



Designation: **B694 – 13 B694 – 19**

Standard Specification for Copper, Copper-Alloy, Copper-Clad Bronze (CCB), Copper-Clad Stainless Steel (CCS), and Copper-Clad Alloy Steel (CAS) Sheet and Strip for Electrical Cable Shielding¹

This standard is issued under the fixed designation B694; 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.

1. Scope*

1.1 This specification establishes the requirements for copper, copper alloy, copper-clad bronze (CCB), copper-clad stainless steel (CCS), and copper-clad alloy steel (CAS) materials, sheet, and strip, in various thicknesses, for use as electrostatic or electromagnetic shielding for insulated power, control, instrumentation, and communication cables.

NOTE 1—See Specification B736, for related standards for aluminum-based shielding materials.

1.2 The products covered are the following:

Copper or Copper Alloy UNS No.	Type of Products
C11000	copper
C19400	copper-iron alloy
C22000	copper-zinc alloy (commercial bronze)
C23000	copper-zinc alloy (red brass)
C66400	copper-zinc-iron-cobalt alloy
C66410	copper-zinc-iron alloy
C66430	copper-zinc-iron-tin alloy
C71000	cupro-nickel 20 %
...	copper-clad bronze (CCB)
...	copper-clad stainless steel (CCS)
...	copper-clad alloy steel (CAS)

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.

1.3.1 The only exception is grain size, which is reported in SI (mm) units.

1.4 *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 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

[A176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip \(Withdrawn 2015\)](#)³

[A505 Specification for Steel, Sheet and Strip, Alloy, Hot-Rolled and Cold-Rolled, General Requirements for](#)

[B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar](#)

[B193 Test Method for Resistivity of Electrical Conductor Materials](#)

[B248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar](#)

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.

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

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

~~B601~~~~B248M~~ Classification Specification for Temper Designations General Requirements for Wrought Copper and Copper Alloys—Wrought and Cast Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)
B736 Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock (Withdrawn 2015)³
B846 Terminology for Copper and Copper Alloys
E3 Guide for Preparation of Metallographic Specimens
~~E8E8/E8M~~ Test Methods for Tension Testing of Metallic Materials—[Metric] E0008_E0008M
E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)³
E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)³
E75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys (Withdrawn 2010)³
E112 Test Methods for Determining Average Grain Size
E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E478 Test Methods for Chemical Analysis of Copper Alloys
2.2 ~~International Standards Organization (ISO) Standards:~~
~~ISO 3110/2~~ Determination of Aluminum; Flame Atomic Absorption Spectrometric Method (TC/26 Ref. No. N698 E/F)⁴

3. General Requirements

3.1 The following sections of Specification **B248** or **B248M** constitute a part of this specification:

- 3.1.1 ~~Terminology;~~Terminology;
- 3.1.2 ~~Materials and Manufacture;~~Manufacture;
- 3.1.3 ~~Workmanship, Finish, and Appearance;~~Appearance;
- 3.1.4 ~~Sampling—except for chemical analysis;~~analysis;
- 3.1.5 ~~Number of Tests and Retests;~~Retests;
- 3.1.6 ~~Specimen Preparation;~~Preparation;
- 3.1.7 ~~Test Methods—except for chemical analysis;~~analysis;
- 3.1.8 ~~Significance of Numerical Limits;~~Limits;
- 3.1.9 ~~Inspection;~~Inspection;
- 3.1.10 ~~Rejection and Rehearing;~~Rehearing;
- 3.1.11 ~~Certification;~~Certification;
- 3.1.12 ~~Test Reports;~~Report;
- 3.1.13 ~~Packaging and Package Marking;~~Marking; and
- 3.1.14 ~~Supplementary Requirements.~~

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;~~requirements which 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**.

