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Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel[1]

This standard is issued under the fixed designation B695; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 This specification covers the requirements for a coating of zinc mechanically deposited on iron and steel basis metals. The coating is provided in several thicknesses up to and including 107 µm. The seven thickest classes are usually referred to as "mechanically galvanized."

1.2 *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.*

NOTE 1—The performance of this coating complies with the requirements of Specification A153/A153M and MIL-C-81562.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents of SI units are given for informational purposes.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A194/A194M Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength (Withdrawn 2016)[3]

A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength (Withdrawn 2016)[3]

A563 Specification for Carbon and Alloy Steel Nuts

B117 Practice for Operating Salt Spray (Fog) Apparatus

B183 Practice for Preparation of Low-Carbon Steel for Electroplating

B242 Guide for Preparation of High-Carbon Steel for Electroplating

B322 Guide for Cleaning Metals Prior to Electroplating

B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B571 Practice for Qualitative Adhesion Testing of Metallic Coatings

B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings

B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 *Military Standard:*

MIL-C-81562 Coating, Cadmium, Tin Cadmium and Zinc (Mechanically Deposited)[4]

2.3 *AISC Standard:*

Specifications for Structural Joints Using ASTM A325 or A490 Bolts[5]

3. Classification

3.1 *Classes*—Zinc coatings are classified on the basis of thickness, as follows:

[1] This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.06 on Soft Metals.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

[5] Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 700, Chicago, IL 60601-2001, http://www.aisc.org.

Class	Minimum Thickness, µm
110	107
80	81
70	69
65	66
55	53
50	50
40	40
25	25
12	12
8	8
5	5

3.2 *Types*—Zinc coatings are identified by types on the basis of supplementary treatment required, as follows:

Type I—As coated, without supplementary treatment (Appendix X2.1).

Type II—With colored chromate conversion treatment (Appendix X2.2).

4. Ordering Information

4.1 Supplying the following information by the purchaser to the seller in the purchase order or other governing document will make the application of this specification complete:

4.1.1 Class, including a maximum thickness, if appropriate, type, and for Type II, color and need for supplemental lubricant (3.1, 3.2, and 6.2.5),

4.1.2 Nature of substrate (for example, high-strength steel), need for stress relief (6.2.1), and cleaning precautions to be followed (6.2.2 and 6.2.3),

4.1.3 Significant surfaces (6.3),

4.1.4 Requirements for and methods of testing for one or more of the following, if required: need for and type of test specimens (8.1), thickness (6.3 and 8.3), adhesion (6.4 and 8.4), corrosion resistance (6.5 and 8.5), absence of hydrogen embrittlement, and the waiting period before testing and testing loads (6.6 and 8.6),

4.1.5 Inspection responsibility (Section 11) and sampling plan for each inspection criterion (Section 7), and

4.1.6 Requirements for certified report of test results (Section 10).

5. Workmanship

5.1 The coating shall be uniform in appearance and free of blisters, pits, nodules, flaking, and other defects that are capable of adversely affecting the function of the coating. The coating shall cover all surfaces as stated in 6.3 including roots of threads, thread peaks, corners, recesses, and edges. The coating shall not be stained or discolored throughout to an extent capable of adversely affecting appearance as a functional requirement. However, superficial staining, that results from rinsing or drying, and variations in color or luster shall not be cause for rejection.

NOTE 2—The nature of the mechanical plating process is such that coatings characteristically will not be as smooth or as bright as some electroplated coatings.

6. Requirements

6.1 *Appearance*—The coating as deposited shall have a uniform silvery appearance, and a matte to medium-bright luster.

6.2 *Process:*

6.2.1 *Stress-Relief Treatment*—All steel parts that have an ultimate tensile strength of 1000 MPa and above and that contain tensile stresses caused by machining, grinding, straightening, or cold-forming operation shall be given a stress-relief heat treatment prior to cleaning and metal deposition. The temperature and time at temperature shall be 190 ± 15°C for a minimum of 3 h so that maximum stress relief is obtained without reducing the hardness below the specified minimum.

6.2.2 High-strength steels (which become embrittled when charged with hydrogen) and that have heavy oxide or scale shall be cleaned before application of the coating in accordance with Practice B242. In general, nonelectrolytic alkaline, anodic-alkaline, and some inhibited acid cleaners are preferred to avoid the risk of producing hydrogen embrittlement from the cleaning procedure.

