



Designation: B 194 – 01

Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar¹

This standard is issued under the fixed designation B 194; 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 establishes the requirements for copper-beryllium alloy plate, sheet, strip, and rolled bar. The following alloys are specified:²

| Copper Alloy UNS No. ² | Previously Used Commercial Designations | Nominal Beryllium Content, % |
|--------------------------------------|--|---------------------------------|
| C17000 | Alloy 165 | 1.7 |
| C17200 | Alloy 25 | 1.9 |

1.2 Unless otherwise required, Copper Alloy UNS No. C17200 shall be the alloy furnished whenever Specification B 194 is specified without any alloy designation.

1.3 *Units*—With the exception of Grain Size values, the values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and not considered standard.

1.4 The following hazard statement pertains only to the test method portions in the annex of this specification:

1.5 *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 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 ASTM Standards:

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar³

B 601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast³

¹ This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

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² The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix “C” and a suffix “00.” The suffix can be used to accommodate composition variations of the base alloy.

³ *Annual Book of ASTM Standards*, Vol 02.01.

B 846 Terminology for Copper and Copper Alloys³

E 8 Test Methods for Tension Testing of Metallic Materials⁴

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁴

E 112 Test Methods for Determining Average Grain Size⁴

E 527 Practice for Numbering Metals and Alloys (UNS)⁵

3. General Requirements

3.1 The following sections of Specification B 248 constitute a part of this specification:

3.1.1 Terminology

3.1.2 Materials and Manufacture

3.1.3 Dimensions, Weights, and Permissible Variations

3.1.4 Workmanship, Finish, and Appearance

3.1.5 Sampling

3.1.6 Number of Tests and Retests

3.1.7 Specimen Preparation

3.1.8 Test Methods

3.1.9 Significance of Numerical Limits

3.1.10 Inspection

3.1.11 Rejection and Rehearing

3.1.12 Certification

3.1.13 Mill Test Report

3.1.14 Packaging and Package Marking

3.2 In addition, when a section with a title identical to that referenced in 3.1 above appears in this specification, it contains additional requirements that supplement those appearing in Specification B 248.

4. Terminology

4.1 For terms relating to copper and copper alloys, refer to Terminology B 846.

5. Ordering Information

5.1 Include the following information in orders for products:

5.1.1 Quantity,

5.1.2 Copper Alloy UNS number (1.1),

5.1.3 Form of material: plate, sheet, strip, or rolled bar,

5.1.4 Temper (7.1),

⁴ *Annual Book of ASTM Standards*, Vol 03.01.

⁵ *Annual Book of ASTM Standards*, Vol 01.01.

*A Summary of Changes section appears at the end of this standard.



- 5.1.5 Dimensions: thickness and width, and length if applicable.
- 5.1.6 How furnished: rolls, stock lengths with or without ends, specific lengths with or without ends,
- 5.1.7 Type of edge, if required: slit, sheared, sawed, square corners, rounded corners, rounded edges, or full-rounded edges (Specification B 248, Section 5.6),
- 5.1.8 Type of width and straightness tolerances, if required: slit-metal tolerances, square-sheared-metal tolerances, sawed-metal tolerances, straightened or edge-rolled-metal tolerances (Specification B 248, Section 5.3),
- 5.1.9 Special thickness tolerances, if required (Specification B 248, Table 3),
- 5.1.10 Tension test or hardness as applicable (Section 8),
- 5.1.11 Bend test, if required (Section 11),
- 5.1.12 Grain size or grain count if required (Section 9 or 10),
- 5.1.13 Certification if required (see Specification B 248, Section 14),
- 5.1.14 Mill Test Report, if required (see Specification B 248, Section 15),
- 5.1.15 Specification number and year of issue, and
- 5.1.16 Special tests or exceptions, if any.
- 5.2 When material is purchased for agencies of the U.S. government, this shall be specified in the contract or purchase order, and the material shall conform to the Supplementary requirements as defined in the current issue of Specification B 248.

