



Standard Guide for Chromium Electroplating on Steel for Engineering Use¹

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1. Scope

1.1 This standard 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 much thicker than decorative deposits.

1.2 This specification 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 steel base. Requirements for chromium electrodeposits on ferrous surfaces are defined in Specification B 650.

1.3 *This standard does not purport to address all of the safety problems, 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 322 Practice for Cleaning Metals Prior to 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 571 Test Methods for Adhesion 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 Chromium²

B 650 Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Surfaces²

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

2.2 Military Standard:

MIL-S-13165B Shot Peening of Metal Parts³

3. Nature of Steel

3.1 *High Strength Steel*—Since steel of high strength is susceptible to cracking, the tensile strength of the steel should not exceed 1000 MPa (150 000 psi) or a hardness of 32 HRC unless the steel has been stress-relieved (3.4). Before electroplating, heat-treated parts should be examined for cracks by suitable techniques such as the fluorescent dye or magnetic powder methods. It is important that the hardness of the steel base be sufficient to withstand the service load without deformation and consequent stress fracturing of the chromium deposit.

3.2 *Smoothness*—The smoothness of the steel 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 steel 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, 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

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

³ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

consideration, the use of mechanical methods such as shot peening (see MIL-S-13165C) or autofrettage to compressively stress the surfaces can increase the fatigue strength. This should be done after all stress relieving heat treatments.

3.4 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, will require one of the following stress relief heat treatments (Table 1) prior to electroplating. In all cases, the duration of the heat treatment 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.

3.4.1.1 Parts having surface hardened areas that would suffer an unacceptable reduction in hardness by treatment in accordance with Table 1 shall be heat-treated 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 steel surface between the final operations of mechanical preparation and electroplating. 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 The parts to be electroplated may be racked at any convenient stage in the preparatory process but preferably prior to the final cleaning and etching.

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 steel 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 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 tape 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 metal, 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 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 greater quantities of scale that may fall 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 the requirement for strength or conductivity. Platinum, platinum clad titanium, platinum clad niobium, or even iron, 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 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.

TABLE 1 Stress Relief Treatments

Class	Temperature (°C)	Time (h) min	Tensile Strength (Rm) MPa
SR-1	200 to 230	24	over 1800
SR-2	190 to 220	24	over 1800
SR-3	200 to 230	18	1401 to 1800
SR-4	190 to 220	18	1450 to 1800
SR-5	177 to 205	3	1034 or greater
SR-6	200 to 230	3	1000 to 1400
SR-7	190 to 220	1	1050 to 1450
SR-8	130 to 160	8	surface hardened parts ≤ 1400

5. Cleaning

5.1 Parts to be electroplated may be cleaned in accordance with Practices B 183, B 242 or B 322.

5.2 Mechanical methods of cleaning 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. Etching

6.1 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 *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 the parts should be thoroughly drained to prevent spillage of the etching solution.

6.3 *Anodic Etching in the Plating Solution*—Using the same times and current density described in 6.2, 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 and requires one less tank, but has the disadvantage of contaminating the bath with iron, copper, etc.

6.4 *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 may be encountered that make this process less attractive than those described in 6.2 or 6.3 are:

6.4.1 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

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

6.5 *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 (6.3), 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. The 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.

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.

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
Temperature	55°C (range 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 slightly less prone to cracking.

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 cocatalyzed 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 increases 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 electrode methods are satisfactory. This bath will deposit chromium at an approximate 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 to 4 A/in. ²)

NOTE 4—**Warning:** The silicofluoride (sometimes shown as fluosilicate) 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!

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. Heat treatment appropriate for the tensile strength of the electroplated part (Table 2) must 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. This heat treatment should be performed as soon as possible after the parts are removed from the plating bath, rinsed, and dried. Under no circumstances should the delay in beginning heat treatment exceed 1.5 h.

NOTE 5—It is suggested that the selection of an appropriate heat treatment be discussed with the purchaser to ensure that the treatment selected does not cause distortion in the part or adversely affect its mechanical properties.

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 MIL-S-13165C) 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.⁴

9. Repair of Chromium Electrodeposits

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

9.2 If the part is completely covered with 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 60 to 75 g/L of sodium carbonate. Either solution should be kept below 27°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 dimensions 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 non-destructive method is required, Test Method B 499 is suitable. Test Method B 504 does not destroy the part, but it does remove the chromium electrodeposit in the area tested, which may necessitate replating. 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 Test Methods B 571 on a panel plated concurrently with the part.

11. Keywords

11.1 chromium electroplating; steel

TABLE 2 Hydrogen Embrittlement Relief Treatments

Class	Temperature (°C)	Time (h) min	Tensile Strength (Rm) MPa
ER-1	190 to 220	22	1701 to 1800
ER-2	190 to 220	20	1601 to 1700
ER-3	190 to 220	18	1501 to 1600
ER-4	190 to 220	16	1401 to 1500
ER-5	190 to 220	14	1301 to 1400
ER-6	190 to 220	12	1201 to 1300
ER-7	177 to 205	12	1525 or greater
ER-8	190 to 220	10	1101 to 1200
ER-9	190 to 220	8	1000 to 1100
ER-10	177 to 205	8	1250 to 1525
ER-11	190 to 220	6	1450 to 1800
ER-12	177 to 205	4	1000 to 1500
ER-13	440 to 480	1	1000 to 1800 unpeened parts only
ER-14	130 to 160	8	surface hardened parts ≤ 1401
ER-17	190 to 220	24	parts ≥ 25 mm thickness with threads or sharp notches

⁴ 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 Forum, 1974, is a helpful discussion of the problems in grinding.

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