Standard Specification for Electrodeposited Coatings of Tin[1]

This standard is issued under the fixed designation B545; 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.

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

1. Scope

1.1 This specification covers the requirements for electrodeposited (electroplated) coatings of tin applied to metallic articles. Tin coatings are used to provide a low contact-resistance surface, to protect against corrosion (see 1.2), to facilitate soldering, to provide anti-galling properties, and to be a stopoff coating in the nitriding of high-strength steels.

1.2 Some corrosion can be expected from tin coatings exposed outdoors. In normal indoor exposure, tin is protective on iron, steel, nickel, copper, and their alloys. Corrosion can be expected at discontinuities in the coating (such as pores) due to galvanic couples formed between the tin and the underlying metal through the discontinuities, especially in humid atmospheres. Porosity increases as the coating thickness decreases, so that minimum thicknesses must be specified for each application. Parts coated with tin can be assembled safely in contact with iron and steel, tin-coated aluminum, yellow chromated zinc, cadmium, and solder coatings. (See X5.1 for oxidation and corrosion properties.)

1.3 This specification applies to electroplated coatings of not less than 99 % tin (except where deliberately alloyed for special purposes, as stated in X6.3) obtained from any of the available tin electroplating processes (see 4.3).

1.4 This specification does not apply to hot-dipped tin or other non-electrodeposited coating; it also does not apply to mill products. For mill products, refer to Specifications A623 or A623M.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A623 Specification for Tin Mill Products, General Requirements
A623M Specification for Tin Mill Products, General Requirements [Metric]
B32 Specification for Solder Metal
B183 Practice for Preparation of Low-Carbon Steel for Electroplating
B242 Guide for Preparation of High-Carbon Steel for Electroplating
B246 Specification for Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes
B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings
B320 Practice for Preparation of Iron Castings for Electroplating
B322 Guide for Cleaning Metals Prior to Electroplating
B374 Terminology Relating 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
B507 Practice for Design of Articles to Be Electroplated on Racks
B542 Terminology Relating to Electrical Contacts and Their Use
B558 Practice for Preparation of Nickel Alloys for Electroplating
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

---

[1] 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.

Current edition approved May 1, 2013. Published July 2013. Originally approved in 1971. Last previous edition approved in 2009 as B545 – 97 (2009). DOI: 10.1520/B0545-13.

[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.

B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings
B659 Guide for Measuring Thickness of Metallic and Inorganic Coatings
B678 Test Method for Solderability of Metallic-Coated Products
B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings
B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings
B765 Guide for Selection of Porosity and Gross Defect Tests for Electrodeposits and Related Metallic Coatings
B809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor (“Flowers-of-Sulfur”)
B849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement
B850 Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement
B851 Specification for Automated Controlled Shot Peening of Metallic Articles Prior to Nickel, Autocatalytic Nickel, or Chromium Plating, or as Final Finish
D3951 Practice for Commercial Packaging

3. Terminology

3.1 *Definitions:*

3.1.1 Many of the terms used in this specification are defined in Terminology B374 or B542.

3.1.2 *rack-plating*—an electrodeposition process in which articles to be coated are mounted on racks or other fixtures during the process.

3.1.3 *significant surface*—that portion of the surface of a coated article at which the coating is required to meet all of the requirements of the coating specification for that article; significant surfaces are usually those that are essential to the serviceability or function of the article, or that can be a source of corrosion products or tarnish films that interfere with the function or desirable appearance of the article; significant surfaces shall be indicated on the drawings of the parts or by the provision of suitably marked samples.

3.1.4 *undercoating (see 3.1.5)*—also called an *underplate* in the electronics industry.

3.1.5 *underplating*—application of a metallic coating layer between the basis metal or substrate and the topmost metallic coating or coatings. The thickness of such an undercoating is usually greater than 0.8 µm (30 µin.). This is in contrast to strikes or flashes, whose thicknesses are generally much smaller.

4. Classification

4.1 *General*—Orders for articles to be plated in accordance with this specification shall specify the service class (4.2) (and underplating, if required), indicating the severity of service required for the coating. Other coatings variations, such as surface appearance type (4.3) or alloy composition (Appendix X6), are optional.