6.2.3 For low-carbon steels, see Practice B183. Useful guidelines are also given in Guide B322.

6.2.4 Mechanical deposition of zinc coatings shall consist, in general, of all of the steps listed below, and in the sequence as shown:

6.2.4.1 Preparation of the surface of the parts to be coated, by chemical (generally acidic) procedure to an extent that permits uniformly satisfactory results from subsequent steps.

6.2.4.2 Deposition of a thin metal coating, generally of copper, by immersion in appropriate chemical solutions, without the use of electric current. There are no thickness requirements for this coating.

6.2.4.3 Tumbling of the parts that have been treated according to 6.2.4.1 and 6.2.4.2 in a container with the following:

(1) The zinc metal to be deposited, in powder form;

(2) Impact media, which includes glass, for example, or other substances that are essentially inert to the chemicals of the deposition process. The function of this media is to aid in providing mechanical forces to drive the metal powder onto the substrate parts;

(3) A "promoter" or "accelerator" which aids in the uniform deposition of the metal powder; and

(4) A liquid medium, generally water.

6.2.4.4 Separation of the parts from the solid and liquid media.

6.2.4.5 Rinsing.

6.2.4.6 Drying.

6.2.5 *Supplementary Treatments:*

6.2.5.1 *Colored Chromate Conversion Treatments (Type II)*—Colored chromate conversion treatment for Type II shall be done in a solution containing hexavalent chromium ions. This solution shall produce a bright or semi-bright continuous, smooth, protective film with a uniform color that is capable of ranging from yellow through bronze and olive-drab to brown and black and that are capable of being dyed to a desired color. Bright dips that do not contain salts that yield films containing hexavalent chromium ions are precluded as treatments for producing Type II coatings.

6.2.5.2 Waxes, lacquers, or other organic coatings are not prohibited from being used to improve lubricity, and the need for them shall be supplied in the purchase order or other governing document (see 4.1.1). Supplemental lubrication

treatments shall not be used to ensure conformance to the salt spray corrosion resistance requirements (see 8.5.4).

6.2.5.3 Lubrication of grade DH nuts processed in accordance with this specification and used with Specification A325 high-strength bolts is a requirement of paragraph 6.5 of Specification A325 and paragraph 4.8 of Specification A563.

NOTE 3—Although not included in Specification A194/A194M, this provision should apply to mechanically galvanized Specification A194/A194M 2H nuts when supplied for use with Specification A325 bolts.

NOTE 4—Specifications for structural joints using Specification A325 or A490 bolts references the use of lubricants on nuts to be used with Specification A325 high-strength bolts and is found in the commentary on this RCSC (Research Council on Structural Connections of the Engineering Foundation) Specification, within the paragraphs entitled "Effect Of Galvanizing Upon Torque Involved In Tightening" and "Shipping Requirements For Galvanized Bolts and Nuts," published November 1985, page 30.[5]

6.2.6 *Surface Defects*—Defects and variations in appearance in the coating that arise from surface conditions of the substrate (scratches, pores, roll marks, inclusions, etc.) and that persist in the finish despite the observance of good metal finishing practices shall not be cause for rejection.

NOTE 5—Applied finishes generally perform better in service when the substrate over which they are applied is smooth and free of torn metal, inclusions, pores, and other defects. It is recommended that the specifications covering the unfinished product provide limits for these defects. A metal finisher can often remove defects through special treatments, such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing. However, these are not normal in the treatment steps preceding the application of the finish. When desired they must be specified on the purchase order (4.1.2).

6.3 *Thickness:*

6.3.1 The thickness of the coating everywhere on the significant surfaces shall be at least that of the specified class as defined in 3.1.

6.3.2 Significant surfaces are defined as those normally visible (directly or by reflection) that are essential to the appearance or serviceability of the article when assembled in normal position; or that are capable of providing the source of corrosion products that deface visible surfaces on the assembled article. When necessary, the significant surfaces shall be indicated on the drawing for the article, or by the provision of suitably marked samples.

NOTE 6—The thickness of mechanically-deposited coatings varies from point-to-point on the surface of a product, characteristically tending to be thicker on flat surfaces and thinner at exposed edges, sharp projections, shielded or recessed areas, interior corners and holes, with such thinner areas often being exempted from thickness requirements.