6. Chemical Composition

- 6.1 The material shall conform to the chemical requirements specified in Table 1.
- 6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established, by agreement between manufacturer or supplier and purchaser. Copper may be given as remainder, and may be taken as the difference between the sum of all elements analyzed and 100 %. When all elements in Table 1 are analyzed, their sum shall be 99.5 % minimum.

7. Temper

7.1 Tempers available under this specification are defined in Practice B 601. The standard tempers of product are as designated in Table 2, Table 3, and Table 4. Plate is generally available in the TB00 (A), TD04 (H), TF00 (AT), and TH04 (HT) tempers.

8. Mechanical Property Requirements

8.1 For product less than 0.050 in. (0.127 mm) in thickness:

TABLE 1 Chemical Requirements

| Element | Composition, % | |
|-----------------------------|--------------------------------|--------------------------------|
| | Copper Alloy UNS No. C17000 | Copper Alloy UNS No. C17200 |
| Beryllium | 1.60–1.79 | 1.80–2.00 |
| Additive elements: | | |
| Nickel + cobalt, min | 0.20 | 0.20 |
| Nickel + cobalt + iron, max | 0.6 | 0.6 |
| Aluminum, max | 0.20 | 0.20 |
| Silicon, max | 0.20 | 0.20 |
| Copper | remainder | remainder |

- 8.1.1 Tensile test results shall be the product acceptance criteria, when tested in accordance with Test Method E 8.
- 8.1.2 The tensile strength requirements are given in Table 2, Table 3, and Table 4.
- 8.2 For product 0.050 in. (1.270 mm) and greater in thickness.
 - 8.2.1 Rockwell hardness is the product acceptance criteria, when tested in accordance with Test Method E 18.
 - 8.2.2 The referee product rejection criteria shall be tensile test results, when tested in accordance with Test Method E 8.
 - 8.2.3 Rockwell hardness and tensile strength requirements are given in Table 2, Table 3, and Table 4.
- 8.3 Product, as specified in 7.1, shall conform to the requirements specified in Table 2, in the solution heat-treated, or solution heat-treated and cold-worked conditions, and in Table 3, after precipitation heat-treatment or Table 4 in the mill-hardened condition. Precipitation heat-treatment parameters for Table 2 and Table 3 are shown in Section 12.

9. Grain Size

9.1 Material over 0.010 in. (0.254 mm) in thickness shall have an average grain size in accordance with Test Method E 112, not exceeding the limits specified in Table 5. The determinations are made on the separate samples and in a plane perpendicular to the surface and perpendicular to the direction of rolling.

10. Grain Count

- 10.1 The grain count of a sample of material, in any temper, over 0.004 to 0.010 in. (0.102 to 0.254 mm), inclusive, in thickness shall not be less than the limits specified in Table 6.
- 10.2 Grain count is the number of grains per stock thickness, averaged for five locations one stock thickness apart. Grain count shall be determined in a plane perpendicular to the surface and perpendicular to the direction of rolling.

11. Bend-Test Requirements

- 11.1 The optional bend test is a method for evaluating the ductility of precipitation heat-treated copper-beryllium strip in thin gages.
- 11.2 When specified in the order (see 5.1.6), material in any temper 0.004 to 0.020 in. (0.102 to 0.508 mm), inclusive, in thickness shall conform to the requirements specified in Table 7, when tested in accordance with 14.2.
- 11.3 Five specimens, $\frac{3}{8} \pm \frac{1}{16}$ in. (9.52 ± 1.59 mm) in width, of any convenient length, with the rolling direction parallel to the $\frac{3}{8}$ -in. dimension, shall be precipitation heat-treated in accordance with 12.2. To pass the bend test, at least four specimens out of five, and at least 80 % of the total specimens tested from a lot shall withstand the 90° bend without visible crack or fracture, when tested in accordance with 15.3.