4.2 *Service Class:*

Class	Minimum Thickness	Typical Applications
A	2.5 µm (100 µin.)	Mild service conditions, particularly where the significant surface is shielded from the atmosphere (as in electronic connector housings). To provide corrosion and tarnish resistance where greater thicknesses may be detrimental to the mechanical operation of the product (for example, small electrical spring contacts and relays). Class A is often used for tin coatings that are not to be soldered, but must function as low-resistance electrical contact surfaces.
B	5 µm (200 µin.)	Mild service conditions with less severe requirements than Class C (below). Applications are as follows: precoating on solderable basis metals to facilitate the soldering of electrical components; as a surface preparation for protective painting; for antigalling purposes; and as a stopoff in nitriding. Also found on baking pans after reflow.
C	8 µm (320 µin.), (10 µm (400 µin.) for steel substrates)	Moderate exposure conditions, usually indoors, but more severe than Class B. Examples are electrical hardware (such as cases for relays and coils, transformer cans, screened cages, chassis, frames, and fittings) and for retention of the solderability of solderable articles during storage.
D	15 µm (600 µin.) (20 µm (800 µin.) for steel substrates)	Severe service, including exposure to dampness and mild corrosion from moderate industrial environments. Examples are fittings for gas meters, automotive accessories (such as air cleaners and oil filters), and in some electronic applications.
E	30 µm (0.0012 in.)	Very severe service conditions, including elevated temperatures, where underlying metal diffusion and intermetallic formation processes are accelerated. Thicknesses of 30 to 125 µm (0.0012 to 0.005 in.) may be required if the coating is subjected to abrasion or is exposed to slowly corrosive liquids or corrosive atmospheres or gases. Thicker coatings are used for water containers, threaded steel couplings of oil drilling strings, and seacoast atmospheres. Coatings subject to mild etchants are included.
F	1.5 µm (60 µin.)	Similar to Class A, but for shorter-term contact applications and short shelf-life requirements, subject to purchaser approval.

4.3 *Surface Appearance Type (Electroplating Process):*

4.3.1 *Matte Tin Electrodeposits*—Coatings with a matte appearance are obtained from tin plating baths (stannate, sulfate, methylsulfonate, and fluoborate) used without the addition of any brightening agents. However, all matte baths (except for stannate baths) do require the addition of grain-refiners, and often of other additives in order to produce the desired matte finish.

4.3.2 *Bright Tin Electrodeposits*—Bright coatings are obtained when proprietary brightening agents are used in specific bright tin plating baths.

4.3.3 *Flow-Brightened Electrodeposits*—Flow-brightened coatings are obtained by heating the matte coating above the melting point of tin for a few seconds, followed by quenching; palm oil and hydrogenated oils and fats are used as heat-transfer medium at a temperature of 240 to 260°C (464 to 500°F), but other heating methods also are in use, such as hot air. The maximum thickness for flow-brightening is, in most cases, approximately 8 µm (300 µin.). The shape of the part is also a factor; flat surfaces dewet more readily than wires or rounded shapes.

NOTE 1—Terms commonly used in soldering, such as *dewet*, are described in soldering textbooks (**1**)[3] or reviews of solderability testing (**2**). Some examples are given in Appendix X6.

5. Ordering Information

5.1 In order to make the application of this specification complete, the purchaser must supply the following information to the seller in the purchase order and drawings:

5.1.1 Title, ASTM designation number, and year of issue of this specification;

5.1.2 Deposit by classification (4.1), including thickness or service class (4.2);

5.1.3 Composition and metallurgical condition of the substrate to be coated (6.1);

5.1.4 Additional underplating, if required (6.8);

5.1.5 Surface-appearance type (for example, matte, flow-brightened, or bright), if required (4.3 and 6.2);

5.1.6 Location of significant surfaces (3.1.3);

5.1.7 Hydrogen embrittlement relief, if required (Supplementary Requirement S2); and

5.1.8 Any other items needing agreement (for example, 6.5.2, 8.4 and 8.5).

6. Coating Requirements

6.1 *Substrate*—The metal substrate shall be subjected to such surface preparation, cleaning, and electroplating procedures as are necessary to yield deposits with the desired quality.

