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Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products[1]

This standard is issued under the fixed designation A 1059/A 1059M; 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.

1. Scope

1.1 This specification covers the general requirements for protective zinc coatings (hereinafter referred to as the coatings) to be applied by the thermo-diffusion coating (TDC) method, to various products made of carbon steel, including low and high tensile parts as well as of wrought iron, sintered iron steel-powder and various steel and stainless alloys. TDC is carried out by immersing the parts in a zinc alloy powder at elevated temperature for a period of time, causing a metallurgical diffusion process of zinc and iron. Further processing may be added, such as, passivation, topcoat application, paint application, etc.

1.2 This specification is applicable to orders in either inch-pound units (as A 1059) or in SI units (as A 1059M). Inch-pound units and SI units are not necessarily exact equivalents. Within the text of this specification and where appropriate, SI units are shown in brackets. Each system shall be used independently of the other without combining values in any way. In the case of orders in SI units, all testing and inspection shall be done using the metric equivalent of the test or inspection method as appropriate. In the case of orders in inch-pound units, such shall be stated to the applicator when the order is placed.

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:*[2]

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 902 Terminology Relating to Metallic Coated Steel Products

B 487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

D 521 Test Methods for Chemical Analysis of Zinc Dust (Metallic Zinc Powder)

D 6386 Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting

E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Examination Methods

F 1789 Terminology for F16 Mechanical Fasteners

F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

F 2674 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners [Metric]

3. Terminology

3.1 The following terms and definitions are specific to this specification. Terminology A 902 contains other terms and definitions relating to metallic-coated steel products. Terminology F 1789 contains other terms and definitions relating to mechanical fasteners.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *thermo-diffusion coating*—a process where the steel product is heated in close contact with zinc powder or zinc mixture.

3.2.2 *thermo-diffusion coating*—a coating made by thermo-diffusion coating process, consisting of zinc/iron alloys.

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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.

3.2.3 *zinc powder*—the coating material used to provide corrosion protection to steel.

3.2.4 *zinc mixture*—a combination of zinc powder and other metallic materials to be used as a coating material in the TDC process.

4. Ordering Information

4.1 Orders for coatings provided under this specification shall include the following:

4.1.1 Quantity (number of pieces to be coated) and total weight.

4.1.2 Description (type and size of products) and weight.

4.1.3 ASTM specification designation and year of issue.

4.1.4 Material identification (see 5.1) and surface condition or contamination.

4.1.5 Sampling plan, if different from Section 8.

4.1.6 Special test requirements, if different from Section 9 (see 9.1).

4.1.7 Special requirements (special stacking, heavier coating weight, etc.).

4.1.8 Tagging or piece identification method.

4.2 *Additional Information*—Additional information may be required in certain circumstances. In these cases the purchaser will furnish the applicator with the following additional information:

4.2.1 Any likely effects on the metallurgical properties of the base material caused by processing temperatures of up to 1092°F [500°C].

4.2.2 Determination of areas considered as significant surfaces. This should be done by drawings or by providing samples with suitable markings.

4.2.3 Any critical thickness tolerances, such as when bolts and nuts are used. This should be done on the product's drawing or on the purchase order.

4.2.4 Any special pre-treatment requirements or the existence of other materials, lubricants, stripping materials, pre-existing corrosion, etc.

4.2.5 Whether quality certificate is required or not.

5. Materials and Manufacture

5.1 Requirements to design of the products to be coated with zinc are detailed in Practice A 385. The following provisions are necessary to produce a high quality coating.

5.1.1 The products to be coated with zinc include parts and assemblies of various sizes: presswork, forged, cast, machined products (nuts, washers, bolts, nails, chains, small round billets, blanks for plumbing fixtures, etc.). When coating is applied to long-length parts (pipes, rods), the appropriate production equipment is required.

5.1.2 The products shall have neither pockets nor closed cavities. All cavities shall be available for applying the coating of diffusion mixture. Should it be impossible to apply the coating to individual portions of surface of the article, the documents shall specify if the coating is allowed to be absent in these cavities.

5.1.3 The fasteners to be coated with zinc shall meet the requirements of standards in force, for the fasteners, and accompanied with certificates from manufacturers.

5.1.4 The products (parts) containing soft solder or resins can not be coated with zinc.

5.1.5 *For Fasteners*—The maximum deviations of threads prior to application of the coating shall comply with the standards for threads. An additional gap for the coating for external and internal threads separately or for both threads at the same time, is to be provided, if the coating with increased thickness is to be applied. Requirements for fasteners to be thermal diffusion coated with zinc are found in Specifications F 2329 and F 2674.

