



Designation: F1941M – 07

Standard Specification for Electrodeposited Coatings on Threaded Fasteners (Metric)¹

This standard is issued under the fixed designation F1941M; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

INTRODUCTION

This specification covers the coating of steel metric screw threaded fasteners by electrodeposition. The properties of the coatings shall conform to the ASTM standards for the individual finishes listed.

Coating thickness values are based on the tolerances for *M* series metric threads having the following tolerance positions: 6g and 4g6g for external threads, and 6H for internal threads. The coating must not cause the basic thread size to be transgressed by either the internal or external threads. The method of designating coated threads shall comply with ASME B1.13M.

With normal methods for depositing metallic coatings from aqueous solutions, there is a risk of delayed failure due to hydrogen embrittlement for case hardened fasteners and fasteners having a hardness 40 HRC or above. Although this risk can be managed by selecting raw materials suitable for the application of electrodeposited coatings and by using modern methods of surface treatment and post heat-treatment (baking), the risk of hydrogen embrittlement cannot be completely eliminated. Therefore, the application of a metallic coating by electrodeposition is not recommended for such fasteners.

1. Scope*

1.1 This specification covers application, performance and dimensional requirements for electrodeposited coatings on threaded fasteners with metric screw threads. It specifies coating thickness, supplementary hexavalent chromate or trivalent chromite finishes, corrosion resistance, precautions for managing the risk of hydrogen embrittlement and hydrogen embrittlement relief for high-strength and surface-hardened fasteners. It also highlights the differences between barrel and rack plating and makes recommendations as to the applicability of each process.

1.2 The following precautionary statement pertains to the test method portion only, Section 9, of this specification: *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.*

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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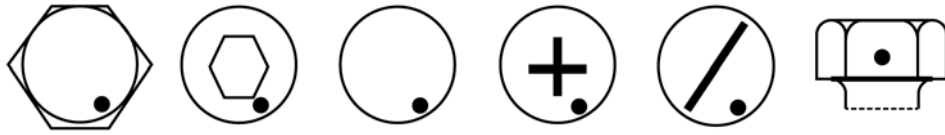
2. Referenced Documents

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
- B504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method
- B567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method
- B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
- B659 Guide for Measuring Thickness of Metallic and Inorganic Coatings
- D6492 Practice for Detection of Hexavalent Chromium On Zinc and Zinc/Aluminum Alloy Coated Steel
- E376 Practice for Measuring Coating Thickness by

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.

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



NOTE 1—Black dot (•) indicates test surface.

FIG. 1 Significant surfaces on Externally Threaded Fasteners



NOTE 1—Black dot (•) indicates test surface.

FIG. 2 Significant surfaces on Internally Threaded Fasteners

Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

F606 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

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

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

2.2 ASME Standard:³

B1.13M Metric Screw Threads - M Profile

2.3 National Aerospace Standard (AIA):⁴

NASM-1312-5 Fast Test Method - Method 5: Stress Durability

2.4 IFI Standard:⁵

IFI-142 Hydrogen Embrittlement Risk Management

3. Terminology

3.1 Definitions:

3.1.1 local thickness—mean of the thickness measurements, of which a specified number is made within a reference area.

3.1.2 minimum local thickness—lowest local thickness value on the significant surface of a single article.

3.1.3 reference area—area within which a specified number of single measurements are required to be made.

3.1.4 significant surface—significant surfaces are areas where the minimum thickness to be met shall be designated on the applicable drawing or by the provision of a suitably marked sample. However, if not designated, significant surfaces shall be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the fastener when assembled in normal position, or which can be the source of corrosion products that deface visible surfaces on the assembled fastener. Figs. 1 and 2 illustrate significant surfaces on standard externally threaded and internally threaded fasteners.

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

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

⁵ Available from Industrial Fasteners Institute (IFI), 1717 East 9th Street, Suite 1105, Cleveland, OH 44114-2879.

4. Classification

4.1 Coating Material—The coating material shall be selected and designated in accordance with Table 1.

4.2 Coating Thickness—The coating thickness shall be selected and designated in accordance with Table 2.

4.3 Chromate Finish—When not specified, the hexavalent or trivalent chromite finish shall be used at the option of the manufacturer and its appearance shall be selected in accordance with the designation selected in Table 3.

