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Standard Specification for Chromium Free Zinc-Flake Composite, with or without Integral Lubricant, Corrosion Protective Coatings for Fasteners[1]

This standard is issued under the fixed designation F3019/F3019M; 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 basic requirements for non-electrolytically applied zinc-flake composite corrosion protective coating systems for fasteners (See Note 1).

NOTE 1—The coating systems do not contain hexavalent chromium, lead, cadmium, or mercury.

1.2 This specification is intended for corrosion protection of inch and metric series threaded fasteners with minimum nominal diameters of 0.250 in. for inch series and [6.00 mm] for metric as well as for non-threaded fasteners such as washers and pins.

1.3 This coating system may be specified to consist of a zinc-flake basecoat, or a zinc-flake basecoat and topcoat (See Note 2).

NOTE 2—For threaded fasteners, the coating system will typically consist of a zinc-flake basecoat and topcoat.

1.3.1 The basecoat is a zinc-rich material containing aluminum flakes dispersed in a compatible liquid medium. The zinc-flake basecoat may be specified to contain integral lubricant.

1.3.2 Topcoats may be organic or inorganic in composition depending upon the specified requirements.

1.3.2.1 Organic topcoats consist of polymer resins, aluminum, dispersed pigments, and are colored in their applied state.

1.3.2.2 Inorganic topcoats consist of water-dispersed silicate compounds and are transparent in their applied state.

1.3.2.3 Topcoats contain integral lubricants and are applied in conjunction with zinc-flake basecoats to form a coating system with enhanced performance attributes such as increased corrosion resistance, total coefficient of friction properties, chemical resistance, and color.

1.4 These zinc-flake basecoats and topcoats are applied by conventional dip-spin, dip-drain, or spray methods to fasteners which can be handled through a cleaning, coating, and curing operation. The maximum curing temperature is 482°F [250°C].

1.5 The friction properties of the coating system may be determined by a standard test to verify process control or by a part specific test which requires the purchaser to establish and communicate technical criteria.

1.6 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.

1.7 *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]

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 Measuring Adhesion by Tape Test

E376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

[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.

F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric)
F788 Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
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

2.2 *International Organization for Standardization (ISO)*[3]
ISO 16047 Fasteners – Torque/clamp force testing

3. Classification

3.1 The coating systems are classified into four (4) grades according to the requirements provided in Table 1. The process application parameters and cure temperatures shall be in accordance to the recommendations of the coating system manufacturer.

3.1.1 *Grade 1*—requires application of the zinc-flake basecoat only. No topcoat is applied in Grade 1. Appearance of the coating in the applied state is silver/grey.

3.1.2 *Grade 2*—requires application of the zinc-flake basecoat containing integral lubricant for friction modification. No topcoat is applied in Grade 2. Appearance of the coating in the applied state is silver/grey.

3.1.3 *Grade 3*—requires application of the zinc-flake basecoat and organic topcoat. The organic topcoat contains integral lubricant for friction modification. Options for coating color and average total coefficient of friction (μ_{tot}) are provided in Table 1.

3.1.4 *Grade 4*—requires application of the zinc-flake basecoat and inorganic topcoat. The inorganic topcoat contains integral lubricant for friction modification. Appearance of the coating in the applied state is silver/grey. Options for average total coefficient of friction (μ_{tot}) are provided in Table 1.

3.2 Regardless of the process or materials used, the zinc-flake basecoat and organic/inorganic topcoats shall conform to all of the applicable requirements of this specification.

4. Ordering Information

4.1 Orders for materials in accordance with this specification shall include the following information:
4.1.1 Quantity of parts,
4.1.2 Grade of coating (See Table 1),
4.1.3 For Grade 3, color code of the coating,
4.1.4 For Grades 3 and 4, friction code of the coating when applicable,
4.1.5 Corrosion resistance requirement expressed in test duration hours,
4.1.6 Maximum coating thickness, if applicable,
4.1.7 Acid free processing certification, if applicable,
4.1.8 Part sampling plan,
4.1.9 Certification and test report requirements, and
4.1.10 Any additions to the specification as agreed upon by the purchaser and the supplier.

