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Standard Guide for Engineering Chromium Electroplating¹

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1. Scope

1.1 This guide provides information about the deposition of chromium on steel for engineering uses. This is sometimes called “functional” or “hard” chromium and is usually applied directly to the basis metal and is usually thicker than decorative deposits.

1.2 This guide is not intended as a standardized procedure, but as a guide for obtaining smooth, adherent coatings of chromium of a desired thickness while retaining the required physical and mechanical properties of the base metals. Specified chromium electrodeposits on ferrous surfaces are defined in Specification B 650.

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 183 Practice for Preparation of Low-Carbon Steel for Electroplating²
- B 242 Practice for Preparation of High-Carbon Steel for Electroplating²
- B 244 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments²
- B 253 Guide for Preparation of Aluminum Alloys for Electroplating²
- B 254 Practice for Preparation of and Electroplating on Stainless Steel²
- B 281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings²
- B 320 Practice for Preparation of Iron Castings for Electroplating²
- B 322 Practice for Cleaning Metals Prior to Electroplating²

- B 481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating²
- B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section²
- B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method Nonmagnetic Coatings on Magnetic Basis Metals²
- B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method²
- B 507 Practice for Design of Articles to Be Electroplated on Racks²
- B 558 Practice for Preparation of Nickel Alloys for Electroplating²
- B 568 Test Method for Measurement of Coating Thickness by X-ray Spectrometry²
- B 571 Practice for Qualitative Adhesion Testing of Metallic Coatings²
- B 578 Test Method for Microhardness of Electroplated Coatings²
- B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings²
- B 630 Practice for Preparation of Chromium for Electroplating with Chromium
- B 650 Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Substrates²
- B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings²
- B 762 Test Method of Variables Sampling of Metallic and Inorganic Coatings²
- B 849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement²
- B 850 Guide for Post-Coating Treatments Steel for Reducing the Risk of Hydrogen Embrittlement²
- B 851 Specification for Automated Controlled Shot Peening of Metallic Articles Prior to Nickel, Autocatalytic Nickel, or Chromium Plating, or as Final Finish²
- F 519 Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments³

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

³ *Annual Book of ASTM Standards*, Vol 15.03.

2.2 Military Standard:

MIL-S-13165B Shot Peening of Metal Parts⁴

3. Substrates

3.1 Engineering chromium may be plated directly to the surface of a number of commonly used engineering metals such as aluminum, nickel alloys, cast iron, steels, copper, copper alloys, and titanium. The bond strengths of the chromium varies with metallic substrate. Nevertheless, if the procedures cited in the appropriate references are followed, the bond strength is such that grinding and honing can be conducted without delamination of the coating.

3.2 *Smoothness*—The smoothness of the material surface to be electroplated should be adequate to meet the requirements of the finished product. Chromium electrodeposits do not exhibit leveling, and consequently the surface roughness of the electrodeposit will always be greater than that of the substrate. Any mechanical operations that can result in grinding checks or glazing of the metal are detrimental and should be eliminated. The required surface smoothness may be obtained by suitable chemical, mechanical, or electrochemical procedures. Depending upon the thickness of the electrodeposit and the smoothness required of the electrodeposit, grinding of the electrodeposit may be required.

3.3 *Fatigue Considerations*—Cracking that can occur in chromium electrodeposits either as a function of the plating bath chemistry or the plating conditions, or both, or as a result of grinding of the electrodeposit can lead to a reduction in the fatigue life of the electroplated part. If this is a design consideration, the use of mechanical methods such as shot peening (see Specification B 851 or MIL-S-13165C, or both) or autofrettage to compressively stress the surface can increase the fatigue strength. This should be done after any stress-relieving heat treatment.

3.4 *High-Strength Steel Stress Relief*:

3.4.1 All steel parts having an ultimate tensile strength of 1000 MPa (150 000 psi, approximately 32 HRC) or greater, which may contain residual stress caused by various fabrication operations such as machining, grinding, straightening, or cold-forming, usually will require one of the stress relief bakes prescribed in Specification B 849 prior to electroplating. In all cases, the duration of the bake shall commence from the time at which the whole of each part attains the specified temperature. This stress relief is essential if hydrogen embrittlement from subsequent operations is to be avoided.

