



Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers requirements for electrodeposited zinc coatings applied to iron or steel articles to protect them from corrosion. It does not cover electrodeposited zinc-coated steel wire or sheets (see Specification A 591/A 591M for sheets).

1.2 The coatings are provided in four standard thickness classes (4.1), in the as-plated condition or with one of three types of supplementary finish (4.2).

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 591/A591M Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications²
- B 117 Practice for Operating Salt Spray (Fog) Apparatus³
- B 183 Practice for Preparation of Low-Carbon Steel for Electroplating⁴
- B 201 Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces⁴
- B 242 Practice for Preparation of High-Carbon Steel for Electroplating⁴
- B 254 Practice for Preparation of and Electroplating on Stainless Steel⁴
- B 320 Practice for Preparation of Iron Castings for Electroplating⁴
- B 322 Practice for Cleaning Metals Prior to Electroplating⁴
- B 374 Terminology Relating to Electroplating⁴
- B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section⁴
- B 499 Test Method for Measurement of Coating Thick-

nesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals⁴

- B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method⁴
 - B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method⁴
 - B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry⁴
 - B 571 Test Methods for Adhesion of Metallic Coatings⁴
 - B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings⁴
 - B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings⁴
 - B 762 Method of Variables Sampling of Metallic and Inorganic Coatings⁴
 - D 2092 Guide for Treatment of Zinc-Coated (Galvanized) Steel Surfaces for Painting⁵
 - F 1740 Guide for Inspection of Nylon, Polyester, or Nylon/Polyester Blend, or Both Kernmantle Rope⁶
- 2.2 *Military Standard:*
- MIL-STD-1312 Fastener Tests, Methods (Test 12)⁷

3. Terminology

3.1 *Definitions*—Definitions of the terms used in this specification are in accordance with Terminology B 374.

4. Classification

4.1 *Thickness*—The coating shall be provided in the four thickness classes defined in Table 1.

4.2 *Finish*—The coating shall have one of the finish types defined as follows:

Type	Description
I	As-plated without supplementary treatment
II	With colored chromate conversion coatings
III	With colorless chromate conversion coatings
IV	With phosphate conversion coatings

5. Ordering Information

5.1 When ordering the electroplating of articles, the purchaser shall state the designation number, the date of issue, the

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² *Annual Book of ASTM Standards*, Vol 01.06.

³ *Annual Book of ASTM Standards*, Vol 03.02.

⁴ *Annual Book of ASTM Standards*, Vol 02.05.

⁵ *Annual Book of ASTM Standards*, Vol 06.02.

⁶ *Annual Book of ASTM Standards*, Vol 13.01.

⁷ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Thickness Classes for Coatings

Classification ^A Number and Conversion Coating Suffix	Service Condition ^{B,C}	Thickness, min µm
Fe/Zn 25	SC 4 (very severe)	25
Fe/Zn 12	SC 3 (severe)	12
Fe/Zn 8	SC 2 (moderate)	8
Fe/Zn 5	SC 1 (mild)	5

^A Iron or steel with zinc electroplate. Numeral indicates thickness in micrometres.

^B See Appendix X2.

^C Where service conditions are valid only for coatings with chromate conversion coating. Type II for SC 4 and SC 3 and Type III for SC 2 and SC 1.

class or service condition number, and the type. (See 4.1, 4.2, and 7.1).

5.2 If necessary, the purchaser shall include on his part drawings or purchase order the following:

5.2.1 Electroplating application to high strength steel, if specified (6.4),

5.2.2 Thickness, if other than specified (4.1, 7.1),

5.2.3 Location of significant surface (7.1.1, 7.1.2),

5.2.4 Luster (7.3),

5.2.5 Corrosion resistance test, if specified (9.3, 10.3),

5.2.6 Hydrogen embrittlement test, if required (9.4, 10.4),

5.2.7 Sample size for inspection, if other than specified, and

5.2.8 Supplementary requirements, if applicable (Supplementary Requirement).

6. Materials and Manufacture

6.1 The coatings shall be essentially pure zinc produced by electrodeposition.

6.2 Defects in the surface of the basis metal, such as scratches, porosity, pits, inclusions, cracks, roll marks, and die marks, may adversely affect the appearance and performance of coatings applied thereto despite the observance of the best electroplating practices. Accordingly, the electroplater's responsibility for defects in the coating resulting from such conditions shall be waived, except when he is the prime contractor supplying electroplated parts. In this event, the basis metal shall be subjected to such polishing or buffing operations as are necessary to yield deposits with the desired final luster and appearance. To minimize problems of this sort, the specifications covering the basis material on the item to be electroplated shall contain appropriate limitations to such basis metal conditions.

