Designation: B633 – 19

Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel[1]

This standard is issued under the fixed designation B633; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

This specification provides a standard to order an electrodeposited zinc coating that mitigates corrosion of iron and steel articles in order to extend the service life of parts. The service life is reduced when such a coating stops protecting the iron or steel substrate resulting in corrosion of the substrate.

The pretreatment and plating process can introduce hydrogen that can cause internal hydrogen embrittlement in high strength steels causing loss of strength and ductility. It is generally agreed that steels below 1200 MPa are not susceptible to such embrittlement.

1. Scope*

1.1 This specification covers material and process requirements for electrodeposited zinc coatings applied to iron or steel articles to protect them from corrosion.

1.2 This specification is not intended to provide the design activity with all the background needed to properly specify their zinc coating requirements. The users of Specification B633 are encouraged to review this specification in its entirety including the appendices, and access the supplementary papers, other standards, and published literature referenced herein and within other related references.

1.3 The coatings are provided in four standard thickness classes (4.1), in the as-plated condition or with one of five types of supplementary finishes (4.2).

1.4 High strength metals, including high strength steels having a tensile strength greater than 1700 MPa (247 ksi, 46 HRC) should not be zinc electroplated in accordance with this specification.

1.5 It does not cover continuous processes for electrodeposited zinc coated steel wire or sheets (see Specification A591/A591M for sheets).

1.6 For zinc electroplating of mechanical fasteners, the purchaser is encouraged to consider Specification F1941/F1941M.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This standard has been revised to address RoHS requirements that seek to limit the exposure of workers and the public from exposure to toxic metals. Additional types V and VI have been added to permit non-chromate passivate treatments to be used in replacement of hexavalent chromium.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A591/A591M Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Weight [Mass] Applications (Withdrawn 2005)[3]

B117 Practice for Operating Salt Spray (Fog) Apparatus

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[1] This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.06 on Soft Metals.

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

B183 Practice for Preparation of Low-Carbon Steel for Electroplating
B201 Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces
B242 Guide for Preparation of High-Carbon Steel for Electroplating
B254 Practice for Preparation of and Electroplating on Stainless Steel
B320 Practice for Preparation of Iron Castings for Electroplating
B322 Guide for Cleaning Metals Prior to Electroplating
B374 Terminology Relating to Electroplating
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
B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings
B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings
B748 Test Method for Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope
B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings
B849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement
B850 Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement
D2092 Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting (Withdrawn 2008)[3]
F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F1941/F1941M Specification for Electrodeposited Coatings on Mechanical Fasteners, Inch and Metric
F2078 Terminology Relating to Hydrogen Embrittlement Testing

2.2 *Military Standard:*[4]
MIL-STD-1312 Fastener Tests, Methods (Test 12)

2.3 *ISO Standard:*[5]
ISO/TR 20491 Fundamentals of Hydrogen Embrittlement in Steel Fasteners

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of the terms used in this specification are in accordance with Terminology B374.

3.1.2 *passivate*—for the purpose of this specification, a conversion coating on zinc shall not contain hexavalent chromium.

4. Classification

4.1 *Thickness*—The coating shall be provided in one of the four thickness classes defined in Table 1.

TABLE 1 Thickness Classes for Coatings

Classification Number and Conversion Coating Suffix	Service Condition	Thickness, min µm
Fe/Zn 25	SC 4 (very severe)	25
Fe/Zn 12	SC 3 (severe)	12
Fe/Zn 8	SC 2 (moderate)	8
Fe/Zn 5	SC 1 (mild)	5

4.2 *Finish*—The coating shall have one of the finish types defined in Table 2.

TABLE 2 Finish Type and Corrosion Resistance Requirements

Type	Description	Minimum Salt Spray h
I	As-plated without supplementary treatments	
II	With colored chromate coatings	96
III	With colorless chromate conversion coatings	12
IV	With phosphate conversion coatings	
V	With colorless passivate	72
VI	With colored passivate	120

5. Ordering Information

5.1 When ordering the electroplating of articles, the purchaser shall state ASTM B633, the date of issue, service condition number, and the Type (see 4.1, 4.2, and 7.1).

