Designation: F3393 – 20

Standard Specification for Zinc-Flake Coating Systems for Fasteners[1]

This standard is issued under the fixed designation F3393; 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 Zinc-flake coating systems are fluid dispersions of zinc-flakes, sometimes with the addition of aluminum flakes, which are non-electrolytically applied to steel substrates. The zinc-flake coating system shall be supplied without hexavalent chromium and can be water based or solvent based systems. Cohesion among the zinc-flakes and adhesion to the steel substrate is achieved through a matrix that is formed during the curing process.

1.2 This specification covers the classification, performance, and basic requirements for non-electrolytically applied zinc-flake coatings on unified inch and metric series threaded fasteners with minimum nominal diameters of 0.250 in. for inch series and 6 mm for metric.

1.3 This standard is a consolidation and replacement of three ASTM standards: Specifications F1136/F1136M, F2833, and F3019/F3019M.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus

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

B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

D610 Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

D3359 Test Methods for Rating Adhesion by Tape Test

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

F788 Specification for Surface Discontinuities of Bolts, Screws, Studs, and Rivets, Inch and Metric Series

F1136/F1136M Specification for Zinc/Aluminum Corrosion Protective Coatings for Fasteners

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

F1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

F1789 Terminology for F16 Mechanical Fasteners

F1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners

F2833 Specification for Corrosion Protective Fastener Coatings with Zinc Rich Base Coat and Aluminum Organic/Inorganic Type

F3019/F3019M Specification for Chromium Free Zinc-Flake Composite, with or without Integral Lubricant, Corrosion Protective Coatings for Fasteners

[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.

F3125/F3125M Specification for High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 ksi and 150 ksi Minimum Tensile Strength, and Metric Dimensions 830 MPa and 1040 MPa Minimum Tensile Strength

2.2 *ASME Standards:*[3]

B1.1 Unified Inch Screws Threads (UN and UNR Thread Form)

B1.2 Gages and Gaging for Unified Inch Screw Threads

B18.18 Quality Assurance for Fasteners

2.3 *ISO Standards:*[4]

ISO 965-1 ISO General Purpose Metric Screw Threads – Tolerances – Part 1: Principles and Basic Data

ISO 965-2 ISO General Purpose Metric Screw Threads – Tolerances – Part 2: Limits of Sizes for General Purpose External and Internal Screw Threads

ISO 965-3 ISO General Purpose Metric Screw Threads – Tolerances – Part 3: Deviations for Constructional Screw Threads

ISO 1502 ISO General Purpose Metric Screw Threads – Gauges and gauging

ISO 9227 Corrosion Tests in Artificial Atmospheres – Salt Spray Tests

ISO 10683 Fasteners – Non-electrolytically applied zinc flake coatings

ISO 16047 Fasteners – Torque/clamp force testing

3. Classification

3.1 *Corrosion Resistance, Minimum Coating Thickness, or Minimum Coating Weight*—Zinc-flake coating systems shall meet the minimum corrosion resistance, coating thickness, or coating weight specified in Table 1.

3.2 *Appearance*—Zinc-flake coating systems shall be present on the part(s) and have an appearance as specified in Table 2.

3.3 *Average Total Coefficient of Friction*—Zinc-Flake coating systems shall have an average total coefficient of friction range as specified in Table 3.

3.4 *Zinc-Flake Coating Systems*—Zinc-flake coating systems (base coat only, base coat(s) plus topcoat(s), including coating thickness or coating weight shall be specified and/or agreed upon at the time of the order.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

TABLE 2 Appearance

Classification Code	Appearance
1	Silver / Gray
2	Black
3	Other Colors (As Agreed Upon)

TABLE 3 Average Coefficient of Total Friction Range and Test Program

Classification Code	Average Coefficient of Total Friction (μ_{tot})[A]
M	0.09 (±) 0.03
N	0.12 (±) 0.03
R	0.15 (±) 0.04
S	0.19 (±) 0.05
T	0.26 (±) 0.06
W	As Agreed Upon

[A] The results for all tested samples must lie within the permissible range

3.4.1 Zinc-flake coating systems typically include a topcoat; however, when it is agreed upon, they can be supplied without a topcoat. The addition of a topcoat, either organic or inorganic, can provide additional performance enhancing characteristics such as corrosion resistance, colored appearance, integral lubricant for friction control, chemical resistance, abrasion resistance, and/or UV resistance. In addition, some zinc-flake coating systems may contain integral lubricants that can modify the average total coefficient of friction.

