Designation: B194 – 22

Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar[1]

This standard is issued under the fixed designation B194; 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 U.S. 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:

Copper Alloy UNS No.	Nominal Beryllium Composition, %
C17000	1.7
C17200	1.9

1.2 Unless otherwise specified in the contract or purchase order, Copper Alloy UNS No. C17200 shall be the alloy furnished.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following safety hazard caveat pertains only to the test method(s) described in this specification:

1.4.1 *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, health, and environmental practices and to determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar

B248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)

B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast

B820 Test Method for Bend Test for Determining the Formability of Copper and Copper Alloy Strip

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

E112 Test Methods for Determining Average Grain Size

3. General Requirements

3.1 The following sections of Specification B248 or B248M 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 Test Reports
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 B248 or B248M.

4. Terminology

4.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

[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] 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.

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

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification as applicable:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper Alloy UNS No. designation,

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

5.1.4 Temper (Section 7),

5.1.5 Dimensions: thickness and width, and length if applicable,

5.1.6 How furnished: coils, stock lengths with or without ends, specific lengths with or without ends,

5.1.7 Quantity—total weight or total length or number of pieces of each size, and

5.1.8 Tension test or hardness as applicable (Section 8).

5.2 The following options are available and should be specified at the time of placing the order when required:

5.2.1 Type of edge: slit, sheared, sawed, square corners, rounded corners, rounded edges, or full-rounded edges (Specification B248 or B248M, Subsection 5.6),

5.2.2 Special width and straightness tolerances: slit-metal tolerances, square-sheared-metal tolerances, sawed-metal tolerances, straightened or edge-rolled-metal tolerances (Specification B248 or B248M, Subsection 5.3 or 5.5),

5.2.3 Special thickness tolerances: (Specification B248 or B248M, Table 3),

5.2.4 Bend test (Section 11),

5.2.5 Grain size (Section 9),

5.2.6 Grain count (Section 10),

5.2.7 Certification (Specification B248 or B248M, Section 14),

5.2.8 Test Report (Specification B248 or B248M, Section 15),

5.2.9 Special tests or exceptions, if any.

5.3 If the product is purchased for agencies of the U.S. Government, see the Supplementary Requirement of Specification B248 or B248M for additional requirements, if specified.

6. Chemical Composition

6.1 The material shall conform to the chemical composition requirements in Table 1 for the Copper Alloy UNS No. designation specified in the ordering information.

6.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance specified in Table 1.

TABLE 1 Chemical Requirements

Element	Composition, %	
	Copper Alloy UNS No. C17000	Copper Alloy UNS No. C17200
Beryllium	1.60–1.85	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

6.2 These composition limits do not preclude the presence of other elements. By agreement between manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

6.3 For alloys in which copper is listed as "remainder," copper is the difference between the sum of results of all elements determined and 100 %. When all elements in Table 1 are determined, the sum of results shall be 99.5 % minimum.

7. Temper

7.1 The standard tempers for products described in this specification are given in Table 2, Table 3, Table 4, and Table 5.

7.1.1 Solution Heat Treated TB00.

7.1.2 Solution Heat Treated and Cold Worked TD00 to TD04.

7.1.3 Solution Heat Treated and Precipitation Heat Treated TF00.

7.1.4 Solution Heat Treated, Cold Worked and Precipitation Heat Treated TH01 to TH04.

7.1.5 Mill Hardened TM00 to TM08.

7.1.6 Plate is generally available in the TB00, TD04, TF00, and TH04 tempers.

8. Mechanical Property Requirements

8.1 *Tensile Strength Requirements:*

8.1.1 Tensile strength for product less than 0.050 in. (1.27 mm) in thickness shall be the standard test, when tested in accordance with Test Methods E8/E8M.

8.1.2 The tensile strength requirements are given in Table 2, Table 3, and Table 4.

8.1.3 Acceptance or rejection for products less than 0.050 in. (1.27 mm) in thickness shall depend only on tensile properties.

8.2 *Rockwell Hardness Requirements:*

8.2.1 Rockwell hardness for product 0.050 in. (1.27 mm) and greater in thickness shall be the standard test, when tested in accordance with Test Methods E18.

8.2.2 The Rockwell hardness requirements are given in Table 2, Table 3, and Table 4.

8.2.3 Acceptance or rejection for product 0.050 in. (1.27 mm) and greater in thickness shall depend only on Rockwell hardness.

8.3 In cases of disagreement with Rockwell results, the acceptance or rejection shall be the tensile properties, when tested in accordance with Test Methods E8/E8M.

