



Standard Guide for Engineering Chromium Electroplating¹

This standard is issued under the fixed designation B 177; 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.

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

2.2 Military Standard:

¹ This guide is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.08 on Engineering Coatings.

Current edition approved Nov. 10, 2001. Published January 2002. Originally published as B 177 – 55. Last previous edition B 177 – 93.

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

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

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 and does not become entrapped so as to prevent electroplating

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

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:

6.2.4.1 If the rinsing following etching is incomplete, the drag-in of sulfuric acid changes the chromic acid to sulfate ratio in the chromium plating bath with deleterious results, and

6.2.4.2 In handling parts that are difficult to manipulate, there is a danger of rusting of the surfaces before the part can be introduced into the chromium electroplating bath.

6.2.5 *Slight Etching by Acid-Immersion*—A slight etching may be obtained by a short dip at room temperature in either 10 to 50 volume % hydrochloric acid (HCl 37 weight %) or 5 to 15 volume % sulfuric acid (H₂SO₄ 98 weight %). This is normally used on highly finished steel requiring only a thin chromium deposit as its use may result in less adhesion than other procedures and in hydrogen embrittlement of the steel. Drag-over of either solution into the chromium electroplating bath because of poor rinsing will cause contamination problems.

7. Chromium Electroplating

7.1 Unless the parts are etched by reverse in the plating bath (6.2.3), they are introduced into the chromium electroplating bath after all preparatory operations. Any auxiliary anodes integrated with the rack are connected to the anode bus bar. Steel or ferrous parts to be plated are allowed to reach the bath temperature and electroplating is then commenced. If the parts were etched in the plating solution, plating is initiated when the parts are made cathodic at the end of the etching period using the reversing switch. Most nonferrous metals enter the chromium plating solution under live current and are not placed in the chromium-plating solution for warming prior to electroplating.

7.2 *Electroplating Baths*—In addition to the following two baths, there are various proprietary baths offered that may be satisfactory and should be operated in accordance with the vendor's instructions. Most proprietary chromium plating baths are co-catalyzed plating solutions in which an additional catalyst is used in conjunction with the traditional sulfate anion catalyst. These co-catalysts may use organic based or inorganic based compounds to achieve higher plating efficiencies and are often employed where higher rates of plating and better throwing and covering power are needed. The most recent baths do not use fluoride co-catalysts and do not etch unprotected low current density areas. These baths produce micro-cracked deposits which may be an advantage in some deposits. There are additives, such as selenium, in the patent-free art which will also produce micro-cracked deposits.

7.2.1 This is the most common bath and will deposit chromium at the approximate rate of 25 μm (0.001 in.) in 80 min at 31 A/dm² (2.0 A/in.²).

Chromic acid (CrO ₃)	250 g/L
Sulfate (SO ₄ ²⁻)	2.5 to 3.1 g/L
Ratio CrO ₃ to SO ₄ ²⁻	80 to 100:1
Temperature	55°C (range from 40 to 65°C)
Current density	31 A/dm ² (2 A/in. ²)
Range	25 to 124 A/dm ² (1.6 to 8.0 A/in. ²)

NOTE 1—Many factors influence the choice of current densities. With very great agitation, the highest current density shown is possible with a concomitant decrease in the plating time. As the electrochemical efficiency decreases somewhat with increasing current density and bath temperature, the increase in the plating rate is not linear with the increase in the current density.

NOTE 2—Chromium will plate satisfactorily from baths with chromic acid as dilute as 75 g/L and as concentrated as 500 g/L. The lower concentrations give increased efficiency but the throwing power, which is

always poor, gets worse. The normal high concentration bath is 400 g/L at the same ratio of chromic acid to sulfate as is used with the common 250-g/L bath. The higher concentration bath gives slightly improved throwing power and a deposit that is less prone to cracking, however softer in micro-hardness than the common 250-g/L bath.

NOTE 3—**Warning:** The sulfate anion (SO₄²⁻) is added to the bath as sulfuric acid. The calculated amount should be diluted by adding it to deionized water prior to adding it to the bath. Face shield, chemical goggles, rubber gloves, and other safety equipment should be used when handling sulfuric acid and when making this addition. Consult with appropriate safety manuals or safety personnel, or both, before handling sulfuric acid or chromic acid!

7.2.2 The following co-catalyzed bath gives greatly improved efficiencies in comparison with the standard bath in 7.2.1 under identical conditions. The addition of fluoride or silicofluoride auxiliary catalysts increase the tendency of the bath to etch steel in unprotected low-current density areas, and more masking may be required than is necessary with the standard bath. Analytical control of the silicofluoride is more difficult than the other components, but ion selective methods are satisfactory. This bath will deposit chromium at an appropriate rate of 37.5 μm (0.0015 in.) in 60 min at 31 A/dm² (2 A/in.²).

Chromic acid (CrO ₃)	250 g/L
Sulfate (SO ₄ ²⁻)	1.5 g/L
Silicofluoride (SiF ₆ ²⁻), see Note 4	2.0 g/L
Temperature	55°C
Current density	31 to 62 A/dm ² (2 to 4 A/in. ²)

NOTE 4—**Warning:** The silicofluoride (sometimes shown as fluorosilicate) anion may most conveniently be added as hydrofluorosilicic (fluorosilicic acid), which is commonly sold at a concentration of 31 weight % H₂SiF₆, in which case the addition of 1.6 mL/L will give the concentration of 2.0 g/L in the bath. This acid also requires great care in handling. Consult safety references or personnel before using.

7.2.3 The following bath produces very soft (usually less than 650 VHN₂₅) deposits that are crackfree. The deposits are dull gray in color and can be buffed, if desired. The efficiency is very high and the chromium evidentially deposits in a different crystal structure than is obtained in other baths. There are many modifications reported in the literature and some manufacturers offer proprietary baths.

