Designation: F1941/F1941M – 16

Standard Specification for Electrodeposited Coatings on Mechanical Fasteners, Inch and Metric[1]

This standard is issued under the fixed designation F1941/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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This specification covers the coating of steel unified inch and metric mechanical fasteners by electrodeposition. The properties of the coatings shall conform to the ASTM standards for the individual finishes. This standard shall be used in place of ASTM B633 for mechanical fasteners.

Coating thickness values are based on standard tolerances for inch and metric external threads. The coating must not cause the basic thread size to be transgressed by either the internal or external threads. The method of designating inch coated threads shall comply with ASME B1.1 and ISO 965-1, ISO 965-2, and ISO 965-3 for ISO metric coated threads.

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 above 39 HRC. 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 unified inch and metric screw threads, but it may also be applied to other threaded parts and non-threaded parts such as washers and pins. It specifies coating thickness, supplementary hexavalent chromate or non-hexavalent conversion coatings, 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 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.

1.3 Terms used in this specification are defined in Terminology F1789.

1.4 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.*

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

[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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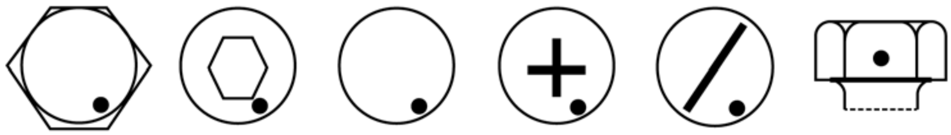
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***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

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
B633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
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 Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods
F519 Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
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, 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
F2078 Terminology Relating to Hydrogen Embrittlement Testing

2.2 *ASME Standards:*[3]
B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)
B1.2 Gages and Gaging for Unified Inch Screw Threads
B1.16M Gages and Gaging for Metric M Screw Threads
B18.6.3 Machine Screws, Tapping Screws, and Metallic Drive Screws (Inch Series)

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

2.5 *ISO Standards:*[6]
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 Construction Screw Threads
ISO 4042 Electroplated Coatings

3. Terminology

3.1 *Definitions:*

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

3.1.2 *sealant*—chemical with or without integral lubricant applied on the substrate which forms a composite layer with a conversion coating in order to improve chemical resistance, corrosion protection, UV resistance, etc.

3.1.3 *significant surface*—Figs. 1 and 2 illustrate significant surfaces on standard externally and internally threaded fasteners and washers.

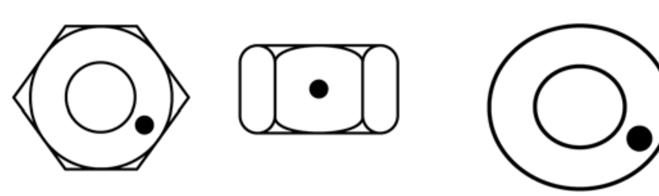
3.1.4 *top coat*—additional layer with or without integral lubricant applied on a substrate in order to achieve functional properties such as torque-tension control, color, chemical resistance, etc.

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 *Conversion Coating*—The conversion coating shall be selected and designated in accordance with Table 3. When not specified, hexavalent chromium, or hexavalent chromium free passivation such as trivalent chromium passivation or other



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

FIG. 2 Significant Surfaces on Internally Threaded Fasteners and Washers

[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 DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

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

[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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 – Inch and Metric

NOTE 1—The conversion factor from inch to microns is 2.54×10^4 (for example, 0.0001 in. = 2.54 µm).

Thickness Designation	Minimum Thickness	
	in.	µm
3	0.0001	3
5	0.0002	5
8	0.0003	8
12	0.0005	12

TABLE 3 Designation of Conversion Coating

Type	Typical Appearance	Conversion Designation	
		Hexavalent Chromium	Hexavalent Chromium Free
Clear	Transparent colorless with slight iridescence	A	AN
Blue-bright	Transparent with a bluish tinge and slight iridescence	B	BN
Yellow	Yellow iridescent	C	CN
Opaque	Olive green, shading to brown or bronze	D	DN
Black	Black with slight iridescence	E	EN

non-chromium passivation 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.

4.4 *Supplemental Lubricant, Sealants or Top Coats*—Additional sealants or top coats (with or without integral lubricant) may be chosen to increase corrosion resistance and to achieve other specific properties such as torque-tension, UV resistance, etc. The selection of the nature of a sealant or top coat should be based on desired additional properties. When sealants or top coats are specified, the classification code in Table 3 shall be appended by adding the letter "S" (for example Fe/Zn 5ANS). When specifying a lubricant, the classification code in Table 3shall be appended with the letter "L" (for example Fe/Zn 5ANSL).

NOTE 1—When using a sealant or top coat, a separate conversion coating layer and/or lubricant layer may not be required to achieve the corrosion performance or provide lubricity.

