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Standard Specification for Electrodeposited Coatings of Gold for Engineering Uses[1]

This standard is issued under the fixed designation B 488; 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.

ε[1] NOTE—Appendix X1 was editorially updated in July 2005.

1. Scope

1.1 This specification covers requirements for electrodeposited gold coatings that contain not less than 99.00 mass % gold and that are used for engineering applications.

1.2 Specifically excluded from this specification are autocatalytic, immersion, and vapor deposited gold coatings.

1.3 Gold coatings conforming to this specification are employed for their corrosion and tarnish resistance (including resistance to fretting corrosion and catalytic polymerization), bondability, low and stable contact resistance, solderability, and infrared reflectivity. Several types of coatings, differing in gold purity and hardness, are covered by this specification.

1.4 The values stated in SI units are to be regarded as the standard. Values provided in parentheses are for information only.

1.5 The following hazards caveat pertains only to the test methods section, Section 9, of this specification: *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]

B 32 Specification for Solder Metal

B 183 Practice for Preparation of Low-Carbon Steel for Electroplating

B 242 Practice for Preparation of High-Carbon Steel for Electroplating

B 253 Guide for Preparation of Aluminum Alloys for Electroplating

B 254 Practice for Preparation of and Electroplating on Stainless Steel

B 281 Practice for Preparation of Copper and Copper Base Alloys for Electroplating and Conversion Coatings

B 322 Practice for Cleaning Metals Prior to Electroplating

B 343 Practice for Preparation of Nickel for Electroplating with Nickel

B 374 Terminology Relating to Electroplating

B 481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating

B 482 Practice for Preparation of Tungsten and Tungsten Alloys for Electroplating

B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section

B 489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals

B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method

B 507 Practice for Design of Articles to Be Electroplated on Racks

B 542 Terminology Relating to Electrical Contacts and Their Use

B 558 Practice for Preparation of Nickel Alloys for Electroplating

B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method

B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

B 571 Test Methods for Adhesion of Metallic Coatings

B 578 Test Method for Microhardness of Electroplated Coatings

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

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

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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.

B 678 Test Method for Solderability of Metallic Coated Products
B 697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings
B 735 Test Method for Porosity in Gold Coatings on Metal Substrates by Nitric Acid Vapor
B 741 Test Methods for Porosity in Gold Coatings on Metal Substrates by Paper Electrography
B 748 Test Method for Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope (SEM)
B 762 Method of Variables Sampling of Metallic and Inorganic Coatings
B 765 Guide for Selection of Porosity Tests for Electrodeposits and Related Metallic Coatings
B 799 Test Method for Porosity in Gold and Palladium Coatings by Sulfurous Acid/Sulfur-Dioxide Vapor
B 809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor (Flowers-of-Sulfur)
D 509 Method of Sampling and Grading Rosin
D 1125 Test Methods for Electrical Conductivity and Resistivity of Water
D 3951 Practice for Commercial Packaging
F 390 Test Method for Sheet Resistance of Thin Metallic Films with a Collinear Four-Probe Array

2.2 *U.S. Government Standards:*[3]

MIL-G-45204 Gold Plating, Electrodeposited
MIL-STD-1916 DOD Preferred Methods for Acceptance of Product

2.3 *ANSI/ASQC Standard:*[4]

ANSI/ASQC Z1.4-1993 Sampling Procedures and Tables for Inspection by Attributes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminologies B 374 or B 542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *significant surfaces*—defined as those normally visible (directly or by reflection) or essential to the serviceability or function of the article. Can be the source of corrosion products or tarnish films that interfere with the function or desirable appearance of the article. The significant surfaces shall be indicated on the drawings of the parts or by the provision of suitably marked samples.

3.2.2 *underplating*—a metallic coating layer between the basis metal or substrate and the topmost metallic coating. The thickness of an underplating is usually greater than 1 µm (40 µin.), in contrast to a strike or flash, which is thinner.

4. Classification

4.1 *Types of Coatings*—A coating shall be specified by a combination of the following:

4.1.1 Type, characterizing minimum purity in accordance with 4.2.1,

4.1.2 Code, designating Knoop hardness in accordance with 4.2.3, and

4.1.3 a numeral designating thickness in micrometres in accordance with 4.3.