NOTE 2—Careful preparation of metal surfaces is necessary in order to assure good adhesion and quality. For suitable methods, see Practices B183, B242, B281, B320, B322, and B558. Also see 6.6.

6.2 Electroplating shall be applied after all basis metal heat treatments and mechanical operations have been completed.

6.3 *Appearance*—Tin coatings shall have the characteristic appearance, including surface texture (4.3), for the process used. The appearance shall be uniform throughout, insofar as the basis metal will permit. They shall be adherent and visually free of blisters, pits, peeled areas, cracks, nodules, and unplated areas. They shall not be stained or discolored. Flow-brightened coatings shall be free of dewetted areas and beads. All surfaces shall be substantially free of grease or oil used in the flow-brightening process.

6.4 All tin-coated articles shall be clean and undamaged. When necessary, preliminary samples showing the finish shall be supplied to and approved by the purchaser. Where a contact mark is inevitable, its location shall be subject to agreement between the supplier and the purchaser.

6.5 *Thickness of Coatings*—Tin coatings on articles shall conform to the thickness requirements specified in 4.2 as to the minimum thickness on significant surfaces.

6.5.1 *Local Thickness*—The thickness values specified in 4.2 are the minimum local thicknesses measured by one or more of the methods given in Practice B659 at any number of desired spots on the significant surface.

6.5.2 *Mean Thickness*—When specified by the purchaser, instead of being a local minimum requirement, the thickness requirement can be a minimum (arithmetic) mean thickness.

NOTE 3—Specification of the coating thickness in terms of the mean is normally made when the coated articles are small and relatively simple, such as connector pins and terminals.

NOTE 4—Thickness of electrodeposited coatings varies from point to point on the surfaces of a product (see Practice B507). The thickness is less in interior corners and holes. Such surfaces are normally exempt from the thickness requirement. If the full thickness is required on these surfaces, the electroplater will have to use special techniques that probably will increase the cost of the process.

NOTE 5—When articles are plated by mass plating techniques (such as barrel plating), such measurement methods as "strip and weigh" or "weigh before and after plating" may be used to determine the mean thickness.

6.6 *Adhesion*—Adhesion of the coating shall be tested by one of the methods given in Practice B571. The coating should adhere to the basis metal when subjected to the agreed test; flaking or blistering of the coating is to be taken as evidence of unsatisfactory adhesion.

6.7 *Integrity of the Coating:*

6.7.1 *Gross Defects/Mechanical Damage*—Coatings shall be free of visible mechanical damage and similar gross defects when viewed at up to 4× magnification. For some applications, this requirement may be relaxed to allow for a small number of such defects (per unit area), especially if they are outside of or on the periphery of significant surfaces (also see 6.7.2), as allowed by the purchaser.

6.7.2 *Porosity*—Almost all as-plated electrodeposits contain some porosity. The amount of porosity in the coating that may be tolerable depends on the severity of the environment that the article is likely to encounter during service or storage. If the pores are few in number, or away from significant surfaces, their presence can often be tolerated. Such acceptance (or pass-fail) criteria, if required, should be part of the product specification for the particular article or coating requiring the porosity test. See 8.5 for porosity testing.

6.8 *Underplating:*

6.8.1 For tin coatings in Class A and Class F (4.2) that will not be exposed to solder temperatures (especially those that must function as electrically conductive surfaces), a nickel underplate or undercoating of at least 1.3 µm (50 µin.) shall be applied before tin plating.

6.8.2 To prevent zinc migration and impairment of solderability during service or storage, substrates of brass or other copper alloys containing more than 5 % zinc must have a copper undercoating of at least 2.5 µm (100 µin.), or a nickel undercoating of at least 1.3 µm (50 µin.), prior to tin plating. A thicker coating of nickel may be required in some situations for additional retardation.

6.9 *Hydrogen Embrittlement Relief*—High-tensile strength steels and severely cold-worked steels are susceptible to embrittlement by hydrogen in both cleaning and electroplating operations. See Supplementary Requirements S1 and S2 for details.

---

[3] The boldface numbers in parentheses refer to the list of references at the end of this specification.

6.10 *Deposit Purity*—The tin coating shall be not less than 99 % tin, when tested in accordance with 8.1. Deliberate alloying for special purposes shall only be allowed when specifically agreed upon between the purchaser and seller (see X6.3).

