned with mineral abrasives, slag abrasives, steel shot, or steel grit in accordance with SSPC-SP 6/NACE No. 3. The blast anchor or profile depth shall be 1.5–3.5 mils (38–89 μm) measured in accordance with ASTM D4417 or as recommended by the liquid adhesive manufacturer. The profile depth shall be determined using a replica tape, a depth micrometer, or a surface profile comparator. Blasted surfaces that rust before the liquid adhesive has been applied shall be cleaned of rust by buffing or wire-brushing or, at the discretion of the purchaser, shall be reblasted.

Adequate air separators shall be used to effectively remove oil and free moisture from the air supply to the blaster.

Pipe showing pits after blasting has begun shall be set aside immediately, pending examination by the purchaser for approval, reconditioning, or rejection.

4.4.2.2 Surface protection after blasting. After being cleaned and blasted, the pipe shall be protected from, and shall be maintained free of, contaminants that might fall on the pipe before it has received the liquid adhesive and final enamel coat.

4.4.3 *Application of liquid adhesives to metal surfaces*. Blasted steel surfaces shall be cleaned of dust and grit and the liquid adhesive shall be applied immediately following blasting and cleaning. The surfaces shall be dry at the time the liquid adhesive is applied.

4.4.3.1 Fouled or thickened Type A liquid adhesive. The use of Type A liquid adhesive that has become fouled or has thickened through evaporation of the solvent shall not be permitted.

4.4.3.2 Methods of liquid adhesive application. At the option of the applicator , the liquid adhesive shall be applied by hand brushing, spraying, or other suitable means in accordance with the application instructions supplied by the manufacturer of the liquid adhesive material. The spray-gun apparatus used

shall include a mechanically agitated pressure pot and an air separator that will remove oil and free moisture from the air supply.

4.4.3.3 Cold-weather/high-humidity liquid adhesive application. During periods of cold weather, when the temperature of the steel is below 45°F (7°C) or at any time when moisture collects on the steel, the steel shall be warmed to a temperature of approximately 85–100°F (30–38°C), which shall be maintained long enough to dry the pipe surface prior to application of the liquid adhesive. The temperature of the steel pipe shall be, at a minimum, greater than 45°F (7°C) or 5°F (2.8°C) above the dew point during application. To facilitate spraying and spreading, the liquid adhesive may be heated and maintained at a temperature of not more than 120°F (49°C) during application.

4.4.3.4 Liquid adhesive drying time. The minimum and maximum drying times of the liquid adhesive, or the allowable time between application of the liquid adhesive and application of the coal-tar enamel, shall be in accordance with recommendations by the manufacturer of the liquid adhesive. Type C epoxy liquid adhesive shall not be allowed to dry or cure prior to application of the hot enamel. If the enamel is not applied within the allowed maximum time after application of the liquid adhesive, the pipe shall be recoated with an additional light coat of liquid adhesive or, at the discretion of the purchaser, the entire adhesive coat shall be removed by reblasting, and the pipe shall be recoated.

4.4.3.5 Condition of liquid adhesive layer after application. The completed liquid adhesive coat shall be uniform and free from floods, runs, sags, drips, and visual voids. Floods, runs, sags, drips, or visual voids shall be removed by scraping and cleaning, and the cleaned area retouched or, at the discretion of the purchaser, remedied by reblasting and recoating. Suitable measures shall be taken to protect wet liquid adhesive from contact with rain, fog, mist, spray, dust, or other foreign matter until the liquid adhesive coat has completely hardened and the enamel coating has been applied.

4.4.4 *Equipment for enamel preparation.*

4.4.4.1 General. The coal-tar enamel shall be heated in agitated heating kettles equipped with accurate, easily read recording thermometers. The thermometers shall be calibrated. The recorded temperature charts therefrom shall constitute a basis for acceptance or rejection of any enamel caused by improper heating or handling, or both.

4.4.4.2 Operating kettles. Operating kettles or supply kettles, or both, shall be provided in sufficient numbers so that the enamel can be properly

heated and coordinated with the application procedure. Operating kettles shall be constructed with mechanical mixers to provide for continuous mixing of the enamel. So-called roofer's kettles, which do not contain agitators and are designed to heat materials used in the roofing industry, are not permitted. Kettles shall be covered with hinged lids that may be fastened down. The lids shall be closed during the heating and application of enamel, except when necessary for loading and stirring. For field patching operations, the purchaser may permit continuous use of a heating kettle not exceeding 50 gal (189 L) in capacity.

4.4.4.3 Kettle screens. When applying the enamel, kettles shall be equipped with screens of ⅛-in. (3.2-mm) mesh or less to exclude particles of foreign matter or other deleterious materials that could flaw the finished coating.

4.4.5 *Enamel preparation and supply.*

4.4.5.1 General. Bulk deliveries of molten enamel may be received in lieu of enamel received solidified in containers. The molten enamel may be transferred directly to the supply or operating kettles. No enamel shall be held in the operating kettles at application temperatures for a period longer than recommended by the manufacturer of the enamel.

The enamel heated in supply kettles shall not exceed the temperatures and melting periods recommended by the manufacturer. Operating kettles (unless of the mechanically agitated type) shall not receive a continuous supply of unmelted enamel during the time they are in use but shall be completely emptied of one charge and cleaned before the next charge of unmelted enamel is added.

4.4.5.2 Kettle charging. When the kettles are being loaded with solidified enamel, the enamel shall be broken into pieces suitable for the heating equipment used.

4.4.5.3 Enamel maintenance. While in either the solidified or molten state, the enamel shall be maintained moisture- and dirt-free, both before and during heating and application.

4.4.5.4 Enamel heating. Solidified enamel charges shall be melted and brought up to application temperature while avoiding excessive kettle-skin temperatures that injure the enamel. Molten enamel received via bulk delivery may be transferred from the supply kettle to the operating kettle or directly to the weir. The temperature at which the enamel will be applied shall be in accordance with the recommendation of the enamel manufacturer. The hot enamel shall be continuously stirred for a minimum of 5 min, and intervals between stirrings shall not exceed 15 min, regardless of whether the enamel is being dispensed from the kettles or is being held ready for use. Iron paddles shall be used for stirring. Wooden paddles shall not be permitted.

4.4.5.5 Enamel temperature and kettle residency limits. The maximum temperature to which the enamel may be heated in the supply and operating kettles and the maximum time the enamel may be held in the kettles at application temperature shall be in accordance with the enamel manufacturer's recommendations.

4.4.5.6 Overheated or extended residency enamel. Enamel heated in excess of the maximum allowable temperature or held at application temperature longer than the maximum recommended time shall be condemned and rejected. Fluxing the enamel is not permitted.

4.4.5.7 Unused enamel. Excess enamel remaining in a kettle at the end of any heating shall not be included in a fresh batch in an amount greater than 10 percent of the batch. Kettles shall be emptied and cleaned. Residual material removed while cleaning the kettles may not be blended with any enamel and shall be discarded.

4.4.5.8 Enamel penetration loss limits. A minimum of 50 percent of the original enamel penetration at 77°F (25°C) shall be retained in the applied enamel. This minimum shall be evidence of satisfactory melting and handling practice. The purchaser may periodically require that samples of the enamel be taken as it is being applied to the pipe. If the penetration is less than 50 percent of the original enamel penetration at 77°F (25°C) in any kettle, the purchaser may reject the enamel in the kettle.

4.4.6 *Condition of the liquid adhesive coated or lined pipe prior to enameling.*

4.4.6.1 Clean-surface/cold-weather/high-humidity conditions. The liquid adhesive coated or lined steel surfaces to be enameled shall be dry and clean at the time the enamel is applied. No enamel shall be applied during cold weather, rain, or fog unless the surface to be coated or lined is protected by suitable housing. During cold weather, when the surface temperature of the pipe falls below 45°F (7°C) or during rainy or foggy weather when moisture tends to collect on cold pipe, the adhesive coated or lined pipe should be heated prior to enameling.

4.4.6.2 Preheating of liquid adhesive coated or lined pipe. Preheating shall be done by any method that will heat the pipe uniformly to the recommended temperature without injury to the liquid adhesive. The temperature of the steel pipe shall not exceed 160°F (71°C).

4.4.7 *Application of enamel to interior pipe surfaces*.

4.4.7.1 General. The application of enamel to the inside surface of pipe other than specials shall be by centrifugal casting, using either the trough method

(Sec. 4.4.7.4) or the retracting-weir or feed-line method (Sec. 4.4.7.5). The application method of elevating one end of the pipe and pouring in hot enamel while rotating the pipe is not acceptable.

4.4.7.2 Condition of applied enamel. During application of enamel, the pipe shall be revolved at the speed best suited to produce a smooth, glossy lining of uniform thickness. The finished enamel lining shall be free from wrinkles, sags, blisters, or blowholes. Lined pipe in which there are excessive rough areas or other irregularities, as determined by the purchaser, shall be stripped of the entire lining and relined.

4.4.7.3 Cooling the enamel lining. Water used for cooling the enamel lining shall not be applied until the enamel has hardened sufficiently to prevent water marks or cracking.

4.4.7.4 Trough method of enamel application.

4.4.7.4.1 Pipe shall be rotated on rubber-tired or steel wheels with suitable guards or hold-down wheels to prevent the pipe from leaving the rolls during spinning operations.