6.3.3 When significant surfaces are involved on which the specified thickness of deposit cannot readily be controlled, it is incumbent upon the purchaser and manufacturer to recognize the necessity for either thicker or thinner deposits. For example, to reduce buildup in thread roots, holes, deep recesses, bases of angles, and similar areas, the deposit thickness on the more accessible surfaces will have to be reduced proportionately.

NOTE 7—The coating thickness requirement of this specification is a minimum requirement; that is, the coating thickness is required to equal or exceed the specified thickness everywhere on the significant surfaces. Variation in the coating thickness from point to point on a coated article is an inherent characteristic of mechanical deposition processes. Therefore, the coating thickness will have to exceed the specified value at some points on the significant surfaces to ensure that the thickness equals or exceeds the specified value at all points. Hence, in most cases, the average coating thickness on an article will be greater than the specified value; how much greater is largely determined by the shape of the article and the characteristics of the deposition process.

In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all of the articles in a production lot are to meet the thickness requirement, the average coating thickness for the production lot as a whole will be greater than the average necessary to ensure that a single article meets the requirement.

6.4 *Adhesion*—The zinc coating shall be sufficiently adherent to the basis metal to pass the tests specified in 8.4.

6.5 *Corrosion Resistance:*

6.5.1 The presence of corrosion products visible to the unaided eye at normal reading distance at the end of the specified test periods stated in Table 1 shall constitute failure, except that corrosion products at edges of specimens shall not constitute failure. Slight "whisps" of white corrosion, as opposed to obvious accumulations, shall be acceptable.

NOTE 8—Mechanical deposition is exclusively a barrel-finishing process. It is recognized that mechanical deposition on parts may therefore produce surfaces that have a different characteristic from those on parts that are finished exclusively by racking. Similarly, corrosion testing of actual parts may produce different results from those on test panels. Salt spray requirements that are appropriate to indicate the technical quality with which a process is carried out may be impractical for acceptance of actual parts. In such cases the purchaser shall indicate his requirements on the purchase order (4.1.4).

NOTE 9—In many instances, there is no direct relation between the results of an accelerated corrosion test and the resistance to corrosion in other media, because several factors that influence the progress of corrosion, such as the formation of protective films, vary greatly with the conditions encountered. The results obtained in the test should not, therefore, be regarded as a direct guide to the corrosion resistance of the tested materials in all environments where these materials may be used. Also, performance of different materials in the test cannot always be taken as a direct guide to the relative corrosion resistance of these materials in service.

6.5.2 On parts with Type II coatings, the greater number of hours for either white corrosion products or rust shall apply. For example, for Type II, Class 8, the test shall be continued until the 72-h requirement is met for white corrosion products; similarly, for Type II, Class 25, if no white corrosion products appear before 72 h, test shall be continued until the 192-h requirement for basis metal corrosion is met (8.5.2).

6.6 *Absence of Hydrogen Embrittlement*—Springs and other high-strength parts subject to flexure shall be held for a minimum of 48 h at room temperature after coating before

TABLE 1 Minimum Hours to Failure (White Corrosion Products and Red Rust for Mechanically Deposited Zinc Coatings on Iron and Steel)

Type	White Corrosion						
Class:	55–110	50	40	25	12	8	5
I	[A]	[A]	[A]	[A]	[A]	[A]	[A]
II	72	72	72	72	72	72	72
	Red Rust						
Class:	55–110	50	40	25	12	8	5
I	no requirement	300	250	192	96	56	36
II	no requirement	300	250	192	96	72	72

[A] No requirement.

being loaded, flexed, or used. Such high-strength steel parts shall be free of hydrogen embrittlement. When specified in the purchase order, freedom from embrittlement shall be determined by the test specified herein (4.1.4 and 8.6).

7. Sampling

7.1 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.

7.1.1 When a collection of coated articles (inspection lot, see 7.2) 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 B602, Guide B697, and Test Method B762 contain sampling plans that are designed for sampling inspection of coatings.

7.1.2 Test Method B602 contains four sampling plans, three for use with tests that are nondestructive and one when they are destructive. Test Method B602 provides a default plan if one is not specified.