7. Sampling

7.1 The sampling plan used for inspection of a quantity of the coated articles shall be as agreed upon between the purchaser and the supplier.

NOTE 6—The procedure for sampling is accomplished by selecting a relatively small number of the finished articles at random. These articles (the inspection lots) are inspected and classified as complying or not complying with the requirements of the specification. The size of the sample and the criteria of compliance are determined by the application of statistics. The procedure is known as sampling inspection. Three standards, Test Method B602, Guide B697, and Test Method B762, contain sampling plans that are designed for the sampling inspection of coatings.

Test Method B602 contains four sampling plans, three for use with tests that are non-destructive and one for use when they are destructive. The buyer and seller may agree on the plan or plans to be used. If they do not, Test Method B602 identifies the plan to be used.

Guide B697 provides a large number of plans and also provides guidance in the selection of a plan. When Guide B697 is specified, the buyer and seller must agree on the plan to be used.

Test Method B762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numerical value, and certain statistical requirements must be met. Test Method B762 contains several plans and also provides instructions for calculating plans to meet special needs. The buyer and seller may agree on the plan or plans to be used. If they do not, Test Method B762 identifies the plan to be used.

7.2 An inspection lot shall be defined as a collection of coated articles that meet the following requirements: they are of the same kind; have been produced to the same specifications; have been coated by a single supplier at one time, or at approximately the same time, under essentially identical conditions; and are submitted for acceptance or rejection as a group.

7.3 *Special Test Specimens*—It may be preferable to use special test specimens to represent product in process control or in acceptance inspection when, for example, destructive tests are used and it is desirable not to destroy product or if the test specimen is better adapted to the test. The use of special test specimens, their number, the material from which they are made, their size and shape, and the conditions of their coating shall be as agreed upon by the purchaser and the seller.

8. Test Methods

8.1 *Deposit Purity*—Atomic absorption or energy dispersion spectrophotometry, or any other methods with a demonstrated uncertainty of less than 10 % of the component measured, may be used to determine impurities. Initial scanning should be conducted for all elements in order to detect any unknown or unexpected impurities. Determine deposit purity by subtracting the total impurities from 100 %.

NOTE 7—Deposit purity is best determined on samples of the actual product (see Section 7). If special test specimens are used (7.3), care must be taken to arrange the specimens so as to electroplate them under the same conditions as typical production pieces.

8.2 *Thickness:*

8.2.1 *Standard Thickness*—The coating thickness shall be measured at locations on significant surfaces by one of the following test methods: Test Methods B487, B499 (magnetic substrates only), B504, B567, and B568. Practice B659 may be consulted to determine the most appropriate test method.

8.2.1.1 When Methods B504 and B568 are used with tin platings that have been alloyed with more than 0.5 % of lead, bismuth, or antimony to reduce whiskering (see X6.3.2.5), the standard shall have the same composition as the coating. When Test Method B567 is used to measure these types of coatings, the measuring instrument shall be calibrated with thickness standards that have the same substrate and same composition of coating as the product.

8.2.2 *Mean Thickness*—If the entire surface of the article is a significant surface, the mean thickness can also be determined by the method described in Appendix X1. Also see Note 5.

8.3 *Adhesion*—Adhesion of the coating shall be tested by one of the recommended methods of Practice B571 (see Appendix X2).

8.4 *Solderability*—For coatings that must be solderable, the method by which solderability is tested shall be specified. Three test methods are described in Appendix X3, while a simple dip test is given in Test Method B678. The purchaser shall specify whether the tested articles are to receive an artificial aging treatment, such as that given in Test Method B678, so as to demonstrate whether the articles may be expected to retain their solderability during long storage periods.

8.5 *Porosity and Gross Defects Testing:*

8.5.1 Coatings on articles of steel (or iron) having a local thickness of 10 µ (0.4 mil) or greater should be subjected to the test given in Appendix X5.

8.5.2 For coatings on articles made from copper or copper alloy as the basis metal, the following tests should be used:

8.5.2.1 To determine mechanical damage or gross defects only, subject samples to the sodium polysulfide immersion test outlined in Specification B246. Black spots or lines are evidence of mechanical damage or gross defects.