4.4.7.4.2 Molten enamel shall be introduced into the pipe by a pouring trough extending the full length of the pipe in either one or two sections. The pouring trough shall be level and shall have a straight and even pouring lip. The trough may be heated, either by electric heating elements or by a gas flame, to a temperature best adapted to the equipment available.

4.4.7.4.3 Transfer of molten enamel from the kettles to the pouring troughs shall be conducted in a manner that prevents excessive loss of heat. Hot enamel shall not be held in the pouring troughs for more than 1 min between filling and pouring. Enamel shall not be poured from troughs into the pipe until the pipe has reached its maximum speed of rotation.

4.4.7.4.4 Enamel shall be poured by inverting the trough with a uniform rate of rotation and at such speed as to distribute the enamel evenly throughout the pipe.

4.4.7.4.5 Immediately after each pouring operation, the trough shall be righted and removed from the pipe. When necessary, the trough shall be cleaned of excess enamel remaining in the trough. If the excess enamel is clean and free from dirt, it may be reused by adding it to fresh batches (not including any material salvaged under the provisions of Sec. 4.4.5.7) in quantities not exceeding 10 percent of unmelted enamel.

4.4.7.5 Retracting-weir or feed-line method of enamel application.

4.4.7.5.1 Pipe shall be rotated on rubber-tired or steel wheels with suitable guards or hold-down wheels to prevent the pipe from leaving the rolls during spinning operations.

4.4.7.5.2 Molten enamel shall be supplied to the weir or feed line from a reservoir through supply pipes. The enamel shall be maintained at application temperature using insulation and heating methods suitable to both the reservoir and the supply line. Enamel shall be supplied using a power-drive circulation pump.

4.4.7.5.3 The hot enamel shall be introduced into the rotating pipe using a retractable feed line or a traveling weir having a pouring lip that is parallel to the longitudinal axis of the pipe. By either method, the discharge element of the supply mechanism shall travel the entire length of the pipe. The speed of travel shall be properly coordinated with the speed of rotation of the pipe to ensure complete, uniform application of the molten enamel.

4.4.8 *Application of enamel and innerwrap and outerwrap systems to exterior pipe surfaces.*

4.4.8.1 Preparation of liquid adhesive coated surfaces. If the liquid adhesive layer has been damaged, it shall be repaired before the enamel is applied.

4.4.8.2 Enamel application. External enamel shall be applied by pouring it on the revolving pipe and spreading it to the specified thickness. Enamel shall be applied so that each spiral resulting from the spreading operations shall overlap the preceding spiral, producing a continuous coat free from defects, skips, or holidays. The thickness of the enamel shall be 3⁄32±1⁄32 in. (2.4±0.8 mm). Thicker coating may be specified by the purchaser. Where the protrusion of the weld seam interferes with this thickness, the thickness of the enamel above the weld seam shall meet the preceding thickness requirements.

4.4.8.3 Innerwrap application. When an innerwrap is specified (see Sec. 4.7), the glass fiber innerwrap shall be of suitable width for smooth spiral application and shall be of approximately uniform width. The lap of the innerwrap shall be not less than ½ in. (13 mm).

Glass fiber innerwrap shall be mechanically applied in a continuous end-feed machine, in a lathe-type machine, or by using suitable innerwrap application equipment. Application shall be simultaneous with the first coat of coal-tar enamel. The roll of glass fiber innerwrap shall be under tension sufficient to embed the mat in the enamel before the enamel sets or cools. The innerwrap shall be placed in the outer third of the first coat of enamel and not pulled through the hot enamel to the

metal surface. A second coat of hot coal-tar enamel shall be applied over the glass fiber innerwrap simultaneously with an outerwrap.

4.4.8.4 Outerwrap application. Outerwrap shall be mechanically applied in a continuous end-feed machine or in a lathe-type machine or by using suitable outerwrap applicating equipment. The outerwrap shall be applied to and fused onto, but not buried in, the outer surface immediately following the final coat of enamel. If specified by the purchaser, the outerwrap should then be immediately followed by kraft-paper final wrap so that it can develop adhesion with the outerwrap.

4.4.8.5 Prevention of outerwrap gassing. If low-porosity outerwrap that has been stored is applied under high-humidity conditions, "gassing" (the formation of craters or voids in the enamel beneath the outerwrap) shall be prevented by applying a film of outerwrap saturant or hot enamel to the underside of the outerwrap before it is drawn into the enamel on the pipe.

4.4.8.6 Overlapping of outerwrap. The outerwrap (Sec. 4.3.4) shall be of suitable width for smooth spiral application and shall be of uniform width. The side lap of the outerwrap shall be at least ½ in. (13 mm). The outerwrap shall be applied neatly and smoothly with bleed-out between laps and shall be free of wrinkles and buckles.

4.4.8.7 Conditioning of outerwrap surface. After application and following visual inspection, the outside surface of the outerwrap is to be given a finish coat of whitewash, water-emulsion latex paint, or kraft-paper finish coat. If kraft paper is specified, it shall be spirally wrapped and shall be tack-bonded with enamel at frequent intervals.

4.4.8.8 Pipe handling immediately after coating application. The coated pipe shall not be rolled or supported on its enameled and wrapped surface until the coating system has cooled and hardened sufficiently to avoid deformation.

4.4.9 *Holdback of lining and coating at ends of pipe sections.*

4.4.9.1 Pipe to be field welded. When pipe sections are to be joined together by field welding, a holdback or band that is free of protective materials and of sufficient width, as specified by the purchaser, to permit the making of welded field joints without injury to the lining or coating shall be left on the inside and outside surfaces at the ends of the sections.

4.4.9.2 Pipe to be joined with mechanical couplings. When pipe sections are to be joined together with mechanical couplings, a holdback or band that is free of protective materials and of sufficient width, as specified by the purchaser, to

permit joint makeup shall be left on the exterior surface at the ends of the sections. The interior enamel lining shall be extended to the pipe end.

4.4.9.3 Pipe with bell-and-spigot ends. For pipe with bell-and-spigot ends and rubber gaskets, the interior enamel lining shall extend from the end of the pipe at the spigot end to the holdback at the bell end. The exterior coating shall extend from the lip of the bell to the holdback on the spigot end. The exposed steel surfaces on the inside of the bell and the outside of the spigot end may be given a coat of Type B (fast-drying, synthetic) liquid adhesive to a dry film thickness of 2.5±0.5 mils (0.06±0.01 mm) or other suitable coating specified by the purchaser.

4.4.9.4 Pipe with other types of joint ends. The holdback or length of pipe to be left bare at the ends of pipe having other types of joints shall be as specified by the purchaser.

4.4.10 *Field lining and coating of pipe joints.*

4.4.10.1 Materials for field lining and coating. The liquid adhesive and enamel used for field lining and coating of bare pipe surfaces at pipe joints shall be from the same manufacturer as the materials as used for shop lining and coating the pipe.

4.4.10.2 Lining and coating field-welded joints.

4.4.10.2.1 For lining interior welds on nominal 24-in. (600-mm) and larger pipe, interior welds of field joints shall be cleaned and dried in accordance with Sec. 4.4.2.1 and 4.4.3.3. Hand-tool cleaning to meet SSPC-SP 2 shall be sufficient provided the pipe surface was previously shop blasted. If a Type B liquid adhesive is used, it shall be applied and allowed to dry according to the coating manufacturer's recommendations. If a Type C liquid adhesive is used, the hot enamel shall be applied while the liquid adhesive is still tacky. Hot enamel shall be applied to a minimum thickness of 3⁄32 in. (2.38 mm) with daubers or other approved methods, and shall overlap the main body of the lining by a minimum of 2 in. (51 mm) on each side of the weld to form a continuous lining, free from defects. Holes shall be located at frequent intervals along the pipe so that hot enamel may be poured into enamel buckets inside the pipe.

4.4.10.2.2 Exterior welded joints shall be cleaned and dried in accordance with Sec. 4.4.2.1 and liquid adhesive applied in accordance with Sec. 4.4.3. Hand-tool cleaning according to SSPC-SP 2 or power-tool cleaning according to SSPC-SP 3 shall be sufficient, provided the pipe surface was previously shop blasted. When the Type A and Type B liquid adhesives are dry, the field joints shall be manually coated in accordance with Sec. 4.4.1.3. If a Type C liquid adhesive

is used, the hot enamel shall be applied while the liquid adhesive is still tacky. The coating system (liquid adhesive, hot enamel, innerwrap, and outerwrap) shall overlap the shop coating by a minimum of 2 in. (51 mm) on each side of the field joint to form a continuous external coating free of defects. The outerwrap shall be bonded to the enamel and overlap seams shall be coated with enamel. Before field coating, the finish coat shall be removed from the overlap area. Alternatively, the exterior of the field-welded joints may be coated using hot-applied coal-tar tapes meeting the requirements of Sec. 4.6 of this standard, cold-applied tapes meeting the requirements of ANSI/AWWA C209, or heat-shrinkable materials meeting the requirements of ANSI/AWWA C216.

4.4.10.2.3 Hand enameling shall be done in accordance with Sec. 4.4.4, 4.4.5, and 4.4.6 of this standard. Heating enamel for field application shall be done in accordance with the procedure outlined in Sec. 4.4.5.4.

