
Standard Practice for Evaluation of Protective Coating Systems for Structural Steel

AASHTO Designation: R 31-09 (2023)¹

Technically Revised: 2009

Reviewed but Not Updated: 2023

Technical Subcommittee: 4c, Markings and Coatings



American Association of State Highway and Transportation Officials
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Standard Practice for

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1. SCOPE

- 1.1. This standard practice covers testing criteria for evaluation of protective coating systems for use on iron and steel surfaces. It is not recommended for the evaluation of hot-dip galvanizing or metalizing.
- 1.2. The protective coating systems are intended for use on bridges, similar structural steel, and other ferrous metal surfaces, both new and existing, prepared by abrasive blast cleaning, which are subject to corrosive atmospheric environments, such as marine, industrial, deicing chemicals, and high humidity.
- 1.3. The values stated in SI units are to be regarded as the standard.
- 1.4. *This standard practice may involve hazardous materials, operations, and equipment. It does not purport to address all safety problems associated with its use. It is the responsibility of the user of this standard practice to establish the appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- Note 1**—The testing format for this standard practice has been developed around a three-coat system consisting of a zinc primer, epoxy or urethane intermediate, and an aliphatic urethane finish coat.

2. REFERENCED DOCUMENTS

- 2.1. Reference to standard specifications, testing procedures, and other standard procedures contained in this document shall be the latest edition of the published document at the date of this specification.
- 2.1.1. *AASHTO Standards:*
- < T 337, Non-Instrumental Determination of Metallic Zinc in Zinc-Rich Primers
 - < T 338, Analysis of Structural Steel Coatings for Hindered Amine Light Stabilizer (HALS)
 - < T 339, Analysis of Structural Steel Coatings for Isocyanate Content
 - < *Standard Specifications for Highway Bridges*
- 2.1.2. *ASTM Standards:*
- < A36/A36M, Standard Specification for Carbon Structural Steel
 - < A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength (withdrawn 2016; replaced by F3125/F3125M)

- < A490, Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength (withdrawn 2016; replaced by F3125/F3125M)
- < A572/A572M, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
- < B117, Standard Practice for Operating Salt Spray (Fog) Apparatus
- < D476, Standard Classification for Dry Pigmentary Titanium Dioxide Products
- < D512, Standard Test Methods for Chloride Ion in Water
- < D520, Standard Specification for Zinc Dust Pigment
- < D521, Standard Test Methods for Chemical Analysis of Zinc Dust (Metallic Zinc Powder)
- < D523, Standard Test Method for Specular Gloss
- < D562, Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer
- < D610, Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces
- < D714, Standard Test Method for Evaluating Degree of Blistering of Paints
- < D1475, Standard Test Method for Density of Liquid Coatings, Inks, and Related Products
- < D1640/D1640M, Standard Test Methods for Drying, Curing, or Film Formation of Organic Coatings
- < D1652, Standard Test Method for Epoxy Content of Epoxy Resins
- < D1654, Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
- < D2073, Standard Test Methods for Total, Primary, Secondary, and Tertiary Amine Values of Fatty Amines, Amidoamines, and Diamines by Referee Potentiometric Method (withdrawn 2007; no replacement)
- < D2196, Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer
- < D2240, Standard Test Method for Rubber Property—Durometer Hardness
- < D2244, Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- < D2369, Standard Test Method for Volatile Content of Coatings
- < D2371, Standard Test Method for Pigment Content of Solvent-Reducible Paints
- < D2697, Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
- < D3335, Standard Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy
- < D3718, Standard Test Method for Low Concentrations of Chromium in Paint by Atomic Absorption Spectroscopy
- < D3723, Standard Test Method for Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing
- < D3960, Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings
- < D4017, Standard Test Method for Water in Paints and Paint Materials by Karl Fischer Method
- < D4060, Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- < D4400, Standard Test Method for Sag Resistance of Paints Using a Multinotch Applicator
- < D4417, Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel
- < D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

- < D4940, Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blast Cleaning Abrasives
- < D5894, Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)
- < D6580, Standard Test Method for the Determination of Metallic Zinc Content in Both Zinc Dust Pigment and in Cured Films of Zinc-Rich Coatings
- < 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
- < E1349, Standard Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry
- < G92, Standard Practice for Characterization of Atmospheric Test Sites

2.1.3. *Federal Standards:*¹

- < 40 CFR 51.100(s)²
- < 40 CFR 59.406(a)
- < 40 CFR 261.24, Table 1
- < Fed. Std. No. 595, Colors Used in Government Procurement
- < EPA SW 846, Method 1311, Toxicity Characteristic Leaching Procedure (TCLP)

2.1.4. *ANSI Standard:*

- < American National Standards Institute (ANSI) B94.50, Style E

2.1.5. *The Society for Protective Coatings (SSPC) Standards:*³

- < AB 3, Abrasive Specification No. 3, Newly Manufactured or Re-Manufactured Steel Abrasive
- < PA 2, Measurement of Dry Paint Thickness with Magnetic Gauges
- < SP 5, White Metal Blast Cleaning
- < SP 10, Near-White Blast Cleaning

2.1.6. *Other Documents:*

- < Commercial Item Description (CID) A-A-1689B; Tape, Pressure Sensitive Adhesive, Plastic Film⁴
- < Commission Internationale de l'Eclairage (CIE) 1976 L*a*b*
- < "Appendix A, Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints," *Specification for Structural Joints Using High Strength Bolts*, as approved by the Research Council on Structural Connections⁵

3. TERMINOLOGY

3.1. *Definitions:*

- 3.1.1. *volatile organic compound (VOC)*—any organic compound that participates in atmospheric photochemical reactions; that is, any organic compound other than those that the U.S. EPA Administrator designates as having negligible photochemical reactivity. For a list of compounds that the U.S. EPA Administrator has designated as having negligible photochemical reactivity, also referred to as "exempt compounds," refer to 40 CFR 51.100(s).
- 3.1.2. *VOC content*—the weight of VOC per volume of coating, calculated according to the procedures in 40 CFR 59.406(a).

- 3.1.3. *dry film paint thickness*—the depth of coating to the top of the surface profile peaks, measured in accordance with SSPC-PA 2.
- 3.1.4. *minimum (laboratory) recoat time*—the period of time required to sufficiently cure the applied coating when applied within the manufacturer's recommended wet film thickness range and to obtain dry film thickness readings of the coating (without causing physical damage to the applied film).

4. CLASSIFICATION

- 4.1. *Primer*—Primers act as the initial barrier over the prepared steel substrate. Single-coat systems shall consist only of the primer. Primers recommended for use on structures with painted connections designed for Class B allowable stress will be evaluated for Class B slip coefficient as detailed in Section 9.1 of this standard practice. Primers intended only for use on structures as maintenance applications (i.e., blast and recoat) may not be evaluated for Class B slip coefficient as detailed in Section 9.1 of this standard practice.
- 4.2. *Touch-Up Primer*—The touch-up primer shall be as recommended by the manufacturer at the time of application. Touch-up procedures for the intermediate and finish coats shall be detailed in the product data sheets or by written submission.
- 4.3. *Intermediate Coat*—The intermediate coat for a three-coat system serves as a tie coat between primer and finish coat as well as a protective barrier for the structural steel. The manufacturers for each (three-coat) coating system submitted for evaluation shall recommend the appropriate intermediate coat.
- 4.4. *Finish Coat*—The finish coat for each system evaluated serves as the final barrier coating and provides the desired aesthetic finish for the surface of the structure. The manufacturers for each coating system submitted for evaluation shall recommend the appropriate finish coat.

5. MATERIALS

- 5.1. *The materials used in the manufacture of the system shall conform to the requirements of the following specifications:*
- 5.1.1. *Zinc Dust*—ASTM D520, Type II.
- 5.1.1.1. Manufacturers shall submit a certificate of analysis from the zinc suppliers showing conformance with the requirements.
- 5.1.1.2. Each coating (primer, intermediate, and finish coat) shall be tested by an NLLAP (National Lead Laboratory Accreditation Program) accredited laboratory to determine its total lead content. The total lead content shall be determined using a dry film sample in accordance with ASTM D3335. The percentage of total lead in each coating shall not exceed 0.01 percent (100 ppm).

6. GENERAL REQUIREMENTS

- 6.1. *Color*—For production, the color of the coatings shall be as mutually agreed, except that the intermediate coat shall contrast in color a minimum of 10.0 ΔE^* from the primer to the finish coat. For testing purposes, the finish coat color shall comply with Section 8.2.7.
- 6.2. *Pigment*—Prime pigments shall be used except for shaders. Leachable, heavy-metal compounds shall not exceed the regulatory limits of 40 CFR, 261.24, Table 1, when tested in accordance with

Section 9.7.4. Total levels of lead, cadmium, and chromium shall not exceed 20 times the specified limits for these elements. If titanium dioxide is used in the finish coat, it shall meet the requirements of ASTM D476, Type IV.