8.5.2.2 To determine all porosity that penetrates down to the copper substrate, especially for coatings in Service Class A, the humid sulfur vapor test (Test Method B809) shall be used. Blackening at pores will be evidence of porosity.

9. Rejection and Rehearing

9.1 Articles that fail to conform to the requirements of this specification may be rejected. Rejection shall be reported to the seller promptly and in writing. In cases of rejection, the seller may make a claim for a rehearing. Product that shows coating imperfections in subsequent manufacturing operations may be rejected.

10. Keywords

10.1 electrodeposited tin; electroplated tin; tin; tin coatings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Pretreatment of Iron and Steel for Reducing the Risk of Hydrogen Embrittlement

S1.1 Parts for critical applications that are made of steels with ultimate tensile strengths of 1000 MPa, hardness of 31 HRC or greater, that have been machined, ground, cold formed, or cold straightened subsequent to heat treatment, shall require stress relief treatment when specified by the purchaser, the tensile strength to be supplied by the purchaser. Specifications B849 (heat treatment) and B851 (shot peening) may be consulted for a list of pretreatments that are used widely.

S2. Post Coating Treatments of Iron and Steel for Reducing the Risk of Hydrogen Embrittlement

S2.1 Parts for critical applications that are made of steels with ultimate tensile strengths of 1000 MPa, hardness of 31 HRC or greater, as well as surface hardened parts, shall require post coating hydrogen embrittlement relief baking when specified by the purchaser, the tensile strength to be supplied by the purchaser. Specifications B850 may be consulted for a list of post treatments that are used widely.

S3. Solderability Requirements

S3.1 If the coating must be solderable, refer to 8.4 for test methods for determining solderability.

S4. Government Packaging Requirements

S4.1 Parts plated for the U.S. government and military, including subcontractors, shall be packaged according to Practice D3951. (**Warning—**Some contemporary packaging materials may emit fumes that are deleterious to the surface of the coating.)

APPENDIXES

(Nonmandatory Information)

X1. DETERMINATION OF MEAN COATING THICKNESS OF SMALL ARTICLES BY THE WEIGHT LOSS METHOD

X1.1 Select at random from the production lot the number of coated articles specified by the purchaser. The number of articles shall be sufficient to have a total weight of coating of at least 0.2 g. Calculate the coated area in mm^2 to an accuracy of at least 1 part in 100.

X1.2 Clean the articles by, for example, washing in a solvent or water-detergent followed by a clean water rinse. Dry and weigh with an accuracy of at least 1 part in 1000.

X1.3 Immerse the articles in a solution of 20 g antimony trioxide in 1 L of concentrated hydrochloric acid (sp gr 1.19) and allow them to remain for 1 min after gas evolution stops. Remove the articles, rinse them in clean water, wipe and brush as necessary to remove smut (antimony residues), and dry. Reweigh.

X1.4 Calculate the mean thickness in µm by dividing the loss in weight of the articles by the area and multiplying the quotient by 1.37×10^5.

X2. ADHESION TESTS

X2.1 *Burnishing Test*—Rub an area of not more than 630 mm^2 (1 $in.^2$) of the electroplated 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 pressure sufficient to burnish the film at every stroke, but not so great as to cut the deposit. Poor adhesion will be shown by the appearance of a loose blister that grows as rubbing is continued. If the quality of the deposit is also poor, the blister may crack, and the plating will peel away from the basis metal.

X2.2 *Quenching Test*—Heat the electroplated article in an oven for a sufficient time to reach 150 ± 10°C (300 ± 20°F), and then quench in water at room temperature. Poor adhesion will be shown if the coating blisters, cracks, or peels.

X2.3 *Reflow Test*—Parts may be evaluated by reflowing in a bath of palm oil at a temperature of 235 to 260°C (455 to 500°F) until the plating melts. A bright coating completely covering the significant surfaces without blisters or cracks will indicate acceptable quality.

X2.4 *Bend Test*—A sample shall be bent, with the coated surface away, over a mandrel until its two ends are parallel. The mandrel shall have a diameter equal to the thickness of the sample. Examination of 4× magnification should show no evidence of peeling or cracking. Some tin coatings, especially of bright tin, may show fine cracks during this test, but if these do not separate from the surface, it should not be considered an adhesional failure.