5. Ordering Information

5.1 Include the following ~~information-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. (or other internationally recognized copper [alloy]) designation (see 1.2),~~
- 5.1.3 ~~Temper (Section 8),~~
- 5.1.4 ~~Dimensions: thickness and width (Section 12),~~
- 5.1.5 ~~How furnished: coils, traverse wound on reels or spools,~~
- 5.1.6 ~~Quantity: total for~~Quantity—total weight of each item, pounds (or kilograms);
- 5.1.7 ~~Name of material: cable shielding (or “cable wrap”);~~or cable wrap, and
- 5.1.4 ~~Form of material: strip,~~
- 5.1.8 ~~Type of product: (or abbreviation, in the case of clad materials) as listed in 1.2~~section 1.2,;
- 5.1.6 ~~Alloy number when appropriate (see 1.2);~~
- 5.1.7 ~~Temper,~~
- 5.1.8 ~~Dimensions: thickness and width (see Section 12);~~
- 5.1.9 ~~How furnished: coils (rolls), traverse wound on reels or spools, etc.,~~

5.2 The following options are available ~~and should be~~ but may not be included unless specified at the time of placing of the order when required:

- 5.2.1 ~~Whether electrical resistivity test is required for any item;~~Electrical resistivity test;
- 5.2.2 ~~Coil dimension: inner or outer coil diameter limitation, or both, if required;~~both;
- 5.2.3 ~~Weight of coils: coil weights or coil size limitations, if required;~~limitations;
- 5.2.4 ~~Cladding ratio when appropriate (see 7.5-47.6.4);~~

- 5.2.5 Certification, if required, Certification;
- 5.2.6 Test Report, if required, Mill Test Report; and
- 5.2.7 Special tests or exceptions, if any, exceptions.

6. Materials and Manufacture

6.1 ~~Material~~—Materials: The material of manufacture shall be of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.1.1 The material of manufacture shall be a form (cast bar, cake, slab, etc.) of the specified copper alloy UNS No. [or other designation] of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.2 Manufacture:

6.2.1 The ~~copper and copper alloy~~ product shall be manufactured by such hot working, cold working, and annealing processes as to produce a uniform wrought structure in the finished product, and conform to the properties and characteristics prescribed in the specification product.

6.2.2 Cladding metals as appropriate may be bonded to the specified base metal by any method that will produce a clad material that will conform to this specification.

7. Chemical Composition

7.1 The ~~copper and copper alloy materials~~ material shall conform to the chemical composition requirements in **Table 1** for the copper [alloy] UNS No. designation [or other designation] specified in the ordering information.

7.2 Copper cladding shall be, unless otherwise specified, a copper conforming in chemical composition to that covered by Specification **B152/B152M**. The grade provided shall be one of the following coppers, such that the final strip meets the conductivity and mechanical properties of this specification. These are:

- C10920
- C11000
- C11020
- C12000

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

7.4 ~~Except for copper C11000, copper may be taken as~~ For alloys in which copper is listed as “remainder,” copper is the difference between all the elements analyzed and 100%. ~~the sum of results of all elements determined and 100%. When all elements in Table 1 are determined, the sum of results shall be as shown in the following table:~~

TABLE 1 Chemical Requirements

Element	Composition, %								
	Copper or Copper-Alloy UNS No. (or other designation)								
	C11000	C19400	C22000	C23000	C66400	C66410	C66430	C71000	C64785 core of Copper-Clad Bronze
Copper (incl silver)	99.90 min	97.0 min	89.0–91.0	84.0–86.0	remainder	remainder	remainder	remainder	remainder
Copper	99.90 min ^A	97.0 min	89.0–91.0	84.0–86.0	Remainder ^A	Remainder ^A	Remainder ^A	Remainder ^A	Remainder ^A
Iron	...	2.1–2.6	0.05 max	0.05 max	1.3–1.7	1.8–2.3	0.6–0.9	1.0 max	0.02 max
Lead, max	...	0.03	0.05	0.05	0.015	0.015	0.05	0.05	0.015
Tin	0.05 max	0.05 max	0.6–0.9	...	0.50–2.0
Zinc	...	0.05–0.20	remainder	remainder	11.0–12.0	11.0–12.0	13.0–15.0	1.0 max	3.0–6.0
Nickel (incl cobalt)	19.0–23.0	0.4–1.6
Nickel	19.0–23.0 ^B	0.40–1.6 ^B
Manganese	1.0 max	0.20–1.0
Phosphorus	...	0.015–0.15	...	...	...	...	0.10 max	...	0.015 max
Cobalt	0.30–0.7	...	...	...	...
Iron and cobalt	1.8–2.3	...	...	...	...
Silicon	0.15 max
Aluminum	3.0–6.0

^A Copper value includes silver.

