Designation: B 650 – 95

Standard Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Substrates[1]

This standard is issued under the fixed designation B 650; 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 Department of Defense.

1. Scope

1.1 This specification covers the requirements for electrodeposited chromium coatings applied to ferrous alloys for engineering applications.

1.2 Electrodeposited engineering chromium, which is sometimes called "functional" or "hard" chromium, is usually applied directly to the basis metal and is much thicker than decorative chromium. Engineering chromium is used for the following:

1.2.1 To increase wear and abrasion resistance,

1.2.2 To increase fretting resistance,

1.2.3 To reduce static and kinetic friction,

1.2.4 To reduce galling or seizing, or both, for various metal combinations,

1.2.5 To increase corrosion resistance, and

1.2.6 To build up undersize or worn parts.

1.3 *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:*

B 117 Practice for Operating Salt Spray (Fog) Apparatus[2]

B 177 Practice for Chromium Electroplating on Steel for Engineering Use[2]

B 183 Practice for Preparation of Low-Carbon Steel for Electroplating[2]

B 242 Practice for Preparation of High-Carbon Steel for Electroplating[2]

B 320 Practice for Preparation of Iron Castings for Electroplating[2]

B 374 Terminology Relating to Electroplating[2]

B 487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section[2]

B 499 Test Method for Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals[2]

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method[2]

B 507 Practice for Design of Articles to Be Electroplated on Racks[2]

B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry[2]

B 571 Test Methods for Adhesion of Metallic Coatings[2]

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings[2]

B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings[2]

B 762 Method of Variables Sampling of Metallic and Inorganic Coatings[2]

B 849 Specification for Pre-Treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement[2]

B 850 Specification for Post-Coating Treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement[2]

D 3951 Practice for Commercial Packaging[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

F 1459 Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement[5]

2.2 *Other Standard:*

MIL-S-13165 Shot Peening of Metal Parts[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *significant surfaces*—all surfaces upon which a deposit of controlled thickness is required.

3.1.1.1 *Discussion*—When a controlled deposit is required in holes, corners, recesses, and similar areas, special racking, auxiliary anodes or shielding, or both, will be necessary. With the best practices there will be areas where a controlled deposit is impossible.

3.2 Definitions used in this specification are in accordance with Terminology B 374.

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[1] This specification is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatingsand is the direct responsibility of Subcommittee B08.08.01on Engineering Coatings.

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[2] *Annual Book of ASTM Standards*, Vol 02.05.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 15.03.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4. Classification

4.1 Electrodeposited chromium coatings in accordance with this specification are classified by the thickness of the coating as follows:

Class No.	Chromium Thickness, µm	Typical Application
1	2.5 to 25	reduce friction; anti-galling, light wear resistance
2	>25 as specified	buildup to dimension specified for salvage or as required for severe wear resistance

4.2 Unless otherwise specified by suitably marked drawings or samples, only those surfaces that can be touched with a 20-mm diameter ball shall be considered significant. In holes, corners, recesses, and other areas where a controlled deposit cannot be obtained under normal electroplating conditions, the thickness of the deposit may be that which results from control on the significant surfaces.

5. Ordering Information

5.1 The purchaser shall exercise the desired options of this standard. Ordering documents shall specify the following information:

5.1.1 Title, ASTM designation, and issue date of this specification,

5.1.2 Alloy and metallurgical condition of the product to be chromium plated,

5.1.3 Ultimate tensile strength of the material to be plated,

5.1.4 Heat treatment required for stress relief and whether it has been performed or is required,

5.1.5 The significant surfaces if different from the 20-mm ball rule (see 3.1.1),

5.1.6 Thickness of the deposit or class (see 4.1),

5.1.7 Control record requirements,

5.1.8 Preproduction test specimens, if required,

5.1.9 Sampling plan, if different from that specified in Test Method B 602 (see Section 8),

5.1.10 The number of test specimens for destructive testing (see 7.1),

5.1.11 Thickness, adhesion, porosity, and hydrogen embrittlement tests required (see Section 6),

5.1.12 Whether separate test specimens will be used (see 7.1 and 7.5),

5.1.13 Where required, any special requirements for parts that are subsequently ground to size,

5.1.14 Where required, the base metal finish in terms of center line average (CLA) or arithmetic average (AA), and

5.1.15 Where required, dimensional tolerances allowed for the specified coating thickness or class.

5.2 The manufacturer of the parts to be electroplated shall provide the electroplating facility with test specimens (see Section 7) to be electroplated for conformance tests as requested for preparation, control, inspection, and lot acceptance unless other arrangements have been made between the purchaser and the electroplating facility.