Chromic acid (CrO ₃)	325 g/L
Sodium dichromate (Na ₂ CrO ₄ 2 H ₂ O)	175 g/L
Sulfate (SO ₄ ²⁻)	0.75 g/L
Temperature range	15 – 25°C
Current density	20 – 90 A/dm ²

NOTE 5—**Warning:** Literature references suggest preparing this bath by adding sodium hydroxide to a 4 Mol chromic acid solution. This is a very dangerous exothermic reaction. The preceding solution should, of course, be handled with all the caution required of standard chromium plating baths.

7.2.4 Black chromium deposits are produced from the following bath. There are also proprietary solutions available. These deposits are frequently used on solar collectors and for applications on steels and other alloys where a more wear-resistant coating than black oxide types is desired. In operating these baths, it is essential that no sulfate be introduced into the bath. All baths of this type include barium salts or other precipitants for sulfate. As the deposit is nonconductive, the maximum thickness that can be expected is 3 to 5 μm which requires 4 to 8 min. Mild steel anodes are usually employed.

Chromic acid (CrO ₃)	250 g/L
Acetic acid, glacial (CH ₃ COOH)	20 mL/L
Barium acetate (Ba(CH ₃ COOH) ₂)	20 g/L
Temperature	20 – 40°C
Current density	5 – 15 A/dm ²

8. Treatments of Chromium Coatings

8.1 *Hydrogen Embrittlement*—Hydrogen evolved during chromium plating is apt to embrittle steel, and the potential for embrittlement increases with the higher strength (harder) steels. Baking appropriate for the tensile strength of the electroplated part must be performed to reduce the risk of hydrogen embrittlement. Guide B 850 lists bakes appropriate for the tensile strength of the electroplated part and should be consulted for post-electroplating baking procedures and classes. In all cases, the duration of the bake shall commence from the time at which the whole part attains the specified temperature. The bake should be performed as soon as possible after the parts are removed from the plating bath, rinsed, and dried in order to reduce the risk of hydrogen embrittlement. Consult Specification B 850 for maximum length of time permitted between plating and baking operations.

NOTE 6—It is suggested that the selection of an appropriate bake be discussed with the purchaser to ensure that the bake selected does not cause distortion in the part or adversely affect its mechanical properties.

NOTE 7—The effectiveness of hydrogen embrittlement relief baking of chromium-plated high-strength steels can be tested in accordance with Test Method F 519.

8.2 *Mechanical Finishing*—Chromium electrodeposits are commonly finished to the required final dimension by grinding, grinding and honing, or lapping. If grinding is very aggressive, removing a large amount of metal per grinding pass and generating high localized temperatures, the chromium is apt to develop a network of macrocracks visible to the naked eye. This condition will greatly reduce the fatigue life of the part and should be avoided. Compressively stressing the substrate surface prior to plating by shot peening (see Specification B 851 or MIL-S-13165C, or both) or other means will help prevent any diminution of the fatigue life. Chromium deposited from the higher concentration sulfate catalyzed baths are less prone to macrocracking during grinding than those deposited under similar conditions from a cocatalyzed bath (see 7.2.2) or the lower concentration sulfate bath (see 7.2.1). Proprietary baths should be evaluated for the tendency towards macrocracking if fatigue life is an important design consideration. For parts loaded in compression or not subject to cyclical applications of stress during operation, or both, this may not be a consideration.¹

9. Repair of Chromium Electrodeposits on Steel Substrates

9.1 A worn chromium electrodeposit may be restored to the original dimension by re-electroplating.

9.2 If the part is completely covered in chromium in the areas originally electroplated, it may be prepared for electroplating in accordance with Practice B 630

9.3 If steel shows through or if the anodic treatment exposes steel, the chromium coating must be completely removed prior to re-electroplating. Stripping the chromium may be done by anodic treatment at 5 to 8 A/dm² (75 A/ft²) in a solution containing 40 to 60 g/L of sodium hydroxide or in a solution containing 40 to 60 g/L sodium carbonate. Either solution should be kept below 25°C during operation using cooling, if necessary. There are also proprietary solutions available which should be operated according to the supplier's instructions.

10. Test Methods

10.1 Guide B 697, with Test Methods B 602 and B 762, will be helpful in choosing statistically appropriate sample sizes for the following test methods.

10.2 *Thickness*—The thickness of the chromium deposit is usually not determined directly, the dimension of the finished part being measured instead. When direct measurement of the thickness of the coating is desired and the part can be sacrificed, it should be done in accordance with Test Method B 487. If a nondestructive method is required, magnetic induction methods in accordance with Test Method B 499 are suitable for chromium over magnetic substrates. Test methods in accordance with Test Methods B 499 can measure coating thicknesses from 2.5 μm to 12 mm (0.1 mil to 0.5 in.). Test Method B 244 may be used accurately for chromium up to 500 μm (0.020 in.) over aluminum or copper alloys but not for titanium. For deposits up to 50 μm (2 mils), Test Method B 504 may be used and does not destroy the part, but does remove the chromium electrodeposit on the area tested, which may necessitate replating. X-Ray fluorescence may be used to measure very thin chromium deposits of 1 to 20 μm (3 μin. to 0.8 mils) in accordance with Test Method B 568. Other test methods may be used by agreement between the purchaser and the seller.

10.3 *Hardness*—Hardness will vary with bath composition and the conditions used for electrodeposition. Hardness should be measured in accordance with Test Method B 578 on a panel plated concurrently with the part unless the part can be sacrificed.

10.4 *Adhesion*—Adhesion should be measured using Practice B 571 on a panel plated concurrently with the part and on the same material as the part.

11. Keywords

11.1 chromium electroplating



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