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Standard Specification for Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium[1]

This standard is issued under the fixed designation B456; 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 requirements for several types and grades of electrodeposited copper plus nickel plus chromium or nickel plus chromium coatings on steel, nickel plus chromium coatings on copper and copper alloys, nickel plus chromium coatings on Type 300 and 400 series stainless steel and copper plus nickel plus chromium coatings on aluminum and its alloys and zinc alloys for applications where both appearance and protection of the basis metal against corrosion are important. Five grades of coatings are provided to correspond with the service conditions under which each is expected to provide satisfactory performance: namely, extended very severe, very severe, severe, moderate, and mild. Definitions and typical examples of these service conditions are provided in Appendix X1.

1.2 This specification does not cover the requirements for the plating on plastics, see Specification B604.

1.3 The following hazards caveat pertains only to the test methods portions, Appendix X2, Appendix X3, Appendix X4, and Appendix X5 of this specification: *This standard does not purport to address all of 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]

B183 Practice for Preparation of Low-Carbon Steel for Electroplating
B242 Guide for Preparation of High-Carbon Steel for Electroplating
B252 Guide for Preparation of Zinc Alloy Die Castings for Electroplating and Conversion Coatings
B253 Guide for Preparation of Aluminum Alloys for Electroplating
B254 Practice for Preparation of and Electroplating on Stainless Steel
B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings
B320 Practice for Preparation of Iron Castings for Electroplating
B368 Test Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)
B380 Test Method for Corrosion Testing of Decorative Electrodeposited Coatings by the Corrodkote Procedure
B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section
B489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals
B490 Practice for Micrometer Bend Test for Ductility of Electrodeposits
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
B530 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates
B537 Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure
B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
B602 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 B08.08.03 on Decorative 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.

B604 Specification for Decorative Electroplated Coatings of Copper Plus Nickel Plus Chromium on Plastics
B659 Guide for Measuring Thickness of Metallic and Inorganic Coatings
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
B764 Test Method for Simultaneous Thickness and Electrode Potential Determination of Individual Layers in Multilayer Nickel Deposit (STEP Test)
D1193 Specification for Reagent Water
D3951 Practice for Commercial Packaging
E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials
G85 Practice for Modified Salt Spray (Fog) Testing

2.2 *ISO Standards:*

ISO 1456 Metallic coatings—Electrodeposited coatings of nickel plus chromium and of copper plus nickel plus chromium[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *significant surfaces*—those surfaces normally visible (directly or by reflection) that are essential to the appearance or serviceability of the article, or both, when assembled in normal position; or that can be the source of corrosion products that deface visible surfaces on the assembled article. When necessary, the significant surfaces shall be specified by the purchaser and shall be indicated on the drawings of the parts, or by the provision of suitably marked samples.

4. Classification

4.1 Five grades of coatings designated by service condition numbers and several types of coatings defined by classification numbers are covered by this specification.

4.2 *Service Condition Number*:

4.2.1 The service condition number indicates the severity of exposure for which the grade of coating is intended:

SC 5 extended severe service
SC 4 very severe service,
SC 3 severe service,
SC 2 moderate service, and
SC 1 mild service.

4.2.2 Typical service conditions for which the various service condition numbers are appropriate are given in Appendix X1.

4.3 *Coating Classification Number*—The coating classification number comprises:

4.3.1 The chemical symbol for the basis metal (or for the principal metal if an alloy) followed by a slash mark, except in the case of stainless steel. In this case, the designation shall be SS followed by the designated AISI number followed by a slash, that is, SS463/,

4.3.2 The chemical symbol for copper (Cu) (if copper is used),
4.3.3 A number indicating the minimum thickness of the copper coating in micrometres (if copper is used),
4.3.4 A lower-case letter designating the type of copper deposit (if copper is used) (see 4.4 and 6.2.3),
4.3.5 The chemical symbol for nickel (Ni),
4.3.6 A number indicating the minimum thickness of the nickel coating, in micrometres,
4.3.7 A lower-case letter designating the type of nickel deposit (see 4.4 and 6.2.4),
4.3.8 The chemical symbol for chromium (Cr), and
4.3.9 A letter (or letters) designating the type of chromium deposit and its minimum thickness in micrometres (see 4.4 and 6.2.5).