12. Precipitation Heat-Treatment

12.1 Solution-heat-treated or solution-heat-treated and cold-worked material is normally precipitation hardened by the purchaser after forming or machining. For the purpose of determining conformance to specified mechanical properties of Table 3, a sample of the as-supplied material shall be heat



TABLE 2 Mechanical Property Requirements for Material in the Solution-Heat-Treated or Solution-Heat-Treated and Cold-Worked Condition

| Temper Designation ^A | | Material Thickness, in. | | Tensile Strength, ksi ^B (MPa) ^C | Elongation ^D in 2 in. or 50 mm, min,% | Rockwell Hardness ^E | | |
|---------------------------------|--------|-------------------------|-------|--|---|--------------------------------|-----------|-----------|
| Standard | Former | Over | Incl | | | B Scale | 30T Scale | 15T Scale |
| TB00 | A | ... | ... | 60–78 (410–540) | 35 | 45–78 | 46–67 | 75–85 |
| TD01 | ¼ H | ... | 0.188 | 75–88 (520–610) | 15 | 68–90 | 62–75 | 83–89 |
| TD02 | ½ H | ... | 0.188 | 85–100 (590–690) | 9 | 88–96 | 74–79 | 88–91 |
| TD04 | H | ... | 0.188 | 100–130 (690–900) | 2 | 96–104 | 79–83 | 91–94 |
| TD04 | H | 0.188 | 0.375 | 90–130 (660–900) | ... | 91–103 | 77 | 90 |
| TD04 | H | 0.375 | 1.000 | 90–120 (620–830) | ... | 90–102 | ... | ... |
| TD04 | H | over 1.000 | | 85–115 (590–800) | 8 | 88–102 | ... | ... |

^A Standard designations defined in Practice B 601.

^B ksi = 1000 psi.

^C See Appendix X1.

^D Elongation requirement applies to material 0.004 in. (0.102 mm) and thicker.

^E The thickness of material that may be tested by use of the Rockwell hardness scales is as follows:

B Scale.....0.040 in. (1.016 mm) and over

30T Scale.....0.020 to 0.040 in. (0.508 to 1.016 mm), excl.

15T Scale.....0.015 to 0.020 in. (0.381 to 0.508 mm), excl.

Hardness values shown apply only to direct determinations, not converted values.

treated as shown in Table 8. Other heat treating temperatures and times may be preferred for end products of this material.

12.2 The solution-heat-treated and cold-worked test specimens shall be heat treated at a uniform temperature of 600 to 675°F (316 to 357°C) for the time shown in Table 8.

12.3 Special combinations of properties such as increased ductility, electrical conductivity, dimensional accuracy, endurance life, and resistance to elastic drift and hysteresis in springs may be obtained by special precipitation-hardening heat treatments. The mechanical requirements of Table 3 do not apply to such special heat treatments.

12.4 Mill-hardened products have been precipitation heat-treated by the manufacturer. Further thermal treatment is not normally required.

13. Sampling

13.1 Sampling shall be in accordance with Specification B 248, Section 7, except that the heat size is defined as 12 000 lbs (5455 kg) or fraction thereof.

14. Specimen Preparation

14.1 The tension specimen direction shall have the longitudinal test-axis parallel to the rolling direction, unless mutually agreed upon between the supplier and purchaser at the time the order is placed.

14.2 When required, five bend-test specimens per test set shall be cut $\frac{3}{8} \pm \frac{1}{16}$ in. (9.52 ± 1.59 mm) in width and any convenient length. Specimens shall be precipitation heat-

treated after cutting and prior to testing. Precipitation heat-treatment parameters for these bend tests shall be in accordance with 12.2.

15. Test Methods

15.1 The method for determining chemical analysis for compliance and preparation of certifications and test reports shall be at the discretion of the reporting laboratory.

15.2 In case of dispute, the test methods found in Annex A1 shall be used for determining chemical requirements for the elements and ranges shown in Table 1.

15.2.1 When analysis for unnamed or residual elements is required in the purchase order, the method of analysis shall be mutually agreed upon between manufacturer or supplier and purchaser.

15.3 Bend-test specimens, shall be tested by clamping them firmly between a flat jaw and the test radius, as shown in Fig. 1. The test specimen shall be bent approximately 90° around the test radius, using a tangential wiping motion with adequate radial pressure to ensure continuous contact between the specimen and the test radius. Test specimens shall be bent to the full 90° bend position. The test radius shall be within ± 6 % of the nominal radius up to 0.010 in. (0.254 mm), exclusive, and within ± 4 % for radii 0.010 in. and over.