6. Coating Requirements

6.1 The appearance of the chromium coating on the significant surfaces of the product shall be smooth and free of visual defects such as blisters, pits, roughness, cracks, burned deposits, uncoated areas, or macrocracking of the deposit that is visible without magnification. The boundaries of electroplating that cover only a portion of the surface shall, after finishing as indicated on the drawing, be free of beads, nodules, jagged edges, or other irregularities that will interfere with the functioning of the plated part. Imperfections and variations that arise from surface conditions of the basis metal (scratches, pores, roll marks, inclusions, etc.) and that persist in the finish despite the observance of good metal finishing practices shall not be cause for rejection.

NOTE 1—Applied finishes generally perform better in service when the substrate over which they are applied is smooth and free of torn metal, inclusions, pores, and other defects. It is recommended that the specifications covering the unfinished product provide limits for these defects. A metal finisher can often remove defects through special treatments such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing, which are not normal in the treatment steps preceding the application of the finish and will add to the cost. When they are desired, they are the subject of a special agreement between the purchaser and the seller.

6.2 In cases where design for maximum fatigue life is a consideration the parts should be shot peened (see MIL-S-13165C) or given an alternate mechanical treatment to compressively stress the surface.

6.3 *Stress Relief Treatment* (See headnote at the beginning of this specification.):

6.3.1 All steel parts having an ultimate tensile strength of 1000 MPa (150 000 psi—approximately 32 HRC) or greater, that may contain residual stress caused by various fabrication operations such as machining, grinding, straightening, or cold forming, will require one of the stress relief heat treatments prescribed in Specification B 849 prior to electroplating. In all cases, the duration of heat treatment shall commence from the time at which the whole of each part attains the specified temperature.

6.3.1.1 The treatment selected, of necessity, must be based upon experience with the part or empirical test data. Therefore, Class SR-0 treatment is provided for parts that the purchaser wishes to exempt from treatment. However, many, if not most, steels with a tensile strength in excess of 1000 MPa will become embrittled when plated with chromium. The stress relief and hydrogen embrittlement relief treatments are essential for the safe performance of chromium plated items fabricated from those steels. Selection of Class SR-0 or ER-0 requires thorough knowledge of the embrittlement susceptibility of the specific steel employed. When the purchaser specifies Class SR-0 or ER-0, the purchaser assumes sole responsibility for any embrittlement failure of the part. The relative susceptibility of a steel can be determined by subjecting it to the Disk Rupture Test of Test Method F 1459. When no stress relief treatment is specified by the purchaser then Class SR-1 shall be applied.

6.3.2 Parts having surface hardened areas that would suffer an unacceptable reduction in hardness by treatment in accordance with Specification B 849 shall be heat-treated at a lower temperature but not less than 130°C for a minimum period of 8 h. This treatment is applicable for parts made of steel with an actual tensile strength below 1400 MPa. The purchaser may

require that the heat-treatment temperature shall not reduce the surface hardness. Shorter times at higher temperatures may be used, if the resulting loss of surface hardness is acceptable.

6.3.3 If stress relief is given after shot peening or other cold working processes to introduce beneficial compressive stresses, the temperature shall not exceed 230°C.

6.4 *Hydrogen Embrittlement Relief*:

6.4.1 Heat treatment appropriate for the tensile strength of the electroplated part (see Specification B 850) shall be performed to reduce the risk of hydrogen embrittlement. In all cases, the duration of the heat treatment shall commence from the time at which the whole part attains the specified temperature. See 6.3.1.1 for important embrittlement relief information regarding the selection of ER-0. When no embrittlement relief treatment is specified by the purchaser then Class ER-1 shall be applied.

6.4.2 Begin the embrittlement relief heat-treatment as soon as practical following the plating process but no longer than 1.5 h.

6.4.3 Parts or representative specimens shall be tested for compliance in accordance with 7.5.

6.5 *Thickness*—The thickness of the coating everywhere on the significant surface(s) shall conform to the requirements of the specified class as defined in Section 3 (see 7.2).

NOTE 2—The coating thickness requirements of this specification are a minimum requirement, that is, the coating thickness is required to equal or exceed the specified thickness everywhere on the significant surfaces (see 4.1). Variation in the coating thickness from point to point on a coated article is an inherent characteristic of electroplating processes. Therefore, the coating thickness must exceed the specified value at some point on the significant surfaces to ensure that the thickness equals or exceeds the specified value at all points. Hence, in most cases, the average coating thickness on an article will be greater than the specified value; how much greater is largely determined by the shape of the article (see Practice B 507) and the characteristics of the electroplating process. In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all of the articles within a production lot are to meet the thickness requirement, the average coating thickness for the production lot as a whole will be greater than the average necessary to ensure that a single article meets the requirement. This may not apply to parts that are ground after plating.