3.4.2 Zinc-flake coating systems can be applied via the dip-spin, dip-drain, rack dip-spin, or spray methods. Special application techniques may be necessary to avoid excessive or insufficient coating thickness and/or part sticking. For guidance in determining the dimensional accommodations of zinc-flake coating systems in the pitch, major, and/or minor diameter refer to ASME B1.1 Section 7 and ISO 965.

NOTE 1—The dip-spin, dip-drain, rack dip-spin, or spray application of zinc-flake coating systems may lead to non-uniform local coating thickness that typically does not impair thread fit.

3.4.3 Zinc-flake coating systems may require a peak metal temperature up to 671 °F (355 °C) for proper curing conditions of the coating; however the curing temperature shall not exceed the tempering temperature of quenched and tempered fasteners. The curing temperature shall not negatively alter the mechanical and/or physical properties of the coated part(s).

3.4.4 Bulk handling processes, which can include secondary operations such as automatic feeding, sorting, transportation, and storage can lead to reductions in corrosion protection depending upon the coating system and geometry of the coated part. This may also occur when topcoats that are sensitive to

TABLE 1 Minimum Corrosion Resistance, Minimum Coating Thickness, or Minimum Coating Weight

Classification Code	Minimum Corrosion Resistance	Minimum Coating Thickness	Minimum Coating Weight
A	240h	0.00016 in. - 4µm	0.0430oz/ft2 – 13g/m2
B	480h	000020 in. - 5µm	0.0524oz/ft2 – 16g/m^2
C	600h	0.00025 in. - 6µm	0.0688oz/ft^2 – 21g/m^2
D	720h	0.00030 in. - 8µm	0.0754oz/ft^2 – 23g/m^2
E	960h	0.00050 in. - 12µm	0.0800oz/ft^2 – 24g/m^2
F	1200h	0.00060 in. - 15µm	0.1180oz/ft^2 – 36g/m^2
G	As Agreed Upon	As Agreed Upon	As Agreed Upon

impact damage or abrasion are applied. During storage and before installation, contact with liquids, condensation, dust, or any other detrimental conditions to the coating system should be avoided. When necessary, an agreement should be reached between the purchaser and the applicator/supplier to reduce the minimum corrosion resistance requirement or increase the minimum coating thickness or minimum coating weight described in Table 1.

4. Surface Preparation

4.1 Surface cleaning may consist of vapor, thermal, alkaline, or other degreasing methods for the removal of organic soils. When used, thermal degreasing temperatures shall not negatively alter or affect the mechanical or physical properties of the part(s). Other surface preparation methods may consist of mechanical cleaning (i.e. shot blasting) or chemical cleaning (that is, phosphating) methods for removal of inorganic soils or scale. Chemical cleaning, such as acid pickling, which has a potential for hydrogen adsorption thus increasing the risk of internal hydrogen embrittlement, shall contain suitable inhibitor(s) and minimal cleaning cycle times.

NOTE 2—While non-electrolytically applied zinc-flake coating systems do not generate hydrogen during the coating process, surface preparation processes which incorporate the use of acid cleaners (that is, acid pickling) can cause hydrogen adsorption.

4.2 Any chemical cleaning process that has a potential for hydrogen adsorption shall not be used for fasteners or related products with a hardness greater than 39 HRC (385 HV). When specified in the purchase order, the applicator shall certify that the process has not exposed the parts to acid during the cleaning and/or coating processes.

5. Ordering Information

5.1 Orders for materials in accordance with this specification shall include the following information (where applicable):

5.1.1 Quantity and description of parts, according to a standard or a drawing.

5.1.2 Minimum Corrosion Resistance, Minimum Coating Thickness, or Minimum Coating Weight (see Table 1).

5.1.3 Appearance (see Table 2).

5.1.4 Average Coefficient of Total Friction Range and Test Program (see Table 3 and 6.6)

5.1.5 Acceptable or preferred surface preparation method (see Section 4).

5.1.6 Any processing restrictions (where applicable).

5.1.7 Part Sampling Plans, Inspection Plans, Testing (including any special testing), and Test Reports shall be as agreed upon between the purchaser and the applicator/supplier prior to processing.