4.5 Fig. 3 illustrates the basic electroplating coating systems.

4.5.1 Only coating material layer(s).

4.5.2 Coating material layer(s) plus conversion coating (for example Fe/Zn 5A).

4.5.3 Coating material layer(s) plus conversion coating plus additional lubricant (example Fe/Zn 5ANL).

4.5.4 Coating material layer(s) plus conversion coating plus sealant top coat (example Fe/Zn 5ANS).

4.5.5 Coating material layer(s) plus conversion coating plus sealant top coat plus additional lubricant (example Fe/Zn 5ANSL).

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 conversion coating, the color and appearance (if applicable), or the classification codes as specified in Tables 1-3 and additional sealants or top coats (for example, Fe/Zn 5C denotes yellow zinc plated with a minimum thickness of 0.0002 in. or 5 µm for metric 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), other than as required by 6.4.1 must be specified. Requirements shall include baking time and temperature.

5.1.5 The requirements, if any, for embrittlement testing other than as required by 6.4.3 must be specified.

NOTE 2—Through hardened fasteners with a specified maximum hardness of 39 HRC and below have a low susceptibility to hydrogen embrittlement and do not require baking.

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

5.1.7 The designation of inch coated thread class shall comply with ASME B1.1 and metric threads shall comply with ISO 965-1, ISO 965-2 and ISO 965-3.

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

FIG. 3 Basic Electroplating Coating Systems

6.1.3 The coating shall not be stained, discolored or exhibit any evidence of 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 nor basis metal corrosion products 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 conversion coating adhesion.

6.3.1.2 *External Threads*—The after-coating dimensions of external threads must not exceed the thread's basic size. Coated external threads must conform to a basic GO gage. Coated inch external threads must accept a class 3A GO gage and coated metric threads must accept a class h (6h or 4h) GO gage (See ASME B1.2 and ASME B1.16M respectively). The NOTGO gage size is the same after coating as before coating. If a coated external thread does not freely enter the basic size GO gage, the thread discontinuity torque test in Specification F788 shall be used to determine thread acceptability.

6.3.1.3 *Internal Threads*—The after-coating dimensions of internal threads must not exceed the thread's basic size. Coated internal threads must conform to a basic GO gage. Coated inch internal threads must accept a class 2B or 3B GO gage and coated metric internal threads must accept a class H (6H, 5H or 4H) GO gage (See ASME B1.2 and ASME B1.16M respectively). The NOTGO gage size is the same after coating as before coating.

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 Unified Inch Screw and M Series Metric Threads:*

6.3.2.1 The applicability of the required coating to unified inch and M series metric screw 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 0.0005 in. or 12 µm for metric is not recommended for a standard screw thread by this method due to the fact that dimensional allowance of most 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 by adjusting pre-plating thread size.

6.3.3 *Applicability to Wood Screws and Thread Forming Screws*—Any classification code in Tables 1-3 may be applied to screws that cut or form their own threads.

6.4 *Hydrogen Embrittlement Relief:*

6.4.1 *Requirement for Baking for Through Hardened Fasteners*—Unless otherwise specified by the purchaser, baking is not mandatory for fasteners with specified maximum hardness 39 HRC and below (see Note 3). Coated fasteners made from steel heat treated to a specified hardness above 39 HRC, and fasteners with captive washers made from hardened steel shall be baked to minimize the risk of hydrogen embrittlement.

NOTE 3—With proper care many steel fasteners can be plated without baking by correlating process conditions, and coating material to the susceptibility of the fastener material to hydrogen embrittlement, and by applying adequate process control procedures, such as those outlined in Appendix 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*—Unless otherwise specified, minimum baking times shall be in accordance with Table 4.

6.4.2.1 Bake temperatures shall always be kept below the tempering temperature of quenched and tempered steel parts to avoid alteration of mechanical properties by re-tempering.

6.4.2.2 Bake temperatures shall not exceed the values specified in Table 4 to avoid the risk of solid or liquid metal embrittlement.

NOTE 4—Bake times and temperatures are lowered to minimize the risk of solid or liquid metal embrittlement resulting from alloy compositions such as those containing lead or from lowering melting point of the coating material. For example, cadmium has a melting point of 610°F or 310°C in comparison to zinc which has a melting point of 786°F or 419°C.

6.4.2.3 Baking to relieve hydrogen embrittlement should be performed after electroplating, prior to the application of the conversion coating and prior to the application of sealant and/or top coat, if any where baking temperatures can damage the conversion film thereby negating its performance. After experimentation, coaters may find other sequences are suitable. The time between coating and baking should be as short as possible. The requirement, if any, for a specific maximum allowable time (in hours) between electroplating and baking shall be explicitly specified by the purchaser at the time of

TABLE 4 Hydrogen Embrittlement Relief Requirements[B]

Specified Core Hardness (HRC)	Min Baking Time	Min – Max Baking Temperature[C,D]	ASTM Hydrogen Embrittlement Test Requirement[E]	Tapping Screw Hydrogen Embrittlement Test Requirement	ASTM Process Control Test Requirement[E]
Over 39 and up to 44[A]	Min 14 h	375 to 425°F or 190 to 220°C	F606/F606M or F1624	ASME B18.6.3 or F1624	F1940 or F519
Over 44[A]	Min 24 h	375 to 425°F or 190° to 220C	F606/F606M or F1624	ASME B18.6.3 or F1624	F1940 or F519