5.2 Requirements for material and surface of substrate:

5.2.1 This is applied to products of standard-quality carbon steel, high-quality structural carbon and low-carbon steel, as well as low-alloyed steel, stainless steels, pig iron and copper.

5.2.2 The following defects are not allowed on the surfaces of the parts:

5.2.2.1 Rolled-in scale, burrs;

5.2.2.2 Separation into layers and cracks including those arising from pickling, polishing and other treatment;

5.2.2.3 Corrosion damages, pores, and holes.

5.2.3 The surfaces of cast and forged products shall be free of blow and shrink holes, slag, and flux contamination.

5.2.4 The surfaces of the parts of hot-rolled metal shall be cleaned from scale, pickling sludge, products of corrosion of the base metal, and other contamination.

5.2.5 After machining, the surfaces of the parts shall be free of visible layer of grease, emulsion, metallic chips, burrs, dust and products of corrosion, and implantation of foreign metal particles.

5.2.6 Sharp corners and edges of the products except for those required for technological reasons shall be machined to a radius of at least 0.001 in. [0.3 mm].

5.2.7 After heat treatment, the surfaces of the parts shall be free of blow holes, corrosion centers, separation into layers, and buckling.

5.2.8 Welds, soldered and brazed joints on the parts shall be scraped bright and continuous over the whole perimeter.

5.2.9 Prior to applying the coating, the surface of the part shall be degreased (chemically or thermally), cleaned by pickling or abrasive blasting.

5.2.10 The degree of cleanness of the surface shall be in accordance with Practice D 6386.

5.2.11 The term for storage of the parts with the surface prepared for coating with zinc shall not exceed 24 hours under conditions excluding the precipitation of a condensate.

5.2.12 For applying coatings, the zinc powder with humidity of not more than 1.5 % in accordance with Test Methods D 521 shall be used.

6. Chemical Composition

6.1 The method described results in the formation of iron-zinc compound layers known as Gamma (Solid Zn ions inside Fe substrate), Delta ($Fe_{11}Zn_{40}$), and Zeta ($FeZn_7$), excluding the external Eta layer of pure free zinc.

6.2 The zinc mixture used in the thermo-diffusion coating process shall contain a mass fraction not less than 94 % of metallic zinc and total impurities (other than Zinc oxide) of not more than 2 % mass fraction.

6.3 It should be noted that there is evidence this coating is subject to premature red staining in atmospheric and accelerated test environments; however, this staining has been found not to be associated with corrosion of the substrate steel, but rather superficial oxidation of the zinc/iron ions present on the surface.

7. Workmanship, Finish and Appearance

7.1 Appearance of the coating:

7.1.1 The coating shall be flat gray, smooth, and reasonably uniform. Smoothness of surface is a relative term. Minor roughness that does not interfere with the intended use of the part, or roughness that is related to the as-received (un-coated) surface condition of the part, shall not be grounds for rejection.

7.1.2 The coating shall be free of swellings, blow holes, cuts, flaking, and embedded quartz sand.

7.1.3 The presence of dark gray spots (variation in the color of the coating without variation in its thickness) not more than 5 % of the total surface of the product is allowed on the coating.

7.1.4 The presence of surface scratches, marks from contact of the part with one another, contact with measuring tools, etc., without damage to the coating, which would cause exposure of the base metal, is allowed.

7.1.5 The presence of residual process mixture on the surface of the part is not allowed.

7.1.6 The thickness of the coating depending on the conditions of operations of the product shall be specified in the standards of specification for the product in accordance with Table 1.

8. Sampling

8.1 Test specimens shall be selected randomly from each inspection lot.

8.2 The method of selection and sample size shall be agreed upon between the applicator and the purchaser. Otherwise, the sample size selected from each lot shall be as follows:

Batch Size (Pieces)	Sample Size
1 to 3	All
4 to 500	3
501 to 1200	5
1201 to 3200	8
3201 to 10 000	13
Above 10 000	20

9. Number of Tests and Retests

9.1 The zinc coating applied shall be tested for appearance and thickness.

9.2 Each lot of parts coated with zinc shall be presented for testing. A lot shall be considered as a group of articles of the same type and size coated with zinc within the same production cycle.

9.3 Approximately 10 % of articles per lot and each article in case of single-unit production shall be examined for appearance.

9.4 At least three articles per lot shall be tested for thickness of the coating.

9.5 When using the metallographic (arbitration) method, it is allowed to test the coating thickness on one part per lot.

9.6 The coating thickness shall be tested prior to the additional treatment of the coating (applying preservation lubricants, etc.). This measurement shall be taken on a non-threaded section of the part.

9.7 The coating thickness on the threaded portion of a bolt shall not be tested but shall be ensured by the correctness of the coating application technology. When developing the coating process it is recommended to take into account the ISO requirements for threaded fasteners.

