



# Standard Specification for Electrodeposited Coatings of Tin-Lead Alloy (Solder Plate)<sup>1</sup>

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

## 1. Scope

1.1 This specification covers the requirements for electrodeposited tin-lead coatings on fabricated articles of iron, steel, copper, and copper alloys, to protect them against corrosion (Note 1), to improve and preserve solderability over long periods of storage, and to improve anti-galling characteristics.

NOTE 1—Some corrosion of tin-lead coatings may be expected in outdoor exposure. In normal indoor exposure, tin-lead is protective on iron, copper, and copper alloys. Corrosion may be expected at discontinuities (pits or pores) in the coating. Porosity decreases as the thickness is increased. A primary use of the tin-lead coating (solder) is with the printed circuit industry as a solderable coating and as an etch mask material.

1.2 This specification applies to electrodeposited coatings containing a minimum of 50 % and a maximum of 70 % tin. The specification applies to mat, bright, and flow-brightened tin-lead coatings.

NOTE 2—Tin-lead plating baths are composed of tin and lead fluoborates and of addition agents to promote stability. The final appearance may be influenced by the addition of proprietary brighteners. Without brighteners, the coatings are mat; with brighteners, they are semibright or bright. Flow-brightened coatings are obtained by heating mat coatings to above the melting point of tin-lead for a few seconds and then quenching; palm oil, hydrogenated oils, or fats are used as a heat-transfer medium at a temperature of  $260 \pm 10^\circ\text{C}$  ( $500 \pm 20^\circ\text{F}$ ), but other methods of heating are also in use. The maximum thickness for flow-brightening is about  $7.5 \mu\text{m}$  (0.3 mil); thicker coatings tend to reflow unevenly. The shape of the part is also a factor; flat surfaces tend to reflow more unevenly than wires or rounded shapes (Note 3).

NOTE 3—Volatile impurities in tin-lead coatings will cause bubbling and foaming during flow-brightening resulting in voids and roughness. The impurities can arise from plating solution addition agents and from improper rinsing and processing.

1.3 This specification does not apply to sheet, strip, or wire in the unfabricated form or to threaded articles having basic major diameters up to and including 19 mm (0.75 in.).

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.06 on Soft Metals.

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## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- B183 Practice for Preparation of Low-Carbon Steel for Electroplating
- B242 Guide for Preparation of High-Carbon Steel for Electroplating
- B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings
- B322 Guide for Cleaning Metals Prior to Electroplating
- B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section
- B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals
- B504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method
- B567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method
- B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
- E105 Practice for Probability Sampling of Materials
- E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

### 2.2 Other Standards:

- MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes<sup>3</sup>
- MIL-STD-414 Sampling Procedures and Tables for Inspection by Variables for Percent Defective<sup>3</sup>

## 3. Classification and Service Condition

3.1 Orders for articles to be plated in accordance with this specification shall specify, in addition to the ASTM designation number and year of issue, the classification notation indicating the basis metal and thickness of tin-lead coating required, or

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

the service condition number indicating the severity of service required for the coating. In addition, when specifying a tin-lead coating composition, the first number shall refer to the tin content in percent.

3.1.1 Classification Notation:

Symbol	Classification
Fe/	Iron or steel basis metals
Cu/	Copper or copper alloy basis metals
/Sn-Pb	Tin-lead coating and its composition number, when required; for example, Sn60-Pb40
Number (5 to 50)	Minimum coating thickness in micrometres
Suffix Letter	
f	flow-brightened
b	bright
m	mat

An example of complete classification notation is as follows: Cu/Sn60-Pb40/5F

3.1.2 Service Condition Number:

No.	Service Condition
4	very severe exposure
3	severe exposure
2	moderate exposure
1	mild exposure

NOTE 4—See Appendix X1 for additional description of exposure conditions and examples of typical end uses. The coating thicknesses given for each service condition are guidelines and are not intended to be absolute values.