5.2 If necessary, the purchaser shall include on the part drawings or purchase order the following:

5.2.1 Basis metal alloy designation and ultimate tensile strength of the steel,

5.2.2 Whether the part underwent cold forming or cold straightening subsequent to heat treatment (see Note 1).

5.2.3 Thickness, if other than specified (4.1, 7.1),

5.2.4 Location of significant surface (7.1.1, 7.1.2),

5.2.5 Luster (7.3),

5.2.6 Exceptions to stress relief heat treatment prior to plating (6.4),

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

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

5.2.7 Baking requirements after plating, if any (6.5).

5.2.8 Corrosion resistance test, if required (9.3, 10.3),

5.2.9 Hydrogen embrittlement test, if required (9.4, 10.4), including the tensile strength of the items,

5.2.10 Sample size for inspection, if other than specified, and

5.2.11 Supplementary requirements, if applicable (see Supplementary Requirement).

NOTE 1—Information in 5.2.1 and 5.2.2 is necessary for proper pretreatment (6.4) and post coating treatment (6.5) if applicable.

6. Materials and Manufacture

6.1 The coatings shall be non-alloyed zinc produced by electrodeposition.

6.2 Defects in the surface of the basis metal, such as scratches, porosity, pits, inclusions, cracks, roll marks, and die marks may adversely affect the appearance and performance of coatings applied thereto despite the observance of the best electroplating practices. Accordingly, the electroplater's responsibility for defects in the coating resulting from such conditions shall be waived, except when they are the prime contractor supplying electroplated parts. In this event, the basis metal shall be subjected to such polishing or buffing operations as are necessary to yield deposits with the desired final luster and appearance. To minimize problems of this sort, the specifications covering the basis material on the item to be electroplated shall contain appropriate limitations to such basis metal conditions.

6.3 *Cleaning of Basis Metal*—Proper preparatory procedures and thorough cleaning of the basis metal are essential to ensure satisfactory adhesion and corrosion resistance performance of the coating. It is recommended that the following appropriate recommended practices and guides be used: B183, B242, B254, B320, and B322.

6.4 *Pretreatment of Iron or Steel for the Purpose of Reducing the Risk of Hydrogen Embrittlement*—Steel parts having an ultimate tensile strength greater than 1000 MPa (31 HRC) that contain tensile stresses caused by cold forming or cold straightening which have not been heat treated after the cold forming process, shall be heat treated for stress relief to reduce the risk of hydrogen embrittlement in the part before clean and electroplate processes. If these heat treatments are not required, the purchaser shall specify in the ordering information their exception (5.2.6). If the purchaser does not specify an exception to heat treatment, then the plater shall use Table 1 in Specification B849 to determine the appropriate heat treatment for the steel based on its tensile strength.

NOTE 2—Secondary machining operations such as grinding, turning, tapping, thread rolling, and milling are not normally problematic. Stress relief treatment is not necessary when compressive residual stresses are intentionally added.

6.5 *Post Coating Treatments of Iron and Steel for the Purpose of Reducing the Risk of Hydrogen Embrittlement (Baking)*—Electroplated steel parts having a tensile strength greater than 1200 MPa (39 HRC) as well as surface hardened parts, shall be baked to reduce the risk of hydrogen embrittlement. Baking of electroplated steel parts with tensile strength 1200 MPa (39 HRC) or less is not mandatory.

6.5.1 Steel parts having a tensile strength greater than 1200 MPa (39 HRC) as well as surface hardened parts, shall be baked to reduce the risk of hydrogen embrittlement. For such parts, purchasers shall specify the baking requirements in the ordering information (5.2.7). Purchasers are directed to the appropriate ER Class in Guide B850 Table 1.

6.5.2 A purchaser wishing to specify baking requirements, irrespective of tensile strength, shall specify such requirements in the ordering information (5.2.7). Purchasers are directed to Guide B850 Table 1.

6.5.3 Any baking treatment done under this section (6.5) shall begin within 4 h of removal from the electroplating process. When applicable, baking treatment shall be done before application of the supplementary treatments if the baking temperature would damage the supplementary film (see Note 4). Application of any supplementary treatment shall be in accordance with the chemical supplier's recommended practice in regards to the treatment's exposure to baking temperature (see Note 4).

