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Standard Guide for Preparation of Aluminum Alloys for Electroplating¹

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

1. Scope

1.1 This guide covers cleaning and conditioning treatments used before metal deposition (Section 5), and immersion deposit/strike procedures (Section 6) that enhance the adhesion of metals that are subsequently applied to aluminum products by electrodeposition or by autocatalytic chemical reduction.

1.2 The following immersion deposit/strike procedures are covered:

1.2.1 Zinc immersion with optional copper strike (6.3).

1.2.2 Zinc immersion with neutral nickel strike (6.4).

1.2.3 Zinc immersion with acetate-buffered, nickel glycolate strike (6.5).

1.2.4 Zinc immersion with acid or alkaline electroless nickel strike.

1.2.5 Tin immersion with bronze strike (6.6).

1.3 From the processing point of view, these procedures are expected to give deposits on aluminum alloys that are approximately equivalent with respect to adherence. Corrosion performance is affected by many factors, however, including the procedure used to prepare the aluminum alloy for electroplating.

1.4 This guide is intended to aid electroplaters in preparing aluminum and its alloys for electroplating.

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

1.6 *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.* For specific precautionary statements see Section 7 and Appendix X1.

2. Referenced Documents

2.1 *ASTM Standards:*²

B85 Specification for Aluminum-Alloy Die Castings

B179 Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes

B209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate

B209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)

B221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

B221M Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes (Metric)

B322 Guide for Cleaning Metals Prior to Electroplating

B432 Practice for Processing of Mandrels for Electroforming³

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Significance and Use

3.1 Various metals are deposited on aluminum alloys to obtain a decorative or engineering finish. The electroplates applied are usually chromium, nickel, copper, brass, silver, tin, lead, cadmium, zinc, gold, and combinations of these. Silver, tin, or gold is applied to electrical equipment to decrease contact resistance or to improve surface conductivity; brass, copper, nickel, or tin for assembly by soft soldering; chromium to reduce friction and obtain increased resistance to wear; zinc for threaded parts where

¹ This guide is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.02 on Pre Treatment.

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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 Withdrawn.

organic lubricants are not permissible; tin or lead is frequently employed to reduce friction on bearing surfaces. Nickel plus chromium or copper plus nickel plus chromium is used in decorative applications. Nickel plus brass plus lacquer or copper plus nickel plus brass plus lacquer is also used for decorative finishes, sometimes with the brass oxidized and relieved in various ways.

3.1.1 Electroless nickel may be applied as a barrier layer prior to other deposits, or for engineering purposes.

3.2 The preparation of aluminum and aluminum alloy mandrels for electroforming is described in Practice B432.

4. Nature of Aluminum and Its Influence on Preparation

4.1 *Microstructure*—It is difficult to find a preplating procedure that is equally satisfactory for all types and tempers of aluminum alloys because the various alloys and products behave differently electrochemically due to their different compositions and metallurgical structures. When elements are added for alloying purposes, they may appear in an aluminum alloy in several different forms: that is, they may be in solid solution in the aluminum lattice, be present as microparticles of the elements themselves, or be present as particles of intermetallic compounds formed by combination with the aluminum. The several solid solution matrices and the 20 or more microconstituents that may occur in commercial alloys may have different chemical reactivities and electropotentials and their surfaces may not respond uniformly to various chemical and electrochemical treatments. In addition, the response may be influenced by variations in the microstructure of different lots of products of the same alloy. In some cases, these variations may be introduced or aggravated by preparation processes; for example, the heat generated in buffing. The electroplater needs to know the aluminum alloy that is to be processed in order to select the best electroplating procedure. In the absence of this information, there are so-called universal procedures that may be used. However these will not necessarily be the best or the most economical procedures for the alloy.

4.2 *Oxide Film*—In addition to differences in microstructure that may affect response to preplating treatments, all aluminum products have an ever-present natural oxide film. This oxide film can be removed by various acid and alkaline treatments and even though it reforms immediately on contact with aqueous solutions or air, it then is usually thinner and more uniform than the original film. The newly formed oxide film provides a more suitable surface for deposition of the first metallic layer.