9. Grain Size

9.1 Acceptance or rejection based upon grain size shall depend on the average grain size of a test specimen from each of two sample portions, and each specimen shall be within the limits prescribed in Table 5 when determined in accordance with Test Methods E112.

9.2 The determinations shall be made on samples in a plane perpendicular to the surface and perpendicular to the direction of rolling.

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. (mm)		Tensile Strength, ksi[B] (MPa)[C]	Elongation[D] in 2 in. or 50 mm, min,%	Rockwell Hardness[E]		
Code	Name	Over	To (incl)			B Scale	30T Scale	15T Scale
TB00	A	...	...	60–78 (415–540)	35	45–78	46–67	75–85
TD01	¼ H	...	0.188 (4.78)	75–88 (520–610)	15	68–90	62–75	83–89
TD02	½ H	...	0.188 (4.78)	85–100 (585–690)	9	88–96	74–79	88–91
TD04	H	...	0.188 (4.78)	100–130 (690–895)	2	96–104	79–83	91–94
TD04	H	0.188 (4.78)	0.375 (9.53)	90–130 (620–895)	...	91–103	77 min	90 min
TD04	H	0.375 (9.53)	1.000 (25.4)	90–120 (620–825)	...	90–102	...	...
TD04	H	over 1.000 (25.4)		85–115 (585–790)	8	88–102	...	...

[A] Standard designations defined in Classification B601.
[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 in. to 0.040 in. (0.508 mm to 1.016 mm), excl.
15T Scale.....0.015 in. to 0.020 in. (0.381 mm to 0.508 mm), excl.
Hardness values shown apply only to direct determinations, not converted values.

TABLE 3 Mechanical Property Requirements After Precipitation Heat-Treatment[A]

Temper Designation		Material Thickness, in. (mm)		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		
Code	Name	Over	To (incl)				C Scale	30N Scale	15N Scale
Copper Alloy UNS No. C17000									
TF00	AT	...	0.188 (4.78)	150–180[F] (1035–1240)	130 (895)	3	33	53	76.5
TF00	AT	0.188 (4.78)	...	165–195[F] (1140–1345)	130 (895)	3	36	56	78
TH01	¼ HT	...	...	160–190[F] (1105–1310)	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] (1140–1345)	140 (965)	3	36	56	78
TH01	¼ HT	...	0.188 (4.78)	175–205[F] (1205–1415)	150 (1035)	2.5	36	56	79
TH02	½ HT	...	0.188 (4.78)	185–215[F] (1275–1480)	160 (1105)	1	38	58	79.5
TH04	HT	...	0.188 (4.78)	190–220[F] (1310–1520)	165 (1140)	1	38	58	80
TH04	HT	0.188 (4.78)	0.375 (9.53)	180–215[F] (1240–1480)	160 (1105)	1	38	58	80
TH04	HT	0.375 (9.53)	1.000 (25.4)	180–210[F] (1240–1450)	155 (1070)	1	38	...	...
TH04	HT	1.000 (25.4)	2.000 (50.8)	175–205[F] (1205–1415)	150 (1035)	2	37	...	...
TH04	HT	over 2.000 (50.8)		165–200[F] (1140–1380)	130 (895)	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 in. to 0.040 in. (0.508 mm to 1.016 mm), excl.
15N Scale.....0.015 in. to 0.02 in. (0.381 mm 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.

10. Grain Count

10.1 The grain count of a sample of material, in any temper, over 0.004 in. to 0.010 in. (0.102 mm 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 When specified in the contract or purchase order (see 5.2.4), the material shall conform to requirements agreed upon between manufacturer or supplier and purchaser when tested in accordance with Test Method B820.

11.2 The bend test is a method for evaluating formability. It applies to the product 0.004 in. to 0.020 in. thick (0.102 mm to 0.508 mm) inclusive in Table 2 and Table 4.

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 treated as shown in Table 7. 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 °F to 675 °F (316 °C to 357 °C) for the time shown in Table 7.

