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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Copper, Copper-Alloy, and Copper-Clad Stainless Steel (CCS), and Copper-Clad Alloy Steel (CAS) Sheet and Strip for Electrical Cable Shielding[1]

This standard is issued under the fixed designation B 694; 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 describes selected copper, copper alloy, 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 B 736, for related standards for aluminum-based shielding materials.

1.2 The materials covered are the following:

Copper or Copper Alloy UNS No.[A]	Type of Material
C11000	copper
C19400	copper-iron alloy
C22000	copper-zinc alloy (commercial bronze)
C66400	copper-zinc-iron-cobalt alloy
C66410	copper-zinc-iron alloy
C71000	cupro-nickel 20 %
...	copper-clad stainless steel (CCS)
...	copper-clad alloy steel (CAS)

[A] Refer to Practice E 527 for an explanation of the Unified Numbering System (UNS).

1.3 The values stated in inch-pound units are the standard, except for temperature and grain size which are given in SI units. Values in parentheses are for information only.

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 specified herein:

2.2 *ASTM Standards:*

A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip[2]

A 505 Specification for Steel, Sheet and Strip, Alloy, Hot-Rolled and Cold-Rolled, General Requirements for[2]

B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar[3]

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar[3]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[3]

B 736 Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock[4]

E 3 Methods of Preparation of Metallographic Specimens[5]

E 8 Test Methods for Tension Testing of Metallic Specimens[5]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronze[6]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[6]

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[6]

E 112 Test Methods for Determining Average Grain Size[5]

E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition[6]

E 478 Test Methods for Chemical Analysis of Copper Alloys[6]

E 527 Practice for Numbering Metals and Alloys (UNS)[7]

2.3 *International Standards Organization (ISO) Standards:*

ISO/DIS 3110/2 Determination of Aluminum; Flame Atomic Absorption Spectrometric Method (TC/26 Ref. No. N698 E/F)[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *cladding ratio, n*—ratio by percent thickness of the component layers, for example, 16/68/16.

4. Ordering Information

4.1 Orders for material should include the following information:

4.1.1 ASTM designation and year of issue,

4.1.2 Quantity: total for each item, pounds (or kilograms),

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet and Strip.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

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

[4] *Annual Book of ASTM Standards*, Vol 02.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 01.01.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

4.1.3 Name of material: cable shielding (or "cable wrap"),
4.1.4 Form of material: strip,
4.1.5 Type of material: copper, copper-zinc alloy (commercial bronze), etc. (see 1.2),
4.1.6 Alloy number when appropriate (see 1.2),
4.1.7 Temper (see Section 7),
4.1.8 Dimensions: thickness and width (see Section 10),
4.1.9 How furnished: coils (rolls), traverse wound on reels or spools, etc.,
4.1.10 Whether the resistivity test is required for any item (Section 8),
4.1.11 Coil dimension: inner or outer coil diameter limitation, or both, if required,
4.1.12 Weight of coils: coil weights or coil size limitations, if required,
4.1.13 Cladding ratio when appropriate (see 6.5.3),
4.1.14 Certification, if required, (see Section 17),
4.1.15 Mill test report, if required,
4.1.16 Specification designation and year of issue, and
4.1.17 Special tests or exceptions, if any.

5. Materials and Manufacture

5.1 The material shall be of such quality that it conforms to the properties and characteristics prescribed in the specification.

5.2 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.

6. Chemical Composition

6.1 Homogeneous copper and copper-alloy materials shall conform to the requirements prescribed in Table 1 for the particular material.

6.2 Copper cladding shall be, unless otherwise specified, a copper conforming in chemical composition to that covered by Specification B 152. The exact grade is typically not specified provided that the final strip meets the conductivity and mechanical properties of this specification. Some typical coppers used are:

C10920
C11000
C11020
C12000

6.3 These specification limits do not preclude the possible presence of other unnamed elements. Limits may be established and determination required for unnamed elements by agreement between the manufacturer and the purchaser.