4. Significant Surfaces

4.1 Significant surfaces are defined as those surfaces normally visible (directly or by reflection) that are essential to the appearance or serviceability of the article when assembled in normal position; or those surfaces that can be the source of corrosion products that will deface visible surfaces on the assembled article. When necessary, the significant surfaces shall be indicated on the drawing of the part, or by the provision of suitably marked samples.

NOTE 5—When significant surfaces include areas on which the specified thickness of deposit cannot readily be controlled, such as threads, holes, deep recesses, bases of angles, and similar areas, the purchaser and the manufacturer should recognize the necessity for either thicker deposits on the more accessible surfaces or for special racking. Special racks may involve the use of conforming, auxiliary bipolar electrodes, or nonconducting shields.

5. Materials and Manufacture

5.1 Defects in the surface of the basis metal, such as scratches, porosity, nonconducting inclusions, roll and die marks, cold shuts, and cracks, may adversely affect the appearance and the performance of coatings applied thereto despite the observance of the best plating practices. Accordingly, the plater’s responsibility for defects in the coating resulting from such conditions shall be waived, except when he is also in the position of prime contractor supplying plated parts.

NOTE 6—In order to minimize problems of this sort, the specifications covering the basis material or the item to be plated should contain appropriate limitations on such basis metal conditions.

5.2 When required the basis metal shall be subjected to such polishing or buffing operations as are necessary to yield deposits with the desired final appearance (Section 6).

5.3 Proper preparatory procedures and thorough cleaning of the basis metal surface are essential in order to assure satisfactory adhesion and corrosion performance of the coating. Accordingly, it is suggested that the following Practices for the preparation of various basis metals for electroplating be followed when appropriate: B183, B281, and B322 and Guide B242.

5.4 When necessary, preliminary samples showing the finish shall be supplied to and approved by the purchaser. Where rack marks are inevitable, their location shall be the subject of agreement between supplier and purchaser.

6. Physical Composition

6.1 Composition—The tin-lead coating composition shall be as follows (Note 7):

Element	Weight, %
Tin (Sn)	50 to 70
Lead (Pb)	remainder

6.1.1 The tin percentage is calculated as follows:

$$\text{Tin, \%} = 134.1 \times (L/A - 1) \tag{1}$$

where:

L = weight of lead coating, g, and

A = weight of alloy coating, g.

NOTE 7—Only the tin content need be determined. Lead is usually determined by difference. A sample of the deposit can be obtained by plating on a stainless steel panel from which the coating can be peeled or by employing any recognized stripping method. The alloy composition of the deposit can be determined by methods such as gravimetric or volumetric analysis, density measurements, atomic absorption spectrophotometry, X-ray fluorescence, and beta backscatter.

In addition, the alloy composition produced by a plating solution may be obtained by comparing the weight of a tin-lead coating deposited by a given number of ampere-hours to the weight of lead coating produced in a lead fluoborate coulometer in series with the plating bath.

6.2 Appearance—The tin-lead coating shall be smooth, fine grained, continuous, adherent, and shall be free of visible blisters, pits, nodules, indications of burning, excessive build-up, staining, and other defects. Flow-brightened coatings shall not have dewetted areas or beads, and shall be free of the oil used in the fusion process.

6.3 Thickness—The thickness of the coating on significant surfaces shall conform to the requirements in Table 1 and Table

TABLE 1 Tin-Lead Alloy Coatings on Steel

Service Condition	Classification Number	Minimum Thickness	
		µm	mil
SC4 <sup>A</sup>	Fe/SnPb 30	30	1.2
SC3 <sup>A</sup>	Fe/SnPb 20	20	0.8
SC2	Fe/SnPb 10	10	0.4
SC1	Fe/SnPb 5	5	0.2
SC1	Fe/SnPb 5f <sup>B</sup>	5	0.2

<sup>A</sup> An undercoat of 2.5 µm (0.1 mil) copper is recommended for SC3 and SC4.