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		
Code	Name[B]				C Scale	30N Scale	15N Scale
Copper Alloy UNS No. C17000							
TM00	AM	100–110[F] (690–760)	70–95 (485–655)	18	18	37	67.5
TM01	¼ HM	110–120[F] (760–825)	80–110 (550–760)	15	20	42	70
TM02	½ HM	120–135[F] (825–930)	95–125 (655–860)	12	24	45	72
TM04	HM	135–150[F] (930–1035)	110–135 (760–930)	9	28	48	75
TM05	SHM	150–160[F] (1035–1100)	125–140 (860–965)	9	31	52	75.5
TM06	XHM	155–175[F] (1070–1205)	135–165 (930–1140)	3	32	52	76
Copper Alloy UNS No. C17200							
TM00	AM	100–110[F] (690–760)	70–95 (485–660)	16	R_B95	37	67.5
TM01	¼ HM	110–120[F] (760–825)	80–110 (550–760)	15	20	42	70
TM02	½ HM	120–135[F] (825–930)	95–125 (655–860)	12	23	44	72
TM04	HM	135–150[F] (930–1035)	110–135 (760–930)	9	28	48	75
TM05	SHM	150–160[F] (1035–1105)	125–140 (860–965)	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 (1035–1240)	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 in. to 0.040 in. (0.508 mm to 1.016 mm), excl.
15N Scale.....0.015 in. to 0.020 in. (0.381 mm 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)	Maximum Average Grain Size, mm
Over 0.010 to 0.030 (0.254 to 0.762), incl	0.035
Over 0.030 to 0.090 (0.762 to 2.29), incl	0.045
Over 0.090 to 0.188 (2.29 to 4.78), incl	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 Precipitation-Heat-Treatment Time for Acceptance Tests

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

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 Refer to sampling section in Specification B248 or B248M, Section 7, except that the heat size is defined as 12 000 lb (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.

15. Test Methods

15.1 *Chemical Analysis:*

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

15.1.2 In case of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer and the purchaser. The methods found in the Annex to this specification contain methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement.

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

15.2 *Other Tests:*

15.2.1 The product furnished shall conform to specified requirements when subjected to test in accordance with the following table:

Test	Method
Formability	B820
Tension Properties	E8/E8M
Hardness	E18
Grain Size	E112

15.2.2 In case of dispute, the intercept method of Test Methods E112 shall be followed

16. Keywords

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

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	A1.25 to A1.35

A1.2 Referenced Documents

A1.2.1 *ASTM Standards:*

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials

E60 Practice for Analysis of Metals, Ores, and Related Materials by Spectrophotometry

E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

E663 Practice for Flame Atomic Absorption Analysis (Withdrawn 1997)[3]

E1024 Guide for Chemical Analysis of Metals and Metal Bearing Ores by Flame Atomic Absorption Spectrophotometry (Withdrawn 2004)[3]

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 Practices E50.

A1.4.2 Flame atomic-absorption spectrophotometric practice prescribed in these test methods shall conform to the requirements prescribed in Practice E663 and Guide E1024.

A1.4.3 Spectrophotometric practice prescribed in these test methods shall conform to requirements prescribed in Practice E60.

A1.5 Hazards

A1.5.1 This test method involves the use of concentrated acids. Read and follow all label precautions and Safety Data Sheet (SDS) information. Also refer to Practices E50 for handling nitric acid and the use of certain other reagents in this test method.

A1.5.2 Processing beryllium and beryllium-containing materials poses a health risk if safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in some individuals. Occupational safety and health regulatory agencies have set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the SDS before working with these materials.

A1.6 Sampling

A1.6.1 Sampling shall conform to the requirements of Practice E255.

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 E29.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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.

A1.9 Summary of Test Methods

A1.9.1 The sample is dissolved in an acid mixture. A small amount of fluorohydric acid (HF) is added to minimize possible interferences. Copper is electrolytically deposited on a tared platinum cathode. Copper remaining in the electrolyte is determined by atomic absorption spectrophotometry.

A1.10 Interferences

A1.10.1 Elements normally present do not interfere.

A1.11 Apparatus

A1.11.1 *Electrodes for Electrolysis*—Apparatus No. 9, in Practices E50.

A1.11.2 *Atomic Absorption Spectrophotometer*—Determine the instrument to be suitable for use as directed in Guide E1024. Instrument response must permit estimation of copper concentration to within 1 mg/L.

A1.11.3 *Operating Parameters*—Wavelength, fuel/oxidant, and flame conditions are as follows:

Wavelength, nm	Fuel/Oxidant	Flame Condition
Copper 327.5	Acetylene/air	Oxidizing

A1.12 Reagents

A1.12.1 *Sulfuric-Nitric Acid Mixture*—While stirring, slowly add 500 mL of sulfuric acid (H_2SO_4) to 1 L of water. Cool and transfer to a 2 L volumetric flask. Add 300 mL of nitric acid (HNO_3). Cool, dilute to volume, and mix.

A1.12.2 *Copper Standard Solution* (1 mL = 1.0 mg Cu)—Transfer 1.000 g of copper metal (purity, 99.9 % min) into a 250 mL beaker. Add 20 mL of the acid mixture. Cover the beaker and allow to stand until dissolution is nearly complete. Heat at 80 °C to 90 °C until dissolution is complete and brown fumes have been expelled. Cool, transfer into a 1 L volumetric flask, dilute to volume, and mix.