4.2 *Purity and Hardness*:

4.2.1 *Purity*—The issue of this standard establishes a new ASTM Type designation, which is identical to the original standard (MILG-45204), established for electrodeposited gold and is outlined in the following table.

Mass Percent Gold, Minimum, Excluding Potassium, Carbon & Nitrogen	New ASTM Type	MIL-G45204 Type	Old ASTM Type
99.70	I	I	2
99.00	II	II	3
99.90	III	III	1

NOTE 1—It is commonly accepted that a gold purity of 99.7 % is defined as no more than 0.3 % of total codeposited metallic components, excluding potassium and sodium. Likewise, 99.9 % purity is recognized to mean no more than 0.1 % of total codeposited metal impurities, excluding potassium and sodium. Almost all gold electrodeposits will contain potassium, carbon and nitrogen that are occluded or precipitated in the deposit. In the case of Type I gold, the occluded potassium has been shown to improve durability and is desirable for that reason.[5,6]

4.2.2 Gold purity is calculated by subtraction of the sum of all non-gold metals in mass %, excluding potassium and sodium, from 100 %. The presence of C, N, H, Na, and K contained in the electrodeposit are not included in the calculation.

4.2.3 *Hardness*—Hardness values shall be specified by ASTM code. The military standard designation of grade is included for reference.

Knoop Hardness Range	ASTM Code	MIL-G-45204
90 HK_{25} maximum	A	A
91–129 HK_{25}	B	B
90–200 HK_{25}	(see Note 2)	. . .
130–200 HK_{25}	C	C
>200 HK_{25}	D	D

NOTE 2—ASTM Code B has previously been specified for hardness grade 90–200. This hardness grade has been eliminated and replaced with hardness grade 91–129 in accordance with MIL-G-45204.

4.2.4 *Relationship Between Purity and Hardness*—The following combinations of purity and hardness ranges are representative of good commercial practice:

New ASTM	Old ASTM Type	Code
I	2	A, B and C
II	3	B, C and D
III	1	A only

4.3 *Thickness*—Thickness shall be specified by an Arabic numeral that designates the minimum linear thickness in micrometres. Examples of commonly specified thicknesses are shown in Table 1.

4.3.1 See 7.4.2 for thickness tolerances.

4.3.2 Instead of specifying the thickness in micrometres, the purchaser may specify the mass of gold per unit area (coating weight) in milligrams per square centimeter. Unless otherwise specified, the density of gold is assumed to be 19.3 g/cm^3 for Type III and 17.5 g/cm^3 for Type I and Type II.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Whitlaw, K. J., Souter, J. W., *Trans. Inst. Metal Fin.*, "The Role of Codeposited Elements in Gold Plated Contacts," 1984, 62(1), pp. 29–31.

[6] Whitlaw, K. J., Souter, J., Wright, I.S., Nottingham, M., *Electrical Contacts*, "Wear Properties of High Speed Gold Electrodeposits," (1984), 30th. pp. 33–45.

TABLE 1 Coating Thickness

Class	Minimum Thickness, μm
0.25	0.25
0.50	0.50
0.75	0.75
1.0	1.0
1.25	1.25
2.5	2.5
5.0	5.0

NOTE 3—The density of Type III gold coatings will be less than or equal to 19.3 g/cm^3, but not less than 18.5 g/cm^3.

NOTE 4—When significant surfaces are involved 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. Ordering Information

5.1 To make the application of this standard complete, the purchaser needs to supply the following information to the seller in the purchase order or other governing document.

5.1.1 The name, designation, and date of issue of this specification.

5.1.2 Classification: type, code, and thickness (or mass per unit area) (see Section 4).

5.1.3 Presence and thickness of underplating, if required (see 3.2.2).

5.1.4 Significant surfaces shall be specified (see 3.2.1).

5.1.5 Requirement, if any, for performance testing such as porosity testing (see 9.6), solderability testing (see Appendix X4), ductility testing (see 9.7), etc.

5.1.6 If the substrate is one that requires a nickel underplating (see 6.5.1 and Appendix X6).

5.1.7 Whether or not stress relief has been or is to be done (steel parts only).

5.1.8 Sampling plan employed (see Section 8).

6. Manufacture

6.1 Any process that provides an electrodeposit capable of meeting the specified requirements is acceptable.

6.2 *Substrate*:

6.2.1 The surface condition of the basis metal should be specified and should meet this specification prior to the plating of the parts.