4.4.10.3 Application to mechanically coupled joints. Couplings shall be cleaned, and liquid adhesive applied at the point of manufacture. The liquid adhesive used shall be compatible with the enamel used on the pipe. The couplings and the exposed pipe ends shall be recoated with liquid adhesive in the field. When the field-applied liquid adhesive is dry, the couplings shall be assembled on the pipe, and the exterior surfaces of the couplings and adjacent exposed pipe ends shall be coated with the coal-tar enamel coating conforming to the requirements of this standard and recommended by the manufacturer of the coating used on the pipe. The coating shall be capable of conforming to the normal movement of the buried pipe without cracking.

4.4.10.4 Electrical inspection of field enameling. Enameling work shall be inspected by the applicator, using the method of electrical inspection stated in Sec. 5.2. Holidays found shall be repaired by the applicator as stated in Sec. 4.4.11 as applicable. Electrical inspection used to detect holidays found in alternate coating systems shall be as stipulated in the standard covering the alternate system.

4.4.10.5 Field finish coat if specified. The outside surface of pipe, specials, and fittings shall be given a finish coat of water-resistant whitewash, a finish coat of water-emulsion latex paint, or a wrap of kraft paper immediately following final inspection.

4.4.11 *Coal-tar repairs*. Areas of the enamel system that are damaged, are flawed, or exhibit holidays shall be repaired using materials from the same manufacturer as those used to protect the pipe. In no case is damaged enamel to be repaired by applying enamel over loose or damaged enamel where the damage

goes down to the metal or where the bond of the enamel has been destroyed. Damaged areas are categorized into three types: (1) pinpoint or bubble type, (2) exposed-metal type, or (3) extensive-damage type. Procedures for the repair of these damage types are described in the following sections. The procedures for the repair of linings are similar, except the outerwraps are omitted and alternative tapes are not permitted.

4.4.11.1 Repair of pinpoint or bubble-type damage. Dirt, foreign matter, kraft paper, and outerwrap shall be removed using a sharp knife, taking care not to damage the surrounding enamel. Correctly heated enamel shall be poured over the prepared area to the specified thickness and covered with a patch of outerwrap.

4.4.11.2 Repair of exposed-metal–type damage. These damaged areas are defined as those up to 4 in. (102 mm) square, 16 in.^{2} (103 cm^2) in size. Repair by removing the dirt, foreign matter, and disbonded enamel, then bevel the surrounding edges. Clean the metal surface properly, using wire brushes if required, and recoat the bare area. After the Type A or Type B liquid adhesives have dried, apply correctly heated enamel over the prepared area to the specified thickness, and cover with a layer of outerwrap. If a Type C liquid adhesive is used, the hot enamel is applied while the liquid adhesive is still tacky.

4.4.11.3 Repair of extensive damage. This type of damage relates to defects, such as partially uncoated areas, unbonded enamel, cracking, excessive holidays, or inadequate film thickness. Enameled pipe with these conditions shall be reprocessed. Alternatively, the above-described external coating holidays may be field repaired using hot-applied coal-tar base tapes, which are part of this standard, or cold-applied tapes meeting the requirements of ANSI/AWWA C209, or heat-shrinkable materials meeting the requirements of ANSI/AWWA C216.

4.4.11.4 Electrical inspection. Repaired areas shall be electrically inspected using a holiday detector in accordance with Sec. 5.2.

Sec. 4.5 Application to Special Connections and Appurtenances, Internal and External

4.5.1 *General.* This section describes the surface cleaning and application of coal-tar materials to the interior and exterior of special connections and appurtenances and the inspection and repair of the coal-tar system after completion of the coating or lining materials application.

4.5.2 *Surface cleaning and coating and lining materials application.* The results of surface cleaning, applying liquid adhesive internal lining, and exterior coating of specials shall be equivalent to work on straight pipe sections. Methods

deviating from the prescribed procedure shall require approval by the purchaser. If the shape of the special precludes spinning, the lining and coating shall be applied using hand daubers and equipment listed below or other methods approved by the purchaser. Fittings, such as manholes, service connections, air valves, and blow-off connections, shall be protected with the materials described in this standard.

4.5.2.1 Enamel application equipment requirements and enameling precautions.

4.5.2.1.1 Hand-enameling daubers shall be of the size best adapted for the work. Daubers shall be made of the best grade of Tampico fiber, set in solid hardwood handles. Mops, sweeps, or knot daubers shall not be used. Long-handled horseshoe daubers or glass mops will be acceptable for large areas and flat work.

4.5.2.1.2 Enameling buckets shall be filled from the heating kettles with ladles or from spigots attached to the kettles. The buckets shall not be dipped for filling. Buckets shall be kept clean and free from dirt and shall be set on suitable pads or blocks, not directly on the ground or on enameled surfaces. Buckets shall not be allowed to accumulate excess chilled enamel but shall be kept clean.

4.5.2.1.3 Enamel from enameling buckets below the minimum temperature recommended by the manufacturer shall not be used.

4.5.2.1.4 Drips and splashes of enamel on adhesive-coated surfaces shall be scraped off before the hand-brushed coat of enamel is applied.

4.5.2.2 Application of the enamel. Liquid adhesive surfaces shall be double coated by applying the enamel with hand daubers. The brush strokes shall overlap and form a continuous film. The daubing may be done by the double-lap or shingling method. No indiscriminate smearing of the enamel shall be permitted. On welds, the strokes of the first coat of enamel shall be applied along the weld. The minimum thickness of the enamel shall be 1⁄16 in. (1.59 mm).

4.5.3 *Electrical inspection—Specials.* Enamel, hand-applied to the exterior of specials, shall be examined with a 7,200-V maximum holiday detector. Holidays shall be repaired before applying the bonding coat of enamel for the outerwrap.

4.5.4 *Material repair—Coating and lining.* Holidays detected by electrical inspection or by other means shall be repaired in accordance with Sec. 4.4.11.

Sec. 4.6 Materials for Hot Coal-Tar Tape Systems

4.6.1 *General.* The protective coating system described in this section consists of a cold-applied liquid adhesive and heated coal-tar base tape used in conjunction with coal-tar enamel and other types of coatings. Liquid adhesive and tape shall be either shop or field applied to the exterior surfaces of steel water

pipe special sections, connections, and fittings. Liquid adhesive and tape shall be provided by the same manufacturer.

4.6.2 *Conditions not covered in this section*. This section does not cover the additional materials and procedures that may be required for difficult installation conditions, such as those encountered in construction of submerged lines, casing pipe, river crossings, or lines that are in exceptionally rocky areas or where soil conditions are known to be severe. Under these conditions, additional layers of material, outerwraps, rockshield, specially prepared backfill, or other methods may be necessary. The manufacturer should be consulted for specific recommendations when these conditions exist.

4.6.3 *Surface preparation*. Special sections, pipe connections, and fittings shall be free of rust, moisture, weld spatter, or foreign contaminants. Surfaces that have been blast cleaned in a mill or shop before shipment to a field location shall be wire-brushed by hand in accordance with SSPC-SP 2 or power-brushed in accordance with SSPC-SP 3 to remove corrosion products prior to applying the liquid adhesive.

4.6.4 *Material compliance*. Materials shall be as set forth in this standard. Unless otherwise specified by the purchaser, components not defined shall be selected by the manufacturer or applicator and shall be subject to applicable provisions of this standard.

4.6.5 *Coating materials—Liquid adhesive and tape*. The coating materials shall consist of cold-applied liquid adhesive and tape meeting the following requirements.

4.6.5.1 Liquid adhesive. Liquid adhesive shall be cold-applied liquid with pollution-control requirements in effect at the location of use. Liquid adhesive shall not settle in the container to form a cake that cannot be mixed easily by hand stirring. Liquid adhesive shall have satisfactory brushing or spraying properties and a minimum tendency to produce bubbles during application.

4.6.5.2 Tape.

4.6.5.2.1 Tape shall be composed of coal-tar base coating material supported on a fabric of organic or inorganic fibers. The tape shall comply with the physical properties listed in Table 4. The fabric shall be covered on both sides by the coating material. Tape shall be provided in standard widths as recommended by the manufacturer. Rolls shall be wound on hollow cores having a minimum inside diameter of 1½ in. (37.5 mm). Tape shall have sufficient pliability at a temperature

Table 4 Physical properties of tape

	Property	Minimum	Maximum	Test Method
Tape:	Width deviation, in. (mm)	—	1/16 (1.6)	Sec. 5.4.13.2
	Thickness, mil (mm)	50 (1.27)	—	Sec. 5.4.13.3
Coating compound:	Softening point, °F (°C)	150 (65)	250 (121)	Sec. 5.4.13.4
	Penetration at 77°F (25°C) 100 g for 5 sec	3	20	Sec. 5.4.13.5
	Filler, percent	20	30	Sec. 5.4.13.6

of 77°F (25°C) to unwind from the roll without disbonding the coating from the fabric.

4.6.6 *Liquid adhesive application*.