4.3.1 Trivalent Chromite Finish—Unless otherwise specified, the typical appearance of the trivalent chromite finish shall be transparent, colorless and shall not be subjected to requirements of the typical appearance as determined in Table 3. In addition, the classification code to be used shall be appended with the letter "T" (for example, Fe/Zn 5CT, as defined in Table A1.1).

5. Ordering Information for Electroplating

5.1 When ordering threaded fasteners to be coated by electrodeposition in accordance with this specification, the following information shall be supplied to the electroplater:

5.1.1 The desired coating, coating thickness, the chromate finish, the color and appearance (if applicable), or the classification codes as specified in Tables 1-3. (For example, Fe/Zn 5C denotes yellow zinc plated with a minimum thickness of 5 µm on significant surfaces.)

5.1.2 The identification of significant surfaces (optional).

5.1.3 The requirement, if any, for stress relief before electroplating, in which case the stress-relief conditions must be specified.

5.1.4 The requirements, if any, for hydrogen embrittlement relief by heat treatment (baking) stating the tensile strength or surface hardness of the fasteners and/or baking time and temperature.

TABLE 1 Designation of Common Coating Materials

Coating Designation	Coating Type
Fe/Zn	Zinc
Fe/Cd	Cadmium
Fe/Zn-Co	Zinc Cobalt Alloy
Fe/Zn-Ni	Zinc Nickel Alloy
Fe/Zn-Fe	Zinc Iron Alloy

TABLE 2 Designation of Coating Thickness

NOTE 1—The conversion factor from microns to inch is 3.94×10^{-5} (for example, $5 \mu\text{m} = 0.0002 \text{ in.}$).

Thickness Designation	Minimum Thickness μm
3	3
5	5
8	8
12	12

TABLE 3 Designation of Chromate Finish

NOTE 1—Coated fasteners with trivalent chromite (Cr^{+3}) are not subjected to the required blue-bright, yellow, opaque, and black color. See [Appendix X6](#).

NOTE 2—When fasteners are coated with trivalent chromite (Cr^{+3}), the classification code to be used shall be appended with the letter "T".

Designation	Type	Typical Appearance
A	Clear	Transparent colorless with slight iridescence
B	Blue-bright	Transparent with a bluish tinge and slight iridescence
C	Yellow	Yellow iridescent
D	Opaque	Olive green, shading to brown or bronze
E	Black	Black with slight iridescence
F	Organic	Any of the above plus organic topcoat

NOTE 1—Fasteners with a specified maximum hardness of 34 HRC and below have a very low susceptibility to hydrogen embrittlement and do not require baking.

5.1.5 The requirements, if any, for the type of electroplating process (barrel-plating or rack-plating). See [Section 10](#) and [Appendix X1](#).

5.1.6 The designation of coated thread class shall comply with ASME B1.13M.

6. Requirements

6.1 *Coating Requirements*—The electrodeposited coating as ordered shall cover all surfaces and shall meet the following requirements:

6.1.1 The coating metal deposit shall be bright or semi-bright unless otherwise specified by the purchaser, smooth, fine grained, adherent and uniform in appearance.

6.1.2 The coating shall be free of blisters, pits, nodules, roughness, cracks, unplated areas, and other defects that will affect the function of the coating.

6.1.3 The coating shall not be stained, discolored or exhibit any evidence of white or red corrosion products.

6.1.3.1 Slight discoloration that results from baking, drying, or electrode contact during rack-plating, or all of these, as well as slight staining that results from rinsing shall not be cause for rejection.

6.2 *Corrosion Resistance*—Coated fasteners, when tested by continuous exposure to neutral salt spray in accordance with [9.3](#), shall show neither corrosion products of coatings (white corrosion) nor basis metal corrosion products (red rust) at the end of the test period. The appearance of corrosion products visible to the unaided eye at normal reading distance shall be cause for rejection, except when present at the edges of the tested fasteners. Refer to [Annex A1](#) for neutral salt spray performance requirements for zinc, zinc alloy and cadmium coatings.

6.3 *Thickness*—The coating thickness shall comply with requirements of [Table 2](#) when measured in accordance with [9.1](#).