A1.12.3 *Calibration Solutions*—Pipet 5 mL, 10 mL, 15 mL, 20 mL, and 25 mL portions of the copper standard solution into individual 1 L volumetric flasks. Add 50 mL of the acid mixture to each flask, dilute to volume, and mix. These solutions are equivalent to 0.005 g, 0.010 g, 0.015 g, 0.020 g, and 0.025 g of copper respectively.

A1.12.4 *Zero-Calibration Solution*—Transfer 50 mL of the acid mixture into a 1 L volumetric flask, dilute to volume, and mix.

A1.13 Procedure

A1.13.1 Transfer a 2.500 g portion into each of two electrolysis beakers, normally 300 mL. Add 50 mL of the mixed acid, cover the beaker, and allow to stand until the reaction subsides. Heat at 80 °C to 90 °C until dissolution is complete and brown fumes have been expelled. Cool and wash down cover glass and inside of beaker. Add 1.0 mL of HF (1 + 9) from a plastic pipet and dilute to about half volume.

A1.13.2 Insert the electrodes and dilute to submerge the cathode. Cover the beaker with a pair of split cover glasses and electrolyze at a current density of about 0.6 A/dm^2 for about 16 h.

A1.13.3 Wash the cover glasses, the electrode stems, and inside the beaker with water, then continue the electrolysis for a minimum of 15 min. Should copper plate-out on the newly exposed cathode surface, dilute a second time and continue electrolysis for an additional 15 min. Copper deposition shall be considered completed, when no copper is deposited on a newly exposed surface.

A1.13.4 Quickly withdraw the cathode from the electrolyte while maintaining current flow (should the electrolysis system permit), and direct a gentle stream of water from a wash bottle over its surface. Rinse the cathode in a water bath and then dip in two successive baths of ethanol or acetone. Dry at 110 °C for 3 min to 5 min, cool at balance room temperature, and weigh.

A1.13.5 Transfer the spent electrolyte into individual 1 L volumetric flask, dilute to volume, and mix.

A1.13.6 Set the atomic-absorption instrument parameters according to Practice E663 and the manufacturer's recommendations. Ignite the burner and aspirate water until the instrument reaches thermal equilibrium.

A1.13.7 Adjust the wavelength, lamp position, fuel, oxidizer, burner, and nebulizer to obtain maximum absorbance, while aspirating the highest calibration solution.

A1.13.8 Aspirate water until a steady signal is obtained and adjust the instrument read-out system to obtain zero absorbance.

A1.13.9 Aspirate the calibration solutions in order of increasing absorbance, starting with the zero calibration solution. When a stable response is obtained, record the readings. Aspirate the test solutions and record their absorbance. Aspirate water between samples to flush the nebulizer and burner systems. Repeat all measurements a minimum of two times.

A1.14 Calculation

A1.14.1 When necessary, convert the average readings for each solution to absorbance. Obtain the net absorbance for each calibration solution by subtracting the average absorbance for the zero-calibration solution from the average absorbance of each of the other calibration solutions.

A1.14.2 Obtain the net absorbance of the zero-calibration solution from the average absorbance of the test solution.

A1.14.3 Prepare a calibration curve by plotting net absorbance for the calibration solutions versus grams of copper.

A1.14.4 Convert the net absorbance of the test solution to grams of copper by means of the calibration curve.

A1.14.4.1 Most atomic-absorption spectrophotometers can be calibrated to yield direct concentration readings. This method may be used, provided additional calibration solutions are analyzed as samples to test for precision and linearity. Should the instrument be equipped for multi-point calibration, make sure that several additional solutions still are analyzed to ensure that error has not been introduced by the curve-fitting routine.

A1.14.5 Calculate the concentration percent copper as follows:

$$\text{Copper, \%} = (A - B + C) \times 100/D \qquad \text{(A1.1)}$$

where:

A = weight of cathode plus deposited copper, g,
B = weight of cathode, g,
C = weight of copper in spent electrolyte, g, and
D = sample used, g.

A1.15 Precision and Bias

A1.15.1 *Precision*—The precision of this test method is dependent upon the care and precision exercised during instrument calibration and sample preparation, as well as, the purity of the reagents.

A1.15.2 *Bias*—The accuracy of this test method can be judged by analyzing material of known composition.

TEST METHOD B—ALUMINUM, BERYLLIUM, COBALT, IRON, LEAD, AND NICKEL BY THE FLAME ATOMIC-ABSORPTION SPECTROPHOTOMETRIC METHOD

A1.16 Scope

A1.16.1 This test method establishes a flame atomic-absorption spectrophotometric procedure for the determination of aluminum, beryllium, cobalt, iron, lead, and nickel in copper-beryllium alloys.