16. Keywords

16.1 C17000; C17200; copper-beryllium; flat products; copper plate; copper rolled bar; copper strip



TABLE 3 Mechanical Property Requirements After Precipitation Heat-Treatment^A

| Temper Designation | | Material Thickness, in. | | Tensile Strength, ksi ^B (MPa) ^C | Yield Strength, ksi (MPa), min, 0.2 % Offset | Elongation in 2 in. (50 mm), min, % ^D | Rockwell Hardness ^E , min | | |
|-----------------------------|--------|-------------------------|-------|--|--|---|--------------------------------------|-----------|-----------|
| Standard | Former | Over | Incl | | | | C Scale | 30N Scale | 15N Scale |
| Copper Alloy UNS No. C17000 | | | | | | | | | |
| TF00 | AT | ... | 0.188 | 150–180 ^F (1030–1240) | 130 (890) | 3 | 33 | 53 | 76.5 |
| TF00 | AT | 0.188 | ... | 165–195 ^F (1140–1340) | 130 | 3 | 36 | 56 | 78 |
| TH01 | ¼ HT | ... | ... | 160–190 ^F (1100–1310) | 135 (930) | 2.5 | 35 | 55 | 77 |
| TH02 | ½ HT | ... | ... | 170–200 ^F (1170–1380) | 145 (1000) | 1 | 37 | 57 | 78.5 |
| TH04 | HT | ... | ... | 180–210 ^F (1240–1450) | 155 (1070) | 1 | 38 | 58 | 79.5 |
| Copper Alloy UNS No. C17200 | | | | | | | | | |
| TF00 | AT | ... | ... | 165–195 ^F (1140–1340) | 140 (960) | 3 | 36 | 56 | 78 |
| TH01 | ¼ HT | ... | 0.188 | 175–205 ^F (1210–1410) | 150 (1030) | 2.5 | 36 | 56 | 79 |
| TH02 | ½ HT | ... | 0.188 | 185–215 ^F (1280–1480) | 160 (1100) | 1 | 38 | 58 | 79.5 |
| TH04 | HT | ... | 0.188 | 190–220 ^F (1310–1520) | 165 (1140) | 1 | 38 | 58 | 80 |
| TH04 | HT | 0.188 | 0.375 | 180–215 ^F (1240–1480) | 160 (1100) | 1 | 38 | 58 | 80 |
| TH04 | HT | 0.375 | 1.000 | 180–210 ^F (1240–1450) | 155 (1070) | 1 | 38 | ... | ... |
| TH04 | HT | 1.000 | 2.000 | 175–205 ^F (1210–1410) | 150 (1030) | 2 | 37 | ... | ... |
| TH04 | HT | over 2.000 | ... | 165–200 ^F (1140–1380) | 130 (890) | 2 | 36 | ... | ... |

^A These values apply to mill products (Section 14). See 12.3 for exceptions in end products.

^B ksi = 1000 psi.

^C See Appendix X1.

^D Elongation requirement applies to material 0.004 in. (0.102 mm) and thicker.

^E The thickness of material that may be tested by use of the Rockwell Hardness scales is as follows:

C Scale.....0.040 in. (1.016 mm) and over

30N Scale.....0.020 to 0.040 in. (0.508 to 1.016 mm), excl.

15N Scale.....0.015 to 0.02 in. (0.381 to 0.508 mm), excl.

Hardness values shown apply only to direct determinations, not converted values.

^F The upper limits in the tensile strength column are for design guidance only.