^B Nickel value includes cobalt.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C19400	99.8
C22000	99.8
C23000	99.8
C66400	99.5
C66410	99.5
C66430	99.5
C64785	99.5
C71000	99.5

7.4.1 Alloys C19400, C22000, and C23000—When all elements specified in Table 1 are determined, the sum of the results shall be 99.8 % min.

7.4.2 Alloys C66400, C66410, C66430, C64785, and C71000—When all elements specified in Table 1 are determined, the sum of the results shall be 99.5 % min.

7.5 For alloys in which zinc is listed as “remainder,” either copper or zinc may be taken as the difference between the sum of results of all other elements determined and 100 %. When all elements in Table 1 are determined, the sum of results shall be as shown in the above table.

7.6 Clad Metal:

7.6.1 For stainless steel clad cores, the stainless steel shall conform in chemical composition to one established by Specification A176. If not specified on the purchase order, stainless steel in accordance with UNS No. S43000 (Type 430) shall be supplied as the core material.

7.6.2 For alloy steel clad cores, the steel shall conform in chemical composition to an alloy steel established by Specification A505. If not specified on the purchase order, alloy steel UNS No. G41300 shall be supplied as the core material.

7.6.3 For bronze clad cores, the bronze shall conform in chemical composition to the requirements of Copper Alloy UNS No. C64785 listed in Table 1.

7.6.4 Unless otherwise stated (see 5.2.4), the cladding ratio shall be one of the standard ratios listed in Table 2 and Table 3, and shall be expressed as XX/XX/XX, copper/bronze/copper, copper/stainless steel/copper, or copper/alloy steel/copper as appropriate.

8. Temper

8.1 As The standard tempers for products described in Classification B601, tempers furnished to this specification shall be: are given in Table 2.

8.1.1 Copper C11000—H00, H01, H02, and O61—Cold rolled tempers H00, H01, and H02.

8.1.2 Copper alloy C19400—H02, O61, and O50—Annealed tempers O50, O60, O61, OS015, and OS035.

8.1.3 Copper alloy C22000—H01, H02, and Annealed-to-temper O81.

8.1.4 Copper alloy C23000—H01, H02, and O81.

8.1.5 Copper alloy C66400, C66410, and C66430—O60.

8.1.6 Copper alloy C71000—H01, H02, OS035, and OS015.

8.1.7 Copper-Clad Steel—O61.

8.1.8 Copper-Clad Bronze—O61 and O81.

9. Grain Size for Annealed Tempers

9.1 There are no minimum or maximum grain size requirements for product in annealed tempers O50, O60, O61, and O81; however, the metal shall be fully recrystallized.

9.2 For copper alloy UNS No. C71000 in annealed tempers OS035, OS015 and OS015, OS035, acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions, and each specimen shall be within the limits prescribed in Table 2 when determined in accordance with Test Method Methods E112.

10. Physical Property Requirements

10.1 Electrical Conductivity Requirement:

10.2 The annealed product furnished shall conform to the electrical conductivity requirement prescribed in Table 3 and Table 4.

10.3 The electrical resistivity of the material shall be determined in accordance with Test Method B193; the conductivity shall be calculated in accordance with Explanatory notes Notes 3 and 4 of Test Method B193.

11. Mechanical Property Requirements

11.1 Tensile Strength Requirements—Requirements:

11.1.1 Product furnished under this specification shall conform to the tensile requirements prescribed in Table 2, when tested in accordance with Test Method Methods E8/E8M E 8 [or E 8M].