5.1.8 Any additions or modifications to this specification shall be agreed upon between the purchaser and the applicator/supplier.

6. Coating System Requirements

6.1 *Corrosion Resistance*—The coating system shall be capable of withstanding exposure to salt spray for the minimum hours specified in Table 1.

6.2 *Cathodic Protection*—The coating shall not exhibit red corrosion after exposure to neutral salt spray testing for a minimum of 72 h when scratched to the base metal with a sharp cutting tool having a nominal width of 0.02 ± 0.005 in. (0.5 ± 0.13 mm).

6.3 *Coating Appearance*—When viewed without magnification, the coating shall have a uniform appearance and be free from uncoated areas, discontinuities, and excess coating which affects fit, form, or part function.

6.4 *Adhesion*—When an adhesive tape with 25 mm width and minimum adhesive strength of 6 N is firmly pressed by hand on to the surface and is subsequently pulled off rapidly and perpendicularly to the surface, the coating shall not be peeled off the base metal. Small amounts of the coating left sticking to the tape are acceptable.

6.5 *Coating Thickness / Coating Weight*—The coating thickness or coating weight shall meet the minimum thickness or coating weight specified in Table 1. Unless otherwise defined, the minimum local thickness measurements shall be taken on the reference areas indicated in Fig. 1 and/or significant surfaces as defined by Terminology F1789.

6.6 *Average Coefficient of Total Friction*—The agreed upon coating system shall meet the applicable average coefficient of total friction in Table 3, or as agreed upon between the purchaser and the applicator/supplier.

7. Test Methods

7.1 *Adhesion*—Adhesion of the coating shall be tested in accordance with Test Methods D3359 Test Method A (with an X-Cut) and visually rated to classify the adhesion result.

7.2 *Corrosion Resistance Testing*—The coating system shall be tested in accordance with Practice B117 or ISO 9227 and be capable of withstanding exposure to salt spray testing for the minimum hours specified in Table 1. Unless otherwise agreed upon, red corrosion visible to the unaided eye shall have a rating of Grade 6 or higher per Practice D610 on significant surfaces (see Terminology F1789 for definition) at the conclusion of the specified exposure period. The corrosion resistance test shall be conducted on the part(s) a minimum of 24 h after application of the coating system. The test shall be performed

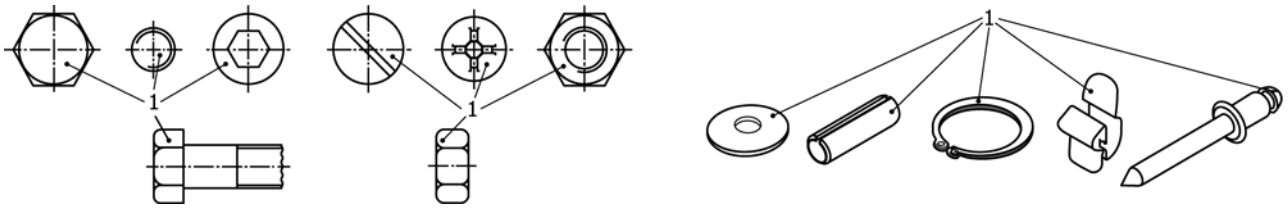

FIG. 1 Reference Areas for Coating Thickness Measurement

on parts in the "as-coated" condition and prior to any subsequent processes including, but not limited to, sorting, packaging, and assembly.

NOTE 3—The duration and results of artificial corrosion resistance, such as neutral salt spray (fog) test environments, may have little correlation to the service life in which the actual coated article will be used. The duration and results of artificial corrosion resistance should not be used as a direct guide for predicting the service life of the actual coated article unless a direct correlation has been established.