9.8 The checked thickness of the coating shall be accepted as an arithmetical mean of the measured values.

9.9 Should the results of the measuring of the test control be unsatisfactory, the test shall be repeated on double quantity of parts.

10. Specimen Preparation

10.1 Specimens for testing should not go through any cleaning process and should be tested as is after the final coating process (including passivation and or other top coats).

11. Test Methods

11.1 Coating appearance check: The coating appearance shall be checked visually with an unaided eye from the distance of 10 in. [25 cm] from the surface. The luminance shall be at least 300Lx.

11.2 Coating thickness testing:

11.2.1 *Magnetic Method*:

11.2.1.1 The method is based on the registration of variation in the magnetic resistance depending on the coating thickness

TABLE 1 Thickness or Weight [Mass] of Zinc Coating for Various Coating Classes

Coating Class	Weight [Mass] of Coating, oz/ft^2(g/m^2) of Surface, Minimum	Coating Thickness, mils (μm), Minimum
130	3.02 (922)	5.14 (130)
110	2.50 (765)	4.33 (110)
90	2.05 (627)	3.54 (90)
80	1.82 (557)	3.15 (80)
70	1.59 (487)	2.76 (70)
65	1.48 (453)	2.56 (65)
55	1.25 (383)	2.17 (55)
50	1.14 (348)	1.97 (50)
45	1.02 (313)	1.77 (45)
40	0.91 (278)	1.57 (40)
25	0.57 (174)	0.98 (25)
12	0.27 (84)	0.47 (12)

in accordance with Practice E 376. The magnetic thickness gauges shall be used as measuring instruments.

11.2.1.2 The arithmetic mean of at least three measured values at edges and center of the surface of one article to be controlled shall be considered as the result of the coating thickness measurement.

11.2.2 *Metallographic Method (Arbitration)*—The method is based on the measurement of the coating thickness on the cross-section metallographic specimen using metallographic microscopes of various types in accordance with Test Method B 487. The specimen shall be cut from a coated article. The thickness of the zinc coating shall be measured on the specimen at least at five point located at equal distances within a linear area with the length of about 0.4 in. [1 cm]. The arithmetic mean of all measured values shall be considered as the result.

11.2.3 *Gravimetric Method*—The gravimetric method shall be used for determining the mean thickness of the coating. The method consists of weighing the representative specimens before and after applying the coating and then before and removing the coating in accordance with Test Method A 90/A 90M.

12. Certification

12.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each inspection lot have been either tested or inspected as directed by this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Packaging and Package Marking

13.1 Unless specified otherwise by the customer in the purchase order, the coated products shall be packaged, transported and stored in accordance with Practices A 700.

14. Keywords

14.1 coatings, zinc; fasteners, zinc coated; iron products, zinc coated; steel hardware, zinc coated; steel products, metallic coated; zinc coatings, steel products

APPENDIX

(Nonmandatory Information)

X1. COATING CHARACTERISTICS

X1.1 The thermo diffusion zinc coating is anodic in relation to ferrous metals and provides for electrochemical protection of steel against corrosion.

X1.2 Thermo diffusion results in a hard surface, usually exceeding 35 Rockwell C, depending on coating parameters.

X1.3 Thermo diffusion does not create hydrogen embrittlement

X1.4 Due to some porosity on the surface of the coating, thermo diffusion coated parts have excellent bonding characteristics with various topcoats and paint system.

X1.5 The thermo-diffusion zinc coating is obtained by heating the parts in a container with the diffusion mixture consisting of zinc powder and some alloying elements. The working temperatures of applying the coating normally range between 710°F to 1092°F [320°C to 500°C].

X1.6 Since the coating application process has a sufficiently long duration, the thermo diffusion coating with zinc can be used for parts made of materials that do not change their properties at these temperatures.

X1.7 The coating obtained shall follow exactly the contours of the article, its thickness shall be very uniform over the whole surface of the part including complex-shaped articles (threaded connections, etc.).

X1.8 When applying the coating, the part shall be placed in a container. Since the size of the parts is restricted by the size of the container, the appropriate size container must be used.

X1.9 The coating has strong adhesion to base metal due to mutual diffusion of zinc and iron. Zinc penetrates the base metal to about ⅓ of the coating thickness.

X1.10 The coating consists mainly of the iron-zinc δ1-phase containing 4 to 10 % of iron.

X1.11 Due to the presence of iron in the coating, red stains or brown spots may appear on the surface of the coated article under the influence of increased humidity or condensate. It is caused by the release of iron ions from the coating. These ions are washed away easily by water

X1.12 Should it be impossible to distinguish the corrosion products of the coating and that of base metal, the presence of the coating shall be checked by metallographic method and mass loss testing.