6.5.4 Electroplated springs and other parts subject to flexure shall not be flexed before the hydrogen embrittlement relief treatment.

NOTE 3—Guide B850 is a guide for post-coating treatments of steel for reducing the risk of hydrogen embrittlement.

NOTE 4—Historically, hexavalent-chromium temperature limitations have restricted their ability to be applied prior to baking. Hexavalent-chromium-free passivates are known to withstand higher temperatures. After consultation with chemical supplier or experimentation, electroplaters may adopt other suitable baking sequences.

6.6 *Reactivation Treatment*—Electroplated surfaces passivated as a result of the baking operation shall be reactivated before receiving a supplementary treatment.

NOTE 5—Surfaces should be activated as soon as possible following baking and handled carefully to avoid contamination and maintain an active surface for post processing. Proprietary methods are available to prepare the surface or a 2 % v/v sulfuric acid in deionized water or a 7 to 10 g/L solution of sulfamic acid in deionized water can be used.

6.7 *Supplementary Treatments*—The supplementary film treatment for Types II, III, V, and VI shall be in accordance with Practice B201 (see Notes 6 and 7). The treatment required for conversion to Type IV shall be in accordance with Guide D2092.

NOTE 6—The zinc surface is attacked by supplementary treatments, thereby diminishing the amount of metallic zinc present. With Classes Fe/Zn25 and Fe/Zn12, this reduction is insignificant; but it is significant with Fe/Zn8 and Fe/Zn5. Therefore, it is recommended that supplementary treatments not be applied to zinc coatings having a nominal thickness less than 5 µm.

NOTE 7—Although Types V and VI are technically not "chromate" films and they do not contain leachable hexavalent chromium ions, they are supplemental coatings that render the active zinc surface passive and provide added protection to the steel part.

7. Coating Requirements

7.1 *Thickness*—The thickness shall be specified in accordance with 4.1 and 5.1 (see Note 6).

7.1.1 *Significant Surfaces*—Significant surfaces are areas where minimum thicknesses to be met shall be designated on

the applicable drawing or by the provision of a suitably marked sample. Significant surfaces may be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the article when assembled in normal position or which are the source of corrosion products that deface visible surfaces on the assembled article.

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

NOTE 8—The dimensional tolerance of most threaded articles, such as nuts, bolts, screws, and similar fasteners with complementary threads, normally does not permit the application of a coating thickness much greater than 8.0 µm. If heavier coatings are required, allowance for the deposit buildup must be made during the manufacture of the threaded articles.

7.2 *Adhesion*—The adhesion of the coating shall be such that when examined in accordance with 10.2, the coating shall not show separation from the basis metal at the interface.

7.3 *Luster*—Unless otherwise specified by the purchaser, a bright, semi-bright, or dull finish shall be acceptable.

7.4 *Corrosion Resistance*—Zinc coatings with Types II, III, V, and VI treatments shall show neither corrosion products of zinc nor basis metal corrosion products at the end of the test periods described in Table 2 when tested by continuous exposure to salt spray in accordance with 10.3. The appearance of corrosion products when examined with 20/20 eyesight at normal reading distance shall be cause for rejection, except that white corrosion products 6 mm or less from the edges of specimens shall not constitute failure. For corrosion resistance requirements, see Table 2.

7.5 *Workmanship*—The surface of the electroplated article shall be uniform in appearance, free of visible coating defects, such as blisters, pits, roughness, nodules, burning, cracks, or unplated areas, and other defects that will affect the function of the coating. The coating shall not be stained or discolored. However, superficial staining that results from rinsing or slight discoloration resulting from any drying or baking operation to relieve hydrogen embrittlement, shall not be cause for rejection. On articles in which a visible contact mark is unavoidable, its position shall be that chosen by the purchaser. The electroplated article shall be clean and free of damage.

8. Sampling

8.1 The purchaser and producer are urged to employ statistical process control in the coating process. Properly performed, statisitical process control will assure coated products of satisfactory quality and will assure the amount of acceptance inspection. The sampling plan used for the inspection of the quality coated article shall be agreed upon between the purchaser and producer.