4.6.6.1 General application. A uniform and continuous coat of liquid adhesive shall be applied in accordance with the manufacturer's recommendations for the specific tape and liquid adhesive system. The liquid adhesive coverage and drying time shall be sufficient to ensure an effective bond between the substrate and the coating. The liquid adhesive shall be allowed to dry to the touch prior to tape application. Liquid adhesive application shall be limited to that amount that can be wrapped during the same workday; otherwise the steel must be recoated.

4.6.6.2 Cold-weather application. If liquid adhesive is to be applied in cold weather, the pipe shall be preheated until it is warm to the touch and traces of moisture are removed. The liquid adhesive shall then be applied and allowed to dry.

4.6.7 *Tape application*. The tape shall be wrapped in accordance with the manufacturer's recommendations in a manner that shall meet the adhesion and holiday-detection requirements of this standard. For single-wrap application, individual layers of the tape shall be overlapped at least 1 in. (25 mm). Applicators shall take care to attain complete contact with the adhesive coated steel.

4.6.8 *Adhesion tests*.

4.6.8.1 General. Adhesion tests shall be made to determine the proper bond between the coating material and the pipe. The number of tests to be made shall be agreed on by the purchaser and the applicator .

4.6.8.2 Procedure. The temperature of the tape and pipe to be tested shall be between 50°F and 80°F (10°C and 27°C), and within 5°F (3°C) of each other. If the temperature is outside this range, appropriately hot or cold water shall be poured over the test area until the temperature range has been attained.

A 6-in. (152-mm) test area in the longitudinal direction of the tape shall be selected by the purchaser. Two knife cuts 6-in. (152-mm) long and 2-in. (51-mm) apart shall be made through the tape. A flat blade shall be used to pry up 2 in. (51 mm) of the fabric. This 2-in. (51-mm) flap of fabric shall be grasped firmly in one hand and shall be pulled up with a quick motion in the direction of the remaining 4 in. (102 mm) of the 6-in. (152-mm) knife cut.

4.6.8.3 Acceptance. The adhesion is satisfactory if (1) the fabric tears at the point of stripping; or (2) the fabric strips from the underlying coating materials, leaving no more than approximately 10 percent or less of the liquid adhesive or bare metal exposed.

4.6.9 *Electrical inspection for continuity*. After wrapping operations have been completed, the applicator shall conduct an electrical inspection of wrapped surfaces with an electrical holiday detector, as stated in Sec. 5.2. Any defect in wrapping shall be repaired.

4.6.10 *Coating repair*.

4.6.10.1 Damages, flawed areas, and holidays. Areas that are damaged, flawed, or contain holidays shall be repaired using repair materials made by the manufacturer of the material originally used to wrap the pipe. In no case shall damaged areas be repaired by applying additional tape over loose, damaged tape where the damage goes down to the metal or where the bond of the tape has been destroyed.

4.6.10.2 Repair of tape. The repair shall be made by removing the hot-applied tape from the area around the holiday and then using the same system of liquid adhesive and hot-applied tape used for the original wrapping. When completed, the area shall be retested following the method of electrical inspection described in Sec. 5.2.

Sec. 4.7 Additional Exterior Protection

4.7.1 *Scope*. This section describes the material and application requirements for additional protective exterior pipeline coating systems beyond the requirements for coal-tar protective exterior coatings stated in Sec. 4.4.8 of this standard. These additional exterior protection systems are designed for use when the pipe is to be installed underground or underwater under unusual conditions.

When the use of an additional protection system is required, the purchaser shall specify the system to be used, together with the size, length, and location of the pipe to be so protected.

4.7.2 *Additional exterior protection systems.*

4.7.2.1 Addition of one innerwrap. Additional coal-tar thickness and a layer of glass fiber innerwrap.

4.7.2.1.1 The innerwrap provides additional protection.

4.7.2.1.2 The construction of this exterior coating shall consist of (1) liquid adhesive; (2) coal-tar enamel 3⁄32±1⁄32-in. (2.4±0.8-mm) thick; (3) glass fiber innerwrap; (4) coal-tar enamel 1⁄32-in. (0.8-mm) minimum; (5) glass fiber outerwrap; and (6) a finish coat.

4.7.2.1.3 The glass fiber innerwrap shall conform to the material requirements in Sec. 4.3.5 and Table 3.

4.7.2.1.4 Application of the glass fiber innerwrap shall conform to Sec. 4.4.8.3.

4.7.2.1.5 Outerwrap shall conform to Sec. 4.3.4 and Table 2.

4.7.2.1.6 Application of the outerwrap shall conform to Sec. 4.4.8.4.

4.7.2.1.7 The pipe shall be whitewashed, painted with water-emulsion latex, or wrapped with kraft paper in accordance with Sec. 4.4.1.2.

4.7.2.2 Addition of two innerwraps. Additional coal-tar enamel thicknesses and two layers of glass fiber innerwrap.

4.7.2.2.1 This type of additional exterior protection is intended for use only on submerged lines, river crossings, or similarly difficult installations, or where trench conditions are extraordinarily severe.

4.7.2.2.2 The construction of this exterior protection shall consist of (1) liquid adhesive; (2) coal-tar enamel, 3⁄32±1⁄32-in. (2.4±0.8-mm) thick; (3) glass fiber innerwrap; (4) coal-tar enamel, 1⁄32-in. (0.8-mm) minimum; (5) glass fiber innerwrap; (6) coal-tar enamel, 1⁄32-in. (0.8-mm) minimum; (7) glass fiber outerwrap; and (8) whitewash, water-emulsion latex paint, or kraft-paper finish coat.

4.7.2.2.3 The glass fiber innerwrap shall conform to the material requirements stated in Sec. 4.3.5 and Table 3.

4.7.2.2.4 Application of the glass fiber innerwrap shall conform to Sec. 4.4.8.3.

4.7.2.2.5 Outerwrap shall conform to Sec. 4.3.4 and Table 2.

4.7.2.2.6 Application of the outerwrap shall conform to Sec. 4.4.8.4.

4.7.2.2.7 The pipe shall be whitewashed, painted with water-emulsion latex, or wrapped with kraft paper in accordance with Sec. 4.4.1.2.

4.7.2.3 Reinforced cement–mortar shield. When a reinforced cement–mortar shield is desired over the exterior coat of coal-tar enamel, the materials and application procedure shall conform to the applicable requirements of ANSI/AWWA C205. The construction of this exterior protection shall consist of (1) liquid adhesive; (2) coal-tar enamel, 3⁄32-in. ±1⁄32-in. (2.4-mm ±0.8-mm) thick; and (3) reinforced cement–mortar shield. The use of glass fiber innerwraps and outerwraps may also be applied with the coal-tar enamel.

4.7.2.4 Holiday inspection and repair. Enamel applied by hand to the exterior of specials or joints shall be examined for holidays in accordance with Sec. 4.5.3, and holidays shall be repaired prior to the application of the glass fiber innerwrap and subsequent enamel and outerwrap.

Sec. 4.8 Field Procedures

4.8.1 *General.* The methods and practices found in AWWA C604 shall be followed for the handling 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. 4.8.2, Special requirements.

4.8.2 *Special requirements.* Coated and lined pipe shall not be shipped or handled when temperatures are lower than 30°F (17°C) above the crack temperature defined by the manufacturer.

SECTION 5: VERIFICATION

Sec. 5.1 Materials Inspection and Rejection

5.1.1 *Purchaser's inspection option.* At the purchaser's option, the entire procedure of applying the protective coating or lining material may be inspected from the time the bare pipe is received until installation of the pipe is completed. This inspection shall not relieve the manufacturer or the applicator of the responsibility to provide material and perform work in accordance with this standard.

5.1.2 *Access of purchaser.* The purchaser shall have free access to those parts of all plants and construction-site facilities that are concerned with providing materials or the performance of work for the purchaser's project.

5.1.3 *Coating and lining materials application, inspection, and rejection.* When requested by the purchaser, coating and lining work shall be done in the presence of the purchaser. Work done in the purchaser's absence shall be subject to rejection unless specifically allowed by the purchaser. If, at any time, it

is found that the procedure of applying the protective material is not in accordance with this standard, the coating and lining work may be rejected.

5.1.4 *Applicator's samples.* When required, the applicator shall submit samples of the coating or lining materials to be provided to the purchaser for testing, prior to any work done according to the provisions of this standard. Samples shall be taken from a production run at the manufacturer's plant and shall be identified by batch or lot numbers. The applicator shall submit with the samples a certified copy of the manufacturer's test results covering the physical and performance characteristics of the samples. This certificate shall indicate the coverage rate of the liquid adhesive in gallons per square foot (liters per square meter), the application temperature of the enamel, and the method of application of the enamel to test plates.

5.1.4.1 Submission, testing, and rejection of samples. Before approval of the applicator's material, samples of material submitted by the applicator may be tested by the purchaser. If any sample is found not to conform to the standard, or if materials that have been previously approved are found not to conform to the standard, such material shall be rejected.

5.1.5 *Certified test reports.* In lieu of Sec. 5.1.4.1, at the purchaser's option, the applicator shall provide the purchaser with a certified copy of the manufacturer's test results. Test reports shall cover physical and performance characteristics of each batch of coating and lining materials to be supplied under the provisions of this standard.

When required, the applicator shall provide, or allow the purchaser to collect, samples representative of each of the coating or lining materials. Certified test reports and samples provided by the applicator shall be properly identified with each batch of enamel and liquid adhesive.

5.1.6 *Coating and lining and application specification submittal.* After the applicator has obtained approval from the purchaser for the coating and lining materials the applicator proposes to provide, the applicator shall submit to the purchaser the manufacturer's detailed specifications for the coating and lining materials supplied for the project with instructions for the handling and application of the material.

Sec. 5.2 Electrical Inspection

5.2.1 *General.* The applicator shall conduct an electrical inspection on the entire surface of completed coal-tar-enamel protective pipe-coating systems, including hot-applied coal-tar-tape–coated special sections, connections, and

fittings to ensure complete continuity of the protective coating. In addition, the applicator shall electrically inspect linings that have been applied or repaired by hand daubing and have been subjected to traffic of personnel entering and exiting the pipe, and any other areas that exhibit evidence of physical damage. Defects in the coating or lining shall be repaired.

5.2.2 *Electrical test equipment*. The electrical equipment used to test enamel and tape systems in the shop, yard, or field shall be a portable, low-amperage, adjustable-voltage, pulse-type holiday detector employing an audible signaling device. The holiday detector shall be provided with a coil-spring electrode or a suitable brush-type electrode.

5.2.2.1 Input power. The primary input wattage shall be no higher than 20 watts, and the minimum number of pulses at crest voltage shall be 20 per sec.

5.2.2.2 Operating voltage.

5.2.2.2.1 For electrical inspection of pipe coatings, the operating voltage of the detector shall be established according to the following procedure, but in no case shall the operating voltage exceed 15,000 V.

A portion of the coated pipe that includes an overlap of the outerwrap and is located approximately 15 in. (380 mm) from one end of the pipe section shall be selected for inspection. (This location shall represent the maximum thickness of the coating and wrapping on the pipe.)

The following steps shall be taken to establish the operating voltage of the detector:

1. Puncture the coating and wrapping with a sharp knife, awl, ice pick, or similar sharply pointed tool.
2. Move the detector electrode back and forth over the puncture, reducing the voltage until the detector ceases to register the known holiday. See Sec. 5.2.4 for electrode travel speed.
3. Place a strip of the same outerwrap used to coat the pipe over the known holiday and move the detector electrode back and forth over the strip of outerwrap.
4. Slowly increase the equipment voltage until the detector begins to register the known holiday under the outerwrap. Set the detector at this voltage for testing the external coating.

CAUTION: Because of the thickness or composition of some outerwraps, the outerwrap may have a dielectric strength greater than that of the coal-tar enamel. Care should be given to the amount of voltage applied when setting the electrical equipment to detect the known holiday so as not to override the dielectric strength

of the enamel. Excessive voltage may induce holidays in the enamel, thereby giving erroneous readings. Contact the manufacturer of the outerwrap for proper test voltage information.

5.2.2.2.2 For the electrical inspection of coal-tar enamel linings, the operating voltage of the detector shall be established according to the following procedure. However, in no case shall the operating voltage exceed 10,000 V.

An interior portion of the lined pipe located at the barrel of the pipe shall be selected for inspection. (This location shall represent the maximum thickness of the lining on the interior of the pipe.)

To establish the operating voltage of the detector, the following steps shall be taken:

1. Puncture the lining with a sharp knife, awl, ice pick, or similar pointed tool.
2. Slowly increase the equipment voltage until the detector begins to register the known holiday. Set the detector at this voltage for the holiday testing of the lining. See Sec. 5.2.4 for electrode travel speed.

5.2.2.2.3 For the electrical inspection of coal-tar tape coatings, the operating voltage of the detector shall be determined by the following formula, but not to exceed 15,000 V:

$$V = 1{,}250\sqrt{t} \pm 10\%$$

Where:

V = inspection voltage
t = total coating system thickness, in mil

5.2.3 *Required detector voltage adjustment*. Because of variables, such as relative humidity and temperature, the detector voltage shall be adjusted no less than twice per 8-hr work shift: once just before starting work at the beginning of the shift, and then again after 4 hr. To ensure proper inspection voltage, the equipment shall be grounded properly and the voltage adjusted in accordance with the instructions of the equipment manufacturer.

Holiday detectors with operable meters that detect variances in the voltage and that are used to assist in adjusting the unit's voltage normally do not need to be corrected more than once during an 8-hr shift. This correction shall be made at the beginning of the shift. To ensure proper inspection voltage, the equipment shall be properly grounded in accordance with the manufacturer's instructions for the equipment.

5.2.4 *Speed of travel during inspection.* After the voltage of the electric holiday detector has been properly adjusted as described in this standard, the electrode shall be passed over the coated and wrapped or taped surfaces, or lined surfaces, one time only, at the rate of travel of approximately 30–60 ft/min (9.2–18.3 m/min). If the electrode is stopped while passing over the coating surface, the current to the electrode should be immediately cut off to avoid damaging the coating.

5.2.5 *Marking and repair of holidays.* Holidays will be indicated by an electric spark between the electrodes and the metal surface and by an audible signal. Holidays so indicated shall be marked and repaired as follows.

5.2.5.1 Coal-tar enamel coatings. To repair holidays in coal-tar enamel coatings, first cut the outerwrap or lining from around the holiday, then recoat the bared area with the same system of materials as used for the original coating or lining. After the repairs are completed, the repaired areas shall be retested with the electric holiday detector.

5.2.5.2 Hot coal-tar-tape coatings. The hot-applied coal-tar-tape wrapping shall pass the electrical inspection test if no electrical spark occurs.

Holiday repairs shall be made in accordance with Sec. 4.6.10. After the repairs are completed, the repaired areas shall be retested with the detector.

Sec. 5.3 Thickness Testing

5.3.1 *Coating thickness measurement.* The thickness of the coating systems shall be measured according to ASTM D7091. Minimum thickness of the coating system shall be the sum total of the stated thickness of the liquid adhesive and coal-tar enamel plus the thicknesses of the individual wraps as shown in Tables 2 and 3. Testing shall be conducted at the frequency specified by the purchaser.

Sec. 5.4 Test Procedures

5.4.1 *General.* This section refers to a number of ASTM and AWWA test methods (including test procedures described in other sections of this standard) to define physical properties of materials or completed coatings and linings. Test procedures have been developed to determine other physical properties of materials that are important and cannot be evaluated using existing ASTM test procedures.

5.4.2 *Laboratory penetration test for coal-tar enamel.*

5.4.2.1 General. This method is based on the penetration test for bitumen as defined in ASTM D5, modified for the determination of penetration of coal-tar enamel. Penetration is defined as the depth, measured in tenths of a

millimeter, that an unrestrained standard needle penetrates vertically into a sample of the material in 5 sec under fixed conditions of temperature and loading.

5.4.2.2 Precautions. Coal dispersion pitches have a tendency to form a hard, thin skin while hot. Penetration values determined by this method tend to show a wide variation dependent on the prior preparations of the sample. Values are also dependent on the point on the sample surface chosen for the test. The behavior and performance of coal dispersion pitches are a function of the property of the body of the material rather than the surface skin.

5.4.2.3 Test apparatus. The required apparatus is described as follows.

5.4.2.3.1 The penetration needle to be used shall be as described in ASTM D5.

5.4.2.3.2 Any penetrometer may be used that permits the needle holder to move in the guide without appreciable friction and is capable of indicating the depth of penetration of the needle to the nearest tenth of a millimeter. The total moving weight (needle, needle holder, and superimposed weight) shall be 1.77 oz±0.009 oz (50 g±0.25 g) or 3.53 oz±0.009 oz (100 g±0.25 g), as required.

5.4.2.3.3 A constant-temperature water bath having a capacity of not less than 10.6 qt (10 L), with equipment to regulate the test temperature within ±0.18°F (0.1°C), shall be used. The bath shall have a perforated shelf supported in a position not less than 1.97 in. (50 mm) from the bottom and not less than 3.94 in. (100 mm) below the top of the bath.

5.4.2.3.4 A transfer dish for the sample container, that is, a dish or tray with the capacity to ensure complete immersion of the sample container during the test, shall be used. The transfer dish shall be provided with some means that will ensure a firm bearing and prevent rocking of the container.

5.4.2.3.5 Sample containers shall be open cylinders constructed of steel or brass. They shall have a wall thickness of 0.12 in. (3 mm), an internal diameter of 1.57 in. (40 mm), and a depth of 1.57 in. (40 mm). Both ends of the container shall be machine-finished smooth and perpendicular to the axis. A suitable flat brass plate shall also be provided. (The container can readily be made from a section of pipe.)

5.4.2.3.6 A bath thermometer conforming to Sec. 6.7 of ASTM D5, as appropriate, shall be used at the temperatures listed in Table 1 and Sec. 4.3.3.1.

5.4.2.3.7 A timing device of suitable accuracy to meet the repeatability requirements of the test method shall be used.

5.4.2.3.8 A sample melting pot constructed of steel that is 0.12-in. (3-mm) thick, 3.15 in. (80 mm) in diameter, and 3.94 in. (100 mm) in height shall be used. The pot shall be provided with a loose-fitting lid.