6.3.1 *Restrictions on Coating Thickness*—This specification imposes minimum local thickness requirements at significant surfaces in accordance with [Table 2](#). Thick or thin local thickness in a location other than a significant surface shall not be a cause for rejection. However the following restrictions apply:

6.3.1.1 Minimum coating thickness at low current density areas, such as the center of a bolt or recesses, must be sufficient to provide for adequate chromate adhesion.

6.3.1.2 *External Threads*—Maximum coating thickness at high current density threaded tips must provide for basic (tolerance position *h*) GO thread gauge acceptance. Therefore, the thread after coating is subject to acceptance using a class 6h GO gauge for plated 6g class external threads and 4h6h GO gauge for plated 4g6g class external threads respectively.

6.3.1.3 *Internal Threads*—Maximum coating thickness of internal threads must provide for basic (tolerance position *H*) Go thread gauge acceptance. Therefore, the thread after coating is subject to acceptance using a class 6H GO gauge for 6H class internal threads.

6.3.1.4 Surfaces such as threads, holes, deep recesses, bases of angles, and similar areas on which the specified thickness of deposit cannot readily be controlled, are exempted from minimum thickness requirements unless they are specially designated as not being exempted. When such areas are subject to minimum thickness requirements, the purchaser and the manufacturer shall recognize the necessity for either thicker deposits on other areas or special racking.

6.3.2 *Applicability to M Series Threads*:

6.3.2.1 The applicability of the required coating to *M* series metric threads is limited by the basic deviation of the threads, and hence limited by the pitch diameter, allowance, and tolerance positions. Refer to [Appendix X3](#) as a guideline for the tolerances of the various thread sizes and classes and the coating thickness they will accommodate.

6.3.2.2 Because of the inherent variability in coating thickness by the barrel-plating process, the application of a minimum coating thickness of $12 \mu\text{m}$ is not recommended for a standard screw thread by this method due to the fact that dimensional allowance of many metric threaded fasteners normally does not permit it. If the size of the fastener is large enough to economically use the rack-plating process, then the latter shall be used to obtain this thickness requirement. If heavier coatings are required, allowance for the deposit buildup must be made during the manufacture of fasteners.

6.3.3 *Applicability to Wood Screws and Thread Forming Screws*—Any classification code in [Table 2](#) may be applied to screws that cut or form their own threads.

6.4 *Hydrogen Embrittlement Relief*:

6.4.1 *Requirement for Baking*—Coated fasteners made from steel heat treated to a specified hardness of 40 HRC or above, case-hardened steel fasteners, and fasteners with captive washers made from hardened steel, shall be baked to minimize the risk of hydrogen embrittlement. Unless otherwise specified by

the purchaser, baking is not mandatory for fasteners with specified maximum hardness below 40 HRC.

NOTE 2—With proper care many steel fasteners can be plated without baking by correlating process conditions to the susceptibility of the fastener material to hydrogen embrittlement, and by applying adequate process control procedures, such as those outlined in X4.2. Test Method F1940 is a recognized verification method for process control to minimize the risk of hydrogen embrittlement. Upon agreement between the supplier and the purchaser, this test method can be used as a basis for determining if baking should be mandated in a controlled process environment.

6.4.2 *Baking Conditions*—At the time of publication of this specification it was not considered possible to give an exact baking duration. Eight hours is considered a typical example of baking duration. However, upon agreement between the purchaser and the manufacturer, baking times between 2 and 24 h at temperatures of 175 to 235°C (350 to 450°F) are suitable depending on the type and size of the fastener, geometry, mechanical properties, cleaning process and cathodic efficiency of the electroplating process used. The baking conditions shall be selected based on the results of recognized embrittlement test procedures such as Test Methods F1940, F1624, F606, or NASM-1312-5.

6.4.2.1 Bake time and temperatures may require lowering to minimize the risk of solid or liquid metal embrittlement resulting from alloy compositions such as those containing lead or from the lower melting point of cadmium 320°C (610°F) in comparison to zinc 419°C (786°F).

6.4.2.2 Fasteners must be baked within 4 h, preferably 1 h after electroplating. Baking to relieve hydrogen embrittlement must be performed prior to the application of the chromate finish because temperatures above 65°C (150°F) damage the chromate film thereby negating its performance.

6.4.3 *Hydrogen Embrittlement Testing*—Hydrogen embrittlement testing is mandatory for fasteners with a specified hardness of 40 HRC or above, unless the electroplating process has been qualified in accordance with Test Method F1940 (that is, the process has been shown not to cause embrittlement for a given product or class of product). This specification does not require mandatory testing of fasteners having a specified hardness below 40 HRC, unless otherwise specified by the purchaser.