<sup>B</sup> f = flow brightened or

m = mat or

b = bright

2.

6.3.1 *Thickness Measurements*—Tin-lead alloy thickness measurements shall be made on those areas of the significant surfaces where the coating would be expected to be thinnest. The method of determining the thickness shall be agreed upon by the manufacturer and purchaser. Several methods are available depending upon the thickness of coating, the shape of the article, and the basis metal. They include beta backscatter, coulometric, magnetic, microscopical, and X-ray fluorescence test methods. The methods are outlined in 9.1.

NOTE 8—Thicknesses determined by beta backscatter, coulometry, and X-ray fluorescence are a function of the composition as well as the thickness of the coating.

6.4 *Adhesion*—The adhesion of the coating shall be adequate to pass the tests described in 9.2.

6.5 *Solderability:*

6.5.1 When specified by the purchaser, the coating shall be tested by one of the methods described in 9.2. The results shall be evaluated in accordance with each procedure described in that section.

6.5.2 When specified by the purchaser, the coating on copper and copper alloys shall, before solderability testing, be subjected to the preliminary artificial aging treatment described in 9.3.6 to determine if they may be expected to retain their solderability during periods of storage.

NOTE 9—See Appendix X2 for design considerations that have an effect on the selection of thickness of the coating and, ultimately, on the solderability of the electrodeposits.

7. **Hydrogen Embrittlement**

7.1 High-tensile strength steels, and severely cold-worked steels, are susceptible to embrittlement by hydrogen in both cleaning and plating operations. The embrittling hydrogen shall be removed by heat treatment. Procedures for baking to minimize embrittlement before and after plating are covered in Sections 2 and 7 of Guide B242.

8. **Sampling**

8.1 Test methods are time consuming and often destructive; therefore 100 % inspection is usually impractical. The purchaser should select a suitable sampling plan for the acceptance testing of lots of coated items. In order that the manufacturer (plater) may know the quality standard he is expected to meet, the plan selected should be made part of the purchase contract.

8.2 General information on sampling procedures is given in Recommended Practices E105 and E122. Standard sampling plans are suggested in Military Standards MIL-STD-105 and MIL-STD-414.

9. **Test Methods**

9.1 *Thickness:*

9.1.1 To meet the thickness specifications of the coatings, the plater is advised to:

- 9.1.1.1 Maintain regular control of all solutions,
- 9.1.1.2 Inspect the equipment at regular intervals, and
- 9.1.1.3 Check thickness at periodic intervals.

9.1.2 The following ASTM methods are acceptable for measuring local thickness of the coating: B487, B499, B504, B567, and B568.

9.2 *Adhesion:*

9.2.1 *Burnishing Test*—Rub an area of not more than 630 mm<sup>2</sup> (1 in.<sup>2</sup>) of the coated surface, selected at the discretion of the inspector, rapidly and firmly for 15 s with a smooth metal implement. A suitable burnishing implement is a copper or steel disk used edgewise and broadside. Maintain a pressure sufficient to burnish the coating at every stroke, but not so great as to cut it. Poor adhesion will be shown by the appearance of a loose blister which grows as burnishing is continued. If the quality of the coating is poor also, the blister may crack and the coating peel away from the basis metal.

9.2.2 *Quenching Test*—Heat the coating article in an oven for a sufficient time to reach 150 ± 10°C (300 ± 20°F) and quench in room-temperature water. The adhesion is inadequate if the coating blisters, cracks, or peels.

9.2.3 *Reflow Test*—Parts may be evaluated by immersion in a bath of palm oil at a temperature of 205 – 260°C (400 – 500°F) until the deposit melts. A bright coating completely covering the significant surfaces indicates adequate adhesion.

9.2.4 *Bend Test*—Bend a sample, with the coated surface away, over a mandrel until its two legs are parallel. The mandrel shall have a diameter equal to the thickness of the sample. Examination at 4× magnification should show no evidence of peeling or cracking.