[A] If Test Method F1940 process control testing is not performed, baking and product testing are mandatory in accordance with Table 4. If Test Method F1940 process control testing is performed and is shown to consistently pass at a minimum of a monthly basis, then product testing and baking are not mandatory. If Test Method F1940 process control testing is performed and does not pass, then baking and product testing are mandatory.
[B] Variables such as coating type, coating thickness, baking temperatures and plating process (barrel or rack plating) can effect baking requirements. ASTM F1940 process control testing can be used to isolate the effect of baking, and shall be the basis to increase or decrease baking times or to eliminate baking altogether. In the absence of Test Method F1940 process control testing, baking and testing requirements specified in Table 4 shall be used as the default for all conditions.
[C] Cadmium baking temperatures should be between 375 to 400°F or 190 to 205°C.
[D] Part temperature.
[E] When agreed upon between supplier and purchaser, alternative hydrogen embrittlement test methods such as NASM 1312-5 and alternative process control test methods may be used.

order. A reasonable tolerance of +2h resulting from normal operational constraints shall be assumed. (See Appendix X4.3 for additional information.)

6.4.3 *Hydrogen Embrittlement Testing*—Unless otherwise specified by the purchaser, hydrogen embrittlement testing in accordance with Table 4 is mandatory for through hardened fasteners with a specified core hardness above 39 HRC unless the electroplating process has been qualified in accordance with a test method in Table 4 (that is, the process has been shown not to cause embrittlement for a given product or class of product).

6.4.4 *Baking and Testing Requirements for Case Hardened Screws*—Surface hardening of case hardened screws introduces variables additional to the hardness of the core, notably case hardness and case depth. Case hardened screws that are electroplated shall adhere to the following baking requirements.

6.4.4.1 All lots of case hardened screws shall be baked for a minimum of 4 h at 375 to 400°F or 190 to 205°C part temperature.

6.4.4.2 All case hardened screws shall be tested for hydrogen embrittlement in accordance with ASME B18.6.3 for all self-tapping screws. For case hardened machine screws, the ASME B18.6.3 method shall be applied except use a hardened threaded test plate having a minimum thickness of one nominal diameter. The tapped holes shall be 2B for inch fasteners or 6H for metric fasteners.

6.4.5 Any lot that fails hydrogen embrittlement testing shall be baked for 24 h at 375 to 400°F or 190 to 205°C part temperature and retest shall be made using twice the original sample size.

6.5 *Stress Relieving Requirements for Work Hardened Fasteners Without Thermal Hardening*—Some cold formed fasteners that are not thermally hardened can fracture due to buildup of high residual stresses at stress concentration points. The types of fastener shapes that make this a particular concern are carriage bolts, thin head parts where the minimum thickness of the head is less than 50% of the nominal diameter of the screw, shoulder type fasteners where the thread major diameter is more than 20% smaller than the shoulder diameter, or where a larger diameter, thin washer or collar is formed on a double ended stud. An indication that high residual stresses may be present in a portion of the fastener is when localized hardness below the surface exceeds 30 HRC.

6.5.1 Fasteners with configurations or conditions described above shall be stress relieved at a minimum temperature of 875°F or 470°C prior to electroplating to avoid brittle fractures. Increased hardness resulting from thread rolling before, after or without thermal hardening are due to the creation of non-detrimental compressive stresses and do not require stress relief before electroplating.

NOTE 5—Stress relieving is not intended in cases where residual stresses are intentionally introduced, such as screws which are thread rolled after heat treatment.

6.6 *Non-Hexavalent Conversion Coating*—When the use of hexavalent chromium is prohibited, 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 inch threads shall comply with ASME B1.1 and metric threads shall comply with ISO 965-1, ISO 965-2, and ISO 965-3 (see 6.3.1.2 and 6.3.1.3). Screw threads that are specifically manufactured to allow the application of 0.0005 in. or 12 µm for metric threads or greater coating thickness by the barrel-plating process, must adhere to a special allowance specified by the manufacturer or in ASME B1.1 or ISO 965-1, ISO 965-2, and ISO 965-3. The other dimensional characteristics shall be as specified in 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*—Unless otherwise specified, the embrittlement test method shall conform to those specified in Test Methods F1940 or F519 for process verification, or F606/F606M, or F1624 for product testing. If agreed upon by the purchaser and supplier, alternative test methods, such as NASM 1312-5 may be used for testing bolt and machine screws. The testing of both inch and metric surface hardened screws shall be conducted in accordance with ASME B18.6.3.

9.3 *Corrosion Resistance*—The requirement to determine corrosion resistance is applicable to significant surfaces only. When specified in the contract or purchase order, a salt spray test 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. The salt spray test shall commence within 72 h of completion of the aging period and prior to sorting, packaging and/or assembling.