3.4.2 Parts having surface-hardened areas that would suffer an unacceptable reduction in hardness by baking in accordance with Specification B 849 may be baked at a lower temperature but not less than 130°C for a minimum period of 8 h. Shorter times at higher temperatures may be used, if the resulting loss in surface hardness is acceptable.

3.5 *Oxidation*—All possible precautions should be taken to prevent oxidation of the metal surface between the final operations of mechanical preparation and electroplating, particularly with steel substrates. Materials such as aluminum and

titanium have an inherent oxide film on the surface that can only be removed or minimized just prior to the electroplating process (see 6.1.1 and 6.1.2). When conditions are especially unfavorable, definite steps must be taken to meet this important requirement, including storage in a noncorrosive environment, or the use of a suitable coating to exclude air and moisture.

4. Racks and Anodes

4.1 Steel, cast iron, and stainless steel parts to be electroplated may be racked at any convenient stage in the preparatory process but preferably prior to the final cleaning and etching. Aluminum, titanium, and certain nickel alloys may need to have cleaning and etching operations done before racking due to entrapment of cleaning and etching solutions in the plating rack which can result in adhesion failures due to seepage during chromium electroplating.

4.2 See Practice B 507 for guidance on rack design, but note that while the general principles of good racking as used in other electroplating processes apply, the use of much higher current densities and the desirability of securing coatings of uniform thickness and quality on desired areas require rack construction designs and methods that are much more exacting. The design of racks for chromium electroplating on the various base metals previously mentioned for functional use should provide for the following to the greatest possible extent.

4.2.1 There must be sufficient current-carrying capacity of both cathode and anode circuits to all parts of the rack.

4.2.2 There must be positive electrical contact to the parts to be electroplated, to the anodes, and to the tank contact bus bars.

4.2.3 There must be uniform current distribution on the parts to be electroplated. This often requires anodes of special shapes conforming to the shape of the part or area to be electroplated.

4.2.4 It may be necessary to use thieves, robbers, or guards, which are auxiliary metallic conductors placed near points of abnormally high current density to attract the current away from such points; and shields, which are parts made of nonconductive materials and placed to disperse the current in areas where it tends to concentrate unduly.

4.2.5 It is important to protect areas that are to remain free of any chromium electroplate by the use of masks made of rigid, nonconductive materials placed against the substrate, or stop-offs, which are especially compounded nonconductive tapes, waxes, lacquers, or plastics for the protection of such substrates. Lead and aluminum tapes will provide a sharp line of demarcation between coated and uncoated areas with a minimum of buildup.

4.2.6 Plugs (conducting and nonconducting) may be used in holes not requiring electroplating to produce a sharp edge without grooves around the periphery of the holes.

4.2.7 It is very important to remember that improperly applied stop-off materials or poorly designed racks can entrap acids that can cause corrosion of the basis material or contamination of the solutions used in subsequent operations, or both.

4.2.8 Construction materials must be used that are sufficiently insoluble and noncontaminating to provide the desired rack life.

4.2.9 Components must be placed in such positions that gas from the parts, rack, thieves, masks, and anodes escapes freely

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

and does not become entrapped so as to prevent electroplating on areas that should be electroplated.

4.3 *Anodes*—Lead anodes containing 4 to 6 % antimony, 4 to 7 % tin, or 1 % silver, or a combination thereof, are satisfactory. Chemical lead is also satisfactory where hardness and rigidity are not important. However, it tends to form great quantities of scale that may fall off on the work and cause pitting or roughness. Lead wire used for small anodes should contain 0.25 % antimony to obtain the best relationship between rigidity and ductility in close tolerance areas. Lead-sheathed steel, copper, or silver may be used when indicated by requirements for strength or conductivity. Platinum, platinum-clad niobium, or even steel rods or wire may be used for internal electroplating of small holes, but the latter will contaminate the bath with iron. If the anode contains little or no lead, the reoxidation of trivalent chromium to the hexavalent state will not take place or will be seriously impaired, which will lead to trivalent buildup in the plating solution and poor results.

4.3.1 Some proprietary baths may require special anodes, which should be recommended by the supplier.

5. Cleaning

5.1 Parts to be electroplated may be cleaned in accordance with Practices B 183, B 242, B 254, B 281, B 320, B 322, B 481, B 558, or B 630, or Guide B 253.