- 6.3. *Slip Coefficient for Primer*—Primer coatings for use on new and rehabilitated structures with painted connections designed for Class B allowable stress shall meet the Class B slip coefficient requirements specified in the AASHTO *Standard Specifications for Highway Bridges*. The test data indicating compliance shall also state the type and quantity of reducer, cure time, and maximum coating thickness for that coating, as tested.

7. MANUFACTURER'S REQUIREMENTS

- 7.1. The manufacturer shall supply chemical test results that will define the character and nature of the coating system being submitted. Actual results shall be verified by the select laboratory, and shall be part of the select laboratory's report. Properties (determined in a mixed condition) shall be stated on the informational spreadsheet, certified Product Data Sheet, and/or the Material Safety Data Sheet as follows:
- 7.1.1. Total solids, percent by mass in accordance with ASTM D2369.
- 7.1.2. Volatile organic compound content in accordance with ASTM D3960.
- 7.1.3. EPA exempt solvents, identify compound and percent by volume.
- 7.1.4. Water, percent by mass, in accordance with ASTM D4017.
- 7.1.5. Pigment, percent by mass, in accordance with ASTM D2371 or D3723.
- 7.1.6. Metallic zinc content, percent by mass, in the primer shall be determined in accordance with ASTM D6580. An optional test method is T 337.
- 7.1.7. Total solids, percent by volume, in accordance with ASTM D2697.
- 7.1.8. Mass per volume (grams per liter) in accordance with ASTM D1475.
- 7.1.9. Viscosity (Stormer at 25°C) KU in accordance with ASTM D562 (not suitable for viscosities above 143 KU).
- 7.1.10. Viscosity (Brookfield at 25°C) cP in accordance with ASTM D2196. The instrument model (i.e., LV, DV, DVII+), spindle size, and revolutions per minute shall be reported.
- 7.1.11. Pot life in hours, at specified temperature and specified humidity, shall be evaluated in the laboratory through viscosity measurements taken at regular intervals and reported in Krebs units. Materials with manufacturer's stated pot life shall be evaluated at 25, 50, 75, and 100 percent of the stated pot life. Materials without manufacturer's stated pot life shall be evaluated at 2-h increments for 8 h.
- 7.1.12. Sag resistance (Leneta) in micrometers wet film thickness in accordance with ASTM D4400.
- 7.1.13. Recommended film thickness in micrometers.
- < Minimum and maximum wet film thickness.
 - < Minimum and maximum dry film thickness.
 - < Maximum allowable dry film thickness for the primer on faying surfaces.

- 7.1.14. Minimum (and maximum, when applicable) drying time in accordance with ASTM D1640/D1640M at 25°C and 50 percent relative humidity.
- < Dry to touch.
 - < Dry to handle.
 - < Dry to recoat.
- 7.1.15. Mixing ratio for multicomponent coatings, by volume.
- 7.1.16. Mixing ratio for multicomponent coatings, by mass.
- 7.1.17. Shelf life of each component stored at 25°C.
- 7.1.18. Total heavy metals content for mixed coatings in accordance with ASTM D3335 and D3718. Heavy metals to be tested will include lead, chromium, and cadmium for each coating.
- 7.1.19. Leachable heavy metals content for mixed coatings in accordance with ASTM D3335 and D3718. Analysis shall include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver for each coating.
- 7.1.20. Epoxide values determined in accordance with ASTM D1652, Method A.
- 7.1.21. Amine values determined on the amine or amidoamine contained in the appropriate component of two component epoxy coatings, in accordance with ASTM D2073.
- 7.1.22. Isocyanate group content determined in accordance with T 339.
- 7.1.23. Hindered amine light stabilizers (HALS) determined in accordance with T 338.
- 7.1.24. Ultraviolet (UV) absorbers.
- 7.1.25. The minimum and maximum surface profile requirements (height in micrometers).
- 7.1.26. *Application requirements for:*
- < Ambient temperature,
 - < Surface temperature,
 - < Material temperature,
 - < Humidity,
 - < Tip size, and
 - < Application pressure.

8. TESTING REQUIREMENTS

- 8.1. *General:*
- 8.1.1. Tests must be administered or performed by an authorized testing facility as approved by AASHTO's National Transportation Product Evaluation Program (NTPEP). The principal facility evaluating a specific coating system or any laboratory performing testing for the principal facility must obtain prior approval from the NTPEP before initiating any testing.
- 8.1.2. All testing equipment shall be cleaned prior to performance of each testing cycle, unless specifications require more frequent cleaning.