9.4 *Non-Hexavalent Conversion Coating*—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 mechanical 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 baking; chromium; conversion coating; corrosion; electroplating; hydrogen embrittlement; protection; resistance; sealant; thickness; topcoat; zinc

ANNEX

(Mandatory Information)

A1. NEUTRAL SALT SPRAY PERFORMANCE

A1.1 See Tables A1.1-A1.5.

NOTE A1.1—The salt spray results are only valid when tested after processing before any handling, sorting, packaging, and/or transportation. Due to surface abrasions associated with types of movement of parts against one another corrosion testing results at any point after processing may be less than exhibited in the as processed condition and shall not be used as criteria for acceptance (see 9.3).

TABLE A1.1 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc and Cadmium Coatings – Inch and Metric[B,C]

Classification Code	Minimum Coating Thickness		Conversion Coating or Supplemental Designation	First Appearance of White Corrosion Product, (hour)	First Appearance of Red Rust Cadmium, (hour)	First Appearance of Red Rust Zinc, (hour)
	in.	µm				
Fe/Zn or Fe/Cd 3A	0.0001[A]	3	A	6	24	12
Fe/Zn or Fe/Cd 3B	. . .	. . .	B	8	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 3AN, 3BN, 3CN or 3DN	. . .	. . .	AN, BN, CN or DN	6	24	12
Fe/Zn or Fe/Cd 5A	0.0002	5	A	8	48	24
Fe/Zn or Fe/Cd 5B	. . .	. . .	B	12	72	36
Fe/Zn or Fe/Cd 5C	. . .	. . .	C	72	120	96
Fe/Zn or Fe/Cd 5D	. . .	. . .	D	72	168	96
Fe/Zn or Fe/Cd 5E	. . .	. . .	E	12	72	
Fe/Zn or Fe/Cd 5AN, 5BN, 5CN, 5DN or 5EN	. . .	. . .	AN, BN, CN or DN	8	48	24
Fe/Zn or Fe/Cd 8A	0.0003	8	A	8	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 8AN, 8BN, 8CN, 8DN or 8EN	. . .	. . .	AN, BN, CN or DN	8	96	48
Fe/Zn or Fe/Cd 12A	0.0005	12	A	8	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 12E	. . .		E	24	192	96
Fe/Zn or Fe/Cd 12AN, 12BN, 12CN, 12DN or 12EN			AN, BN, CN or DN	8	144	72

[A] Low coating thickness impairs chromate adhesion and performance.
[B] White haze is not considered as white corrosion.
[C] Black spots shall not be cause of rejection because it does not impair corrosion resistance.

TABLE A1.2 Classification Code and Neutral Salt Spray Protection of Zinc Coatings with Hexavalent Chromium free Passivate Finish with Sealant Top Coat – Inch and Metric[A,B]

Classification Code	Minimum Coating Thickness		Conversion Coating or Supplemental Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
	in.	µm			
Fe/Zn 5 ANS, BNS, CNS, DNS or ENS	0.0002	5	ANS, BNS, CNS, DNS or ENS	96	120
Fe/Zn 8 ANS, BNS, CNS, DNS or ENS	0.0003	8	...	96	192
Fe/Zn 12 ANS, BNS, CNS, DNS or ENS	0.0005	12	...	96	240

[A] White haze is not considered as white corrosion.
[B] Black spots shall not be cause of rejection because it does not impair corrosion resistance.

TABLE A1.3 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Cobalt Coatings – Inch and Metric

Classification Code	Minimum Coating Thickness		Conversion Coating or Supplemental Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
	in.	µm			
Fe/Zn-Co 5C	0.0002	5	C	96	240
Fe/Zn-Co 5D	. . .		D	96	240
Fe/Zn-Co 5E	. . .		E	100	240
Fe/Zn-Co 5S	. . .		S	196	340
Fe/Zn-Co 8C	0.0003	8	C	96	240
Fe/Zn-Co 8D	. . .		D	96	240
Fe/Zn-Co 8E	. . .		E	100	240
Fe/Zn-Co 8S			S	200	340
Fe/Zn-Co 12B	0.0005	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 12S			S	196	500

TABLE A1.4 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Nickel Coatings – Inch and Metric

Classification Code	Minimum Coating Thickness		Conversion Coating or Supplemental Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
	in.	µm			
Fe/Zn-Ni 5B	0.0002	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 5BS	. . .		BS	150	300
Fe/Zn-Ni 5CS	. . .		CS	240	620
Fe/Zn-Ni 5DS	. . .		DS	300	1000
Fe/Zn-Ni 5ES	. . .		ES	220	620
Fe/Zn-Ni 8B	0.0003	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 8BS	. . .		BS	150	400
Fe/Zn-Ni 8CS	. . .		CS	240	840
Fe/Zn-Ni 8DS	. . .		DS	300	1200
Fe/Zn-Ni 8ES	. . .		ES	220	840
Fe/Zn-Ni 12B	0.0005	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 12BS	. . .		BS	150	620
Fe/Zn-Ni 12CS	. . .		CS	240	1080
Fe/Zn-Ni 12DS	. . .		DS	300	1500
Fe/Zn-Ni 12ES	. . .		ES	220	1080

TABLE A1.5 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Iron Coatings – Inch and Metric

Classification Code	Minimum Coating Thickness		Conversion Coating or Supplemental Designation	First Appearance of Zinc Alloy Corrosion Product (hour)	First Appearance of Red Rust (hour)
	in.	µm			
Fe/Zn-Fe 5E	0.0002	5	E	144	312
Fe/Zn-Fe 8E	0.0003	8	E	144	312
Fe/Zn-Fe 12E	0.0005	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 of 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 solution chemistry and efficiency, anodic/cathodic efficiency, average current density and plating time.