8.1.1 When a collection of coated articles (inspection lot, see 8.2) is examined for compliance with the requirements placed on the articles, a relatively small number of the articles (sample) is selected at random and is inspected. The inspection lot is then classified as complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria for compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B602, Guide B697, and Test Method B762 contain sampling plans that are designed for sampling inspection of coatings.

8.1.2 Test Method B602 contains four sampling plans, three for use with tests that are nondestructive and one when they are destructive. Test Method B602 provides a default plan if one is not specified.

8.1.3 Guide B697 provides a large number of plans and also gives guidance in the selection of a plan. Guide B697 provides a default plan if one is not specified.

8.1.4 Test Method B762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numeric value and certain statistical requirements must be met. Test Method B762 contains several plans and also gives instructions for calculating plans to meet special needs. Test Method B762 provides a default plan if one is not specified.

8.1.5 Practice F1470 may be used for fasteners such as internally threaded, externally threaded, and nonthreaded fasteners and washers. This practice provides for two plans: one designated the "detection process" and one designated the "prevention process." The purchaser and producer shall agree on the plan to be used.

8.2 An inspection lot shall be defined as a collection of coated articles that are the same kind, that have been produced to the same specification, that have been coated by a single supplier at one time or approximately the same time, under essentially identical conditions, and that are submitted for acceptance or rejection as a group.

9. Specimen Preparation

9.1 *Electroplated Parts or Separate Specimens*—When the electroplated parts are of such form, shape, size, and value as to prohibit use thereof, or are not readily adaptable to a test specified herein, or when destructive tests of small lot sizes are required, the test shall be made by the use of separate specimens plated concurrently with the articles represented. The separate specimens shall be of a basis metal equivalent to that of the articles represented. "Equivalent" basis metal includes chemical composition, grade, condition, and finish of surface before electroplating. For example, a cold-rolled steel surface shall not be used to represent a hot-rolled steel surface. Due to the impracticality of forging or casting separate test specimens, hot-rolled steel specimens may be used to represent forged and cast steel articles. The separate specimens may also be cut from scrap castings when ferrous alloy castings are being electroplated. These separate specimens shall be introduced into a lot at regular intervals before the cleaning operations, preliminary to electroplating, and shall not be separated therefrom until after completion of electroplating. Conditions affecting the electroplating of specimens, including the spacing, plating media, bath agitation, temperature, etc., in

respect to other objects being electroplated, shall correspond as nearly as possible to those affecting the significant surfaces of the articles represented. Unless a need can be demonstrated, separately prepared specimens shall not be used in place of production items for nondestructive and visual examinations.

9.2 *Thickness and Adhesion Specimens*—If separate specimens for thickness and adhesion tests are required, they shall be strips approximately 25 mm wide, 100 mm long, and 1 mm thick.

9.3 *Corrosion Resistance Specimens*—If separate specimens for corrosion resistance tests are required, they shall be panels not less than 150 mm long, 100 mm wide, and approximately 1 mm thick.

9.4 *Hydrogen Embrittlement Specimens*—If specimens are required, the configuration shall be that specified by the purchaser (see 9.1).

10. Test Methods

10.1 *Thickness:*

10.1.1 Unless otherwise specified, the thickness of the coating shall be determined by Test Methods B487, B499, B504, B567, B568, or B748 as applicable.

NOTE 9—Thickness methods that rely on the purity of the zinc deposit may not be sufficiently accurate when evaluating coatings produced from non-cyanide zinc solutions. These methods would include Test Methods B504, B567, and B568.

10.1.2 MIL-STD-1312, Test 12, is not prohibited from being used for thickness measurements of electroplated fastener hardware.

10.1.3 Other methods may be used if it can be demonstrated that the uncertainty of the measurement with these methods is less than 10 %.

10.1.4 Make thickness measurements of zinc electroplatings, Types II, III, IV, V, and VI after application of the supplementary treatments. When Test Methods B504, B567, or B568 are used, remove the supplementary treatment prior to testing. The chromate, passivate, or supplemental film may be removed from the underlying zinc coating by using a very mild abrasive (a paste of levigated alumina rubbed on with a suitable applicator such as a swab). The phosphate coating may be removed from Type IV coating by a concentrated (28 %) ammonia solution that quickly dissolves the phosphate coating but does not attack the underlying zinc.