6.3 *Cleaning of Basis Metal*—Proper preparatory procedures and thorough cleaning of the basis metal are essential to ensure satisfactory adhesion and corrosion resistance performance of the coating. It is recommended that the following appropriate recommended practices be used: B 183, B 242, B 254, B 320, and B 322.

6.4 *High-Tensile Strength Metals*—Unless otherwise specified, high strength steels having a tensile strength greater than 1700 MPa shall not be electroplated.

6.5 *Stress Relief*—All steel parts having an ultimate tensile strength of 1000 MPa and above, and that have been machined, ground, cold formed or cold straightened, shall be heat treated at a minimum of 190°C for 3 h or more for stress relief before cleaning and electroplating.

6.6 *Hydrogen Embrittlement Relief*—All electroplated parts

having a tensile strength of 1200 MPa or higher shall be baked at a minimum of 190°C for 3 h or more within 4 h after electroplating to provide hydrogen embrittlement relief. Electroplated springs and other parts subject to flexure shall not be flexed before the hydrogen embrittlement relief treatment. The baking treatment shall be done before the application of the supplementary treatments. Baked parts shall not crack or fail by fracture when tested in accordance with 10.4.

6.7 *Reactivation Treatment*—Electroplated surfaces passivated as a result of the baking operation shall be reactivated before receiving a supplementary treatment. Surfaces intended for supplementary treatments (Types II and III) may be reactivated by immersion in a dilute acid solution. Surfaces should be activated as soon as possible following baking and should be handled carefully to avoid contamination.

6.8 *Supplementary Treatments*—The supplementary film treatment for Types II and III shall be in accordance with Practice B 201. The treatment required for conversion to Type IV shall be in accordance with Guide D 2092.

NOTE 1—The zinc surface is attacked by supplementary treatments, thereby diminishing the amount of metallic zinc present. With Classes Fe/Zn25 and Fe/Zn13, this reduction is insignificant; but it is significant with Fe/Zn8 and Fe/Zn5. Therefore, it is recommended that supplementary treatments not be applied to zinc coatings having a nominal thickness less than 5 µm.

7. Coating Requirements

7.1 *Thickness*—The thickness shall be specified in accordance with 4.1 and 5.1.

7.1.1 *Significant Surfaces*—Significant surfaces are areas where minimum thicknesses to be met shall be designated on the applicable drawing or by the provision of a suitably marked sample. Significant surfaces may be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the article when assembled in normal position; or which can be the source of corrosion products that deface visible surfaces on the assembled article.

7.1.2 Surfaces on which the specified thickness of deposit cannot readily be controlled, such as threads, holes, deep recesses, bases of angles, and similar areas, are normally exempt from minimum thickness requirements, unless they are specially designated as not exempt. When such areas are designated, and thus made subject to minimum thickness requirements, the purchaser and the manufacturer shall recognize the necessity for either thicker deposits on other areas or for special racking.

NOTE 2—The dimensional tolerance of most threaded articles, such as nuts, bolts, screws, and similar fasteners with complementary threads, normally does not permit the application of a coating thickness much greater than 8.0 µm. If heavier coatings are required, allowance for the deposit build-up must be made during the manufacture of the threaded articles.

7.2 *Adhesion*—The adhesion of the coating shall be such that when examined in accordance with 10.2, the coating shall not show separation from the basis metal at the interface.

7.3 *Luster*—Unless otherwise specified by the purchaser, a bright, semi-bright, or dull luster shall be acceptable.

7.4 *Corrosion Resistance*—Zinc coatings with Types II and III treatments shall show neither corrosion products of zinc nor

basis metal corrosion products at the end of the test period, as shown below, when tested by continuous exposure to salt spray in accordance with 10.3. The appearance of corrosion products visible to the unaided eye at normal reading distance shall be cause for rejection except that white corrosion products at the edges of specimens shall not constitute failure.