6.6 *Adhesion*—The coating shall be sufficiently adherent to the basis metal to pass the adhesion test specified (see 7.3). These tests are, with the possible exception of the heat quench test, all destructive and therefore, in most cases, should be performed on test panels.

NOTE 3—Adhesion may be influenced by the method of pretreating the base metal and the type of steel used as a basis metal. Helpful information is given in Practices B 177, B 183, B 242, and B 320.

6.7 The coating shall be sufficiently free of pores to pass the porosity test specified (see 7.4).

6.8 *Workmanship*—Adding to (spotting in) or double electroplating, unless evidence of a satisfactory bond is established, shall be cause for rejection. Stripping and replating is permitted but parts having an ultimate tensile strength greater than 1000 MPa or a hardness greater than 32 HRC that are acid stripped shall be rebaked (see 6.3) before plating. Baking after stripping is not necessary if the parts are stripped anodically in an alkaline solution.

6.9 *Supplemental Requirements*—If parts are electroplated and subsequently ground to size, the grinding shall be done with a proper coolant, never dry, and with a sufficiently light cut to prevent cracking.[7] Macrocracking, visually observed without magnification after grinding, shall be cause for rejection.

6.10 *Packaging*—Part(s) plated for the U.S Government and Military, including subcontracts, shall be packaged in accordance with Practice D 3951.

7. Test Methods

7.1 *Separate Specimens*—When the coated articles are of such a form as not to be readily adaptable to a test specified herein, when destructive tests would unreasonably reduce the number or pieces in small lots, when the pieces are too valuable to be destroyed, and when specified by the purchaser, tests 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 prior to electroplating. The purchaser is responsible for providing these specimens (see section 5.3). These specimens shall be introduced into a lot 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 and positioning in respect to anodes and to other objects being electroplated, shall correspond as nearly as practicable 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 tests and visual examination.

7.2 *Thickness*—Measure the thickness of the chromium by one of the following methods; other methods may be used if it can be demonstrated that the uncertainty of the method is less than 10 % or unless direct physical measurement by mechanical means of the final part dimension is specified.

7.2.1 *Microscopical*—Test Method B 487 (this method is destructive).

7.2.2 *Magnetic*—Test Method B 499.

7.2.3 *Coulometric*—Test Method B 504 (this method destroys the coating in the test location).

7.2.4 *X-Ray Spectrometry*—Test Method B 568.

7.3 *Adhesion*:

7.3.1 The coated article or designated test specimen shall pass one of the following tests, or any special test particular to the function of the part as specified by the purchaser.

7.3.1.1 *Bend Test*—This method is destructive.

7.3.1.2 *File Test*—This method is destructive.

7.3.1.3 *Heat and Quench Test*—This method may affect the heat treatment of the basis metal.

7.3.1.4 *Push Test*—This method is destructive.

7.3.2 These and other adhesion tests are described in Test

[7] Messler, R. W., and Maller, R. R., "A New Inspection Process for Detecting Abusive Grinding Damage in Hard Chromium Plated Parts," *Proceedings of the Airline Plating Symposium*, 1974, is a helpful discussion of the problems in grinding.

Methods B 571. The test selected should take into consideration the size, shape, or thickness of the part. Adhesion tests may at times fail to detect adhesion in the process of degradation; subsequent fabrication may reveal poor or inadequate adhesion that shall be cause for rejection.

7.4 *Porosity*—The coating shall pass one of the following tests as specified by the purchaser:

NOTE 4—It is important to realize that the test duration specified for each test must be used exactly for valid results.

7.4.1 *Ferroxyl Test*—Conduct in accordance with the procedure described in Appendix X1. Observe the results after 10 min. The part fails if more than the number of pores specified by the purchaser per part or per unit area are found.

7.4.2 *Neutral Salt Spray*—Conduct in accordance with Practice B 117. Observe results after 16 h. The part fails if more than the number of pores specified by the purchaser per part or per unit area are found.

7.4.3 *Copper Sulfate Test*—Immerse the coated part in a 15-g/L solution of copper sulfate ($CuSO\ 5H_2O$) for 2 min. Inspect for copper spots that indicate pores. The part fails if more than the number of pores specified by the purchaser per part or per unit area are found.