7.3 *Coating Thickness*—Coating thickness shall be tested in accordance with Test Method B499 magnetic induction (see Note 4), Practice E376 eddy current; or Test Method B568 X-Ray Spectrometry (see Note 5). For referee purposes, microscopic examination in accordance with Test Method B487 shall be used.

NOTE 4—Coating thickness test results determined by magnetic induction may be influenced if the parts have undergone magnetic particle inspection.

NOTE 5—Coating thickness test results measured by X-Ray spectrometry are limited to the thickness of the zinc-flake base coat only. The thickness of the topcoat layer is not measured by X-Ray spectrometry. In addition, coating thickness results determined by X-Ray spectrometry may be influenced if the parts have been processed with a pretreatment containing zinc.

7.4 *Coating Weight*—the coated parts shall be weighed and the coating shall be chemically or mechanically removed. Once the coating is removed down to the base metal, the parts shall be re-weighed and the weight difference calculated. The weight difference shall be divided by the surface area of the stripped parts and the resulting calculation is the coating weight of the coating system.

NOTE 6—Coating deposition may be established by methods described in 7.3 or 7.4.

7.5 *Hydrogen Embrittlement*—When specified in the purchase order, or as agreed upon between the purchaser and the applicator/supplier, testing shall be conducted in accordance with Test Methods F606/F606M or F1940. In the event that hardness reductions occur in test specimens due to coating curing times and temperatures, testing shall be conducted alternatively in accordance with Test Method F1624.

7.6 *Thread Acceptability*—The coating system shall not have an adverse effect on the normal installation and removal practices as determined by the proper GO thread gages.

7.6.1 Prior to application of the coating system, external threads may be produced undersized and internal threads may be produced oversized to accommodate additional coating thickness or coating weight provided the finished fastener after coating meets all specified mechanical requirements agreed upon in the purchase order.

7.6.2 Where mechanical properties are not specified, oversizing or undersizing of threads is subject to the approval of the purchaser.

NOTE 7—For reference, see Specification F788, Section 6.5.1.4 and ISO 10683 Annex A – Section A.2 for additional acceptance criteria that can be specified in the purchase or as agreed upon between the purchaser and applicator/supplier.

7.7 *Average Total Coefficient of Friction*—Testing shall be performed in accordance to ISO 16047 or as agreed upon between the purchaser and the applicator/supplier and as specified in the purchase order. The results of testing shall be kept on file and submitted to the purchaser when required. Test Program A or B shall be agreed upon at the time of the order.

NOTE 8—If unspecified and requested in the purchase order, the default test materials should be the corresponding mating nuts or bolts for the parts to be tested. The mating nuts or bolts and washers are plain steel, uncoated and degreased in accordance to ISO 16047, Sections 7.2, 7.3 or 7.4.

7.7.1 *Test Program A*—When permissible, testing shall be performed using M10-1.5 surrogate test bolts processed with the production parts. With this test program, it is recommended that friction testing be performed at a frequency which demonstrates control of the applicator's coating process.

7.7.2 *Test Program B*—The use of surrogate bolts is not permitted in this test program. Samples for friction testing are selected from the production lots which have been coated.

NOTE 9—Test hardware, fixturing specific to the part, and capable instrumentation will be required to conduct testing per Program B. These required materials may not be readily available at all test facilities or coating applicators. When necessary, a facility with the capability to perform the test may be designated as agreed upon.

8. Sample Inspection and Testing Reports

8.1 Samples for inspection may be taken in accordance with Practice F1470, ASME B18.18, or as agreed upon between the purchaser and the applicator/supplier.

8.2 The party responsible for providing a test report for the coated fastener shall be the organization that supplies the coated article(s) or coated fastener assembly to the purchaser.

8.3 Test reports may include, but are not limited to, the test methods described in Section 7. Reports shall be made available upon request after the coating process as agreed upon between the purchaser and the applicator/supplier at the time of the order (see 5.1.7).

9. Disposition of Non-Conforming Lots

9.1 The disposition of non-conforming lots shall be in accordance with Guide F1470 Section titled "Disposition of Non-Conforming Lots".

10. Keywords

10.1 coating; corrosion; dip-drain; dip-spin; embrittlement; fasteners; flake; friction; non-electrolytically; protection; resistance; rust; spray; topcoat; zinc