X3. SOLDERABILITY TESTS

X3.1 *General*:

X3.1.1 Methods for testing the solderability of tin-coated articles are based on measurement of the extent of wetting by molten solder or determination of the minimum time required to produce full or perfect wetting by the solder (**1**, **2**).

X3.1.2 The extent of wetting can be observed by simple immersion in solder under controlled conditions, or by performing dip tests with automated equipment. Visual examination, time of wetting, measurement of area of spread, and calculation of spread values are used to assess solderability (**1**, **2**).

X3.1.3 The minimum wetting time is determined by carrying a specimen in a fixture through a standing wave of solder at a controlled speed and measuring the time of immersion required to achieve complete wetting.

X3.2 *Simple Dip Test*—The test in Test Method B678 is recommended.

X3.3 *Wetting Balance* (**1**, **3**, **4**):

X3.3.1 The wetting balance provides the most objective, operator-independent, and reproducible measure of the solderability of a surface of currently known methods. Numerous models are available under different names such as the surface-tension balance, and various trade names, such as "meniscograph," but all share certain common features.

X3.3.2 The base structure holds a heated solder bath that can be raised or lowered at a specific rate. The test piece is held in a clamp that extends from an arm directly over the solder bath. The clamp is attached to a load cell and to a transducer, which transmits a signal to a converter that adjusts the signal to a useful mode (analog or digital) for the recording instrument, computer, or strip-chart recorder.

X3.3.3 The parameters of the test are set on the instrument, according to the manufacturer's instructions, to reveal the most information concerning the solderability of the test piece.

X3.3.4 The bath temperature must be held within precise limits at a suitable temperature with respect to the solder alloy. The immersion rate, which may vary from 1 to 25 mm/s, must be constant from sample to sample.

X3.3.5 The immersed surface area of the standards and samples should be similar, as well as the depth of immersion and the type and weight of flux on the test piece.

X3.3.6 The opposing forces of buoyancy and wetting, versus time, which is transmitted from the transducer to the strip-chart recorder or the computer during the test, is plotted.

X3.3.7 The most significant information obtained from the graph are the wetting time, rate of wetting, total wetting force, and whether the wetting force remains constant over the time of the test.

X3.3.8 Test samples are to be run against a series of standards that have been run to establish averages and to define precision windows. The goal is to define minimum acceptable solderability in terms of a maximum wetting time, minimum wetting rate, minimum force, and stable wetting at a set dwell time.

X4. SOME DEFINITIONS OF WETTING TERMINOLOGY

X4.1 *dewetting*—a condition that results when molten metal has coated a surface and then receded, leaving irregularly shaped mounds of metal separated by areas covered with a thin metal film; basis metal is not exposed.

X4.2 *nonwetting*—a condition whereby a surface has contacted molten metal, but the metal has not adhered to all of the surfaces; basis metal remains exposed.

X4.3 *wetting*—the formation of a relatively uniform, smooth, unbroken, and adherent film of the metal coating to a basis metal.

X5. SULFUR DIOXIDE POROSITY TEST (STEEL SUBSTRATES)

X5.1 *Principle*—Exposure to a moist atmosphere containing a low concentration of sulfur dioxide causes spots of substrate corrosion product to appear at discontinuities in the coating. If the sulfur dioxide concentration in the atmosphere is too high, the corrosion product formed is too fluid to permit easy observation of pore sites. The method provided, which depends on the production of sulfur dioxide from the reaction between sodium thiosulfate and sulfuric acid within the test chamber, ensures suitable conditions for the development of immobile corrosion products at discontinuities.

X5.2 *Apparatus*:

X5.2.1 The test cabinet shall be a chamber fitted with a lid or door, and should preferably be made of glass or a transparent plastic material. The size should be sufficient to accommodate the test specimens with their lowest part at least 75 mm (3 in.) above the surface of a solution occupying at least 1/30 of the total capacity.

X5.2.2 The closure of the vessel and other joints should be gas tight but need not be capable of resisting pressure. A glass plate makes an adequate joint on the lubricated ground edges of a glass tank.

X5.2.3 The cabinet should be of uniform cross section, and the solution placed in it should cover the base completely.