6.2.2 Defects in the surface of the basis metal such as scratches, porosity, pits, inclusions, roll and die marks, laps, cracks, burrs, cold shuts, and roughness may adversely affect the appearance and performance of the deposit, despite the observance of the best plating practice. Any such defects on significant surfaces shall be brought to the attention of the purchaser.

6.2.3 The basis metal shall be subject to such cleaning procedures as are necessary to ensure a satisfactory surface for subsequent electroplating (see Practices B 183, B 242, Guide B 253, Practices B 254, B 281, B 322, B 343, B 481, B 482, and B 558).

6.2.4 Proper preparatory procedures and thorough cleaning of the basis metal are essential for satisfactory adhesion and performance of these coatings. The surface must be chemically clean and continuously conductive, that is, without inclusions or other contaminants. They must be smooth and as free of scratches, gouges, nicks, and similar imperfections as possible.

NOTE 5—A metal finisher can often remove defects through special treatments such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing. However, these may not be normal in the treatment steps preceding the plating and a special agreement is indicated.

6.3 If required (see 5.1.7), steel parts with a hardness greater than 31 HRC shall be given a suitable stress relief heat treatment prior to plating. Such stress relief shall not reduce the hardness to a value below the specified minimum. Acid pickling of high strength steels shall be avoided.

6.3.1 The coating shall be applied after all basis metal heat treatments and mechanical operations on significant surfaces have been completed.

6.4 *Racking*—Parts should be positioned so as to allow free circulation of solution over all surfaces. The location of rack or wire marks in the coating shall be agreed upon between the producer and the supplier.

6.5 *Plating Process*:

6.5.1 *Nickel Underplating*—For thickness classes except 5.0, a nickel underplating shall be applied before the gold coating when the product is made from copper or copper alloy. Nickel underplatings are also applied for other reasons (see Appendix X6).

NOTE 6—When the thickness of the nickel underplate has a detrimental impact on the mechanical properties or bondability of the substrate, the nickel thickness may be reduced to a non-detrimental level as specified by the purchaser.

NOTE 7—In certain instances in which high-frequency analog signals are employed, such as in wave guides, the magnetic properties of nickel may attenuate the signal.

NOTE 8—In applications in which forming or flaring operations are to be applied to the plated component, a ductile nickel electrodeposit should be specified.

6.5.2 *Strikes*—It is recommended to apply a gold strike to the underplate or substrate, except if the latter is silver or platinum, prior to applying the gold top coating.

6.5.3 *Plating*—Good practice calls for parts to be electrically connected when entering the gold plating solution. A minimum of 0.5 V is suggested.

NOTE 9—For rack and barrel plating processing, residual plating salts can be removed from the articles by a clean, hot (50 to 100°C) water rinse. A minimum rinse time of 2.5 min (rack) or 5 min (barrel) is suggested. Best practice calls for a minimum of three dragout rinses and one running rinse with dwell times of 40 s in each station when rack plating and 80 s when barrel plating. Modern, high-velocity impingement-type rinses can reduce this time to a few seconds. This is particularly useful in automatic reel-to-reel applications in which dwell times are significantly reduced.

7. *Coating Requirements* Coating Requirements

7.1 *Nature of Coating*—The gold deposit shall meet the appropriate purity requirements as put forth in the following:

7.1.1 Type I coatings shall contain at least 99.70 mass % gold, excluding potassium, sodium, carbon and nitrogen. For Type I Code A ("soft") coatings only, metallic hardening agents such as nickel, cobalt or iron combined, shall be less than 0.05 mass % and none of these three elements shall be present in an

