



Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners¹

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1. Scope*

1.1 This specification covers the requirements for hot-dip zinc coating applied to carbon steel and alloy steel bolts, screws, washers, nuts, and special threaded fasteners. It also provides for minor coating repairs. Nails and rivets are not included in this specification.

1.2 It is intended to be applicable to fasteners that are centrifuged or otherwise handled to remove excess galvanizing bath metal (free zinc).

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *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:²

- A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
- A563 Specification for Carbon and Alloy Steel Nuts
- A563M Specification for Carbon and Alloy Steel Nuts (Metric)

¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.03 on Coatings on Fasteners.

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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.

- A780/A780M Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
- B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section
- E376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods
- F606/F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F1789 Terminology for F16 Mechanical Fasteners

3. Terminology

3.1 Definitions:

3.1.1 Terms used in this specification are defined in Terminology F1789 unless otherwise defined in this specification.

3.1.2 *batch lot*—quantity of identical parts cleaned, pickled, fluxed, and galvanized together at one time in a galvanizing basket.

3.1.3 *galvanizing*—hot-dip zinc coating.

3.1.4 *high temperature galvanizing*—galvanizing process carried out in a ceramic vessel (kettle) at an approximate temperature ranging between 990°F and 1040°F [530°C and 560°C].

3.1.5 *hot-dip zinc coating of mechanical fasteners*—process whereby fasteners are zinc coated by immersion in a bath of molten zinc, resulting in the formation of the iron/zinc alloy coating and a zinc coating at the surface of the fastener. This process involves the removal of excess zinc by spinning the parts in a centrifuge, or brushing the threaded portion, or handling otherwise to remove the excess zinc.

3.1.6 *production lot*—batches of parts originating from the same manufacturing lot, processed continuously through cleaning, pickling, fluxing, dipping in molten zinc and spun in a centrifuge, or other means, without any significant change in time, temperature, and concentration of the constituents of the process.

*A Summary of Changes section appears at the end of this standard

3.1.7 *stress relief*—process of heating parts for a definite time at a given temperature in order to relieve stress induced by work hardening.

4. Ordering Information

4.1 Orders for zinc coating of fasteners to this specification shall include the following:

- 4.1.1 Name of product (that is bolt, stud, nut, washers, or other);
- 4.1.2 ASTM designation and year of issue, including fastener specification number;
- 4.1.3 Hydrogen embrittlement relief treatment, as required by the purchaser (see, 7.2.3);
- 4.1.4 Quantity of fasteners to be hot-dip zinc coated;
- 4.1.5 Stress relief or tempering temperature to which the fasteners where subjected, if applicable;
- 4.1.6 Secondary processing such as chromating, phosphating, or lubrication, if applicable;
- 4.1.7 Average galvanizing temperature to which fasteners will be subjected, if required by the purchaser (see 7.2.2);
- 4.1.8 Specify baking if required (see 7.2.3); and
- 4.1.9 Certification, if required (see 14.1).
- 4.1.10 Supplementary Requirements (See S1).

5. Materials and Manufacture

5.1 *Condition of the As-Received Fasteners*—The fasteners as received by the galvanizer shall be free from contaminants that are not readily removed in the cleaning process and would adversely affect the galvanizing.

5.2 *Process*—Unless otherwise covered in this specification, all processing parameters shall be in accordance with the requirements of Specification A153/A153M.

5.2.1 *Process Control*—Galvanized fasteners subjected to a process control plan based upon batch lot level shall comply with the batch lot sampling plan in Table 1, and the sampling plan for production lot (prevention process) as determined in 10.2.2 shall be applied.

5.3 *Spinning and Quenching:*

5.3.1 Parts shall be spun immediately following removal from the galvanizing bath and quenched in water. In addition, small parts shall be air cooled, as needed, in order to prevent the formation of zinc oxide.

5.3.2 Parts, which cannot be spun shall be brushed or handled otherwise to remove the excess zinc.

5.4 *Alteration of Threaded Fasteners:*

5.4.1 Fasteners that have been hot-dip galvanized shall not be further altered (such as subjected to a cutting, rolling, or finishing-tool operation) by the galvanizer unless specifically authorized in writing by the purchaser.

5.4.2 Hot-dip galvanizing of externally threaded fasteners shall meet the thread fitting requirements of the specified product standard or specific allowance as determined by the customer.

NOTE 1—The scope of this specification does not cover the requirements regarding the overtapping of galvanized nuts. These requirements are established by the applicable product standard, such as Specification A563, Specification A563M (or others), or in writing by the purchaser, if needed.