X1.2 *Rack-Plating Process*—The preparation and metallic coating of threaded fasteners can be accomplished by the rack-plating process, particularly on large size fasteners where thread fit or damage, or both, is a concern, or for smaller size fasteners, when it is economically feasible. In this process, quantities of an item are placed on a support, called a rack. The rack 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. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The electrical continuity is maintained between the parts by the rack itself. The average current density is usually low enough such that the extremity-to-center coating thickness ratio is much lower than with barrel-plating. The external thread damage is also minimized in comparison to barrel-plating due to the absence of tumbling.

X2. GUIDELINES FOR CHOOSING BETWEEN BARREL-PLATING AND RACK-PLATING

X2.1 Short screws and bolts are those with a length-to-diameter ratio equal to or less than 5. Long screws and bolts have a length-to-diameter ratio greater than 5 but less than 10. Special processing is normally required for bolts with a ratio greater than 10 in order to minimize the extremity-to-center thickness ratio.

X2.2 Tables X2.1-X2.3 indicate the recommended electroplating process for each size of externally inch series coarse (UNC), fine (UNF), and metric threaded fasteners for all thickness classes in Table 2. For externally threaded fasteners with UNS and UN thread series, rack-plating is recommended. For internally threaded fasteners barrel-plating is generally suitable.

TABLE X2.1 Recommended Electroplating Process for Each Size of Externally Coarse Threaded Fasteners (UNC)

NOTE 1—Barrel-plating process (B) and rack-plating process (R).

Diameter (D), (in.)	Length (L)				
	L ≤ 5D	5D < L ≤ 10D	10D < L ≤ 20D	20D < L ≤ 30D	L > 30D
1⁄4	B	B	B	B	R
5⁄16	B	B	B	B	R
3⁄8	B	B	B	R	R
7⁄16	B	B	B	R	R
1⁄2	B	B	R	R	R
9⁄16	B	B	R	R	R
5⁄8	B	B	R	R	R
3⁄4	B	R	R	R	R
7⁄8	R	R	R	R	R
1 – 4	R	R	R	R	R

TABLE X2.2 Recommended Electroplating Process for Each Size of Externally Fine Threaded Fasteners (UNF)

NOTE 1—Barrel-plating process (B) and rack-plating process (R).

Diameter (D), (in.)	Length (L)				
	L ≤ 5D	5D < L ≤ 10D	10D < L ≤ 20D	20D < L ≤ 30D	L > 30D
¼	B	B	B	B	R
5⁄16	B	B	B	R	R
⅜	B	B	B	R	R
7⁄16	B	B	R	R	R
½	B	B	R	R	R
9⁄16	B	B	R	R	R
⅝	B	R	R	R	R
¾	R	R	R	R	R
⅞	R	R	R	R	R
1 – 4	R	R	R	R	R

TABLE X2.3 Recommended Electroplating Process for Each Size of Externally Threaded Metric Fasteners

NOTE 1—Barrel-plating process (B) and rack-plating process (R).

Diameter (D), (mm)	Length (L)				
	L ≤ 5D	5D < L ≤ 10D	10D < L ≤ 20D	20D < L ≤ 30D	L > 30D
M1.6-M4	B	B	B	B	R
M5-M6	B	B	B	R	R
M8-M10	B	B	B	R	R
M12	B	B	R	R	R
M14	B	B	R	R	R
M16	B	B	R	R	R
M20	B	R	R	R	R
M24	R	R	R	R	R
M30-M100	R	R	R	R	R

X3. COATING ACCOMMODATION TOLERANCES FOR EXTERNALLY AND INTERNALLY THREADED FASTENERS

X3.1 This specification does not impose maximum thickness values on high current density areas, where the coating thickness tends to be the greatest. On an externally threaded fastener this occurs at the threaded tip. Measuring coating thickness on the threaded portion of a fastener is possible but impractical for in-process quality control verification. For this reason the control mechanism specified in this document is by means of GO thread gages. Nevertheless Tables X3.1-X3.5 illustrate maximum coating thickness permitted by inch series Class 2A allowance, metric tolerance class 6g and are supplied as an informative guideline.

NOTE X3.1—The following information is based on ASME B1.1 Section 7 and ISO 965-1, ISO 965-2, and ISO 965-3. Those standards should be consulted for more detailed information.