11.1.2 Acceptance or rejection based upon mechanical properties shall depend only on tensile strength.

TABLE 2 Tensile Strength Requirements and Approximate Hardness Values for Shielding Materials in Commonly Ordered Tempers

Copper or Copper Alloy UNS No. (or other designation)	Description	Code	Temper Designation	Tensile Strength, ksi ^A (MPa/MPa ^B)		Approximate Rockwell Hardness ^C					
				Min	Max	Other Scales Thicknesses >0.020 in.	Superficial 30T Thicknesses >0.012 in.				
C11000	Copper	H00 H01 H02	Name	<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>				F54–82 F60–84 F77–89	up to 49 18–51 43–57		
				eightth hard	32 (220)	40 (275)					
				quarter hard	34 (235)	42 (290)					
				half hard	37 (255)	46 (315)					
				<i>Annealed Tempers:</i>							
				O61	annealed	...	34 (235)		
C19400	Copper-iron alloy	O61 O50 O50	Name	<i>Annealed Tempers:</i> <i>Annealed Tempers:</i>				...	...
				annealed ^D	45 (310)	55 (380)					
				light annealed ^D	50 (345)	60 (415)					
				light anneal ^D	50 (345)	60 (415)					
				<i>Cold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>							
				H02	half hard	53 (365)	63 (435)			B49–69	52–63
C22000	Commercial bronze	H01 H02	Name	<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>				B27–52 B50–63	38–53 52–61		
				quarter hard	40 (275)	50 (345)					
				half hard	47 (325)	57 (395)					
				<i>Annealed Tempers:</i> <i>Annealed-to Tempers:</i>							
				O81	quarter hard	39 (270)	46 (315)		
				<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>							
C23000 C23000	Red brass Red brass	H01 H01 H02	Name	<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>				B33–58 B33–58 B56–68	45–60 45–60 58–66		
				quarter hard	44 (305)	54 (375)					
				quarter hard	44 (305)	54 (370)					
				half hard	51 (350)	61 (420)					
				<i>Annealed Tempers:</i> <i>Annealed-to Tempers:</i>							
				O81 O81	quarter hard	44 (305)	54 (375) 54 (370)		
C66400 C66410 C66430	Copper-zinc-iron-cobalt alloy Copper-zinc-iron alloy Copper-zinc-iron-tin alloy	O60 O60 O60	Name	<i>Annealed Tempers:</i> <i>Annealed Tempers:</i>				...	... ... 59–69	
				soft anneal ^D	53 (365)	60 (415)					
				soft anneal ^D	53 (365)	60 (415)					
				soft anneal ^D	59 (405)	69 (475)					
				<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>							
				C71000	Cupro-nickel 20 %	H01 H02	Name			<i>Gold-Rolled Tempers:</i> <i>Cold Rolled Tempers:</i>				B45–72 B64–78	46–65 59–69
quarter hard	47 (325)	63 (435)									
half hard	56 (385)	70 (485)									
<i>Annealed Tempers:</i>											
OS035	0.025–0.050 mm	52 (365)	...					B18–35	28–40		
OS035	0.025–0.050 mm	52 (360)	...					B18–35	28–40		
OS015	0.010–0.020 mm	53 (365)	...	B35–88	40–58						
Copper-Clad Stainless (CCS) and Copper-Clad Alloy Steel (CAS)											
Cladding Ratio	Total Thickness										
	in. (mm)	Annealed Tempers									
16/68/16	0.005 (0.13)	O61	annealed ^D	55 (380)	68 (470)	15T 89 max	...				
33.3/33.3/33.3	0.006 (0.15)	O61	annealed ^D	44 (305)		15T 89 max	...				
Copper-Clad Bronze (CCB)											
Cladding Ratio	Total Thickness										
	in. (mm)	Annealed Tempers									
12.5/75/12.5	^E	O61	annealed ^D	55 (380)	68 (470)	15T 89 max	...				
		O81	annealed to temper— quarter hard	62 (425)	75 (515)	15T 92 max	...				
16/68/16	^E	O61	annealed ^D	55 (380)	68 (470)	15T 89 max	...				
		O81	annealed to temper— quarter hard	62 (425)	75 (515)	15T 92 max	...				

^A ksi = 1000 psi.

^B See Appendix X3.