4.4 *Symbols for Expressing Classification*—The following lower-case letters shall be used in coating classification numbers to describe the types of coatings:

a	—	ductile copper deposited from acid-type baths
b	—	single-layer nickel deposited in the fully-bright condition
d	—	double- or triple-layer nickel coatings
r	—	regular (that is, conventional) chromium
mc	—	microcracked chromium
mp	—	microporous chromium

4.5 *Example of Complete Classification Numbers*—A coating on steel comprising 15 µm minimum (ductile acid) copper plus 25 µm minimum (duplex) nickel plus 0.25µ m minimum (micro-cracked) chromium has the classification number: Fe/Cu15aNi25d Cr mc (see 4.3 and 6.2 for explanation of symbols).

5. Ordering Information

5.1 When ordering articles to be electroplated in conformance with this standard, the purchaser shall state the following:

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

5.1.1 The ASTM designation number of this standard.

5.1.2 Either the classification number of the specific coating required (see 4.3) *or* the substrate material and the service condition number denoting the severity of the conditions it is required to withstand (see 4.2). If the service condition number is quoted and not the classification number, the manufacturer is free to supply any of the types of coatings designated by the classification numbers corresponding to the specified service condition number, as given in Table 1, Table 2, Table 3, Table 4, or Table 5. On request, the manufacturer shall inform the purchaser of the classification number of the coating applied.

5.1.3 The appearance required, for example, bright, dull, or satin. Alternatively, samples showing the required finish or range of finish shall be supplied or approved by the purchaser.

5.1.4 The significant surfaces, to be indicated on drawings of the parts, or by the provision of suitably marked specimens (see 3.1).

5.1.5 The positions on significant surfaces for rack or contact marks, where such marks are unavoidable (see 6.1.1).

5.1.6 The extent to which defects shall be tolerated on nonsignificant surfaces.

5.1.7 The elongation of copper if other than the standard value (see 6.4).

5.1.8 The ducitility of the nickel if other than the standard value (see 6.5).

5.1.9 The extent of tolerable surface deterioration after corrosion testing (see 6.7.3).

5.1.10 Sampling methods and acceptance levels (see Section 7).

5.1.11 The minimum values of the electrode potential differences between individual nickel layers as measured in accordance with Test Method B764 within the limits given in 6.8.

5.1.12 *Adhesion Test*—The adhesion test to be used (see 6.3).

6. Product Requirements

6.1 *Visual Defects*:

6.1.1 The significant surfaces of the electroplated article shall be free of clearly visible plating defects, such as blisters, pits, roughness, cracks, and uncoated areas and shall not be stained or discolored. On articles where a visible contact mark is unavoidable, its position shall be agreed upon by the purchaser and the plater. The electroplated article shall be clean and free of damage.

6.1.2 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 electroplating practices. Accordingly, the plater's responsibility for defects in the coating resulting from such conditions shall be waived.

NOTE 1—To minimize problems of this type, the specifications covering the basis material or the item to be electroplated should contain appropriate limitations on such basis metal conditions.

6.2 *Process and Coating Requirements*:

6.2.1 Proper preparatory procedures and thorough cleaning of the basis metal surface are essential for satisfactory adhesion and corrosion performance of the coating. Accordingly, the applicable practices for the preparation of various basis metals for electroplating shall be followed. Practices B183, B242, B252, B281, and B320 are examples of practices that may be used for the preparation of basis metals.

6.2.2 Following the preparatory operations, the parts (articles) to be electroplated are introduced in such plating baths as required to produce the types of deposits described by the specific coating classification numbers or one of the coating classification numbers listed in Table 1, Table 2, Table 3, Table 4, or Table 5 appropriate for the specified service condition number.

6.2.3 *Type of Copper and Deposit Thickness*:

TABLE 1 Nickel Plus Chromium Coatings on Steel

NOTE 1—When permitted by the purchaser, copper may be used as an undercoat for nickel but is not substitutable for any part of the nickel thickness specified. If the use of copper is permitted, Table 2 may be used to obtain the same service conditions.