Corrosion Resistance Requirements	
Types	Test Period, h
II	96
III	12

7.5 *Workmanship*—The surface of the electroplated article shall be uniform in appearance, free of visible coating defects, such as blisters, pits, roughness, nodules, burning, cracks, or unplated areas, and other defects that will affect the function of the coating. The coating shall not be stained or discolored. However, superficial staining that results from rinsing or slight discoloration resulting from any drying or baking operation to relieve hydrogen embrittlement, shall not be cause for rejection. On articles where a visible contact mark is unavoidable, its position shall be that chosen by the purchaser. The electroplated article shall be clean and free of damage.

8. Sampling

8.1 The purchaser and producer are urged to employ statistical process control in the coating process. Properly performed, statistical process control will assure coated products of satisfactory quality and will reduce the amount of acceptance inspection. The sampling plan used for the inspection of the quality coated article shall be agreed upon between the purchaser and producer.

8.1.1 When a collection of coated articles (inspection lot, see 8.2) is examined for compliance with the requirements placed on the articles, a relatively small number of the articles (sample) is selected at random and is inspected. The inspection lot is then classified as complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria for compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B 602, Guide B 697, and Method B 762 contain sampling plans that are designed for sampling inspection of coatings.

8.1.2 Test Method B 602 contains four sampling plans, three for use with tests that are nondestructive and one when they are destructive. Test Method B 602 provides a default plan if one is not specified.

8.1.3 Guide B 697 provides a large number of plans and also gives guidance in the selection of a plan. Guide B 697 provides a default plan if one is not specified.

8.1.4 Test Method B 762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numeric value and certain statistical requirements must be met. Test Method B 762 contains several plans and also gives instructions for calculating plans to meet special needs. Test Method B 762 provides a default plan if one is not specified.

8.1.5 Guide F 1740 can be used for fasteners such as internally threaded, externally threaded and nonthreaded fasteners and washers. This guide provides for two plans: one designated the “detection process” and one designated the

“prevention process.” The purchaser and producer shall agree on the plan to be used.

8.2 An inspection lot shall be defined as a collection of coated articles that are the same kind, that have been produced to the same specification, that have been coated by a single supplier at one time or approximately the same time, under essentially identical conditions, and that are submitted for acceptance or rejection as a group.

9. Specimen Preparation

9.1 *Electroplated Parts or Separate Specimens*—When the electroplated parts are of such form, shape, size, and value as to prohibit use thereof, or are not readily adaptable to a test specified herein, or when destructive tests of small lot sizes are required, the test shall be made by the use of separate specimens plated concurrently with the articles represented. The separate specimens shall be of a basis metal equivalent to that of the articles represented. “Equivalent” basis metal includes chemical composition, grade, condition, and finish of surface prior to electroplating. For example, a cold-rolled steel surface should not be used to represent a hot-rolled steel surface. Due to the impracticality of forging or casting separate test specimens, hot-rolled steel specimens may be used to represent forged and cast steel articles. The separate specimens may also be cut from scrap castings when ferrous alloy castings are being electroplated. These separate specimens shall be introduced into a lot at regular intervals before the cleaning operations, preliminary to electroplating, and shall not be separated therefrom until after completion of electroplating. Conditions affecting the electroplating of specimens, including the spacing, plating media, bath agitation, temperature, etc., in respect to other objects being electroplated, shall correspond as nearly as possible to those affecting the significant surfaces of the articles represented. Unless a need can be demonstrated, separately prepared specimens shall not be used in place of production items for nondestructive and visual examinations.

9.2 *Thickness and Adhesion Specimens*— If separate specimens for thickness and adhesion tests are required, they shall be strips approximately 25 mm wide, 100 mm long, and 1 mm thick.

9.3 *Corrosion Resistance Specimens*— If separate specimens for corrosion resistance tests are required, they shall be panels not less than 150 mm long, 100 mm wide, and approximately 1 mm thick.

9.4 *Hydrogen Embrittlement Specimens*— If specimens are required, the configuration shall be that specified by the purchaser.

10. Test Methods

10.1 Thickness:

10.1.1 The thickness of the coating may be determined by Test Methods B 487, B 499, B 504, B 567, or B 568, as applicable.

10.1.2 MIL-STD-1312, Test 12, may be used for thickness measurements of electroplated fastener hardware.

10.1.3 Other methods may be used if it can be demonstrated that the uncertainty of the measurement with these methods is less than 10 %.