X3.2 Size limits for standard external inch series 1A and 2A thread classes and metric tolerance classes 6g apply prior to coating. The external thread allowance may thus be used to accommodate the coating thickness on threaded fasteners, provided the maximum coating thickness is no more than ¼ of the allowance. Thus, threads after coating are subject to acceptance using a basic Class 3A GO gage for inch series threads, and 6h GO gage for metric series threads. Class 2A and 6g shall be used as respective NOT-GO gages.

X3.3 In certain cases size limits must be adjusted, within the tolerances, prior to coating, in order to insure proper thread fit. This applies to the following cases:

X3.3.1 Standard internal threads, because they provide no allowance for coating thickness.

X3.3.2 Where the external thread has no allowance, such as Class 3A threads.

X3.3.3 Where allowance must be maintained after coating for trouble free thread fit.

X3.4 Tables X3.1-X3.5 provide maximum thickness values based only on the allowance for the 2A inch series thread classes and metric thread classes 6g. It assumes that the external thread pitch diameter is at the maximum and that the internal thread pitch diameter is at the minimum of the tolerance (see Fig. X3.1 and Fig. X3.2).

TABLE X3.1 Coating Accommodation Tolerances for Externally Coarse Threaded (UNC) Fasteners

Thread Pitch, TPI	Diameter, in.	Pitch Diameter Allowance for 1A and 2A Thread Classes, in.	Maximum Allowable Coating Thickness on Threaded Tip, × 0.0001 in.
20	¼	0.0011	2.75
18	5⁄16	0.0012	3.00
16	⅜	0.0013	3.25
14	7⁄16	0.0014	3.50
13	½	0.0015	3.75
12	9⁄16	0.0016	4.00
11	⅝	0.0016	4.00
10	¾	0.0018	4.50
9	⅞	0.0019	4.75
8	1	0.0020	5.00
7	1⅛ and 1¼	0.0022	5.50
6	1⅜ and 1½	0.0024	6.00
5	1¼	0.0027	6.75
4 ½	2 and 2¼	0.0029	7.25
4	2½	0.0031	7.75
4	2¾ and 3	0.0032	8.00
4	3¼ and 3½	0.0033	8.25
4	3¾ and 4	0.0034	8.50

TABLE X3.2 Coating Accommodation Tolerances for Externally Fine Threaded (UNF) Fasteners

Thread Pitch, TPI	Diameter, in.	Pitch Diameter Allowance for 1A and 2A Thread Classes, in.	Maximum Allowable Coating Thickness on Threaded Tip, × 0.0001 in.
28	¼	0.0010	2.50
24	5⁄16 and ⅜	0.0011	2.75
20	7⁄16 and ½	0.0013	3.25
18	9⁄16 and ⅝	0.0014	3.50
16	¾	0.0015	3.75
14	⅞	0.0016	4.00
12	1, 1⅛ and 1¼	0.0018	4.50
12	1⅜ and 1½	0.0019	4.75

TABLE X3.3 Coating Accommodation Tolerances for Externally Threaded (UNS) Fasteners

Thread Pitch, TPI	Diameter, in.	Pitch Diameter Allowance for 1A and 2A Thread Classes, in.	Maximum Allowable Coating Thickness on Threaded Tip, × 0.0001 in.
14	1	0.0017	4.25

TABLE X3.4 Coating Accommodation Tolerances for Externally Threaded (UN) Fasteners

Thread Pitch, TPI	Diameter, in.	Pitch Diameter Allowance for 2A Thread Classes, in.	Maximum Allowable Coating Thickness on Threaded Tip, × 0.0001 in.
8	1 ⅛ and 1 ¼	0.0021	5.25
8	1⅜ , 1½ and 1⅝	0.0022	5.50
8	1¾ , 1⅞ and 2	0.0023	5.75
8	2¼ and 2½	0.0024	6.00
8	2¾	0.0025	6.25
8	3, 3¼ and 3½	0.0026	6.50
8	3¾ and 4	0.0027	6.75

TABLE X3.5 Coating Accommodation Tolerances for Externally Threaded Class 6g and 4g6g Metric Fasteners

Thread Pitch, mm	Diameter, in.	Pitch Diameter Allowance for 6g Tolerance Positions, µm	Maximum Allowable Coating Thickness on Threaded Tip, µm
0.35	M1.6	–19	4
0.4	M2	–19	4
0.45	M2.5	–20	5
0.5	M3	–20	5
0.6	M3.5	–21	5
0.7	M4	–22	5
0.8	M5	–24	6
1	M6	–26	6
1.25	M8	–28	7
1.5	M10	–32	8
1.75	M12	–34	8
2	M14, M16	–38	9
2.5	M20	–42	10
3	M24	–48	12
3.5	M30	–53	13
4	M36	–60	15
4.5	M42	–63	15
5	M48	–71	17
5.5	M56	–75	18
6	M64, M72, M80, M90, M100	–80	20