TABLE 4 Strip Mechanical Property Requirements—Mill-Hardened Condition^A

| Temper Designation | | Tensile Strength, ksi ^B (MPa) ^C | Yield Strength, ksi (MPa), 0.2 % Offset | Elongation in 2 in. (50 mm), min, % ^D | Rockwell Hardness ^E , min | | |
|-----------------------------|---------------------|--|---|--|--------------------------------------|-----------|-----------|
| Standard | Former ^B | | | | C Scale | 30N Scale | 15N Scale |
| Copper Alloy UNS No. C17000 | | | | | | | |
| TM00 | AM | 100–110 ^F (690–760) | 70–95 (480–660) | 18 | 18 | 37 | 67.5 |
| TM01 | ¼ HM | 110–120 ^F (760–830) | 80–110 (550–760) | 15 | 20 | 42 | 70 |
| TM02 | ½ HM | 120–135 ^F (830–930) | 95–125 (660–860) | 12 | 24 | 45 | 72 |
| TM04 | HM | 135–150 ^F (930–1040) | 110–135 (760–930) | 9 | 28 | 48 | 75 |
| TM05 | SHM | 150–160 ^F (1030–1100) | 125–140 (860–970) | 9 | 31 | 52 | 75.5 |
| TM06 | XHM | 155–175 ^F (1070–1210) | 135–165 (930–1140) | 3 | 32 | 52 | 76 |
| Copper Alloy UNS No. C17200 | | | | | | | |
| TM00 | AM | 100–110 ^F (690–760) | 70–95 (480–660) | 16 | R _B 95 | 37 | 67.5 |
| TM01 | ¼ HM | 110–120 ^F (760–830) | 80–110 (550–760) | 15 | 20 | 42 | 70 |
| TM02 | ½ HM | 120–135 ^F (830–930) | 95–125 (660–860) | 12 | 23 | 44 | 72 |
| TM04 | HM | 135–150 ^F (930–1030) | 110–135 (760–930) | 9 | 28 | 48 | 75 |
| TM05 | SHM | 150–160 ^F (1030–1100) | 125–140 (860–970) | 9 | 31 | 52 | 75.5 |
| TM06 | XHM | 155–175 ^F (1070–1210) | 135–170 (930–1170) | 4 | 32 | 52 | 76 |
| TM08 | XHMS | 175–190 ^F (1210–1310) | 150–180 (1030–1240) | 3 | 33 | 53 | 76.5 |

^A These values apply to mill products (Section 14). See 12.3 for exceptions in end products.

^B ksi = 1000 psi.

^C See Appendix X1.

^D Elongation requirement applies to material 0.004 in. (0.102 mm) and thicker.

^E The thickness of material that may be tested by use of the Rockwell Hardness scales is as follows:

C Scale.....0.040 in. (1.016 mm) and over

30N Scale.....0.020 to 0.040 in. (0.508 to 1.016 mm), excl.

15N Scale.....0.015 to 0.020 in. (0.381 to 0.508 mm), excl.

Hardness values shown apply only to direct determinations, not converted values.

^F The upper limits in the tensile strength column are for design guidance only.

TABLE 5 Grain-Size Requirements for TB00 (Solution-Heat-Treated) Material

| Thickness, in. (mm) | Grain Size Specified | Maximum Average Grain Size, mm |
|--|----------------------|--------------------------------|
| Over 0.010 to 0.030 (0.254 to 0.762), incl | OS035 | 0.035 |
| Over 0.030 to 0.090 (0.762 to 2.24), incl | OS045 | 0.045 |
| Over 0.090 to 0.188 (2.24 to 4.78), incl | OS060 | 0.060 |

TABLE 6 Grain-Count Requirements

| Thickness, in. (mm) | Minimum Number of Grains |
|--|--------------------------|
| Over 0.004 to 0.006 (0.102 to 0.152), incl | 6 |
| Over 0.006 to 0.008 (0.152 to 0.203), incl | 7 |
| Over 0.008 to 0.010 (0.203 to 0.254), incl | 8 |

TABLE 7 Bend-Test Requirements After Precipitation Heat Treatment

| Temper Designation | | Test Radius ^A |
|--------------------|--------|--------------------------|
| Standard | Former | |
| TF00 | AT | 5t |
| TH01 | ¼ AT | 6t |
| TH02 | ½ HT | 9t |
| TH04 | HT | 15t |

^A The t refers to the measured average stock thickness to be tested.