A1.17 Summary of Test Methods

A1.17.1 The sample is dissolved in dilute nitric acid and aspirated into the flame of an atomic absorption spectrophotometer. The absorption of the resonance line energy specific to each element is measured and compared with the absorption measured for calibration solutions prepared in the same matrix.

A1.18 Interferences

A1.18.1 Elements normally present in copper-beryllium alloys do not interfere.

A1.19 Apparatus

A1.19.1 *Atomic-Absorption Spectrophotometer*— Determine the instrument to be suitable for use as directed in Guide E1024. Instrument response for each analyte element must be adequate to permit an estimation of analyte concentration to within 0.01 % for aluminum, iron, and lead and 0.02 % for beryllium, cobalt, and nickel on a sample basis.

A1.19.2 *Operating Parameters*—The flame conditions and wavelengths for the analyte elements are as follows:

Element	Wavelength, nm	Fuel/Oxidant and Flame Condition
Aluminum	309.3	Acetylene/nitrous oxide and reducing
Beryllium	234.9	Acetylene/nitrous oxide and reducing
Cobalt	240.7	Acetylene/air and oxidizing
Iron	248.3	Acetylene/air and oxidizing
Lead	283.3	Acetylene/air and oxidizing
Nickel	341.5	Acetylene/air and oxidizing

A1.20 Reagents

A1.20.1 *Copper Stock Solution*—Transfer 50.0 g of copper (purity, 99.99 % min) into a 2 L beaker. Cover with 200 mL of water. Cover the beaker and cautiously add 200 mL of nitric acid (HNO_3) in small increments. Allow to stand until dissolution is nearly complete. Boil to complete dissolution and expel brown fumes. Cool, transfer the solution into a 1 L volumetric flask, dilute to volume, and mix.

A1.20.2 *Aluminum Standard Solution* (1 mL = 0.15 mg Al)—Weigh 0.1500 g of aluminum wire (purity, 99.9 % min) into a 400-mL beaker. Add 20 mL of water and cover with a watch glass. Cautiously add 40 mL of HNO_3 (1 + 1) in small increments. Add a small crystal of mercurous nitrate ($HgNO_3$) and two drops of hydrochloric acid (HCl) after the first increment to catalyze the reaction. Boil to expel the brown fumes. Rinse the watch glass and inside of the beaker with water. Transfer the solution into a 1 L volumetric flask.

A1.20.3 *Beryllium Standard Solution* (1 mL = 1.25 mg Be):

A1.20.3.1 Transfer 1.250 g equivalent of beryllium, containing less than 1000 ppm each of cobalt, iron, lead, and nickel, into a 600 mL beaker, add 20 mL of water and cover with a watch glass. Cautiously add 35 mL of HNO_3 in small increments. Add two drops of HCl after the first increment to catalyze the reaction. After the reaction subsides, rinse the watch glass and inside of the beaker with water and dilute to approximately 200 mL. Boil to expel the brown fumes. Filter hot water through a fine porosity ashless paper into a 1 L plastic volumetric flask. Rinse the beaker several times with water and filter, collecting the rinse solutions into the volumetric flask. Rinse the filter paper ten times with small portions of hot water, collecting the rinse solutions in the volumetric flask.

A1.20.3.2 Transfer the filter paper into a platinum crucible and reduce to a white ash over a Meker type burner, heating gently initially to avoid losses. Allow the crucible to cool and add 5 drops of HF and 10 drops of sulfuric acid (H_2SO_4). Place the crucible on a hot plate and slowly evaporate just to dryness. *Do not bake.* Allow the crucible to cool. Add 5 mL of HNO_3, 1 drop of fluorohydric (HF), and heat to boiling. Allow the crucible to cool, add 10 mL of water, and filter the solution through a medium porosity filter paper collecting the solution into the original 1 L volumetric flask. Rinse the filter paper a minimum of four times, collecting the rinse solutions into the same 1 L volumetric flask.

A1.20.3.3 Dilute the combined solutions to volume and mix.

A1.20.4 *Cobalt Standard Solution* (1 mL = 1.5 mg Co)—Dissolve 1.500 g of cobalt (purity, 99.9 % min) in 80 mL of HNO_3 (1 + 1). Boil to expel the brown fumes. Cool, transfer into a 1 L volumetric flask, dilute to volume, and mix.

A1.20.5 *Iron Standard Solution* (1 mL = 0.3 mg Fe)—Dissolve 0.3000 g of iron (purity, 99.9 % min) in 80 mL of