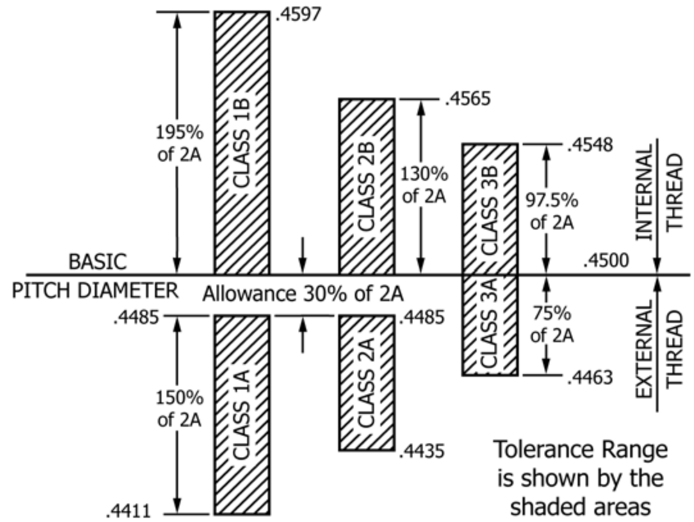


FIG. X3.1 Relationship of Pitch Diameter Allowance for Classes of Fit on ½-13 UNC Thread

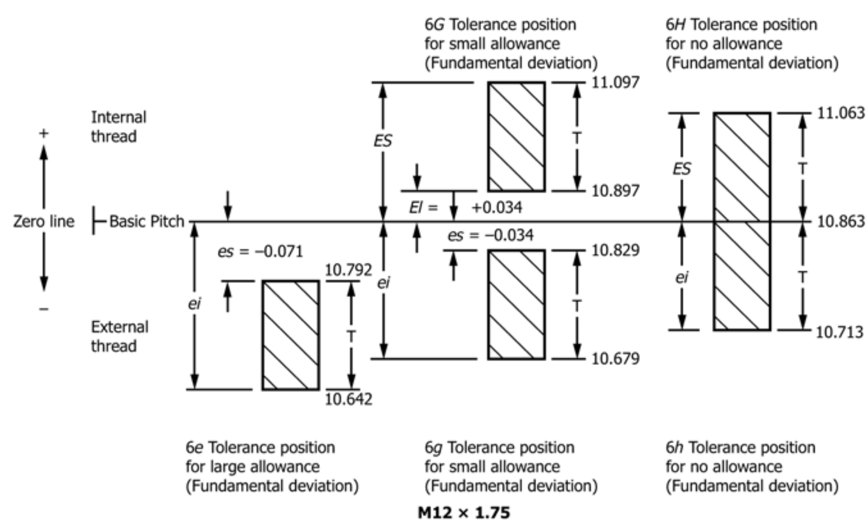


FIG. X3.2 Metric Tolerance System for Screw Threads

X4. APPLICATION REQUIREMENTS

X4.1 *Cleaning of Basis Metal*—Thorough cleaning of the basis metal is essential in order to ensure satisfactory adhesion, appearance and corrosion resistance of the coating.

X4.2 *Hydrogen Embrittlement Consideration*:

X4.2.1 *General Discussion*—When atomic hydrogen enters steel and certain other metals and alloys, it can with time cause loss of ductility and/or strength, which can lead to cracking (usually micro-cracks) and eventually to catastrophic brittle failures at applied stresses below the normal strength of the material. A typical definition for hydrogen embrittlement in literature and standards is as follows.

X4.2.1.1 *Hydrogen Embrittlement (HE)*—a permanent loss of ductility in a metal or alloy caused by hydrogen in combination with stress, either externally applied or internal residual stress. [Terminology F2078]

X4.2.2 *Research Information*—— Results of ongoing research related to hydrogen embrittlement of steel fasteners are summarized in the following technical reports endorsed by the fastener industry.

(1) Fundamentals of Hydrogen Embrittlement in Steel Fasteners, S. Brahimi, 2014. Available from the Industrial Fasteners Institute (IFI), www.indfast.org/info/free-technical-info.asp

(2) ISO Technical Report ISO/TR 20491:2015, Fundamentals of Hydrogen Embrittlement in Steel Fasteners.

NOTE X4.1—As of the publication of F1941/F1941M-15, the ISO technical report was undergoing final draft revision as ISO/DTR

20491:2015, by ISO Technical Committee TC2 on Fasteners.

These reports summarize into "know-how" findings flowing out of scientific research at McGill University, Montreal, Canada. McGill's hydrogen embrittlement (HE) research program began in 2006 as a collaborative research and development (CRD) project, co-sponsored by a number of industrial partners and the government of Canada. The ongoing research follows two distinct tracks:

(i) fastener materials susceptibility, and

(ii) interactions of fastener materials with coatings and coating processes.

NOTE X4.2—One of many tangible outcomes is that the research results have informed the revision of fastener electroplating standards, notably, F1941/F1941M and ISO 4042.