5. Cleaning and Conditioning Treatments

5.1 To obtain consistent results for electroplating on aluminum alloys, it is essential that the various cleaning and conditioning treatments provide a surface of uniform activity for the deposition of the initial metallic layer. First, the surface should be free of any oil, grease, buffing compound, or other foreign material. For removing oil, grease, or buffing compound, use vapor degreasing,⁴ solvent washing, or solvent emulsion cleaning. For removing buffing compound, specially formulated detergent type or modified detergent type buffing compound removers may also be used. If the deposits of soil are relatively light and fairly uniformly distributed, a mild etching type cleaner may also be used. A convenient one is a hot, aqueous carbonate-phosphate solution (X1.1). Other types of cleaners are used; for example, mildly alkaline or acidic soak cleaners are used to remove gross soils. Also available are a wide range of proprietary cleaners of the “non-etching” type. Some of these are actually buffered mixtures, similar to the carbonate-phosphate mixture (X1.1) where the so-called non-etching characteristics are obtained by buffering the solution to pH levels where the etching action becomes minimal. Others are truly non-etching types where etching is prevented by using silicate inhibitors, such as sodium metasilicate (Na_2SiO_3). These inhibitors always leave a film of aluminum silicate on the surface. When these materials are used, subsequent deoxidizing solutions should contain controlled amounts of fluoride salts to insure complete removal of the film.

NOTE 1—General information on the cleaning of metals is given in Guide B322.

5.2 After cleaning, a conditioning treatment of the surface is generally required. For this to be effective, it must accomplish two things: (1) remove the original oxide film and (2) remove any microconstituents that may interfere with the formation of a continuous deposited metallic layer or that may react with subsequent electroplating solutions.

5.2.1 An effective conditioning treatment is immersion of the work in a warm sodium hydroxide solution (Appendix X1.3) followed by water rinsing and immersion in a nitric acid-bifluoride desmutting solution (Appendix X1.4). An alternative desmutting solution is sulfuric acid-hydrogen peroxide (Appendix X1.5).

NOTE 2—When an unmodified sodium hydroxide solution is used, etching may become nonuniform and heavy concrete-like scales may form on tank walls and heating surfaces, their development becoming more rapid as the concentration of dissolved aluminum increases. The incorporation of controlled amounts of deflocculating complexors such as sodium gluconate, sodium glucoheptonate, certain sugar derivatives, and certain substituted sugar amines will eliminate this problem. Many proprietary etching materials are so modified.

NOTE 3—The universal acid mixture (Appendix X1.9) is applicable to almost all alloys, and is especially desirable for use with alloys containing magnesium.

5.2.2 For heat-treated alloys (alloys in a “T” temper), it is important to remove the relatively thick, heat-treated oxide film before proceeding with subsequent conditioning treatments. Normally, heat-treated films are removed by machining, or by the polishing action on metal surfaces that are buffed.

5.2.2.1 In the absence of machining or buffing, controlled abrasive blasting may be used to remove this oxide. Fine abrasives such as aluminum oxide, ceramic beads, or glass beads may be used. Silicon carbide abrasives should be avoided. If aluminum

⁴ For details on the proper operation and safety precautions to be followed in vapor degreasing, see *Handbook of Vapor Degreasing, ASTM STP 310*, ASTM, 1976.

oxide, or glass beads are used, subsequent treatments should include the use of an acid fluoride to ensure that any embedded aluminum oxide or silica is removed. However, surfaces of heat-treated alloys that are not machined or buffed should have the heat-treated film removed with a deoxidizing etch to obtain uniform electroplating results. An effective deoxidizing etch is a hot sulfuric-chromic acid solution (Appendix X1.2). Suitable proprietary deoxidizing etches including some with no chromates are available. They should be used as recommended by the manufacturer.

5.2.3 For wrought alloys of the UNS A91100 and UNS A93003 types (see Specifications B209 and B209M) fairly good conditioning may be obtained by using the carbonate-phosphate cleaner (Appendix X1.1) followed by a nitric acid dip at room temperature (Appendix X1.6). These alloys do not contain interfering constituents and for some applications, this method of conditioning may be ample. If a silicate inhibited cleaner is used (see 5.1) the fluoride containing smut remover (Appendix X1.4) is preferred.