10.2 *Adhesion*—Determine adhesion by any suitable procedure in accordance with Practice B571.

10.3 *Corrosion Resistance*—When specified in the contract or purchase order, determine the corrosion resistance in accordance with Practice B117. Subject the selected samples to the salt spray test; the length of time to be applicable for the type of supplementary coating shall be in accordance with the requirements of 7.4. To secure uniformity of results, age Types II, III, V, and VI supplementary coatings at room temperature for 24 h before subjection to the salt spray. The salt spray test shall commence within 72 h of the completion of the aging period.

NOTE 10—Salt spray testing is much more severe on chromated zinc deposits when these deposits are subjected to greater than 15° from vertical in the chamber as specified in Practice B117 and very severe on horizontal surfaces. For these reasons a flat test panel should be used to evaluate the process capability and the angle should be controlled to ensure consistent results.

10.4 *Hydrogen Embrittlement Relief*—When specified in the contract or purchase order, prepare and test the satisfactory behavior of parts or specimens to indicate freedom from hydrogen embrittlement. When tested, parts or specimens representative of those parts tested shall not crack or fail by fracture.

10.5 *Visual Examination*—Examine material for compliance with the requirements of luster (7.3) and workmanship (7.5) after electroplating.

11. Rejection

11.1 Coatings not conforming to this specification or to authorized modification shall be rejected. They may be reconsidered for inspection in accordance with Test Method B602.

12. Certification

12.1 The purchaser may require in the purchase order or contract that the producer or supplier provide certification that the finish was produced and tested in accordance with this specification and found to meet the requirements. The purchaser may similarly require that a report of the test results be furnished.

12.2 When specified by the purchaser, the test report shall include the following information:

12.2.1 A reference to this specification,

12.2.2 A reference to the test method(s) used (see Section 10),

12.2.3 The location(s) of the test area(s) on each specimen,

12.2.4 The quantity of specimens tested,

12.2.5 The name of the operator and the testing laboratory,

12.2.6 The date(s) on which the test(s) was (were) performed,

12.2.7 Any circumstances or conditions thought likely to affect the results or their validity,

12.2.8 Any deviation from the test method specified, and

12.2.9 The results of the test(s) (see Section 7).

13. Packaging and Packing

13.1 Preservation, packaging, and packing methods for zinc-electroplated parts or articles used by a supplier shall be such as to preclude damaging during shipment and handling.

14. Keywords

14.1 electrodeposited coatings, passivates, chromates; electrodeposited coatings, zinc

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser as part of the purchaser's order or contract and for all agencies of the United States Government.

S1. Responsibility for Inspection

S1.1 The producer or supplier shall be responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser retains the right to perform any of the inspections and tests set forth in this specification where such inspections and tests are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

APPENDIXES

(Nonmandatory Information)

X1. SERVICE LIFE OF ZINC

X1.1 The service life of zinc coating is a function of its thickness and the type of environment to which it is exposed. While the conditions of exposure and uses of electroplated metal are so varied that it is not definitely possible to predict the exact life of articles protected by a coating of a given thickness, those using zinc coatings can draw on the wealth of practical experience at hand, supplemented by results of corrosion tests carried out over the years. As a result of large-scale and long-range tests conducted by ASTM and other organizations, there is excellent information on the corrosion behavior of zinc and zinc coatings. The following data, based on worldwide testing, can be used to compare the behavior of electrodeposited coatings of zinc in various atmospheres. The values are only relative, since individual studies in various parts of the world have resulted in figures which vary widely from these averages.

Atmosphere	Mean Corrosion Rate
Industrial	5.6 µm/year
Urban nonindustrial or marine	1.5 µm/year
Suburban	1.3 µm/year
Rural	0.8 µm/year
Indoors	considerably less than 0.5 µm/year

NOTE X1.1—The mean corrosion rate given pertains to zinc only and does not include a corrosion rate when zinc is passivated or in contact with other materials.

X2. EXAMPLES OF APPROPRIATE SERVICE CONDITIONS AND DESCRIPTION OF SERVICE CONDITIONS

X2.1 *SC 4—Very Severe*—Exposure to harsh conditions, or subject to frequent exposure to moisture, cleaners, and saline solutions, plus likely damage by denting, scratching, or abrasive wear. Examples are: plumbing fixtures, pole line hardware.