7.1.3 Guide B697 provides a large number of plans and also gives guidance in the selection of a plan. Guide B697 provides a default plan if one is not specified.

7.1.4 Test Method B762 shall 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 B762 contains several plans and also gives instructions for calculating plans to meet special needs. Test Method B762 provides a default plan if one is not specified.

7.1.5 Use Guide F1470 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.

7.2 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.

8. Test Methods

8.1 *Test Specimens:*

8.1.1 If needed, use test specimens to represent the coated articles in a test if the articles are of a size, shape, or material that is not suitable for the test, or if it is preferred not to submit articles to a destructive test because, for example, the articles are expensive or few. The permission or the requirement to use test specimens, their number, the material from which they shall be made, and their shape and size shall be stated in the purchase order or other governing document.

8.1.2 The test specimen shall duplicate those characteristics of the article that influence the property being tested, and it shall be processed with the article through those process steps that influence the property.

8.1.2.1 The test specimen used to represent an article in an adhesion, corrosion resistance, or appearance test shall be made of the same material, shall be in the same metallurgical condition, and shall have the same surface condition as the article it represents, and it shall be placed in the production lot of, and be processed along with, the article it represents.

8.1.2.2 A test specimen used to represent an article in a coating thickness test shall be introduced into the process at the point where the coating or coatings are applied and it shall be carried through all steps that have a bearing on the coating thickness.

8.1.2.3 When a test specimen is used to represent a coated article in a thickness test, the specimen will not necessarily have the same thickness and thickness distribution as the article unless the specimen and the article are of the same general size and shape. Therefore, before accepting coated articles on the basis of a thickness test performed on representative test specimens, the relationship between the thickness on the specimen and the thickness on the part shall be established. The criterion of acceptance shall be that thickness on the specimen that corresponds to the required thickness on the article.

8.2 *Workmanship*—Quality of workmanship shall be determined by the unaided eye at normal reading distance.

8.3 *Thickness:*

8.3.1 The thickness of the coating shall be determined by the microscopical method (Test Method B487) or the magnetic method (Test Method B499), as applicable. Other methods are not prohibited, provided that they demonstrate a measurement uncertainty less than 10 %.

8.3.2 The thickness of the coating shall be measured at the location or locations for both significant and nonsignificant surfaces of the product where the coating is expected to be the thinnest or at such locations as specified on the purchase order (4.1.3 and 6.3).

8.3.3 Thickness measurements of Type II deposits shall be made after application of the supplementary treatment. The Type II chromate conversion coatings shall be removed from the test area before the thickness is measured. Removal shall be done by using a very mild abrasive (such as a paste of levigated alumina or magnesium oxide) rubbed on gently with the finger.

NOTE 10—The process by which Type II coatings are produced dissolves a small amount of the zinc. For this reason the thickness requirement to be checked refers to the thickness of the deposit after the application of the Type II coatings.

8.4 *Adhesion*—Adhesion of the zinc deposit to the basis metal shall be tested in a manner that is consistent with the service requirements of the coated article. The ability to separate the coating from the substrate by peeling, as distinct from flaking caused by rupture of the deposit or of the basis metal, shall be evidence of failure. One of the following methods for determining adhesion shall be used:

8.4.1 The part shall be plastically deformed, if possible, to rupture as specified on the purchase order (4.1.4).

8.4.2 The surface of the coated article shall be scraped or sheared with a sharp edge, knife, or razor blade through the coating down to the basis metal and examined under 4× magnification.

NOTE 11—There is no single satisfactory test for evaluating the adhesion of mechanically deposited coatings. Those given above are widely used; however, other tests may prove more applicable in specific cases. Various qualitative methods are discussed in Practice B571. A review of methods of measuring adhesion is given in the *Proceedings*, American Electroplaters' Soc., Vol 50.[6]

8.5 *Salt Spray Corrosion Resistance:*

8.5.1 The 5 % neutral salt spray (fog) test as defined in Practice B117 shall be used.

8.5.2 If samples with Type II coatings are to be examined both for white corrosion products and for rust, use separate samples to determine the end point for white corrosion and for rust. This is to permit uninterrupted exposure for the longer of the two test periods required without having to wash specimens for examination, in accordance with Practice B117.

8.5.3 Parts with Type II supplementary chromate film shall be aged at room temperature for 24 h before subjection to the salt spray test.