5.4.2.4 Procedure for laboratory penetration test. Break 8.8–10.6 oz (250–300 g) of the sample into small pieces not greater than ½ in. (13 mm) in size. Heat the sample slowly in a melting pot, stirring continuously. The pieces of sample must be continuously stirred until they have melted to prevent localized overheating and excessive loss of vapor.

NOTE: It is convenient to fill the penetration vessels, the rings for the softening-point tests, and the mold for the specific-gravity test all together from the same sample of melted material.

Before pouring the melted sample, the brass plate should be cleaned with an acceptable solvent, polished well, and preferably coated with a nonmigratory, smooth, film-forming release agent to prevent sticking of the enamel to the plate. The sample containers shall then be placed on the plate so that close contact is maintained between the rim and the plate. When the temperature of the sample is about 140–158°F (60–70°C) above the expected softening point, pour the melted material into the heated sample container until it is about half full, then allow the sample and container to cool to ambient temperature.

When the sample has cooled properly, invert the sample container and place it in a transfer dish immersed in the water bath maintained at the appropriate temperature for a period of 1 hr.

Clean the penetrometer needle with a soft cotton cloth wetted with an acceptable solvent, then dry it. Insert the needle into the penetrometer and load the needle holder so that the total moving weight will be that required for the test (1.77 oz or 3.53 oz [50 g or 100 g]). Place the transfer dish, containing the sample container and filled with water from the constant-temperature bath, on the penetrometer table. (NOTE: Care must be taken during the test to ensure the sample container does not move or rock.)

Slowly lower the needle until the tip just makes contact with its image on the surface of the sample, or, if the surface is matte, until scratch contact can just be detected. (A suitably placed light can help obtain precise adjustment of the needle to the sample surface.) The needle should be applied to the sample surface at least 0.39 in. (10 mm) from the edge of the dish and 0.39 in. (10 mm) from any previous hole.

Depending on the type of penetrometer used, note the dial reading and return it to zero. The needle holder is then released quickly, held free for exactly 5 sec, and locked. If the sample container moves in any way, the determination shall be discarded. The depth of penetration, in tenths of a millimeter, is then read from the scale and recorded. Three readings shall be made within the limits of repeatability.

5.4.3 *Preparation and enameling of plates for laboratory testing of enamels*.

5.4.3.1 General. The high-temperature sag test, the low-temperature cracking test, the impact tests, and the laboratory peel test (all described in the following sections) are each conducted on 12-in. × 12-in. (305-mm × 305-mm) steel test plates of prescribed thickness: 7⁄64 in. (2.8 mm) for the high-temperature, low-temperature, and impact tests; and ½ in. (12.7 mm) for the peel test. These test plates are to be prepared and coated in the laboratory with the sample enamel as outlined in following sections.

5.4.3.2 Preparation of test plates. Enamel performance tests are to be conducted on steel plates free from oil and grease. One side of each plate shall be blasted to a uniform, steel-gray surface between SSPC-SP 6/NACE No. 3 and SSPC-SP 10/NACE No. 2. For blasting, use No. 50 steel grit to achieve a blast profile with a minimum height of 3 mils (0.076 mm).

5.4.3.3 Application of liquid adhesive to test plates. Test plates shall be freshly prepared as stated in Sec. 5.4.3.1 and coated using the coverage rate recommended by the liquid adhesive manufacturer. The Type A, B, and C liquid adhesives shall be applied with a new, clean, flat-bristle brush of 1-in. (25-mm) width. Test plates shall be coated with a liquid adhesive and allowed, while in a horizontal position and coated side up, to remain in a room where the temperature ranges between 70°F and 90°F (21°C and 32°C) and the relative humidity is not more than 60 percent. Type A and Type B liquid adhesives shall dry in accordance with Sec. 5.4.3.4 prior to the application of the enamel. Type C liquid adhesive shall not dry or cure, as outlined in Sec. 5.4.3.4, prior to the application of the enamel.

5.4.3.4 Time limits between liquid adhesive and enamel applications.

5.4.3.4.1 If Type A liquid adhesive is used, the enamel shall not be applied in less than 16 hr nor more than 72 hr after the liquid adhesive has been applied.

5.4.3.4.2 If Type B liquid adhesive is used, the enamel shall not be applied in less than 1 hr nor more than 5 days after the liquid adhesive has been applied.

5.4.3.4.3 If the Type C liquid adhesive is used, the enamel shall be applied within 10 min after the liquid adhesive has been applied. The liquid adhesive shall not be allowed to cure or set before the application of the enamel.

5.4.3.5 Laboratory preparation of enamel for testing.

5.4.3.5.1 Approximately 30 lb (13.6 kg) of enamel shall be broken into pieces, each approximately 4 in. (102 mm) in maximum cross section. Place the pieces of enamel in an agitated cylindrical metal container having a diameter of not less than 8 in. (200 mm) nor more than 12 in. (300 mm). Interpose a ⅛–¼-in. (3.2–6.4-mm) thick steel plate between the bottom of the container and the large gas burner to avoid superheating. The container shall be covered, and the sample melted rapidly, being agitated during the process.

5.4.3.5.2 As soon as the enamel sample reaches the application temperature recommended by the enamel manufacturer, it shall be applied to the liquid-adhesive-coated test plates by flooding a minimum of 1 qt (0.9 L) of enamel over each plate. An enamel thickness of 2/32–3/32 in. (1.6–2.4 mm) shall be achieved on all test plates. The desired thickness may be achieved by adjusting the angle of the plate during the pouring process or by use of a doctor blade.

5.4.4 *Laboratory high-temperature sag test.* Prepare two test plates 12 in. × 12 in. × 7/64 in. (305 mm × 305 mm × 2.8 mm) as stated in Sec. 5.4.3, except that an uncoated border ½-in. (13-mm) wide shall be left around all four edges of each plate.

After the plates have been coated and cooled, scribe lines across the face of the enamel surface and the uncoated border, so that the lines extend from edge to edge of the plates. The lines shall be spaced 1 in. (25 mm) apart.

Place the scribed plates in a vertical position so that the scribed lines are horizontal and store them for 24 hr in a chamber in which the temperature is maintained at a constant 160°F (71°C). At the end of this period, remove the plates from the chamber and cool them to room temperature.

After cooling, place the plates in the identical position as when they were initially scribed and rescribe the face of the enamel. Measure the distance between the old and new scribe lines. Average the measurements and record the result as the sag of the enamel.

5.4.5 *Laboratory low-temperature cracking test.* Following completion of the high-temperature sag test, place the two previously used plates in an air chamber in which the temperature is maintained at a constant –10°F to –20°F (–23.3°C to –28.9°C), as specified for this test, for a period of 6 hr. At the end of this period,

the plates shall be removed from the air chamber, placed on an insulated surface, and allowed to warm to room temperature. Thereafter, the enameled surfaces of the plates shall be examined for any evidence of cracking or disbonding of the enamel.

5.4.6 *Laboratory peel test.*

5.4.6.1 Plates for peel test. Two plates having dimensions of 12 in. × 12 in. × ½ in. (300 mm × 300 mm × 13 mm) shall be prepared and enameled on one side, as stated in Sec. 5.4.3, and cooled to room temperature.

5.4.6.2 Knife used in peel test. The knife to be used in the peel test shall have a moderately stiff steel blade and handle. The total length shall not exceed 7 in. (178 mm). The dimensions of the exposed blade shall be ⅝–¾-in. (16–19-mm) wide, ⅛-in. (3.2-mm) thick, and approximately 3 in. (76 mm) in length. The blade's front edge shall be ground square and then sharpened by a suitable means to produce a 40° to 50° beveled edge over the entire front edge.

5.4.6.3 Laboratory test for bond (12 hr). The purpose of this test is to examine the quality of the enamel bond at successive temperature intervals between 80°F and 160°F (27°C and 71°C). The temperature levels to be tested are 80°F (27°C), 100°F (38°C), 120°F (49°C), 140°F (60°C), and 160°F (71°C). The tolerance on each temperature level is ±2°F (1°C).

Store one of the test plates at room temperature in a horizontal position with the enamel side up for a period of at least 12 hr but not more than 24 hr. Then immerse the plate for approximately 30 min in a water bath set at the appropriate temperature. Use of the water bath may be omitted for the 80°F (27°C) test when the room temperature is in the range of 80°F ±2°F (27°C ±1°C). The 80°F (27°C) test shall be omitted if the penetration at 77°F (27°C) of the applied enamel is less than 10.

Immediately following removal of the plate from the water bath, use the knife edge to cut two 4-in. (100-mm) parallel lines, spaced approximately ¾ in. (19 mm) apart, through the enamel. Place the cutting edge of the knife blade, beveled edge up, on the enamel between, and at the beginning of, the parallel cuts. Push the knife at an angle of approximately 45° into the enamel and, after ensuring knife-to-steel-plate contact exists over the full width of the area between the parallel cuts, apply an even pressure and loosen the enamel from the plate for a length of approximately ½ in. (13 mm). Then place the knife blade under the loosened end. Grasping the loose end of the enamel strip between the knife blade and thumb, pull slowly and steadily upward. Measure and record the length that the enamel

strip has peeled or lifted before breaking. Peeling, stripping, or lifting of not more than ⅛ in. (3.2 mm) shall be recorded as "no peeling."

Repeat the procedure for each successive higher temperature level until the 160°F (71°C) test has been completed.