6.5 *Trivalent Chromite Finish*—The use of hexavalent chromium is prohibited when processing coated fasteners to the requirement of 4.3.1. Coated fasteners shall be free of hexavalent chromium when tested in accordance with the test method defined in 9.4.

7. Dimensional Requirements

7.1 Threaded components, except those with spaced and forming threads, supplied for electrodeposited coating shall

comply with ASME B1.13M. Screw threads that are specifically manufactured to allow the application of 12 µm or greater coating thickness by the barrel-plating process, must adhere to a special allowance specified by the manufacturer or in ASME B1.13M. The other dimensional characteristics shall be as specified on the applicable standard or drawing. It should be noted that modifications to the threads of a fastener could affect its properties or performance, or both. Refer to Appendix X3 for further information on effects of coating on pitch diameter, allowances and tolerances for external and internal threads.

8. Sampling

8.1 Sampling for coating thickness, salt spray and embrittlement testing shall be conducted based on lot size in accordance with Guide F1470.

9. Test Methods

9.1 *Coating Thickness*—Unless otherwise specified, the requirement to measure coating thickness is applicable to significant surfaces only. The test methods for determining the coating thickness are defined in Test Methods B487, B499, B504, B567, B568, Guide B659 or Practice E376 as applicable.

9.2 *Embrittlement Test Method*—The embrittlement test method shall conform to those specified in Test Method F1940 for process verification, or Test Methods F606, F1624, or NASM-1312-5 for product testing.

9.3 *Corrosion Resistance*—The requirement to determine corrosion resistance is applicable to significant surfaces only. When specified in the contract or purchase order, salt spray testing shall be conducted in accordance with Practice B117. To secure uniformity of results, samples shall be aged at room temperature for 24 h before being subjected to the salt spray test.

9.4 *Trivalent Chromite Finish*—The presence of hexavalent chromium shall be determined in accordance with Practice D6492.

10. Electroplating Processes

10.1 Two electroplating processes are most commonly used to apply a metallic coating by electrodeposition on threaded fasteners: barrel-plating and rack-plating. When thread fit or thread integrity, or both, is a concern for externally threaded fasteners, rack-plating is preferable to barrel-plating. Refer to Appendix X1.

11. Keywords

11.1 chromate finish; electrodeposited coating; fasteners; hydrogen embrittlement relief; hydrogen embrittlement testing; surface treatment

ANNEX
(Mandatory Information)
A1. NEUTRAL SALT SPRAY PERFORMANCE
TABLE A1.1 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc and Cadmium Coatings

 NOTE 1—When fasteners are coated with trivalent chromite (Cr^{+3}), the classification code to be used shall be appended with the letter "T".

Classification Code	Minimum Coating Thickness (μm)	Chromate Finish Designation	First Appearance of White Corrosion Product, (hour)	First Appearance of Red Rust Cadmium, (hour)	First Appearance of Red Rust Zinc, (hour)
Fe/Zn or Fe/Cd 3A	3 ^A	A	3	24	12
Fe/Zn or Fe/Cd 3B		B	6	24	12
Fe/Zn or Fe/Cd 3C		C	24	36	24
Fe/Zn or Fe/Cd 3D		D	24	36	24
Fe/Zn or Fe/Cd 5A	5	A	6	48	24
Fe/Zn or Fe/Cd 5B		B	12	72	36
Fe/Zn or Fe/Cd 5C		C	48	120	72
Fe/Zn or Fe/Cd 5D		D	72	168	96
Fe/Zn or Fe/Cd 5E		E	12	72	
Fe/Zn or Fe/Cd 8A	8	A	6	96	48
Fe/Zn or Fe/Cd 8B		B	24	120	72
Fe/Zn or Fe/Cd 8C		C	72	168	120
Fe/Zn or Fe/Cd 8D		D	96	192	144
Fe/Zn or Fe/Cd 8E		E	24	120	72
Fe/Zn or Fe/Cd 12A	12	A	6	144	72
Fe/Zn or Fe/Cd 12B		B	24	192	96
Fe/Zn or Fe/Cd 12C		C	72	240	144
Fe/Zn or Fe/Cd 12D		D	96	264	168
Fe/Zn or Fe/Cd 12Bk		E	24	192	96

^A Low coating thickness impairs chromate adhesion and performance.