NOTE 4—In accordance with current ASTM practice and for international usage, the aluminum alloys have been classified in accordance with the Unified Numbering System (UNS) as detailed in Practice E527 and listed in D556C.⁵

5.2.4 Another effective conditioning treatment for removing the surface oxide film and any undesirable microconstituents comprises the use of a hot sulfuric acid etch (Appendix X1.7). The time of the dip depends on the alloy involved. Generally the shorter time is used on castings. This treatment is satisfactory for all aluminum-magnesium alloys, both wrought and cast. It not only leaves the surface in an excellent condition for the deposition of the first metallic layer, but it also eliminates the undesirable effects of the magnesium-containing constituents in alloys of the UNS A95052, UNS A96061, and UNS A96063 types (see Specifications B221 and B221M).

5.3 The following are types of casting alloys containing high percentages of silicon: UNS A04130, UNS A14130, UNS A03800, (see Specification B85), UNS A03561, and UNS A13560, (see Specification B179). A dip at room temperature in a mixed acid solution (Appendix X1.8) containing nitric and hydrofluoric acids is recommended for conditioning the surface of these alloys. This treatment also removes the heat-treated film from unpolished, heat-treated castings.

6. Immersion Deposit/Strike Procedures

6.1 Following the cleaning and conditioning treatments, it is necessary to further treat the surface to obtain adequate adhesion of an electrodeposited metal on aluminum alloys. This section describes five commercially used procedures:

6.1.1 Zinc immersion with optional copper strike (6.3).

6.1.2 Zinc immersion with neutral nickel strike (6.4).

6.1.3 Zinc immersion with acetate buffered, nickel glycolate strike (6.5).

6.1.4 Zinc immersion with an acid or alkaline electrodeless nickel strike (6.6).

6.1.5 Tin immersion with bronze strike (6.7).

6.1.6 Electrodeposition of polyamines and polyamides (6.8)

6.2 The immersion deposit/strike conditions recommended for each procedure give good results with many alloys of aluminum. However, some alloys and tempers may require slight modification of the processing conditions for best results.

6.3 *Zinc Immersion with Optional Copper Strike:*

6.3.1 In the zinc immersion step, the oxide film is removed from the surface to be electroplated and is replaced by a thin and adherent layer of metallic zinc. This provides a surface that responds to most of the electroplating procedures for plating other metals on zinc.

6.3.2 For the immersion step, a highly alkaline solution⁶ containing the following components can be used at room temperature (15 to 27°C).

	Zinc Immersion Solution, Bath I	
Sodium hydroxide (commercial)		525 g/L
Zinc oxide (technical grade)		100 g/L

6.3.2.1 For best results, the sodium hydroxide must be low in sodium carbonate content (preferably under 2 % by weight) and the zinc oxide must be free of contamination.

NOTE 5—In the zinc immersion solutions in this standard, the purity of the ingredients often plays an important role in the successful operation of the process. This is particularly true of the zinc oxide used. Contamination of the zinc oxide with lead or arsenic can be especially troublesome. Proprietary, prepared powdered or liquid zincates are frequently used therefore, since they will have had all raw materials properly checked for purity.

6.3.2.2 The thickness and quality of the immersion film are influenced by the conditions of deposition. When deposition is too rapid, heavy, coarse, crystalline, and porous, non-adherent deposits are formed. Since the thinner zinc deposits give the best results, it is recommended that the temperature of the zincate solution be kept below 27°C and the immersion time be from 30 s to 1 min.

6.3.3 A modification of the basic zincate solution in most applications gives more uniform and satisfactory results. The modified zinc immersion procedure has the following advantages: (1) more uniform coverage by subsequent electroplating baths, (2) greater operating range for the “double immersion” version of the treatment (see 6.3.5), and (3) improved resistance to corrosion on all

⁵ DS 56C *Metals and Alloys in the Unified Numbering System*, available from ASTM Headquarters. Order PCN 05-0564-02.

⁶ Sodium zincate solutions of this general type are now being replaced by newer modified zincate compositions.

electroplated aluminum alloys except for the UNS A92024 and UNS A97075 alloys. The modified solution is prepared by dissolving the zinc oxide in a sodium hydroxide solution and cooling to room temperature. Before the bath is diluted to volume, a water solution of ferric chloride crystals and Rochelle salt (potassium sodium tartrate) is added. The bath should be stirred while the ferric chloride-Rochelle salt solution is added.⁷ The modified zincate solution is made up as follows:

Zinc Immersion Solution, Bath II	
Sodium hydroxide	525 g/L
Zinc oxide	100 g/L
Ferric chloride hexahydrate	1.0 g/L
Rochelle salt	10 g/L

6.3.3.1 This bath should also be operated under 27°C and for immersion times of the order of 30 s to 1 min. It is recommended that Bath II be utilized whenever the “double immersion” treatment is employed. Likewise, it will be found advantageous on all wrought and cast alloys, except the UNS A92024 and UNS A97075 types, for corrosion-resistant applications.