5.2 Mechanical methods of cleaning steel prior to electroplating, including abrasive blasting or light grinding, are also suitable. If parts have been shot-peened to develop a compressively stressed surface, it is important to avoid removing that surface by excessive grinding.

6. Deoxidizing and Etching

6.1 Prior to chromium electroplating, most metals need special preparation in order to achieve maximum adhesion of the chromium to the substrate. Depending on the type and nature of the metal and prior surface preparation steps, various deoxidation and etching methods may be used to activate the substrate prior to chromium electroplating.

6.1.1 *Aluminum*—Chromium may be electroplated directly onto most cast and wrought aluminum materials used for engineering purposes. Guide B 253 offers many useful methods for preparing aluminum prior to chromium electroplating. The removal of the ever-present, tenacious oxide film on the surface of aluminum is what makes electroplating difficult. When using test methods in which a zinc immersion film is applied to the aluminum surface for protection against oxide formation, the article to be plated must enter the chromium-plating solution under live current.

6.1.2 *Titanium*—Like aluminum, titanium has an ever-present tenacious oxide film that must be removed prior to plating. Practice B 481 offers many ways to prepare titanium prior to chromium electroplating.

6.1.3 *Nickel Alloys*—Several different activation methods are available in Practice B 558 for the preparation of different nickel alloys. The main difficulty with these materials when chromium plating is polarization of the nickel alloy surface prior to plating which results in deactivation of the material and skip plating.

6.1.4 *Copper and Copper Alloys*—Practice B 281 offers many suitable methods for preparing copper and copper alloys prior to chromium electroplating. In general, only deoxidizing of the copper or copper alloy surface is necessary for chromium electroplating.

6.1.5 *Stainless Steel*—Practice B 254 offers many suitable activating procedures for the preparation of stainless steel prior to chromium electroplating. Some stainless steels benefit from a Woods nickel strike prior to chromium electroplating. Polarized surfaces in high-nickel stainless steels can cause skip plating if not properly activated.

6.1.6 *Cast Iron*—Practice B 320 offers many suitable procedures for activating cast iron prior to chromium electroplating. In general, anodic etching in the chromium plating solution is not recommended. Due to the high carbon content in iron castings, anodic etching leaves a carbon smut on the surface of the metal which results in poor adhesion of the chromium.

6.2 Chromium plating on steel is among the most common combination for engineering purposes. Unique activation procedures for steel exist with chromium plating that merit a separate discussion for successful plating as follows.

6.2.1 Etching of the steel before electroplating is ordinarily desirable to obtain satisfactory adhesion of the chromium to the steel. To reduce the increase in roughness resulting from etching, the etching times should be kept as short as is consistent with good adhesion, particularly in the case of highly finished surfaces.

6.2.2 *Anodic Etching in Chromic Acid Solution*—The part to be electroplated may be anodically etched in a solution of approximately the same concentration of chromic acid as the plating solution (for example, 250 g/L (33 oz/gal) at approximately the temperature used in plating. There should not be any sulfuric acid present. Enter the tank with the current off and make the part anodic for 10 s to 2 min at a current density of 11 to 32 A/dm²(100 to 400 A/ft²). Tank voltage is normally 4 to 5 V. There does not have to be rinsing before transfer to the plating tank, but parts should be thoroughly drained to prevent spillage of the etching solution.

6.2.3 *Anodic Etching in the Plating Solution*—Using the same times and current density described in 6.2.2, parts can be etched in the plating solution itself. A reversing switch should be provided to make the part anodic. This process is much simpler than that in 6.2.2 and requires one less tank, but has the disadvantage of contaminating the bath with iron, copper, and so forth.

6.2.4 *Anodic Etching in Sulfuric Acid Solution*—A sulfuric acid (H₂SO₄) solution of 50 to 70 volume % 66 Be H₂SO₄ may be used for etching. The temperature should be kept below 30°C and preferably below 25°C. The time of treatment is 10 s to 2 min, and the current density 11 to 54 A/dm²(100 to 500 A/ft²) at 4 to 6 V. Lead cathodes should be used and the tank constructed of a material, such as lead or vinyl, that is resistant to sulfuric acid. Two difficulties that may be encountered that make this process less attractive than those described in 6.2.2 or 6.2.3 are: