Standard Specification for Electrodeposited Coatings on Threaded Fasteners [Metric][1]

This standard is issued under the fixed designation F 1941M; 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 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 chromate 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.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

B 117 Practice for Operating Salt Spray (Fog) Apparatus

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

B 499 Test Method for Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method

B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method

B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

B 659 Guide for Measuring Thickness of Metallic and Inorganic Coatings

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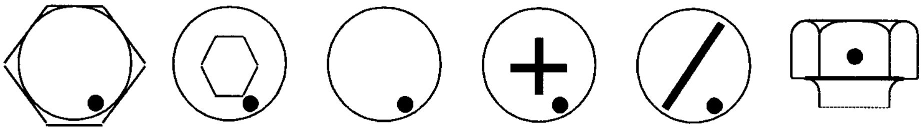
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



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

FIG. 1 Significant surfaces on Externally Threaded Fasteners

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

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

F 1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

F 1940 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.

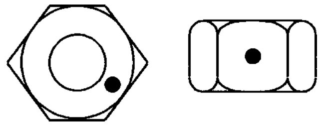
3.1.2 *minimum local thickness*—lowest local thickness value on the significant surface of a single article.

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.

4. Classification

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



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

FIG. 2 Significant surfaces on Internally Threaded Fasteners

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

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

4.3 *Chromate Finish*—The chromate finish shall be selected and designated in accordance with Table 3.

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 and the chromate finish, 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.

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.

TABLE 2 Designation of Coating Thickness

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

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

[3] Available from American Society of Mechanical Engineers (ASME), 345 E. 47th Street, New York, NY 10017.

[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.

TABLE 3 Designation of Chromate Finish

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

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 µm 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 F 1940 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 F 1940, F 1624, F 606, 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 F 1940 (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.

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 F 1470.

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 B 487, B 499, B 504, B 567, B 568, Guide B 659 or Practice E 376 as applicable.

9.2 *Embrittlement Test Method*—The embrittlement test method shall conform to those specified in Test Method F 1940 for process verification, or Test Methods F 606, F 1624, 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 B 117. To secure uniformity of results, samples shall be aged at room temperature for 24 h before being subjected to the salt spray test.

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

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.

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 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 and/or damage 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 Table X2.1 indicates the recommended electroplating process for each size of externally threaded metric fasteners for all thickness classes in Table 2. For internally threaded fasteners barrel-plating is generally suitable.

TABLE X2.1 Recommended Electroplating Process for Each Size of Externally Threaded Metric Fasteners

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
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 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.

X3.2 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 gauges. Nevertheless Table X3.1, which is supplied as an informative guideline, illustrates the maximum coating thickness permitted by the allowance for tolerance classes 6g and 4g6g.

NOTE X3.1—The following information is based on ASME B1.13M. That standard should be consulted for more detailed information.

X3.3 Size limits for standard tolerance classes 6g and 4g6g 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 (see Fig. X3.1). Thus, threads after coating are 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. Class 6g and 4g6g shall be used as respective NOT-GO gauges.

X3.4 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:

X3.4.1 Standard internal threads, because they provide no allowance for coating thickness.

X3.4.2 Where the external thread has no allowance, such as in class h external threads.

X3.4.3 Where allowance must be maintained after coating for trouble free thread fit.

X3.5 Table X3.1 provides maximum coating thickness values based only on the allowance for external thread tolerance classes 6g and 4g6g. 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.

TABLE X3.1 Coating Accommodation Tolerances for Externally Threaded Class 6g and 4g6g Metric Fasteners

Thread Pitch, mm	Diameter, (in.)	Pitch Diameter Allowance for 6g and 6g4g 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

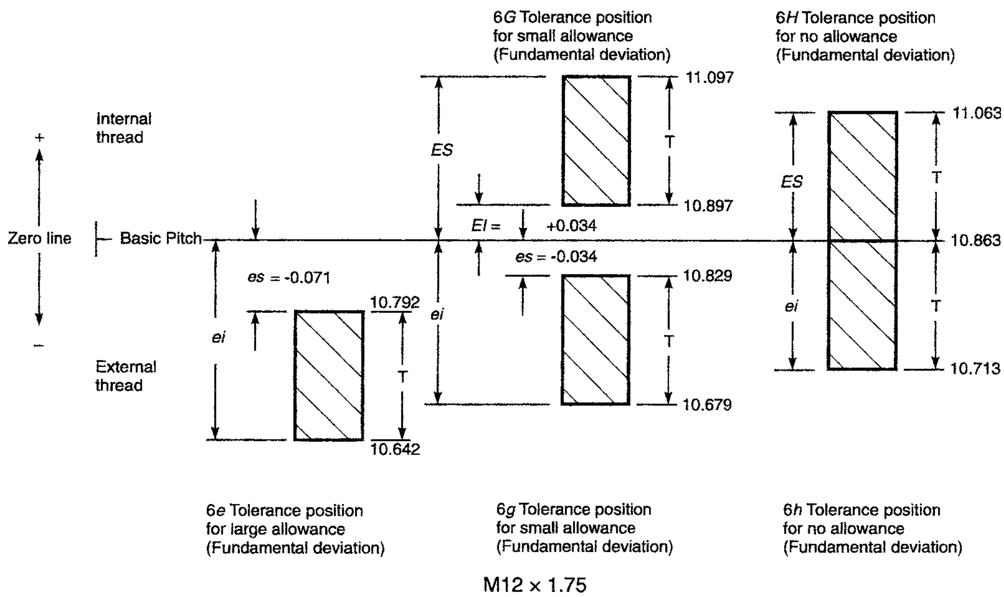


FIG. X3.1 Metric Tolerance System for Screw Threads

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 Risk Management*:

X4.2.1 *Process Considerations*—The following are some general recommendations for managing the risk of hydrogen embrittlement. For more detailed information refer to IFI-142.

X4.2.1.1 Clean the fasteners in non-cathodic alkaline solutions and in inhibited acid solutions.

X4.2.1.2 Use abrasive cleaners for fasteners having a hardness of 40 HRC or above and case hardened fasteners.

X4.2.1.3 Manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

X4.2.1.4 Use high efficiency plating processes such as zinc chloride or acid cadmium

X4.2.1.5 Control the plating bath temperature to minimize the use of brighteners.

X4.2.1.6 Select raw materials with a low susceptibility to hydrogen embrittlement by controlling steel chemistry, microstructure and mechanical properties.

X4.2.2 *Process Control Verification*—Test Method F 1940 should be used as a test method for process control to minimize the risk of hydrogen embrittlement. Periodic inspections should be conducted according to a specified test plan. The test plan should be designed based upon the specific characteristics of a process, and upon agreement between the purchaser and the manufacturer. The testing frequency should initially establish and subsequently verify over time, the ability of a process to produce parts that do not have the potential for hydrogen embrittlement.

X5. COMPARISON OF THE REQUIREMENTS OF SPECIFICATION F 1941M – 00 VERSUS ISO 4042 – 99

X5.1 Table X5.1 provides the main differences that exist between Specification F 1941M–00 versus ISO 4042–99. In many cases, both standards do not use the same numbering system to address a similar provision. If needed, the reader must refer to the related paragraph(s) of each standard in its entirety to fully appreciate the comparison.

TABLE X5.1 Comparison of the Requirements of Specification F 1941M–00 vs. ISO 4042–99

	ASTM Specification F 1941M–00	ISO 4042–00
Scope	*1*—Electrodeposited coatings on threaded fasteners with metric screw threads.	*1*—May also be applied to non-threaded parts such as washers and pins.
Standard Methods and References	*2 Referenced Documents*—Listed standards are: ASTM, ASME, NASM, and IFI standards.	*2 Normative References*—Listed standards are ISO standards.
	For example, ASTM Specification F 1941M refers to ASME B1.13M for threaded tolerances, whereas ISO 4042 refers to ISO 965–1.	
Terminology	*2*—Terms defined are: local thickness, minimum local thickness, reference area, and significant surface.	*2*—Terms defined are: batch, production run, batch average thickness, baking, and baking duration.
Coating Material	*4.3*—Materials listed in Table 1 are: Fe/Zn, Fe/Cd, Fe/Zn-Ni, Fe/Zn-Co, and Fe/Zn-Fe.	*Annex E*—Materials listed in Table E.1 are: Zn, Cd, Cu, CuZn, Ni, NiCr, CuNi, CuNi Cr, Sn, CuSn, Ag, CuAg, ZnNi, ZnCo, and ZnFe.
	ISO 4042 covers other types of coatings not covered by ASTM Specification F 1941, such as Cr, Ni.	
Ordering Information	*5*—Among others, the purchaser shall specify: barrel or rack plating, and any organic topcoat (Table 3, Code F).	*5*—Among others, the purchaser shall specify: preference, if any, for batch average thickness measurement, any selective electroplating, and supplementary coating requirements, for example, subsequent lubrication.
Coating Thickness	*6.3*—Requirements are defined in Table 2 (3, 5, 8, and 12 µm) and specify local thickness only. Non-mandatory information is given on plating processes (barrel and rack).	*5*—Requirements are defined in Table 1 (3, 5, 8, 12, 15, 20, 25, and 30 µm). Table 1 includes alternative requirements for batch average thickness. Table 2 gives extensive guidelines for plating thickness maximum when using the batch average measurements.
	ISO 4042 covers a wider thickness range.	
Risk of Hydrogen Embrittlement	*Introduction*—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 of 40 HRC or above.	*6*—When the core or surface hardness is above 320 HV, process investigation shall be conducted using a test to detect hydrogen embrittlement, for example, the "parallel bearing surface method" in accordance with ISO 15330, to be sure that the process with regard to embrittlement is under control. If embrittlement is discovered, modification of the manufacturing process will be necessary, such as the inclusion of a baking process (see informative Annex A for more information). For fastener of hardness in excess of 365 HV, a written agreement should exist between the customer and manufacturer to define how to manage the risk.

Hydrogen Embrittlement (Bake)	*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 F 1940 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 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 F 1940, F 1624, F 606, 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 composition, 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.	*Annex A.5 Baking Process*—With increasing hardness, increasing degree of cold working and increasing content of carbon or certain other elements of steel parts, or both, the solubility of hydrogen, and therefore the amount of absorbed hydrogen during an acid cleaning or electroplating process increases. At the same time, the critical amount of hydrogen which may cause brittle fracture deceases. The beneficial effect of baking process after electroplating is removal of hydrogen by effusion or irreversible trapping of hydrogen in the steel, or both. Parts should be baked within 4 h and preferably within an hour of electroplating and before chromating, to a part temperature of 200 to 230°C. The maximum temperature should take into account the coating material and type of base material. Certain coatings, for example, tin, and the physical properties of some parts may be adversely affected by these temperatures. In such cases, lower temperatures and longer temperature duration will be required. This should be agreed between purchaser and supplier. With increasing coating thickness, the difficulty of removing hydrogen increases. The introduction of an intermediate baking process when the coating is only 2 to 5 mm thick may reduce the risk of hydrogen embrittlement. The user may agree that other conditions for embrittlement reduction may be used, provided they can be shown to be effective. It should not be assumed that the baking recommended will completely prevent hydrogen embrittlement in all cases. Alternative baking times and temperatures may be used if they have been shown to be effective for a part, but parts should not be baked at a temperature above the temperature at which parts were originally tempered. Generally, lower baking temperatures require longer times at temperature. The chemical compositions of some steels, in combination with process conditions, may produce a higher susceptibility to a hydrogen embrittlement. Fasteners with larger diameters are less susceptible than those with small diameters. At the time of publication of the international standard, it was not considered possible to give exact baking duration. Eight hours is considered a typical example of baking duration. However, baking duration is in the range of 2 to 24 h at 200 to 230°C may be suitable according to the type and size of part, part geometry, mechanical properties, cleaning processes and electroplating processes used.
Hydrogen Embrittlement Testing	*6.4.3*—Mandatory for HRC 40 and above (unless process is qualified in accordance with ASTM Specification F 1940) Test Method: F 606, NAMS 1312–5.	Any investigation method (for example, ISO 15330; parallel surface method).
	ISO 4042 calls for investigation for material above HRC 32 and give recommendations for hydrogen embrittlement management, while Specification F 1941M requires baking for material above HRC 40.	