X2.2 *SC 3—Severe*—Exposure to condensation, perspiration, infrequent wetting by rain, and cleaners. Examples are: tubular furniture, insect screens, window fittings, builder's hardware, military hardware, washing machine parts, bicycle parts.

X2.3 *SC 2—Moderate*—Exposure mostly to dry indoor atmospheres but subject to occasional condensation, wear, or abrasion. Examples are: tools, zippers, pull shelves, machine parts.

X2.4 *SC 1—Mild*—Exposure to indoor atmospheres with rare condensation and subject to minimum wear or abrasion. Examples are: buttons, wire goods, fasteners.

X3. HYDROGEN EMBRITTLEMENT CONSIDERATION

X3.1 *General Discussion*—In the discussion of material susceptibility and the evaluation of fractures of plated items, users are cautioned to be aware that many failure mechanisms are possible. It is important to understand that often multiple conditions drive appropriate requirements for plating, thickness, stress relief baking, in-application protection, etc.

X3.1.1 When atomic hydrogen enters steel and certain other metals and alloys, with time it can cause loss of ductility or strength, or both, 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.

X3.1.2 *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 (see Terminology F2078).

X3.2 *Research Information*—Findings from ongoing research related to hydrogen embrittlement of steel are summarized in ISO Technical Report ISO/TR 20491.

X3.3 *Material Susceptibility*—Material susceptibility is a function of the material condition (metallurgical/ mechanical) 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 or hardness, or both) has a first order effect on HE susceptibility. As strength/hardness increase, steel becomes less ductile, less tough, and more susceptible to HE. By the same token, at equal strength/hardness, steel that exhibits lower toughness is inherently more brittle and more susceptible to HE. The susceptibility of steel increases significantly when the specified tensile strength is above 1200 MPa (39 HRC). Steels with specified tensile strengths below 1200 MPa (39 HRC) normally have no significant susceptibility to internal HE failure due to the electroplating process. 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 steels were produced by well controlled manufacturing processes using adequate quality chemical composition. The critical strength/hardness threshold for heat treated quench and tempered steel will vary for a given product due to second order effects of chemistry, tempering temperature, and sub-microstructure. Additionally, nonhomogeneity of the metallurgical structure resulting from poorly controlled heat treatment (for example, incomplete martensite transformation or unintended carburization) or impurities such as non-metallic inclusions, or both, can dramatically increase the susceptibility of the steel in ways that are measurable but unpredictable. Based on both scientific research and longstanding industry practice, with respect to Internal HE avoidance it is appropriate to consider susceptible steel products as those having minimum specified strength/hardness above 1200 MPa (39 HRC).

X3.4 *Process and Material Considerations*—The following are some general recommendations for managing the risk of HE.

X3.4.1 Clean the steel in non-cathodic alkaline solutions and in inhibited acid solutions.

X3.4.2 Use abrasive cleaners for high strength steels having strengths above 1200 MPa (39 HRC).

X3.4.3 Manage anode/cathode surface area and efficiency for proper control of applied current densities. High current densities increase hydrogen charging.

X3.4.4 Use high efficiency plating processes such as zinc chloride or acid cadmium.

X3.4.5 Control the plating bath temperature to minimize the use of brighteners.

X3.4.6 Select raw materials with a low susceptibility to HE by controlling steel chemistry, microstructure, and mechanical properties.

X3.5 *Process Control Verification*—Test Method F1940 is designed to be used as a test method for process control to minimize the risk of Internal HE. Periodic sampling inspections are conducted according to a test plan designed for each specific process. The periodic inspections are designed to initially establish, and subsequently verify over time, the ability of a process to coat parts that are not at risk of failing from Internal HE.

SUMMARY OF CHANGES

Committee B08 has identified the location of selected changes to this standard since the last issue (B633 – 15) that may impact the use of this standard. (Approved March 1, 2019.)

(1) Added the Introduction.
(2) Raised mandatory post baking requirements for electroplated steel parts from 1000 MPa to 1200 MPa tensile strength.
(3) Added Appendix X3.

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