Service Condition No.	Classification No.	Nickel Thickness, µm
SC 5	Fe/Ni35d Cr mc	35
	Fe/Ni35d Cr mp	35
SC 4	Fe/Ni30d Cr mc	30
	Fe/Ni30d Cr mp	30
SC 3	Fe/Ni25d Cr mc	25
	Fe/Ni25d Cr mp	25
SC 2	Fe/Ni20b Cr r	20
	Fe/Ni15b Cr mc	15
	Fe/Ni15b Cr mp	15
SC 1	Fe/Ni10b Cr r	10

TABLE 2 Copper Plus Nickel Plus Chromium Coatings on Steel

Service Condition No.	Classification No.	Nickel Thickness, µm
SC 5	Fe/Cu15a Ni30d Cr mc	30
	Fe/Cu15a Ni30d Cr mp	30
SC 4	Fe/Cu15a Ni25d Cr mc	25
	Fe/Cu15a Ni25d Cr mp	25
SC 3	Fe/Cu12a Ni20d Cr mc	20
	Fe/Cu12a Ni20d Cr mp	20

TABLE 3 Copper Plus Nickel Plus Chromium Coatings on Zinc Alloy

Service Condition No.	Classification No.	Nickel Thickness, µm
SC 5	Zn/Cu5 Ni35d Cr mc	35
	Zn/Cu5 Ni35d Cr mp	35
SC 4	Zn/Cu5 Ni30d Cr mc	30
	Zn/Cu5 Ni30d Cr mp	30
SC 3	Zn/Cu5 Ni20d Cr mc	20
	Zn/Cu5 Ni20d Cr mp	20
SC 2	Zn/Cu5 Ni20b Cr r	20
	Zn/Cu5 Ni15b Cr mc	15
	Zn/Cu5 Ni15b Cr mp	15
SC 1	Zn/Cu5 Ni10b Cr r	10

TABLE 4 Nickel Plus Chromium Coatings on Copper or Copper Alloy

Service Condition No.	Classification No.	Nickel Thickness, µm
SC 4	Cu/Ni25d Cr mc	25
	Cu/Ni25d Cr mp	25
SC 3	Cu/Ni20d Cr mc	20
	Cu/Ni20d Cr mp	20
	Cu/Ni30b Cr r	30
	Cu/Ni25b Cr mc	25
	Cu/Ni25b Cr mp	25
SC 2	Cu/Ni15b Cr r	15
	Cu/Ni10b Cr mc	10
	Cu/Ni10b Cr mp	10
SC 1	Cu/Ni5b Cr r	5

6.2.3.1 *Type of Copper*—The type of copper is designated by the following symbols that are placed after the thickness value:

a for ductile copper deposited from acid-type baths containing additives that promote leveling by the copper deposit and that have an elongation not less than 8 %.

No symbol is placed after the thickness value if a minimum elongation is not required or if a deposit from a non-leveling bath is permitted.

6.2.3.2 *Thickness of Copper Deposits*—The number following the chemical symbol for copper (Cu) indicates in micrometres the minimum thickness of the copper deposit at points on significant surfaces (see 3.1).

6.2.4 *Type of Nickel and Deposit Thickness*:

6.2.4.1 *Type of Nickel*—The type of nickel is designated by the following symbols, which are placed after the thickness value (Note 5):

b for nickel deposited in the fully bright condition.

d for a double-layer or triple-layer nickel coating.

The bottom layer of this coating system shall contain less than 0.005 mass % sulfur (Note 3), and a minimum ducitility of 67 % (see Practice B490). The top layer of this system shall contain more than 0.04 mass % sulfur (Note 2 and Note 3), and have a minimum ductility of 11 %. Its thickness shall be not less than 20 % nor more than 40 % (see Table 6) of the total nickel thickness. The thickness of the bottom layer in double-layer coatings shall not be less than 60 % nor more than 80 % of the total nickel thickness. In triple-layer coatings, the bottom layer shall be not less than 50 % nor more than 70 %. If there are three layers, the intermediate layer shall contain not less than 0.15 mass % sulfur and shall not exceed 10 % of the total nickel thickness. These requirements for multilayer nickel coatings are summarized in Table 6.

NOTE 2—The sulfur contents are specified in order to indicate which type of nickel electroplating solution must be used. Although at present, no simple method is available for determining the sulfur content of a nickel deposit on a coated article, chemical determinations are possible using specially prepared test specimens (see Appendix X3).