9.3 *Solderability:*

9.3.1 *General:*

9.3.1.1 Methods for testing the solderability of tin-lead coated articles are based on the measurement of the extent of wetting by molten solder or the determination of the minimum time required to produce full or perfect wetting by solder.

9.3.1.2 The extent of wetting can be observed by manual or automatic immersion in molten solder under controlled conditions.

9.3.1.3 Determine the minimum wetting time by carrying a specimen in a fixture through a standing wave of solder at a controlled speed and by measuring the shortest time of immersion that will give complete wetting.

9.3.2 *Dip Tests (Non-Automated):*

**TABLE 2 Tin-Lead Alloy Coatings on Copper, Copper Alloys<sup>A</sup>, and Nonmetals<sup>B</sup>**

Service Condition	Classification Number	Minimum Thickness	
		µm	mil
SC4	Cu/SnPb 30	30	1.2
SC3	Cu/SnPb 15	15	0.6
SC2	Cu/SnPb 8	8	0.3
SC1	Cu/SnPb 5	5	0.2
SC1	Cu/SnPb 5 <sup>C</sup>	5	0.2

<sup>A</sup> If the basis metal is a brass containing more than 15 % zinc, the tin-lead coating shall be preceded by an undercoat of at least 2.5 µm (0.1 mil) of copper and nickel to prevent the diffusion of zinc into the tin-lead. The same undercoating shall also be applied when the basis metal is beryllium copper to assure adhesion of tin-lead coating.

<sup>B</sup> Nonmetals shall be suitably sensitized and metalized prior to tin-lead coating.

<sup>C</sup> f = flow-brightened or

m = mat or

b = bright

9.3.2.1 *Sample*—For small articles of suitable shape and size take the whole article for testing. For larger articles, cut a portion of suitable size for testing. A recommended panel size is 25 mm<sup>2</sup> (1 in.<sup>2</sup>). For articles not falling into these categories, take samples as agreed upon between the plater and the purchaser.

9.3.3 *Dip Tests (Automated)*—The use of automated testers eliminates possible operator errors and assures repeatable results; in these units, the dipping operation, temperature control, and timing sequences are automated. One available unit provides a means for testing flat surfaces, wires, and component terminations by vertical immersion into the solder; in addition, a holding fixture is available to lower wire samples horizontally and face down through the solder, the speed of rotation being varied to produce a range of immersion times. Progressively increase contact times with the solder using separate specimens, and determine the least time required for complete wetting and the onset of dewetting by visual examination of the series of specimens. The best conditions of solderability would have the shortest wetting time, and would show no signs of dewetting within the longest contact time required. A minimum wetting time under 2 s is evidence of good solderability. An auxiliary attachment is available for the determination of spread values. The specimen is lowered onto the surface of the solder and a delay timer built into the equipment holds the test piece in contact with the solder for any preselected time up to 10 s. Determine spread values as in 9.3.4.

#### 9.3.4 *Spread Test:*

9.3.4.1 This method involves placement of a fixed volume of solder on the surface of a specimen with a few drops of rosin flux (Type W flux, MIL-F-14256) and heating the specimen for a fixed period of time at a controlled temperature.

9.3.4.2 The area of spread can be measured with a planimeter.

9.3.4.3 The height of the solder blob can be measured with a stage micrometer which can be set to subtract the thickness of the basis metal and the “spread factor” calculated. A hot

plate held at 250 ± 5°C (480 ± 9°F) may be substituted for the oven, used in the Pessel method, as a source of heat.<sup>4</sup>

#### 9.3.5 *Globule Test:*

9.3.5.1 This test method was devised for assessing the solderability of wires, component leads, etc.

9.3.5.2 This method consists of lowering the specimen of wire (or component lead) previously fluxed, horizontally onto a molten globule of solder, which is thereby cut in two. The time in seconds for the solder to flow around the wire and unite above it is a measure of the solderability. Use a fresh pellet of solder for each test, the size of the pellet being determined by the diameter of the specimen wire. Commercial test machines are available.