5.5 *Secondary Processing:*

5.5.1 When requested by the purchaser, treatments such as chromating or phosphating shall be applied to reduce the possibility of wet storage staining (white corrosion) or to assist subsequent painting.

5.5.2 When specified on the purchase order, the nuts, bolts, or screws shall be lubricated to enhance assembly.

5.6 *Touch-up and Repair*—Bare, cut, or damaged spots found on fasteners after galvanizing, totaling less than 1% of the coated surface area, may be repaired with paints containing zinc dust. Such paints shall have zinc-dust concentrations of 65 to 69% or concentrations above 92% in the dried film. The repairing party shall select the paint and follow its application instructions. The applied coating shall provide barrier protection, and preferably be anodic to steel. Thickness measurements of repaired areas shall not be required.

NOTE 2—Experience shows that, in general, organic zinc-rich systems are tolerant of marginal surface preparation and are not critical of climatic or atmospheric conditions for curing. Corrosion resistance and service performance are very dependent on the properties of the paint system, the extent of surface preparation, and the skills of individual applicators. See Practice A780/A780M.

6. Chemical Composition of Zinc

6.1 Unless otherwise specified in the product standard, the zinc used for the coating shall conform to the requirements of the section on Zinc of Specification A153/A153M.

7. Safeguards Against Alteration of Fasteners Mechanical Properties

7.1 *Stress Relief*—Fasteners subjected to severe work hardening shall be stress-relieved by the fastener manufacturer prior to hot-dip zinc coating (galvanizing).

7.2 *Hot-Dip Zinc Coating:*

7.2.1 *Effect of Temperature on Mechanical Properties:*

7.2.1.1 Galvanizing carried out at a temperature above 800°F [425°C] can adversely affect the final mechanical properties of the fasteners. Therefore, the supplier of the fasteners submitting the product to the galvanizer shall be aware of the tempering temperature of the fasteners relative to the temperature of the galvanizing bath and the potential effect it may have on the product. When requested by the purchaser,

TABLE 1 Process Control of Batch Lot^A
Sampling Plan

Batch Lot Size	Sample Size ^B		
	Average Coating Thickness ^C	Adhesion	Appearance ^D
5 to 25	1	1	1
26 to 50	1	1	2
51 to 150	2	1	2
151 and over	2	2	2

^A The acceptance criterion in all cases is zero defects.

^B The sample size is the number of specimen(s) required to be tested/inspected to the applicable criteria.

^C Frequency of coating thickness measurements: one set of specimen(s) for every five batch lots. For test method, see 11.1.

^D Visual inspection for conformance.

the average galvanizing temperature that the fasteners will be subjected to shall be furnished.

7.2.1.2 Unless otherwise required by the product standard or by the purchaser, testing for mechanical properties is not necessary if the galvanizing process is carried out at a lower temperature than the stress relief or tempering temperature of the fasteners. If the galvanizing process is carried out at a higher temperature than the stress relief or the tempering temperature of the fasteners, than the purchaser shall make provision for mechanical testing.

7.2.1.3 Threaded fasteners made from carbon or alloy steel heat treated to a minimum specified hardness of 40 HRC, or case hardened steel fasteners shall not be hot-dip zinc coated.

7.2.2 *Effect of Hydrogen on the Mechanical Properties after Galvanizing*—Hydrogen has the potential of being introduced into the steel during acid pickling, prior to hot-dip galvanizing. For high strength fasteners (having a specified minimum product hardness of 33 HRC), there is a risk of internal hydrogen embrittlement. If required by the product standard or by the purchaser, mechanical descaling (with or without flash pickling) or baking shall be conducted to reduce the risk of internal hydrogen embrittlement. Baking shall be conducted after pickling and prior to hot-dip galvanizing.

7.2.3 *Effect of the Galvanizing Temperature*—Externally threaded ferrous fasteners over 1.00 in. [M24] diameter with a specified minimum hardness of HRC 33 and higher shall not be hot-dip zinc coated at high temperature (see definition in 3.1.4) in order to avoid microcracks.

8. Coating and Dimensional Requirements

8.1 *Coating Thickness*—The zinc coating thickness shall meet the requirements of Table 2. See Supplementary Requirement S1 when specifying coating thickness for fasteners meeting the requirements of Specification A394.