X4.2.3 *Material Susceptibility*—Material susceptibility is a function of the material (metallurgical/ mechanical) condition and is the fundamental basis for understanding HE phenomena, which when simply stated is the study of how a stressed material performs in the absence and then in the presence of absorbed hydrogen. Material strength (that is, tensile strength and/or hardness) has a first order effect on HE susceptibility. As strength increases, steel becomes less ductile, less tough and more susceptible to HE. By the same token, at equal strength, steel that exhibits lower toughness is inherently more brittle and more susceptible to HE. The susceptibility of steel fasteners increases significantly when the specified hardness is above 39 HRC (380 HV). Steel fasteners with a specified hardness below 39 HRC (380 HV), for example, SAE J429 Grade 8, ISO 898-1 PC 10.9 bolts) normally have no significant susceptibility to hydrogen embrittlement failure. In other words, they can tolerate the presence of higher concentrations of hydrogen without any delayed degradation of their mechanical strength. This assertion assumes that the fasteners were produced by well controlled manufacturing processes using appropriately selected steel of adequate quality. The critical hardness threshold for heat treated quench and tempered steel fasteners will vary for a given product due to second order effects of chemistry, tempering temperature and sub-microstructure. These second order effects may vary the threshold value by as much as ± 1.0 HRC (~± 10 HV). Additionally, non-homogeneity of the metallurgical structure resulting from poorly controlled heat treatment (for example, incomplete martensite transformation, unintended carburization) and/or impurities such as non-metallic inclusions can dramatically increase the susceptibility of the steel in ways that are measurable but unpredictable. With respect to IHE avoidance, some standards have defined critical hardness limits that are lower, ranging from 31 to 35 HRC. However, these values are largely unsupported by data, and have been adopted primarily as a precaution against manufacturing errors that could render the material significantly more susceptible than it should be. Rather, it is appropriate to classify susceptible fastener products as those having minimum specified hardness above 39 HRC (380 HV). This classification is based on both scientific research and longstanding fastener industry practice.

X4.2.4 *Process Considerations*—The following are some general recommendations for managing the risk of hydrogen embrittlement. For more detailed information refer to IFI-142.

X4.2.4.1 Clean the fasteners in non-cathodic alkaline solutions and in inhibited acid solutions.

X4.2.4.2 Use abrasive cleaners for fasteners having a hardness of 40 HRC or above and case hardened fasteners.

X4.2.4.3 Manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

X4.2.4.4 Use high efficiency plating processes such as zinc chloride or acid cadmium.

X4.2.4.5 Control the plating bath temperature to minimize the use of brighteners.

X4.2.4.6 Select raw materials with a low susceptibility to hydrogen embrittlement by controlling steel chemistry, microstructure, and mechanical properties.

X4.3 The time between coating and baking should be kept as short as possible as a matter of good practice. The intent of such practice is to minimize the extraction of interstitial hydrogen; it is possible that a portion of the interstitial hydrogen becomes trapped and more difficult to bake out. It is not possible to tie a subjective matter of good practice to an exact length of time between coating and baking. The often used approach of specifying an exact time is intended as a quality assurance mechanism for managing good practice. It should not be used as a fixed criteria for acceptability of a fastener lot and it definitely should not be misused as the basis for explain the cause of a fastener failure.

X4.4 *Process Control Verification*—Test Method F1940 is designed to be used as a test method for process control to minimize the risk of internal hydrogen embrittlement. Periodic sampling inspections are conducted according to a test plan designed for each specific process. The frequency of testing must initially establish and subsequently verify over time, the ability of a process to coat parts that are not at risk of failing from internal hydrogen embrittlement.

X4.4.1 A historical perspective of the topic of Hydrogen Embrittlement Risk Management is given in IFI-142.

X5. USE OF TRIVALENT CHROMIUM (Cr^{+3}) ON COATED FASTENERS

X5.1 In applications where the use of hexavalent chromium (Cr^{+6}) is prohibited, coated fasteners with a supplementary finish can be supplied with a trivalent chromium (Cr^{+3}).

X5.1.1 Additionally, since yellow iridescence noted in the designation C of Table 3 is characteristic of hexavalent chromium (Cr^{+6}), the use of yellow dye with trivalent chromium (Cr^{+3}) does not give the same corrosion resistance as yellow hexavalent chromium. Therefore to achieve the same salt spray resistance with trivalent chromium, the addition of a sealant is necessary.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue (F1941/F1941M–15) that may impact the use of this standard. (Approved December 1, 2016.)

(1) Replaced "conversion finish" throughout the standard with "conversion coating".

Committee F16 has identified the location of selected changes to this standard since the last issue (F1941–10) that may impact the use of this standard. (Approved September, 2015.)

Committee F16 undertook a major initiative to consolidate F1941 and F1941M and clarify it requirements, some details of which are listed below.

(1) This revision is a combination of ASTM F1941 and F1941M to create a consolidated standard. As a result, numerous added references to metric specifications and SI units are located throughout standard.

(2) Added allowance for standard to be used with non-threaded fasteners.

(3) Added conversion finish designations and introduced the use of sealants and top coats in 4.4 and illustrated the coating systems in Fig. 3.

(4) Modified hydrogen embrittlement baking and testing requirements throughout 6.4 and added Table 4.

(5) Modified the salt spray requirements for zinc and cadmium coatings in Table A1.1.