5. Requirements

5.1 *Appearance*—When viewed without magnification, the coating shall have a uniform appearance and be free from uncoated areas and discontinuities which affect part function such as excess coating.

5.2 *Adhesion*—The coating shall show only trace peeling or removal along incisions or at their intersection, acceptance criteria 4A per Test Method D3359, following the X-Cut tape adhesion test (See Note 3).

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

TABLE 1 Coating System Classification

Grade	Coating System		Color Code	Finished Appearance	Friction Code	Average Total Coefficient of Friction (μ_{tot})[A]
	Basecoat	Topcoat				
1	Zinc-Flake	None	...	Silver / Grey	...	...
2	Zinc-Flake w/Integral Lubricant	None	...	Silver / Grey	...	0.14±0.03
3	Zinc-Flake	Organic	B	Black	L2	0.14±0.03
					L3	0.17±0.03
			D	Dark Blue	...	0.17±0.03
			G	Green	...	0.17±0.03
			K	Light Blue	...	0.17±0.03
			R	Red	...	0.17±0.03
			S	Silver	L2	0.14±0.03
					L3	0.17±0.03
			Y	Yellow	...	0.17±0.03
4	Zinc-Flake	Inorganic	...	Silver / Grey	L1	0.11±0.02
					L2	0.14±0.03
					L3	0.17±0.03

[A] The average result of the Total Coefficient of Friction (μ_{tot}) as determined in accordance to ISO 16047 shall lie within these limits when tested per 6.5.1 Program A. Friction values are applicable to a minimum sample set of ten tested fasteners.

NOTE 3—Due to the nature of the coating, some removal upon testing is expected, but removal of the coating to expose the substrate is an indicator of poor coating adhesion.

5.3 *Corrosion Resistance*—Corrosion resistance is related to the applied coating thickness of these coating systems.

5.3.1 The coating system shall withstand neutral salt spray testing for the minimum time specified in Table 2 (See Note 4). Unless otherwise defined, acceptable corrosion resistance shall be considered to be met where there is no red corrosion of the base metal on significant surfaces (See Terminology F1789 for definition).

NOTE 4—Bulk handling, transportation, and automatic sorting processes may lead to a reduction in the corrosion protection of the coating system. Depending upon the fastener, it may be necessary to reduce the corrosion test duration or increase the minimum applied coating thickness.

5.4 *Blisters*—There shall be no visible presence of blisters after testing in accordance with 6.2.

5.5 *Thread Fit*—The coating shall not have an adverse effect on normal installation and removal practices, as determined by the appropriate basic size "GO" thread gage or fit and function inspection method. For external threaded fasteners after coating, the torque applied to the "GO" screw ring gauge shall not exceed $145d^3$ inch-pounds for inch series or $0.001d^3$ Nm for metric series, where d is the nominal thread diameter.

5.5.1 The maximum thickness of the coating which may be applied to threads on threaded fasteners is limited by the basic thread size: for external threaded fasteners, 3A tolerance for inch or tolerance h (6h or 4h) for metric series, and for internal threaded fasteners, 2B tolerance for inch or tolerance H (6H, 5H, or 4H) for metric series. Prior to the application of the coating system, external threads may be produced undersized and internal threads may be produced oversized to accommodate the coating thickness, provided the finished fastener after coating meets all specified mechanical requirements.

5.5.2 For external threaded fasteners which are not permitted to be produced undersized due to specified requirements, the maximum thickness of the coating which may be applied is limited by the basic thread size: 3A tolerance for inch and 6h tolerance for metric series. In these cases, the maximum coating thickness which may be applied shall be established prior to coating in consultation with the applicator.

5.5.3 For internal threaded fasteners which are not permitted to be produced oversized due to specified requirements, the maximum thickness of the coating which may be applied is limited by the basic thread size: 2B tolerance for inch and 6H tolerance for metric series. In these cases, the maximum coating thickness which may be applied shall be established prior to coating in consultation with the applicator.