8.2 *Dimension*—The dimensional characteristics of the fasteners shall be in accordance with the requirements of the purchaser, when specified in the order. The purchaser shall ensure that the effect of the heat generated by the galvanizing process is compatible with the fastener regarding the final dimensional characteristics of the parts. Furthermore, the

galvanizer shall not be held responsible for any unanticipated distortion of parts. In addition, the purchaser shall provide fasteners having sufficient dimensional allowance to accommodate the zinc thickness deposition, as required in 8.1.

8.3 *Adhesion of Zinc Coating*—The zinc coating shall adhere tenaciously to the surface of the base metal. The method for testing the condition of adherence is specified in 11.5.

9. Workmanship, Finish, and Appearance

9.1 Appearance of Zinc Coating:

9.1.1 After hot-dip galvanizing, the fasteners shall meet the requirements of the section on Workmanship, Finish, and Appearance of Specification A153/A153M. Galvanized washers shall not be bonded to each other (See Note 3). Parts may be dull due to the presence of silicon in the steel. The dull appearance shall not be cause for rejection.

NOTE 3—Hot-dip washers tend to bond to each other. Suitable acceptance criteria shall be agreed between the purchaser and the galvanizer before placing the order. Unless otherwise agreed to in the purchase order, delivered galvanized washers shall not be bonded to each other.

9.1.2 The test method shall be in accordance with 11.3.

9.2 Smoothness of Zinc Coating:

9.2.1 The zinc coating shall be smooth and reasonably uniform in thickness, as defined in the section on Workmanship, Finish, and Appearance of Specification A153/A153M. Smoothness of a surface is a relative term. Minor roughness that does not impair the intended use of the part, or roughness that is related to the uncoated surface condition of the part, shall not constitute grounds for rejection of the parts.

9.2.2 The test method shall be in accordance with 11.3.

10. Sampling

10.1 Test specimens shall be selected at random from each production lot or batch lot, when applicable.

10.2 *Selection of the Sampling Plan—Production Lot*—Two sampling plans are proposed, one based on detection process and one based on prevention process as defined in Terminology F1789. The selection of the sampling plan shall be in accordance with Guide F1470.

TABLE 2 Zinc Coating Thickness

Dimension ^{A,B}	Minimum Thickness on Surface		
	Average Thickness of All Specimens Tested (Production Lot) ^{C,B}	Average Thickness of All Specimens Tested (Batch Lot) ^{D,B}	Average Thickness of Individual Specimen ^B
Fasteners and nuts over 3/16 in. [M10] in diameter	0.0020 in. [50 µm]	0.0017 in. [43 µm]	0.0017 in. [43 µm]
Washers 3/16 in. [4.7 mm] and over in thickness			
Fasteners and nuts 3/16 in. [M10] and under in diameter	0.0017 in. [43 µm]	0.0015 in. [38 µm]	0.0015 in. [38 µm]
Washers under 3/16 in. [4.7 mm] in thickness			

^A In the case of long pieces, such as anchor rods and similar articles over 5 ft [1.5 m] in length, the thickness measurement shall be determined at each end and the middle of the article. In the case of a fully threaded rod, the thickness measurements shall be determined at each end of the article. In no case shall the average of the measurements be below the average thickness shown in the Average Thickness on Individual Specimen column (see 11.2). The number of specimens to be tested per order shall be as specified in Section 10. Note—Based upon mathematical calculations, 1.0 oz /ft² [305 g/m²] of zinc surface corresponds to an average coating thickness of 0.0017 in. [43 µm].

^B Inch-pound and SI units may not be exact equivalents. See 1.3.

^C For test method, see 11.2. In no case shall the average reading of a single specimen be below the average thickness shown in the Average Thickness on Individual Specimen column.

^D See 5.2.1 and Table 1. For test method, see 11.2. In no case shall the average reading of a single specimen be below the average thickness shown in the Average Thickness on Individual Specimen column.

10.2.1 *Production Lot–Detection Process*—Sampling for coating thickness and for visual appearance shall be conducted in accordance with Table 1, Sample Level A, and Table 3, Sample Size A, of Guide **F1470**. Sampling for adhesion test shall be in accordance with Table 1, Sample Level C, and Table 3, Sample Size C, of Guide **F1470**.

10.2.2 *Production Lot–Prevention Process*—Sampling for coating thickness and for visual appearance shall be conducted in accordance with Table 2, Sample Level B, and Table 3 Sample Size B, of Guide **F1470**. Sampling for adhesion test shall be in accordance with Table 2, Sample Level D, and Table 3, Sample Size D, of Guide **F1470**.