TABLE 5 Nickel Plus Chromium[A] on Stainless Steels, AISI Designated Type 300 and 400 Series,[B] and Copper Plus Nickel Plus Chromium on Aluminum and Its Alloys

NOTE 1—Before nickel-chromium plating, the stainless steel surface and the aluminum substrate shall be prepared by a pretreatment from Practice B254,[C] Guide B253,[D] or equivalent, which is agreed upon between the supplier and the user.

Service Condition No.	Classification No.	Nickel Thickness, μm
SC 4	SS-3XX[E]/Ni20b/Cr mp	20
SC 4	SS-4xx[E]/Ni25b/Cr mp	25
SC 5	Al/Cu15a/Ni40d/Cr mp	40

[A] Data in Table 5 were obtained using only microporous chromium systems. No data are available for the use of standard or microcracked systems.
[B] The stainless steel alloy numbers used in this specification are based on the AISI system. They may not be interchangeable with other numbering systems such as the United Numbering System (UNS) or foreign designations.
[C] Preplate for stainless steel substrates.
[D] Preplate for aluminum substrates.
[E] Insert number for specific 300 or 400 alloy.

TABLE 6 Summary of the Requirements for Double- and Triple-Layer Nickel Coatings

Type of Nickel Layer	Ductility	Sulfur Content	Thickness Relative to Total Nickel Thickness	
			Double Layer	Triple Layer
Bottom	67 %	<0.005 mass %	60 to 80 %	50 to 70 %
Middle (high-sulfur)	...	>0.15 mass %	...	≤10 %
Top (bright)	11 %	>0.04 mass %	20 to 40 %	≥30 %
Test Method	See B490	See Note 2[A]	...	Note 3[A]

[A] For Note 2 and Note 3, see Section 6.

NOTE 3—It will usually be possible to identify the type of nickel by microscopical examination of the polished and etched section of an article prepared in accordance with Test Method B487. The thickness of the individual nickel layers in double-layer and triple-layer coatings, as well as the electrochemical relationships between the individual layers, can also be measured by the STEP test,[4] in accordance with Test Method B764.

6.2.4.2 Thickness of Nickel Deposit—The number following the chemical symbol Ni indicates, in micrometres, the minimum thickness of the nickel electrodeposit at points on the significant surface (see 3.1).

6.2.5 *Type of Chromium and Deposit Thickness*:

6.2.5.1 *Type of Chromium*—The type of chromium deposit is designated by the following symbols placed after the chemical symbol Cr:

r for "regular" (that is, conventional) chromium.

mc for microcracked chromium, having more than 30 cracks/mm in any direction over the whole of the significant surface. The cracks shall be invisible to the unaided eye (see 6.10).

mp for microporous chromium containing a minimum of 10 000 pores/10 mm by 10 mm square (10 000/cm^2). The pores shall be invisible to the unaided eye (see 6.10).

NOTE 4—A specially formulated nickel strike in between the bright nickel and the chromium deposits may be used to induce micropores or microcracks in the chromium deposits. Controlled particle impingement of the plated standard chromium deposit may also be used to induce microporous chromium. Trivalent chromium deposits, as plated, may be microporous, microcracked, or both.

6.2.5.2 *Thickness of Chromium Deposit*—The minimum thickness of the chromium deposit shall be 0.25 μm on significant surfaces (see 3.1), except that for service condition SC 1 (see 4.2.1) the minimum thickness may be reduced to 0.13 μm. The thickness of chromium is designated by the same symbol as the type instead of by numerals as in the case of copper and nickel.

6.2.5.3 When plating chromium over a nickel strike containing micro-particles used to induce microporosity in the subsequent chromium deposit, excess chromium thickness will bridge the nonconductive particles within the nickel layer. A maximum of 0.5 μm is recommended.

6.3 *Adhesion*—The coating shall be sufficiently adherent to the basis metal, and the separate layers of multilayer coatings shall be sufficiently adherent to each other, to pass the appropriate tests detailed in Test Methods B571. The particular test or tests to be used shall be specified by the purchaser.

[4] Harbulak, E. P., "Simultaneous Thickness and Electrochemical Potential Determination of Individual Layers in Multilayer Nickel Deposits," *Plating and Surface Finishing*, Vol 67, No. 49, February 1980.