8.5.4 Parts with coatings of wax, etc., shall not be used as samples for corrosion testing for conformance to the requirements of 6.5.

8.6 *Absence of Hydrogen Embrittlement:*

8.6.1 Coated parts to be tested for the absence of embrittlement from cleaning shall be tested for brittle failure in accordance with a suitable method to be specified on the purchase order (4.1.4). The description of the method shall include the means of applying a load to the part, the stress or load level to be applied, the duration of the test, the waiting time that must elapse between deposition of the zinc and testing or use of the part, and the criterion of failure.

8.6.2 Parts that must conform to U.S. Government requirements shall be subjected to such loading conditions described above for 200 h minimum.

NOTE 12—It is recommended that tests for embrittlement involve subjecting parts to the specified operating conditions for at least 100 h (except as noted in 8.6.2). The stress level induced by the test and the waiting period prior to test depend upon many factors such as shape of the part, carbon content of the steel, hardness of the part, and stress level in use. Parts with a tensile strength of over 1000 MPa, for example, may require a 48-h waiting period; parts with lower tensile strength may require less than a 24-h waiting period. High-carbon steel parts or those cold-worked or heat-treated to tensile strengths of 1450 MPa or more, where these parts will be subjected to a sustained load in use, may require testing at loads specified by the purchaser or at 75 % of the ultimate tensile strength.

9. Rejection and Rehearing

9.1 Materials that fail to conform to the requirements of this specification are subject to rejection. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of a test, the producer or supplier is capable of making a claim for rehearing. Finishes that show imperfections during subsequent manufacturing operations are again subject to rejection.

10. Certification

10.1 If required by the purchaser, the purchase order or contract that the producer or supplier gives to the purchaser will include a certification that the finish was produced and tested in accordance with this specification and found to meet the requirements. The purchaser is also capable of requiring that a report of the test results be furnished.

11. Quality Assurance Provisions

11.1 For parts processed for U.S. Government procurement, the producer or supplier shall be responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer or supplier is not prohibited from using his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to the prescribed requirements.

12. Keywords

12.1 chemical zinc; corrosion resistant coatings; mechanical galvanize; mechanical zinc; zinc coatings

[6] For availability of this publication, contact American Electroplaters' Society, 12644 Research Parkway, Orlando, FL 32826.

APPENDIXES

(Nonmandatory Information)

X1. CHARACTERISTICS

X1.1 Mechanical deposition in itself greatly reduces the risk of hydrogen embrittlement and is suitable for coating bores and recesses in many parts that cannot be conveniently electroplated (see Appendix X3).

X1.2 Zinc coatings are usually applied to provide corrosion resistance. The performance of a zinc coating depends largely on its thickness, the supplementary treatment if any, and the kind of environment to which it is exposed. The seven heaviest classes of coatings offer suitable alternatives to hot-dip galvanizing. The following data, based on widespread testing, may be used to compare the behavior of zinc in various atmospheres. The values are only indicative, because individual studies in various parts of the world have resulted in figures that vary widely from these averages.

Atmosphere	Mean Corrosion Rate
Industrial	5.6 µm (0.22 mil)/year
Urban nonindustrial or marine	1.5 µm (0.06 mil)/year
Suburban	1.3 µm (0.05 mil)/year
Rural	0.8 µm (0.03 mil)/year
Indoors	considerably less than 0.5 µm (0.01 mil)/year

X2. SPECIFIC TYPES

X2.1 *Type I (plain zinc)* is useful for lowest cost protection where early formation of white corrosion products is not detrimental. It is also used for higher temperature applications up to approximately 120°C where the effectiveness of chromates is greatly reduced.

X2.2 *Type II (colored chromates)*—Chromates that have a color (yellow, olive drab, bronze, etc.) are used to delay the appearance of white or red corrosion products on the plated article, or to provide a color desired by a customer for a specific purpose.

X3. HYDROGEN EMBRITTLEMENT

X3.1 A major advantage of mechanical deposition is that it does not produce hydrogen embrittlement in hardened steel during the coating process. However, pronounced embrittlement can be produced in certain cleaning processes. The mild degree of embrittlement that might result from following proper procedures with cleaning methods permitted in this specification normally is self-relieving within a day's time at room temperature.