X5.2.4 The specimens under testing should be supported by a glass or plastic stand inside the cabinet. The significant surfaces may be inclined at any angle, but it may be desirable to choose the same method of support for similar articles.

X5.3 *Corrosive Medium*—The corrosive medium should be moist air containing sulfur dioxide prepared by adding 1 part by volume of 0.1 N sulfuric acid to 4 parts of a solution containing 10 g of sodium thiosulfate crystals in 1 L of water.

X5.4 *Temperature of Test*—Conduct the test at 20 ± 5°C (60 ± 9°F), taking precautions against rapid temperature fluctuation in the course of the test.

X5.5 *Procedure*:

X5.5.1 Before the test, clean the specimens with an organic solvent (for example, trichloroethane), wipe with a lint-free cloth, and allow to attain room temperature. Introduce into the test cabinet a volume of aqueous sodium thiosulfate solution equal to 1/50 of the volume of the cabinet. Suspend the test specimens above this solution on nonmetallic supports, with the surfaces of the specimens not less than 25 mm (1 in.) apart, not less than 25 mm (1 in.) from any wall of the cabinet, and not less than 75 mm (3 in.) from the surface of the sodium thiosulfate solution. Add to the sodium thiosulfate solution a volume of 0.1 N sulfuric acid equal to a quarter of the volume of the thiosulfate solution and seal the cabinet, keeping it shielded from draughts or other causes of rapid temperature fall. Addition of the sulfuric acid may be made before the test specimens are placed in position, provided that the cabinet is closed within 5 min of addition of the acid.

X5.5.2 Leave the specimens in the closed vessel for 24 h. After removing the specimens from the corrosive atmosphere, allow them to dry without wiping or cleaning in any way, and then examine them using the options outlined in Guide B765, Sections 6 and 7.

X6. DESIGN CONSIDERATIONS

X6.1 *General*—Properties of electrodeposited tin coatings are affected to various degrees by their service and storage environments (4.2). These should be taken into account when designing for special applications.

X6.2 *Temperature and Other Environmental Effects*:

X6.2.1 *Diffusion and Intermetallic Formation*—Interdiffusion between tin coatings and copper or copper alloys does occur. The diffusion is slow at room temperature and rapid at elevated temperatures. Evidence of diffusion is the formation of a layer of copper-tin intermetallic at the interface and diffusion of zinc to the surface if the substrate is brass. Diffusion may lead to darkening of a thin coating and impairment of its solderability characteristics, particularly after long storage. With such thin coatings, a diffusion barrier of nickel may be advantageous, although users should also consider the use of thicker coatings when solderability must be maintained over a period of years (6.8). An underplating of nickel or copper must be used as a diffusion barrier on brass.

X6.2.2 *Tin Phase Transformation*—Tin coatings, like pure metal, may be subject to allotropic transformation at low temperatures (also called tin pest or disease). Where electroplated tin coatings are subject to long-term storage or use at very low temperatures, it may be advisable, when specified by the purchaser, to codeposit small amounts (<1 %) of bismuth, antimony, or lead with the tin. These alloying additions, particularly the first, have been shown to inhibit the transformation.

X6.2.3 *Tin Oxidation* (**5, 6**)—In clean, dry atmospheres at room temperature, tin is covered quickly with a very thin, but continuous, air-formed oxide film. Although the tin surface will remain bright for long periods in the absence of moisture, this invisible surface oxide layer is not truly protective. It gradually thickens, and it may eventually produce a dull gray appearance.

X6.2.3.1 In the presence of water vapor (humidity), the oxidation rate tends to increase greatly. The oxide film has been found to increase (as determined by weight gain measurements) almost linearly with time, with the formation of a gray film, or even of a slight yellow discoloration.

X6.2.3.2 Tin coatings begin to oxidize rapidly in air at 150°C and melt at 232°C.

X6.2.3.3 When exposed out of doors, the tin surface may acquire a very thin accumulation of light gray or white corrosion product. The original oxide film, in comparatively short or dry exposures, is primarily in the gray-to-black stannous oxide form, which is then hydrated by atmospheric moisture to the white hydroxyl form. Drying can reverse the reaction. Fortunately, these oxidation products are not hygroscopic, so that (according to Britton (**5**)) "tin is not attacked below 100 % relative humidity (RH), unless the dust falling on the surface is hygroscopic."