10.1.4 Make thickness measurements of zinc electroplatings, Types II, III, and IV, after application of the supplementary treatments. When Test Methods B 504, B 567, or B 568 are used, remove the supplementary treatment prior to testing. The chromate film may be removed from Type II and Type III coatings by using a very mild abrasive (a paste of levigated alumina rubbed on with the finger). The phosphate coating may be removed from Type IV coating by a concentrated (28 %) ammonia solution that quickly dissolves the phosphate coating but does not attack the underlying zinc.

10.2 *Adhesion*—Determine adhesion by any suitable procedure in accordance with Test Method B 571.

10.3 *Corrosion Resistance*—When specified in the contract or purchase order, determine the corrosion resistance in accordance with Practice B 117. Subject the selected samples to the salt spray test; the length of time to be applicable for the type of supplementary coating shall be in accordance with the requirements of 7.4. To secure uniformity of results, age Types II and III supplementary coatings at room temperature for 24 h before subjection to the salt spray.

10.4 *Hydrogen Embrittlement Relief*— When specified in the contract or purchase order, prepare and test the satisfactory behavior of parts to indicate freedom from hydrogen embrittlement.

10.5 *Visual Examination*—Examine material for compli-

ance with the requirements of luster (7.3) and workmanship (7.5) after electroplating.

11. Rejection

11.1 Coatings not conforming to this specification or to authorized modification shall be rejected. They may be reconsidered for inspection in accordance with Test Method B 602.

12. Certification

12.1 The purchaser may require in the purchase order or contract that the producer or supplier provide certification that the finish was produced and tested in accordance with this specification and found to meet the requirements. The purchaser may similarly require that a report of the test results be furnished.

13. Packaging and Packing

13.1 Preservation, packaging, and packing methods for zinc-electroplated parts or articles employed by a supplier shall be such as to preclude damaging during shipment and handling.

14. Keywords

14.1 electrodeposited coatings; zinc; zinc, electrodeposited coatings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser as part of the purchaser's order or contract and for all agencies of the United States Government.

S1. Responsibility for Inspection

S1.1 The producer or supplier shall be responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein

unless disapproved by the purchaser. The purchaser retains the right to perform any of the inspections and tests set forth in this specification where such inspections and tests are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

APPENDIXES

(Nonmandatory Information)

X1. SERVICE LIFE OF ZINC

X1.1 The service life of zinc coating is a function of its thickness and the type of environment to which it is exposed. While the conditions of exposure and uses of electroplated metal are so varied that it is not definitely possible to predict the exact life of articles protected by a coating of a given thickness, those using zinc coatings can draw on the wealth of practical experience at hand, supplemented by results of corrosion tests carried out over the years. As a result of large scale and long range tests conducted by ASTM and other organizations, there is excellent information on the corrosion behavior of zinc and zinc coatings. The following data, based

on world-wide testing, may be used to compare the behavior of electrodeposited coatings of zinc in various atmospheres. The values are only relative, since individual studies in various parts of the world have resulted in figures which vary widely from these averages.

Atmosphere	Mean Corrosion Rate
Industrial	5.6 µm/year
Urban non-industrial or marine	1.5 µm/year
Suburban	1.3 µm/year
Rural	0.8 µm/year
Indoors	Considerably less than 0.5 µm/year

NOTE X1.1—The mean corrosion rate given pertains to zinc only and

does not include a corrosion rate when zinc is passivated or in contact with other materials.

X2. EXAMPLES OF APPROPRIATE SERVICE CONDITIONS AND DESCRIPTION OF SERVICE CONDITIONS

X2.1 *SC 4—Very Severe*—Exposure to harsh conditions, or subject to frequent exposure to moisture, cleaners, and saline solutions, plus likely damage by denting, scratching, or abrasive wear. Examples are: plumbing fixtures, pole line hardware.

X2.2 *SC 3—Severe*—Exposure to condensation, perspiration, infrequent wetting by rain, and cleaners. Examples are: tubular furniture, insect screens, window fittings, builder's hardware, military hardware, washing machine parts, bicycle parts.

X2.3 *SC 2—Moderate*—Exposure mostly to dry indoor atmospheres but subject to occasional condensation, wear, or abrasion. Examples are: tools, zippers, pull shelves, machine parts.

X2.4 *SC 1—Mild*—Exposure to indoor atmospheres with rare condensation and subject to minimum wear or abrasion. Examples are: buttons, wire goods, fasteners.

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