TABLE 2 Neutral Salt Spray Test Requirements

Test Duration to First Appearance of Red Corrosion	Minimum Average Coating Thickness of the Applied Coating System[A]	
Hours	Inch	[Metric]
240	0.157 mils	[4 µm]
480	0.197 mils	[5 µm]
600	0.236 mils	[6 µm]
720	0.315 mils	[8 µm]
960	0.394 mils	[10 µm]

[A] The coating thickness is applicable to the complete coating system, basecoat and topcoat.

5.6 *Hydrogen Embrittlement*—When specified in the purchase order, the applicator shall certify that the process does not expose the parts to acid (See Note 5).

NOTE 5—Non-electrolytically applied zinc-flake coating systems do not generate hydrogen during the coating process. Pre-treatment processes which incorporate the use of acid cleaners (that is, acid pickling) may cause hydrogen adsorption.

5.7 *Total Coefficient of Friction*—Coating systems containing integral lubricant shall be demonstrated to meet the applicable average total coefficient of friction requirement specified in the purchase order.

6. Test Methods

6.1 *Adhesion*—Adhesion of the coating shall be tested in accordance with Test Method D3359 X-Cut Tape Test and visually rated to classify the adhesion result.

6.2 *Corrosion*—Corrosion resistance shall be tested in accordance with Practice B117 followed by Test Method D610 to rate the percentage of corrosion.

6.3 *Coating Thickness*—Coating thickness shall be tested in accordance with Test Method B499, magnetic induction (See Note 6); Practice E376, eddy current; or Test Method B568, X-ray spectrometry. For referee purposes, microscopic examination in accordance with Test Method B487 shall be used.

NOTE 6—Coating thickness test results determined by magnetic induction may be influenced if the parts have undergone magnetic particle inspections.

6.4 *Hydrogen Embrittlement*—When specified in the purchase order, 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 temperature, testing shall be conducted alternatively in accordance with F1624.

6.5 *Total Coefficient of Friction*—The test shall be performed in accordance to ISO 16047 as specified in the purchase order (See Note 7). The results of testing shall be kept on file and submitted to the purchaser when required.

NOTE 7—If unspecified in the purchase order, the default test materials are zinc electroplated washers and zinc electroplated nuts or bolts in accordance to ISO 16047 Sections 7.3 or 7.4.

6.5.1 *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 statistical control of the applicator's coating process.

6.5.2 *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 (See Note 8).

NOTE 8—Test hardware and 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.

7. Application

7.1 A conventional pre-treatment procedure using alkaline or solvent cleaner may be used, followed by shot blasting. Micro-crystalline zinc-phosphating with coating weight in the range of 2 – 6 g/m^2 may be applied as an alternate pre-treatment.

7.2 The coatings shall be non-electrolytically applied by conventional dip-spin, dip-drain, or spray methods.

7.3 The coatings shall be applied under suitable control conditions and in the stages necessary to meet the requirements of the specification. Unless otherwise specified, these coatings shall be applied after all machining, forming, and heat treatments have been completed, but prior to final inspection.

8. Inspection

8.1 When requested by the purchaser, samples shall be acquired in accordance with Practice F1470.

8.1.1 A coating lot shall consist of a quantity of fasteners with the same part number and lot number coated to the same specification and processed at the same time.

8.2 *Fit and Function Inspection*—The following fit and function thread inspection procedure may be used:

8.2.1 *Bolt or Screw*—External thread acceptance shall be determined using the thread acceptance test in Section 6 of Specification F788.

8.2.2 *Nut*—A 2B for inch series or 6H for metric "GO" thread plug gauge (without chip groove) must pass freely through coated nuts.

9. Rejection and Rehearing

9.1 Disposition of nonconforming lots shall be in accordance with Guide F1470 section titled "*Disposition of Nonconforming Lots*."

10. Certification Requirement

10.1 Product designations used in the coating system are to be reported to the purchasing organization, along with certification that the parts meet the requirements of this specification.

10.2 When applicable, test reports affirming acceptance are to be attached to the certification.

11. Keywords

11.1 basecoat; coating; corrosion; dip-drain; dip-spin; embrittlement; fasteners; flake; friction; inorganic; non-electrolytically; organic; protection; resistance; rust; spray; topcoat; zinc