TABLE 8 Precipitation-Heat-Treatment Time for Acceptance Tests

| Temper Designation (Before Precipitation Heat Treatment) | | Time at 600 to 675°F (316 to 357°C), h |
|--|--------|---|
| Standard | Former | |
| TB00 | A | 3 |
| TD01 | ¼ H | 2 |
| TD02 | ½ H | 2 |
| TD04 | H | 2 |

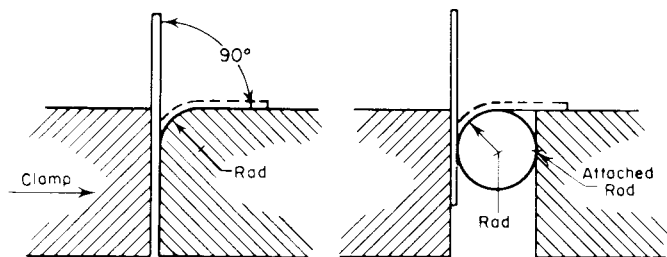


FIG. 1 Methods for Clamping Specimen to Radius for Bend Test

ANNEX

(Mandatory Information)

A1. TEST METHODS FOR DETERMINATION OF COMPLIANCE WITH COPPER-BERYLLIUM ALLOYS—CHEMICAL COMPOSITION REQUIREMENTS

A1.1 Scope

A1.1.1 These test methods establish the procedure(s) for the determination of chemical composition of copper-beryllium alloys.

A1.1.2 The analytical procedures appear in the following order:

| Procedure | Sections |
|--|------------------|
| Test Method A—Copper by the Electrolytic Method | A1.8 to A1.15 |
| Test Method B—Aluminum, Beryllium, Cobalt, Iron, and Nickel by the Flame Atomic Absorption Spectrophotometric Method | A1.16 to A1.24 |
| Test Method C—Silicon by the Ammonium Molybdate Spectrophotometric Method | A1.28.2 to A1.35 |

A1.2 Referenced Documents

A1.2.1 ASTM Standards:

- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁶
- E 50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials⁷
- E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Color Composition⁷
- E 60 Practice for Analysis of Metals, Ores, and Related Materials by Molecular Absorption Spectrometry⁷
- E 663 Practice for Flame Atomic Absorption Analysis⁸
- E 1024 Guide for Chemical Analysis of Metals and Metal Bearing Ores by Flame Atomic Absorption Spectrophotometry⁸

A1.3 Significance and Use

A1.3.1 These test methods are primarily intended to test for compliance with composition specifications. It is assumed that all who use these test methods will be trained analysts capable of performing common laboratory procedures skillfully and safely. It is expected that work will be performed in a properly equipped laboratory.

A1.4 Apparatus, Reagents, and Photometric Practice

A1.4.1 Apparatus and reagents required for each determination are listed in separate sections preceding the procedure. The apparatus, standard solutions, and certain other reagents are referred to by number and shall conform to the requirements prescribed in Practice E 50.

A1.4.2 Flame atomic-absorption spectrophotometric practice prescribed in these test methods shall conform to the requirements prescribed in Practice E 663 and Guide E 1024.

A1.4.3 Spectrophotometric practice prescribed in these test methods shall conform to requirements prescribed in Practice E 60.

A1.5 Hazards

A1.5.1 For precautions to be observed in these test methods, refer to Practice E 50.

A1.5.2 Both beryllium metal and its compounds may be toxic. Exercise care to prevent contact of beryllium-containing solutions with the skin. Especially avoid the inhalation of any beryllium-containing substance, either as a volatile compound or as a finely divided powder. The proper precautions are to be observed in the disposition of beryllium-containing residues, especially ignited oxide.

A1.6 Sampling

A1.6.1 Sampling shall conform to the requirements of Practice E 55.

A1.7 Rounding Off Calculated Values

A1.7.1 Calculated values shall be rounded off to the proper number of places in accordance with the method given in 3.4 and 3.5 of Practice E 29.

TEST METHOD A—COPPER BY ELECTROLYTIC DEPOSITION AND ATOMIC-ABSORPTION SPECTROPHOTOMETRY

A1.8 Scope

A1.8.1 This test method establishes a procedure for the determination of copper in copper-beryllium alloys with silver reported as copper.

⁶ Annual Book of ASTM Standards, Vol 14.02.

⁷ Annual Book of ASTM Standards, Vol 03.05.

⁸ Annual Book of ASTM Standards, Vol 03.06.