^C Rockwell values normally apply as follows: The B and F scales apply to metal 0.020 to 0.036 in. (0.5 to 0.91 mm) in thickness. The Superficial 30-T scale applies to metal 0.012 to 0.028 in. (0.30 to 0.71 mm) in thickness.

^D There is no grain size requirement but all annealed metal shall be fully recrystallized.

^E See Appendix X2, Table X2.1.

11.2 Rockwell Hardness Requirement – Requirement:

TABLE 3 Preferred Cladding Ratios—Copper-Clad Materials

Clad Material	Nominal Total Thickness of Strip		Cladding Ratio	Nominal Thickness, in. (mm)			Conductivity, % IACS	
	in.	mm		Copper	Core	Copper	Nominal	Minimum
CCS or CAS	0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	30	28
CCS or CAS	0.006	0.15	33.3/33.3/33.3	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	61	60
CCB	0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	32	30
CCB	0.005	0.13	12.5/75/12.5	0.0006 (0.016)	0.0038 (0.1)	0.0006 (0.016)	30	28

TABLE 4 Electrical Resistivity and Conductivity

UNS Alloy No.	Mass Resistivity, $\Omega \cdot \text{g}/\text{m}^2$ (Ref. only)	Conductivity %, IACS min	
A. Copper Alloy Materials			
C11000	0.153 28	100.00	
C19400	0.256 03	60	
C22000	0.379 30	40	
C23000	0.407 73	37	
C66400	0.504 01	30	
C66410	0.504 01	30	
C66430	0.540 63	28	
C71000	2.568 91	6	
B. Copper-Clad Bronze Material			
Total Thickness, in.	Cladding Ratio	Mass Resistivity, $\text{Ohm} \cdot \text{g}/\text{m}^2$	Conductivity %, IACS
all	12.5/75/12.5	...	28 min
all	16/68/16	...	30 min
C. Copper-Clad Steel Material			
Total Thickness, in.	Cladding Ratio	Mass Resistivity, $\text{Ohm} \cdot \text{g}/\text{m}^2$	Conductivity %, IACS
0.005	16/68/16	...	28 min
0.006	33.3/33.3/33.3	...	60 min

11.2.1 The hardness test is a quick and convenient method for estimating tensile strength and grain size. Approximate hardness values are given in Table 2. For copper-clad materials, copper is etched off with a suitable reagent before testing the steel. This test is not required and are for general information and assistance in testing, and shall not be used as a basis of for product rejection.

NOTE 2—The Rockwell hardness test offers a quick and convenient method of checking for general conformity to the specification requirements for temper, tensile strength, and grain size. For copper-clad materials, copper is etched off with a suitable reagent before testing the steel.

12. Dimensions, Mass, and Permissible Variations

12.1 *General*—For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

12.2 *Thickness*—The standard method of specifying thickness shall be in decimal fractions of an inch. For material 0.021 in. (0.53 mm) and under in thickness, it is recommended that the nominal thickness be stated not closer than the nearest half-thousandth. (For example, specify 0.006 or 0.0065 in. (0.15 or 0.165 mm), but not 0.0063 in. (0.160 mm).) A list of preferred thicknesses is shown in Appendix X2. The thickness tolerance shall be those shown in Table 5 and Table 6.

12.3 *Width*—The width tolerances shall be those required by Specification B248 or B248M, unless otherwise stated in the purchase order.

12.4 *Straightness*—The straightness tolerances shall be those required by Specification B248 or B248M, unless otherwise stated in the purchase order.

12.5 *Cladding Ratio*—Cladding ratios shall be within $\pm 10\%$ of the outer clad layer percentage (for example, the outer layers of a 16/68/16 clad product can have an outer layer clad thickness of $\pm 6\%$ ~~$\pm 1.6\%$~~ ; $16 \pm 1.6\%$). The thickness percentage of the core shall not be used for basis of rejection. The test method shall be metallurgical microsection of at least three samples per lot.

13. Workmanship, Finish, and Appearance

13.1 All material shall be uniform in quality and condition, sound and free of internal and external defects of a nature that interferes with normal fabrication or the performance of the cable shielding. It shall be well cleaned and free of dirt. A superficial film of residual light lubricant is permissible, unless otherwise specified.