5.4.6.4 Laboratory test for bond (72 hr). Store the second test plate in a horizontal position with the enamel side up in an air chamber with the temperature maintained at 160°F ±2°F (71°C ±1°C) for a period of 72 hr ±2 hr. Remove the test plate from the air chamber and cool to room temperature.

Thereafter, test the enamel surfacing for the condition of its bond over a temperature range of 80°F to 160°F (27°C to 71°C) using the procedure stated in Sec. 5.4.6.3.

If the penetration of the applied enamel is less than 10 when tested at 77°F (25°C), the bond test at 80°F (27°C) shall be omitted.

5.4.7 *Laboratory impact tests.* Use two plates 12 in. × 12 in. × 7⁄64 in. (300 mm × 300 mm × 2.8 mm), enameled on one side as stated in Sec. 5.4.3. The plates used in the high-temperature test (Sec. 5.4.4) may be used in the impact test. After the plates have reached room temperature, immerse them in a water bath maintained at a temperature of 77°F (25°C) for a period of at least 1 hr. Thereafter, individually remove each plate from the water bath, dry with a soft clean cloth, and immediately subject it to the direct and indirect impact tests as follows.

5.4.7.1 Laboratory direct impact test. Support each plate on a clean plane surface of a block of wood. Drop a 650-g steel ball with a well-polished spherical surface from a height of 8 ft (2.4 m) above the plate. Drop the ball so it strikes the enamel at a point at least 4 in. (102 mm) from any edge of the plate. After one single impact, determine the area of enamel that has been shattered and loosened from the plate. Shattered enamel is defined as coating that has been knocked off the plate by the impact of the steel ball. Loosened enamel is defined as coating that has not been shattered but that can be removed from the plate easily and readily by the finger or, with very little force, by the use of a knife blade or similar instrument. Record the average of the disbondment areas of the two plates, in square inches (square millimeters).

5.4.7.2 Laboratory indirect impact test. After each of the two test plates has been subjected to direct impact, both plates shall be placed coated-face down on a wooden block through which a 3½-in. (89-mm) hole has been cut. The same ball used in the direct impact test is again dropped from a height of 8 ft (2.4 m) above the surface of the plate, aligned to strike the steel plate at a point directly over

the center of the hole in the wooden support block. The point of impact shall be at least 4 in. (102 mm) from any edge of the plate and at least 3 in. (76 mm) from the point of direct impact. After one single impact, estimate the area of enamel that has been shattered and loosened from the plate, as defined in Sec. 5.4.7.1. Record the average of the disbonded areas of the two plates, in square inches (square millimeters).

5.4.8 *Shop or field peel test procedure.* The peel test to be conducted in the shop or in the field for measuring the adhesion of the liquid adhesive and coal-tar enamel shall be performed using a knife as described in Sec. 5.4.6.2. The test is conducted at a temperature between 50–80°F (10–27°C) and is applicable to both the lining and coating with or without reinforcement. If the coating or lining temperature measured with a surface thermometer is above 80°F (27°C) or below 50°F (10°C), pour sufficient hot or cold water over the test area to adjust the enamel and substrate temperature within this range. Unless the temperatures of the steel pipe and the enamel system at the peel test location are within 5°F (3°C) of each other and also within temperature limits stated in this standard, incorrect peel test results will be obtained. If the penetration of the enamel after application is less than 10, the peel test shall be performed between 65°F and 80°F (18°C and 27°C). Not more than one test each of the lining and the coating shall be performed on each pipe section unless the test fails.

Using a knife as described in Sec. 5.4.6.2, heated if necessary (but not as much to cause the enamel to fume) and ensuring knife-blade-to-pipe contact, make two parallel cuts through the coating or lining, approximately 4-in. (100 mm) long and ⅝ in. to ¾ in. (16–19 mm) apart. Place the cutting edge of the knife blade, beveled edge up, on the enamel between and at the beginning of the parallel cuts. Push the knife at an approximate 45° angle into the enamel and, after ensuring knife-to-pipe contact exists over the full width of the enamel between the parallel cuts, apply an even pressure and loosen the enamel from the pipe for a length of about ½ in. (13 mm).

Applying an even steady pressure is necessary to avoid imparting shock stresses within the enamel between the parallel cuts, thereby causing a shattering separation of the enamel from the pipe that may be erroneously interpreted as bond failure. With the knife blade placed under the loosened end of the enamel, grasp the strip of loosened enamel between the knife blade and the thumb. Pull slowly and steadily upward. The bond is satisfactory if the length of peel is no greater than the width of cut before the enamel breaks.

Enamel remaining on the liquid adhesive layer due to cohesive separation during the peel test does not constitute a test failure.

If the peel length exceeds the cut width, the test is a failure and two additional tests shall be made at two different locations on the same pipe section, a minimum of 3 ft (0.9 m) from the point of test failure. If both tests are satisfactory, the pipe section shall be approved. If either additional test fails, the pipe section shall be rejected.

5.4.9 *Outerwrap pliability tests.* Cut five 6-in. (152-mm) test strips of outerwrap from samples taken from the inside of the roll and aged in free air for 72 hr. The test strips shall be cut as shown in ASTM D146, Figures D-1 through D-5, and then immersed in water at a temperature of 77±2°F (25±1°C) for 10 to 15 min. Thereafter, bend each test strip over a 1-in. (25-mm) mandrel through 180° at a uniform speed in 2 sec.

5.4.10 *Glass fiber felt outerwrap weight-loss-on-heating tests.* Cut two samples 6 in. × 12 in. (152 mm × 305 mm) in size. Remove loose surfacing material from both sides of the sample to prevent any loose particles from falling off in the oven during heating or during the test. Weigh each strip and suspend the strips on wire hooks in an oven maintained at 180±5°F (82±3°C). Exercise care to ensure the samples do not touch each other or the sides of the oven and that localized overheating does not occur.

After 2 hr, remove the samples from the oven, cool them in desiccators, and reweigh. Compute the percentage of loss in weight based on the original weight of the sample. The average of the results from the two samples shall be reported as the weight loss on heating.

5.4.11 *Thickness test for outerwrap.* The thickness shall not be less than 30 mils (0.76 mm). The test method shall be in accordance with TAPPI T411, modified. At 10 equally spaced areas selected for sampling, measure the thickness with an Ames dial reading in units of ten thousandths of an inch (2.5 μm). Use a circular foot and anvil, both 1 $in.^2$ (645 mm^2) in area, exerting a pressure of 2 psi (13.8 kPa). Make measurements in an atmosphere of 50±2 percent humidity and at 73±2°F (23±1°C).

5.4.12 *Breaking strength test for outerwrap.* Test samples of the outerwrap taken from the inside of the roll shall be aged at 73±4°F (23±2°C) for at least 2 hr. Then, in accordance with ASTM D882, modified, cut 10 specimens 2 in. × 12 in. (50 mm × 300 mm), with the longer dimension along the roll. Cut another 10 specimens the same size with the longer dimension across the roll.

The tensile testing machine shall have clamps that are wider than 2 in. (51 mm) and are attached to swivels that are free to move in any direction.

Grip the specimen from each end, leaving a distance between the jaws of at least 6 in. (152 mm). Initiate the breaking of the load by causing the lower clamp of the machine to travel at a uniform speed of 12 in./min (305 mm/min). Disregard the reading of any specimen that breaks nearer than ¼ in. (6.4 mm) from either clamp and test an additional specimen in its place.

Report the average of the results of the 10 individual specimens cut along the roll as the longitudinal breaking strength, and the average of the results of the 10 individual tests on specimens cut across the roll as the transverse breaking strength. Readings should be to the nearest pound of force (N/m).

5.4.13 *Manufacturer's tests for physical properties of tapes, coal-tar base, hot-applied for special sections, connections, and fittings.*

5.4.13.1 Applicable tests. The following tests may be conducted in the manufacturer's plant or laboratory to ensure the delivery of a product conforming to the requirements of this standard. The method of sampling and number of samples shall be as stated in the following subsections, unless otherwise specified by the purchaser.

5.4.13.2 Tape width test. Remove a specimen of tape at least 3 ft (0.9 m) long from each of three randomly selected rolls. Place the specimens on a smooth, flat surface. Measure the width of each specimen at the widest and the narrowest points to the nearest 1⁄16 in. (1.6 mm) using a standard steel scale. The allowable width deviation shall be as stated in Table 4.

5.4.13.3 Tape thickness test. Measure the thickness of the tape at no less than 10 locations at intervals of no less than 1 ft (300 mm) on the three rolls of tape used in Sec. 5.4.13.2. The measurement shall be made with a micrometer calibrated to read in thousandths of an inch (25.4 μm) or smaller units and having contact feet of not less than ¼ in. (6.4 mm) in diameter. Any thickness measurement outside the limits stated in Table 4 shall constitute failure of this test.

5.4.13.4 Softening-point test. Three test specimens shall be taken from separate 6-ft (1.8-m) sections of the three rolls of tape used in Sec. 5.4.13.2 and shall be chilled in a refrigerator to a temperature that will permit removal of the coating material from the fabric by cracking and peeling when the tape is flexed. Care shall be taken that backing fibers are not included in the coating sample. Heat the coating in a covered container to a temperature just high enough to cause the material to flow. Pour part of the liquid coating material into a softening-point

mold, another part into a cup for use in the penetration test and keep a portion as a small specimen for use in the filler-content test. Determine the softening point in accordance with ASTM D36. A value outside the limits stated in Table 4 shall constitute failure of the tape to meet the softening-point requirement.