11. Test Methods

11.1 Tests shall be made to ensure that the zinc coating is being furnished in accordance with this specification and as specified for the following:

11.2 Coating Thickness:

11.2.1 Average Coating Thickness on an Individual Specimen:

11.2.1.1 To calculate the average coating thickness of one specimen, a minimum of five readings shall be taken. In case the geometry of the specimen does not permit five readings, five test specimens shall be used to establish the average reading.

11.2.1.2 The determination of the coating thickness shall be made on a portion of the fastener that does not include any threads in accordance with Practice **E376**.

11.2.1.3 In case of arbitration, the thickness of coating shall be determined by cross section and optical measurement, in accordance with Test Method **B487**. Thus, the thickness determined is a point value. No less than five measurements shall be made at locations on the test specimen, which are as widely dispersed as practical, so as to be representative of the whole surface of the test specimen. The average of those selected measurements is the average coating thickness.

11.3 *Finish and Appearance*—Finish and appearance shall be visually inspected.

11.4 *Embrittlement Test*—If the product standard requires testing for hydrogen embrittlement of galvanized fasteners, testing shall be done in accordance with Test Methods **F606/F606M** or other test method(s), as required by the purchaser.

11.5 *Adhesion Test*—Testing for adherence shall be conducted as determined in the section on Adherence of Specification **A153/A153M**.

12. Inspection

12.1 When the purchaser requires dimensional inspection of the fasteners by the galvanizer, the purchaser shall provide the necessary inspection tools and gages to the galvanizer.

12.2 The representative of the purchaser shall have access at all times while work on the contract of the purchaser is being performed, to those areas of the galvanizer's work which concern the application of the zinc coating to the fastener ordered. The manufacturer shall afford the representative of the purchaser all reasonable facilities to satisfy this representative that the zinc coating is being furnished in accordance with this specification. All inspections and tests shall be made at the place of manufacture prior to shipments, unless otherwise specified, and shall be conducted so as not to unnecessarily interfere with the operation of the works.

13. Rejection and Rehearing

13.1 When partial inspection of fasteners to determine conformity with visual requirements of Section 9 warrants rejection of a lot, the galvanizer may sort the lot and submit it once again for inspection.

13.2 Disposition of nonconforming lots shall be in accordance with the section on Disposition of Nonconforming Lots of Guide **F1470**.

13.3 Fasteners that have been rejected for reasons other than embrittlement may be stripped and re-galvanized and submitted for test and inspection. They shall then conform to the requirements of this specification.

14. Certification

14.1 When specified in the purchase order or contract, certification shall be furnished declaring that samples representing each lot have been either tested or inspected, as required by this specification, and that the requirements have been met. When specified in the purchase order or contract, the average galvanizing temperature shall be reported and the average thickness of the production lot shall be furnished.

15. Packaging and Package Marking

15.1 When the galvanizer is required to pack hot-dip galvanized fasteners, they shall not be packed in unventilated containers, if fabricated from unseasoned wood. The packaging shall comply with the purchaser requirements.

16. Keywords

16.1 coatings, zinc; galvanized coatings; steel zinc coated; steel fastener products, metallic coated; zinc coating fastener products

SUPPLEMENTARY REQUIREMENTS

The following requirements shall be applied when specified by the purchaser on the inquiry and order. Details of these requirements shall be agreed upon in writing between the manufacturer and purchaser.

S1. ASTM A394 Coating Thickness

S1.1 When Supplementary Requirement S1 is specified on the order, the minimum average thickness of zinc shall be 0.0028 in. or (70 μ m) and the minimum average thickness of any one item shall be 0.0025 in. or (63 μ m).

APPENDIXES

(Nonmandatory Information)

X1. GALVANIZING TEMPERATURE

X1.1 Normally galvanizing is carried out at a bath temperature of 820°F to 900°F [435°C to 480°C]. High temperature galvanizing is used to produce a smoother and thinner coating

and is carried out at a bath temperature of 990°F to 1040°F [530°C to 560°C]. The finish obtained using the high temperature process is dull.

X2. VARIATION IN COATING

X2.1 During galvanizing of a production lot, variation can be experienced due to factors inherent to the galvanizing process, such as immersion time, zinc temperature, time span

between removal of fasteners from the zinc bath and the centrifuging, and the like.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue (F2939–13) that may impact the use of this standard.

(1) Added Supplementary Requirement S1 for added zinc thickness to comply with the requirements of Specification **A394**.

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