#### 9.3.6 *Artificial Aging (When Specified By the Purchaser):*

9.3.6.1 Place the sample for test in a suitable vessel above boiling water and leave it there, with the water boiling continuously, for 24 h. Keep the vessel covered and ensure that the sample does not come into contact with the wall of the vessel and that its lower edge is not less than 50 mm (2 in.) or more than 100 mm (4 in.) above the surface of the boiling water. Arrange the cover on the vessel and the steam condenser, if used, so that they do not discharge condensed water over the sample. Disregard any discoloration of the sample occurring during this aging treatment. After the 24-h treatment, remove the sample from the steam and allow it to dry in the air.

9.3.6.2 Test methods outlined in 9.3.2, 9.3.3, 9.3.4, or 9.3.5 are used to assess the solderability of the aged specimens.

## 10. Keywords

10.1 electrodeposited coatings, tin-lead alloy (solder plate); solder, tin-lead alloy; tin-lead

<sup>4</sup> Details of this modification are given in Pessel, “Plating,” *Symposium on Solder*, ASTM STP 189, ASTM, 1965, p. 315. Although out of print, STP 189 is now available from University Microfilms, Inc., 300 N. Zeeb Rd., Ann Arbor, MI 48106.

## APPENDIXES

### (Nonmandatory Information)

#### X1. EXAMPLES OF APPROPRIATE SERVICE CONDITIONS

X1.1 *SC4*—Very severe service conditions require a complete coating of tin-lead free of pores. If the coating is subjected to abrasion or is exposed to corrosive liquids or gases, a deposit of 30 to 125 μm (1.2 to 5.0 mil) may be required to maintain maximum protection.

X1.2 *SC3*—Severe service conditions include exposure to dampness and to industrial atmospheres. Coatings of 12 to 30 μm (0.5 to 1.0 mil) have been reported to be satisfactory, particularly for preserving a solderable coating after a long storage period (for example, 9 months). Another application considered in this category is the use of the tin-lead as an etch

resist in the production of printed-circuit boards.

X1.3 *SC2*—Moderate service conditions include dry or interior atmosphere. Coatings of 8 to 12 μm (0.3 to 0.5 mil), including flow-brightening, have been reported to be satisfactory, particularly for preserving a solderable coating for a shorter storage period than that given in SC3. Also, as in SC3, another application considered in this category is the use of the tin-lead as an etch resist in the production of printed-circuit boards.

X1.4 *SC1*—Mild service conditions with less severe requirements than SC2. Deposits of 5 μm (0.2 mil) and less have

been reported satisfactory for providing and preserving a solderable coating for short periods of storage (for example, 3 months).

## **X2. DESIGN CONSIDERATIONS**

### **X2.1 General:**

X2.1.1 The properties of electrodeposited tin-lead coatings satisfy the requirements of solderability, corrosion resistance, etc., outlined in the scope of this specification and their use can be recommended for most applications. Attention is drawn to the effects of temperature and to long-term storage of tin-lead plated articles which may be factors in designing for special applications.

### **X2.1.2 Temperature Effects:**

X2.1.2.1 Tin-lead coatings are soft and will withstand considerable flexing and twisting of the basis metal without serious damage. At room temperature, mat tin-lead coatings will oxidize slowly but flow-brightened and bright tin-lead coatings oxidize less readily.

X2.1.2.2 Interdiffusion between tin-lead coatings and copper or copper alloys does take place. The diffusion is slow at room temperature and rapid at elevated temperatures. Evidence of diffusion is the formation of a layer of copper-tin compound at the interface and, if the substrate is brass, diffusion of zinc to the surface. Diffusion may lead to darkening of a thin coating and impairment of its solderability, particularly after long storage. With such thin coatings, a diffusion barrier of nickel may be advantageous, but users should consider the use of a thicker coating when solderability has to be maintained over a period of years. An undercoat of nickel or copper must be used as a diffusion barrier on brass.

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