5.4.13.5 Penetration test. The coating specimen prepared in Sec. 5.4.13.4 shall be tested for penetration in accordance with ASTM D5. A value outside the limits stated in Table 4 shall constitute failure of the tape to meet the penetration test requirements.

5.4.13.6 Filler-content test. The coating specimen prepared in Sec. 5.4.13.4 shall be tested for filler content in accordance with ASTM D2415. A value outside the limits stated in Table 4 shall constitute failure of the tape to meet the filler requirements.

5.4.13.7 Laboratory adhesion test. Clean a section of 2-in. (50-mm) nominal diameter steel pipe or a flat steel panel to the requirements of Sec. 4.4.2.1. The cleaned section of pipe shall be no less than 2 ft (600 mm) in length. The flat panel shall be no less than 2 in. × 6 in. (51 mm × 152 mm).

Apply the liquid adhesive to the cleaned metal surface and apply a 2-in. (51-mm) width of tape in accordance with the manufacturer's instructions. The coating shall be allowed to set at room temperature for 18 hr. After the test sample has completely set, grasp one end of the tape and pull it off by hand. The coating is considered to have satisfactory adhesion if (1) the fabric tears at the point of stripping; or (2) the fabric strips from the underlying coating material leaving no more than approximately 10 percent or less of the adhesive layer or bare metal exposed.

5.4.14 *Testing of glass fiber innerwrap*.

5.4.14.1 Elmendorf tear-strength test. The innerwrap shall have an Elmendorf tear strength in both the longitudinal direction and in the transverse direction of not less than 0.22 lb (100 g) in each case, as determined by TAPPI T414.

The test shall be conducted using an Elmendorf tear tester, Thwing-Albert Model 60-16, or equivalent, with a capacity of 0–3.5 lb (0–1,600 g). The instrument shall be anchored to a table and leveled. The pendulum shall be tested for zero by moving it to the left to the pendulum stop and releasing. Adjustments shall be made if the pointer does not read zero after the pendulum stop has been released. The friction of the apparatus and the condition of the knife shall be verified and adjusted, if required, as provided in ASTM D689. Tests shall be made at a

temperature of 73±4°F (23±2°C) and a relative humidity of 40–60 percent. Ten specimens shall be cut from the glass fiber innerwrap using either a sample cutter or template, noting machine direction (MD) and machine direction plus cross direction (MD plus CD). Sample size shall be 3±1/16-in. (76±1.6-mm) wide by 2½±1/16-in. (63±1.6 mm) high. Initially, the test shall be performed using two plies. The number of plies may subsequently be varied as indicated in ASTM D689. The pendulum is moved to the left until the stop is engaged. After the specimen has been clamped into the apparatus so that the 2½-in. (63.5-mm) slit will be in the vertical direction, the knife is depressed to make the slit, and the stop is depressed to release the pendulum. Record the number of plies, the reading of the pointer, and whether MD tears or MD plus CD tears. The entire procedure shall be repeated to obtain 10 individual readings, and the readings averaged. This average, divided by the number of plies tested, equals the Elmendorf tear strength.

5.4.14.2 Breaking-strength test. Nonreinforced glass fiber innerwrap shall have a minimum breaking strength in the longitudinal direction of 4 lbf/in. (700 N/m) width. Reinforced glass fiber innerwrap shall have a minimum breaking strength in the longitudinal direction of 13 lbf/in. (2.28 kN/m) width. In either case, the minimum breaking strength in the transverse direction shall be 4 lbf/in. (700 N/m) width, as determined by ASTM D146, modified. Ten specimens, each 3 in. × 22 in. (76 mm × 559 mm), shall be cut with the longer dimension across the roll. In those instances where the wrapper width is less than 22 in. (559 mm), the specimen length shall be that of the wrapper length. Both ends of each specimen shall be impregnated with a protective shellac or methacrylate for a distance of 2½ in. (63.5 mm) and allowed to dry. Specimens shall be tested at 73±2°F (23±1°C) using a tension-testing machine of adequate capacity in which the clamps are attached to swivels that are free to move in any direction. The clamps shall be 1 in. × 3 in. (25 mm × 76 mm) and shall be covered with masking tape. The specimen to be tested shall be gripped 2 in. (51 mm) from each end, leaving 18 in. (457 mm) between the clamps. This gauge length may have to be adjusted, depending on the glass fiber innerwrap width. However, the gauge length should be the maximum consistent with good clamping. The breaking of the load shall be increased by causing the lower clamps of the machine to travel at a uniform speed of 12 in./min (305 mm/min). The reading on any specimen that breaks nearer than ½ in. (13 mm) from either clamp shall be disregarded and an additional specimen shall be tested in its place. The average of the results of 10 individual tests on specimens cut along the roll shall be reported as the longitudinal breaking

strength and the average of 10 individual tests on specimens cut across the roll reported as the transverse breaking strength.

5.4.14.3 Pliability test. There shall be no cracking of the glass fiber innerwrap when it is bent over a ⅛-in. (3.2-mm) radius at 7±2°F (23±1°C), as determined by ASTM D146, modified. Five specimens, 1 in. × 8 in. (25 mm × 203 mm), shall be cut with the long dimension parallel to the length of the roll and then immersed in water having a temperature of 73±2°F (23±1°C) for a period of 10 to 15 min. Each specimen shall be individually removed from the bath and bent over a ¼-in. (6.4-mm) mandrel through a 90° arc at a uniform speed in approximately 2 sec. Each specimen shall then be examined for cracks and breaks.

5.4.14.4 Porosity test. When related to pressure difference across the sample, the glass fiber innerwrap shall have porosity of not less than 0.022 in. (0.6 mm) and not more than 0.076 in. (1.9 mm) of water at an average air velocity of 200 ft/min (61 m/min), as determined by ASTM D737, modified. Five specimens, at least 10 in. × 10 in. (254 mm × 254 mm), representative of the unsaturated glass fiber innerwrap to be tested, shall be provided. Alternatively, five places on the unsaturated glass fiber innerwrap, separated as widely as possible, may be tested without cutting. The apparatus shall consist essentially of a suction fan for drawing air through a known area of unsaturated glass fiber innerwrap, a circular orifice over which the wrap to be tested can be clamped, a means of measuring the pressure drop across the mat, and a means of measuring the volume of air flowing through the wrap. The clamp shall effectively eliminate edge leakage. The apparatus shall be capable of testing unsaturated glass fiber innerwrap of different thicknesses and of testing large pieces of glass fiber innerwrap without cutting. The instrument shall be calibrated directly with a precision instrument. All tests shall be made at 73±2°F (23±1°C) and 50±2 percent relative humidity.

The test specimen shall be mounted between the clamp and the circular orifice with sufficient tension to draw the unsaturated glass fiber innerwrap smooth. The test specimen shall not be distorted in its own plane. Conditioned air shall be drawn through the known area of the innerwrap and through the calibrated flowmeter at the rate of 200 ft/min (61 m/min). The pressure drop across the innerwrap shall be recorded in inches (millimeters) of water. The average of the test results for the five test specimens or the five different test locations of the glass fiber innerwrap shall be reported as the porosity.

5.4.15 *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 minimum 2-in. (50-mm) diameter laboratory-coated steel pipe prepared and coated in accordance with 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.

5.4.16 *Inspection and testing*. Unless otherwise specified by the purchaser, the manufacturer shall be responsible for the performance of laboratory test requirements as stated in this standard. Except as otherwise specified, the manufacturer may use the manufacturer's own facilities or a commercial testing laboratory acceptable to the purchaser.

SECTION 6: DELIVERY

Sec. 6.1 Marking

The containers shall be plainly marked with the name of the manufacturer, type of material, batch or lot number, date of manufacture, and information as required by federal, state or provincial, and local regulations.

Sec. 6.2 Packaging and Shipping

6.2.1. *Packaging*. Tapes and liquid adhesives purchased or used according to this standard shall be packaged in containers that ensure acceptance and safe delivery to their destination. Preferences for the individual or multiple packaging of tape and the size of liquid adhesive containers may be specified by the purchaser.

6.2.1.1 Individual roll. Each roll of tape shall be packaged in a manner that prevents the roll from adhering to either the packaging material or the container.

6.2.1.2 Multiple rolls. Each roll of tape shall be protected from adhering to other rolls of tape, to the box, or to the packaging material by using separators.

6.2.1.3 Liquid adhesive. The liquid adhesive shall be packaged in sealed, airtight, properly marked containers of 1-gal (3.78-L) cans, 5-gal (18.9-L) pails, or 55-gal (208-L) drums.

6.2.2. *Shipping, Handling, and Storage*.

6.2.2.1 Shipping and handling. Both tape and liquid adhesive shall be packaged to ensure acceptance and safe delivery at the destination.

6.2.2.2 Storage. Materials shall be stored and protected from the elements as required by current applicable federal, provincial or state, 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 manufacturer that the materials comply with 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 all applicable requirements of this standard.

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