7.5 *Hydrogen Embrittlement*—Representative sample parts or test specimens (see 7.5.1) plated concurrently with the parts, shall be subjected to a sustained load test. In the case of parts, the samples shall be subjected for 200 h to a sustained tensile load equal to 115 % of the maximum design load for which the part was designed as specified by the purchaser. If test specimens are employed, they shall be subjected for 200 h to a load equal to 75 % of the ultimate tensile strength of the alloy employed. Any fractures or signs of cracks shall be cause for rejection.

7.5.1 Separate specimens for embrittlement relief testing shall be round notched specimens of the alloy being plated or a metallurgically equivalent alternative specified by the purchaser. The specimens shall be prepared with the axis of the specimen perpendicular to the short traverse grain direction and shall conform to Fig. 8 of Test Methods E 8 and shall have a 60 V-notch, the bottom of which shall have a radius of curvature of 0.254 ± 0.0127 mm and the area of which shall be approximately equal to half the area of the specimen's reduced section.

7.5.1.1 The specimen or the raw material from which they may be machined shall be provided by the purchaser or as agreed upon between the purchaser and the seller.

7.5.2 Alternative methods for the determination of the efficacy of the hydrogen embrittlement relief may be used as agreed upon between the purchaser and the seller.

8. Sampling Requirements

8.1 The use of statistical process control in the coating process is strongly recommended. Properly performed, this will help ensure coated products of satisfactory quality and will reduce the amount of acceptance inspection required.

8.2 The sampling plan shall be Test Method B 602 unless otherwise specified by the purchaser. Other sampling plans are contained in Guide B 697 and Method B 762.

8.3 Select a random sample of the size required by the test method selected from the inspection lot (see 8.2). Inspect the articles in the lot for conformance to the requirements of this specification and classify the lot as conforming or not conforming to each requirement in accordance with the criteria of the sampling plans in the method selected.

NOTE 5—Test Method B 602 contains four sampling plans, three of which are to be used with nondestructive test methods. The fourth plan is used where the test method is destructive. The three plans for nondestructive tests differ in the quality level they require of the product; Test Method B 602 requires use of the plan with the intermediate quality level, unless the purchaser specifies otherwise. It is recommended that the purchaser compare the plans with his/her needs and state which plan is to be used. If the plans in Test Method B 602 do not serve those needs, additional ones are given in Guide B 697. Both Test Method B 602 and Guide B 697 list references where additional information on sampling inspection and additional plans are given.

NOTE 6—When both destructive and nondestructive tests exist for the measurement of a characteristic, the purchaser needs to state which is to be used so that the proper sampling plan is selected. Whether or not a test is destructive may not always be clear. A test may destroy the coating but in a noncritical area, or, although it may destroy the coating, the part can be reclaimed by stripping and recoating. The purchaser needs to state whether or not the test is to be considered destructive or nondestructive. The decision is important because the plans for destructive tests are significantly less able to discriminate between acceptable and unacceptable lots. This is because fewer parts are tested in destructive plans.

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

8.5 All specimens used in the sampling plan shall be made of the same basis material in the same metallurgical conditions as the articles being plated to this specification.

8.6 All specimens shall be provided by the purchaser unless otherwise agreed upon by the producer.

9. Keywords

9.1 chromium plating standard; steel

APPENDIX

(Nonmandatory Information)

X1. FERROXYL TEST

X1.1 *Scope*—This method reveals discontinuities, such as pores, in coatings of chromium on iron or steel.

X1.2 *Material*—The test solution is prepared by dissolving 10 g of agar, 10 g of sodium chloride (NaCl), and 1 g of potassium ferricyanide (K Fe(CN)) in 1 L of warm distilled or deionized water.

X1.3 *Procedure*—Clean and degrease the surface to be tested with methyl alcohol or other suitable solvent (avoid inhalation of fumes). Slowly warm the test solution to 93°C to liquify (a borosilicate glass double boiler arrangement is suggested). Apply the warmed test solution to the specimen by one of the following methods: (*1*) dip the specimen in the solution, (*2*) pour the solution over the specimen, or (*3*) dip a piece of filter paper into the solution, allow the excess to drain off, and then apply the wet paper to the test area and allow to remain undisturbed. (Do not apply the solution if its temperature is below 60°C.) Place the test specimen in a horizontal position allowing it to cool to between 21 and 27°C. Begin timing the 10-min test period from the time the agar solution is on the test specimen. At the end of the test period examine the coating or remove the filter paper and examine the aside that was in contact with the specimen. Blue spots indicate basis metal corrosion or porosity.

X1.4 *Report:*

X1.4.1 Report the following information:

X1.4.1.1 Area of the surface tested,

X1.4.1.2 Total number and diameter of all spots visible to the unaided eye, and

X1.4.1.3 The highest number of spots visible at one time through a template placed on the surface with a 25 by 25-mm opening.