TABLE 7 Corrosion Tests Appropriate for Each Service Condition Number

Basis Metals	Service Condition No.	Corrosion Test and Duration h		
		CASS Method B368	Corrodkote Method B380	Acetic-salt Method G85
Steel, zinc alloy,	SC 5	66	...	...
or copper and	SC 4	22	Two 16-h cycles	144
copper alloy,	SC 3	16	16	96
stainless steel and	SC 2	8	4	24
aluminum alloys	SC 1	...	...	8

6.4 *Elongation*—The elongation of copper shall be such that it will not be less than stated in 6.2.3.1 when tested by the method given in Appendix X2. Greater elongation may be requested but shall be subject to agreement between the purchaser and the manufacturer.

6.5 *Ductility*—The ductility of the composite nickel deposit on a finished part is considered acceptable when foils plated out of the individual nickel processes meet or exceed the values listed in Table 6. See test details in Test Method B490.

6.6 *Coating Thickness*:

6.6.1 The minimum coating thickness shall be as designated by the coating classification number.

6.6.2 It is recognized that requirements may exist for thicker coatings than are covered by this specification.

6.6.3 The thickness of a coating and its various layers shall be measured at points on the significant surfaces (See 3.1.1 and Note 5).

NOTE 5—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, or bipolar electrodes or nonconducting shields.

6.6.3.1 The coulometric method described in Test Method B504 may be used to measure thickness of the chromium, the total thickness of the nickel, and the thickness of the copper. The STEP test, Test Method B764, which is similar to the coulometric method, may be used to closely estimate the thicknesses of individual layers of nickel in a multilayer coating.

6.6.3.2 The microscopial method described in Test Method B487 may be used to measure the thickness of each nickel layer and of the copper layer.

6.6.3.3 The X-ray method described in Test Method B568 ~~may be used when the total thickness of a copper/nickel/chromium composite coating is to be measured, without any indication of the thickness of each individual layer.~~ may be used to measure thickness of the chromium, thickness of a single layer nickel as well as the thickness of copper. In the case of duplex/triple nickel coatings, the X-ray method will give a total nickel thickness reading based on the average density of the individual nickel coatings.

6.6.3.4 Other methods may be used if it can be demonstrated that the uncertainty of the measurement is less than 10 %, or less than that of any applicable method mentioned in 6.6.3. Other methods such as B499 and B530, as outlined in Guide B659, may be used if agreed upon between the purchaser and manufacturer.

6.7 *Corrosion Testing:*

6.7.1 Coated articles shall be subjected to the corrosion test for a period of time that is appropriate for the particular service condition number (or for the service condition number corresponding to a specified classification number) as shown in Table 5. The test is described in detail in the referenced ASTM designation.

NOTE 6—There is no direct relation between the results of an accelerated corrosion test and the resistance to corrosion in other media, because several factors, such as the formation of protective films, influence the progress of corrosion and vary greatly with the conditions encountered. The results obtained in the test should, therefore, not be regarded as a direct guide to the corrosion resistance of the tested materials in all environments where these materials may be used. Also, performance of different materials in the test cannot always be taken as a direct guide to the relative resistance of these materials in service.

6.7.2 After the article has been subjected to the treatment described in the relevant corrosion test method, it shall be examined for corrosion of the basis metal or blistering of the coating. Any basis metal corrosion or blistering of the coating shall be cause for rejection. It is to be understood that occasional widely scattered, small corrosion defects such as surface pits may be observed after the testing period. In general, "acceptable resistance" shall mean that such defects are not, when viewed critically, significantly defacing or otherwise deleterious to the function of the electroplated part. A method of rating corrosion is given in Practice B537.

6.7.3 Surface deterioration of the coating itself is expected to occur during the testing of some types of coatings. The extent to which such surface deterioration will be tolerated shall be specified by the purchaser.

6.8 *STEP Test Requirements:*

6.8.1 The electrode potential differences between individual nickel layers shall be measured for multilayer coatings corresponding to SC5, SC4, and SC3 in accordance with Test Method B764 (STEP Test).

NOTE 7—Universally accepted STEP values have not been established but some agreement in the value of ranges has been obtained. The STEP values depend upon which two nickel layers are being measured.

The STEP potential difference between the semi-bright nickel layer and the bright nickel layer has an accepted range of 100 to 200 mV with a typical range of 110 to 140 mV. For all combinations of nickel layers, the semi-bright nickel layer is more noble (cathodic) than the bright nickel layer.