amount greater than 0.03 mass %. All other metals excluding potassium and sodium are considered impurities and shall not be present in amounts greater than 0.05 mass % combined. For Type I Code B nd C coatings, metallic hardening agents such as nickel, cobalt or iron combined shall be equal to or less than 0.3 mass %. All other metals are considered impurities and shall not be present in amounts greater than 0.05 % mass % each, 0.1 % combined. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.1.2 Type II coatings shall contain at least 99.00 mass % gold, excluding potassium, sodium, carbon and notrogen. Type II coatings may contain metallic hardening agents, such as nickel, cobalt or iron, which may be present in amounts greater than 0.3 mass %. All other metals, excluding potassium and nitrogen, shall be considered impurities and shall not be present in amounts greater than 0.1 mass % each. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.1.3 Type III coatings shall contain at least 99.90 mass % gold, excluding potassium, sodium, carbon and nitrogen. Individual metal impurities shall not be present in a quantity greater than 0.04 mass %. Iron, nickel and cobalt combined shall be less than 0.05 mass %, and none of these three elements shall be present in an amount greater than 0.03 mass %. All non-gold metals, excluding potassium and sodium, are considered impurities and shall not be present in amounts greater than 0.1 mass % combined. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.2 *Hardness*—The gold coating shall have a Knoop hardness within the specified range as shown in 4.2.3 when tested in accordance with 9.2.

7.3 *Appearance*—Gold coatings shall be coherent, continuous, and have a uniform appearance to the extent that the nature of the basis metal and good commercial practices permit.

7.4 *Thickness*:

7.4.1 The gold coating shall have a thickness on the significant surfaces in accordance with 4.3 unless otherwise specified.

NOTE 10—Where Type I (Code B or C) or Type II (Code B or C) gold is specified, improved protection of the underlying metals can be obtained by applying a duplex gold composite coating consisting of an underlying layer of Type III (Code A) gold. Typical thicknesses of the Type III gold underlayer are 10 to 30 % of the total specified thickness. However, care must be taken to ensure that the thickness of the Type I or Type II gold topcoat is sufficient so as not to compromise wear properties. When measuring the total gold thickness of duplex composite coatings, a density of 17.5 g/cm^3 should be employed (see 9.4).

7.4.2 The thickness of the gold coating shall be equal to or exceed the specified thickness throughout the significant surface (see 3.2.1). When plated parts are used in mating applications, the maximum thickness shall not exceed the tolerance specified for the part on its engineering drawing. It is customary that allowance for plated coatings be included within the part tolerance.

NOTE 11—The coating thickness requirement of this specification is a minimum requirement: that is, the coating thickness is required to equal or exceed the specified thickness throughout the significant surfaces, while conforming to all maximum allowed thicknesses created by part dimensional tolerances given in the engineering drawing. Variation in the coating thickness from point to point on a coated article is an inherent characteristic of electroplating processes. Therefore, the coating thickness at any single point on the significant surface will sometimes have to exceed the specified value in order to ensure that the thickness equals or exceeds the specified value at all points. Hence, most average coating thicknesses will be greater than the specified value; how much greater is largely determined by the shape of the article (see Practice B 507) and the characteristics of the plating process. In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all the articles in a production lot are to meet the thickness requirement, the average coating thickness for the production lot as a whole will be greater than the average necessary to ensure that any single article meets the requirment (see 8.1).

7.5 *Adhesion*—The gold coatings shall be adherent to the substrate when tested by one of the procedures summarized in 9.5.

7.6 *Integrity of the Coating*:

7.6.1 *Gross Defects/Mechanical Damage*—The coatings shall be free of visible mechanical damage and similar gross defects when viewed at magnifications up to 10×. 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 or on the periphery of the significant surfaces (see 7.6.2).

7.6.2 *Porosity*—Almost all as-plated electrodeposits contain some porosity. The tolerable amount of porosity in the coating 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 the significant surfaces, their presence can often be tolerated. Such acceptance (or pass-fail) criteria, if required, shall be part of the product specification for the particular article or coating requiring the porosity test (see 9.6 for porosity testing).

8. Sampling

8.1 The producer is urged to employ statistical process control in the coating process. Properly performed, this process will ensure coated products of satisfactory quality and will reduce the amount of acceptance inspection. The sampling plan used for the inspection of the quality of the coated articles shall be as agreed upon between the purchaser and the supplier.

NOTE 12—Usually, with a collection of coated articles, the inspection lot (see 8.2) is examined for compliance with the requirements placed on the articles, a relatively small number of the articles, the sample, is selected at random and is inspected. The inspection lot is then classified as complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria of compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B 602, Guide B 697, and Method B 762 contain sampling plans that are designed for the sampling inspection of coatings. Test Method B 602 contains four sampling plans, three for use with tests that are nondestructive and one with those that are destructive. The buyer and seller may agree on the plan or plans to be used. If they do not, Test Method B 602 identifies the plan to be used. Guide B 697