6.3.3.2 With both of the solutions (Baths I and II), the rinse immediately after the zinc immersion step is critical. The activity of the solution increases rapidly with dilution. Because of the high concentrations used, the solution is viscous. If this viscous layer is not promptly removed in the rinsing step, the diluted film may deposit a loose, spongy zinc film in the rinse, thereby destroying an otherwise acceptable zinc film. Therefore, rinses must be strongly agitated so that this film is rapidly and uniformly removed. Spray rinsing at moderate to high pressure is preferred where the part configuration is such that the sprays can impinge on all surfaces.

6.3.4 Dilute versions of the modified zinc immersion procedures⁷ have been developed for applications where rinsing and drag-out are problems. The bath viscosity is reduced by lowering the concentration of the principal components. In using the dilute baths, a low film weight must be maintained by a closer control of operating conditions and by addition agents. Two typical dilute baths are prepared as follows:

Zinc Immersion Solution, Bath III	
Sodium hydroxide	50 g/L
Zinc oxide	5 g/L
Rochelle salt	50 g/L
Ferric chloride hexahydrate	2 g/L
Sodium nitrate	1 g/L

Zinc Immersion Solution, Bath IV	
Sodium hydroxide	120 g/L
Zinc oxide	20 g/L
Rochelle salt	50 g/L
Ferric chloride hexahydrate	2 g/L
Sodium nitrate	1 g/L

6.3.4.1 Bath IV will provide a much greater zinc reserve for high-production work with only a small sacrifice in rinsing and drag-out properties. When using these dilute solutions, the temperature must be maintained between 20 to 25°C and the immersion time must not exceed 30 s.

6.3.4.2 A more highly modified zincate (modified with copper, nickel, and iron) has been described by Wyszynski.⁸ It has much greater tolerance for variations in operating conditions, especially temperature and time of immersion, and permits processing a wider variety of alloys without resorting to the double zincating treatment (6.3.5). Because the quaternary alloy deposited by immersion is much less active than the relatively pure zinc from many immersion baths, subsequent electroplated deposits are applied with less difficulty.

6.3.5 A variation of the zincate treatment that has considerable merit consists of a double zinc immersion treatment with the first zinc layer being removed by a dip in a room temperature solution of 500 mL of concentrated, nitric acid (67 mass %, density 1.40 g/mL) diluted to 1 L. With this procedure, the first immersion dip removes the original oxide film and replaces it with a zinc layer. Removal of the zinc layer by the nitric acid dip leaves the surface in suitable condition for deposition of the final zinc immersion layer.

6.3.6 The concentrated zincate solutions (Baths I and II) are very viscous and losses occur largely from drag-out. This is advantageous as it limits the accumulation of impurities resulting from attack on the aluminum. It has the disadvantage however in that it increases the load on the waste disposal system.

6.3.7 The specific gravity of the concentrated solutions should be checked occasionally and any loss made up by adding more of the components. Loss of volume by dragout should be corrected by the addition of more solution of the specific composition. The dilute solutions (Baths III and IV and those recommended by Schaer and Wyszynski) should be controlled by chemical analysis of the caustic, zinc, and modifying metal concentration.

6.3.8 When a properly conditioned aluminum alloy article is immersed in the zincate solution, the thin natural oxide film that is present on the surface of the article dissolves and, as soon as underlying aluminum is exposed, it also starts to dissolve and is

⁷ There are proprietary zincate solutions available containing cations other than iron (also various other additions such as complexing agents or chelating agents or both). A solution containing copper and nickel, as well as zinc, is described by Schaer, G., *Plating and Surface Finishing*, 68,51 (March 1981).

⁸ Wyszynski, A. E., et al, *Transactions of the Institute of Metal Finishing*, (England), Vol 45, 1967, pp. 147–154; Vol 59, 1981, pp. 17–24. Wyszynski, A. E., and Such, T. E., *Plating*, Vol 10, 1965, pp. 1027–1034.