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<https://standards.iteh.ai/catalog/standards/sist/f63c665d-7d59-4536-9a00-db0ee76a5d15/astm-f1941m-07>
TABLE A1.2 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Cobalt Coatings

Classification Code	Minimum Coating Thickness (μm)	Chromate Finish Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
Fe/Zn-Co 5C	5	C	96	240
Fe/Zn-Co 5D		D	96	240
Fe/Zn-Co 5E		E	100	240
Fe/Zn-Co 5F		F	196	340
Fe/Zn-Co 8C	8	C	96	240
Fe/Zn-Co 8D		D	96	240
Fe/Zn-Co 8E		E	100	240
Fe/Zn-Co 8F		F	200	340
Fe/Zn-Co 12B	12	B	12	240
Fe/Zn-Co 12C		C	96	400
Fe/Zn-Co 12D		D	96	400
Fe/Zn-Co 12E		E	100	400
Fe/Zn-Co 12F		F	196	500

TABLE A1.3 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Nickel Coatings

Classification Code	Minimum Coating Thickness (µm)	Chromate Finish Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
Fe/Zn-Ni 5B	5	B	20	150
Fe/Zn-Ni 5C		C	120	500
Fe/Zn-Ni 5D		D	180	750
Fe/Zn-Ni 5E		E	100	500
Fe/Zn-Ni 5B/F		B/F	150	300
Fe/Zn-Ni 5C/F		C/F	240	620
Fe/Zn-Ni 5D/F		D/F	300	1000
Fe/Zn-Ni 5E/F		E/F	220	620
Fe/Zn-Ni 8B	8	B	20	240
Fe/Zn-Ni 8C		C	120	720
Fe/Zn-Ni 8D		D	180	960
Fe/Zn-Ni 8E		E	100	720
Fe/Zn-Ni 8B/F		B/F	150	400
Fe/Zn-Ni 8C/F		C/F	240	840
Fe/Zn-Ni 8D/F		D/F	300	1200
Fe/Zn-Ni 8E/F		E/F	220	840
Fe/Zn-Ni 12B	12	B	20	500
Fe/Zn-Ni 12C		C	120	960
Fe/Zn-Ni 12D		D	180	1000
Fe/Zn-Ni 12E		E	100	960
Fe/Zn-Ni 12B/F		B/F	150	620
Fe/Zn-Ni 12C/F		C/F	240	1080
Fe/Zn-Ni 12D/F		D/F	300	1500
Fe/Zn-Ni 12E/F		E/F	220	1080

TABLE A1.4 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Iron Coatings

Classification Code	Minimum Coating Thickness (µm)	Chromate Finish Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
Fe/Zn-Co 5E	5	E	144	312
Fe/Zn-Co 8E	8	E	144	312
Fe/Zn-Co 12E	12	E	144	480

APPENDIXES

(Nonmandatory Information)

X1. STANDARD ELECTRODEPOSITION PROCESSES

X1.1 *Barrel-Plating Process*—The preparation and metallic coating of threaded fasteners is usually accomplished by the barrel-plating process. In this process, quantities of an item are placed within a containment vessel, called a barrel. The barrel is designed to move the group of items, together, through each of the process steps, allowing ready ingress and egress of processing solutions and rinses. As the barrel is moved through the process steps, it is also rotated such that the individual items are constantly cascading over one another. This can damage the external threads of fasteners. The effect of thread damage is worse on heavy fine threaded fasteners than on light coarse threaded fasteners. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The cascading action randomly

exposes the surface of each individual piece to the process electrodes while also maintaining electrical continuity between all the parts. The local coating thickness on a part is a result of the electrical current density at that location. Therefore, the coating thickness on an individual screw or bolt tends to be greatest at the extremities (head and threaded tip). The extremities being the high current density areas receive the greatest coating thickness. In contrast, the center or recesses such as the bottom of the threads, which are the low current density areas, receive the lowest coating thickness. This phenomenon is accentuated with increasing length and decreasing diameter of the screw or bolt. The extremity-to-center coating thickness ratio increases with increasing length and decreasing diameter, but is also a function of process parameters such as plating