X6.2.4 *Oxides and Solderability*—Tin oxide films are not as easily reduced as copper oxide. However, the non-hydrated films are not an impediment to soldering, because as soon as a break is made in the oxide, the molten solder can interact with the layer of free tin below the oxide film. The mechanical forces of the molten solder and tin flowing together break up the oxide layer. There needs to be sufficient free tin below the oxide layer in order for this to occur, because the intermetallic compounds formed from tin and the basis metal will not react in this way (**7**).

X6.3 *Whisker Growth*:

X6.3.1 Sometimes metal filaments, usually called *whiskers*, grow spontaneously from the surface of electrodeposited metals (for example, tin, cadmium, and zinc) within a period after plating that may vary from weeks or months to years. These whiskers frequently are approximately 2.5 µm (0.0001 in.) in diameter, but they can grow to 10 mm (⅜ in.) or longer (25-mm whiskers have been recorded) and can have a current carrying capacity of as much as 10 mA. In many applications for tin coatings, whisker growth has not been a problem, but there are critical applications (X6.3.2) in which it may create a problem.

X6.3.2 Whiskers are particularly undesirable when associated with miniaturized low-voltage apparatus where narrow spacing exists between adjacent components that must remain electrically isolated to avoid short circuits. In this specialized application, the occurrence of whisker growth is sufficiently frequent to be an obstacle to the use of tin. Therefore, in designing for low-voltage electronic equipment where components are closely spaced, tin coatings should either not be used, or whisker formation should be inhibited or prevented by the application of prevention methods. Practically all of the following methods take into account the chief cause of tin whiskering, which is the presence of stresses in the tin coating (**8**):

X6.3.2.1 Flow brightening (**1**) or annealing the tin plating to reduce the internal stresses.

X6.3.2.2 Plating the tin to sufficient thickness to minimize stress-producing epitaxial effects.

X6.3.2.3 Use of compatible underplatings, especially nickel.

X6.3.2.4 Avoiding high compressive loads and stresses while making joints or connections.

X6.3.2.5 Codepositing lead, bismuth, antimony, copper, or nickel with the tin reduces the risk of whisker growth (**9**). A tin-lead plating that is used extensively for the prevention of whiskering has a nominal lead composition of 7 % (with allowed variations of ±5 %) by mass, the balance being tin. However, some of these platings cannot be used in contact with food.

REFERENCES

(1) For example, Wassink, R. J., Klein, *Soldering in Electronics*, Electrochemical Publications, Ltd., Ayr, Scotland, 1989.

(2) Long, J. B., "A Critical Review of Solderability Testing," in *Properties of Electrodeposits, Their Measurement and Significance*, Sard, R., Leidheiser, H., and Ogburn, F., Eds., The Electrochemical Society, 1975, Chapter 7.

(3) Wooldridge, J. R., "Lessons Learned During a Year of Production Solderability Testing with a Wetting Balance," in *12th Annual Electronics Manufacturing Seminar Proceedings*, Naval Weapons Center, China Lake, CA 1988.

(4) Yoshida, H., Warwick, M. E., Hawkins, S. P., "The Assessment of the Solderability of Surface Mounted Devices Using the Wetting Balance," *Brazing & Soldering*, No. 12, Spring 1987.

(5) Britton, S. C., *Corrosion*, L. L. Shreir, Ed., John Wiley and Sons, New York, 1963.

(6) Leidheiser, H., *The Corrosion of Copper, Tin, and Their Alloys*, John Wiley and Sons, New York, 1971.

(7) Wassink, R. J., Klein, *Soldering in Electronics*, Electrochemical Publications Ltd., Ayr, Scotland, 1984, pp. 144 and 149.

(8) Diehl, R. F., and Cifaldi, N. A., "Elimination of Tin Whisker Growth on Interconnections," in *Proceedings 8th Annual Connector Symposium*, 1975, p. 328; also references cited therein.

(9) Arnold, S. M., "Repressing Growth of Tin Whiskers," *Plating*, PLATA, Vol 53, January 1966, p. 96.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the ASTM website (www.astm.org/COPYRIGHT/).