6.4 Except for copper C11000, copper may be taken as the difference between all the elements analyzed and 100 %.

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

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

6.5 *Clad Metal*:

6.5.1 For stainless steel clad cores, the stainless shall conform in chemical composition to any of those covered by Specification A 176. Unless otherwise specified, stainless in accordance with UNS No. S43000 (Type 430) shall be supplied.

6.5.2 For alloy steel clad cores, the steel shall conform in chemical composition to any of those covered by Specification A 505. Unless otherwise specified, alloy steel in accordance with UNS No. G41300 shall be supplied.

6.5.3 Unless otherwise stated (4.1.12), 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/stainless steel/copper or copper/alloy steel/copper as appropriate.

7. Temper

7.1 As described in Practice B 601, tempers furnished to this specification shall be:

7.1.1 Copper C11000 — H00, H01, H02, and O61.
7.1.2 Copper alloy C19400 — H02, O61, and O50.
7.1.3 Copper alloy C22000 — H01, H02, and O81.
7.1.4 Copper alloy C66400 and C66410 — O60.
7.1.5 Copper alloy C71000 — H01, H02, OS035, and OS015.
7.1.6 Copper-Clad Steel — O61.

8. Physical Properties

8.1 Annealed material shall conform to the requirements of Table 4.

9. Mechanical Properties

9.1 *Grain Size*:

TABLE 1 Chemical Requirements

Element	Composition, %					
	Copper or Copper Alloy UNS No.					
	C11000	C19400	C22000	C66400	C66410	C71000
Copper (incl silver)	99.90 min	97.0 min	89.00–91.0	remainder	remainder	74.0 min
Iron	...	2.1–2.6	0.05 max	1.3–1.7	1.8–2.3	1.0 max
Lead, max	...	0.03	0.05	0.015	0.015	0.05
Tin	...	...	...	0.05 max	0.05 max	...
Zinc	...	0.05–0.20	remainder	11.0–12.0	11.0–12.0	1.0 max
Nickel (incl cobalt)	...	...	...	...	0.05 max	19.0–23.0
Manganese	...	...	...	...	0.05 max	1.0 max
Phosphorus	...	0.0015–0.15	...	...	0.02 max	...
Cobalt	...	...	...	0.30–0.7	...	...
Silver	...	...	...	...	0.05 max	...
Silicon	...	...	...	...	0.05 max	...
Aluminum	...	...	...	...	0.05 max	...

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

Description		Temper Designation		Tensile Strength, ksi[A] (Mpa[B])		Approximate Rockwell Hardness[C]	
Copper or Copper Alloy UNS No.	Type of Material	Standard	Former	Min	Max	Other Scales Thicknesses >0.020 in.	Superficial 30T Thicknesses >0.012 in.
			Cold-Rolled Tempers:				
C11000	Copper	H00	eighth hard	32 (220)	40 (275)	F 54–82	up to 49
		H01	quarter hard	34 (235)	42 (290)	F 60–84	18–51
		H02	half hard	37 (255)	46 (315)	F 77–89	43–57
			Annealed Tempers:				
		O61	annealed	...	34 (235)	...	...
			Annealed Tempers:				
C19400	Copper-iron alloy	O61	annealed[D]	45 (310)	55 (380)	...	...
		O50	light annealed[D]	50 (345)	60 (415)	...	...
		H02	half hard	53 (365)	63 (435)	B 49–69	52–63
			Cold-Rolled Tempers:				
C22000	Commercial bronze	H01	quarter hard	40 (275)	50 (345)	B 27–52	38–53
		H02	half hard	47 (325)	57 (395)	B 50–63	52–61
			Annealed Tempers:				
		O81	quarter hard	39 (270)	46 (315)	...	...
			Annealed Tempers:				
C66400	Copper-zinc-iron-cobalt alloy	O60	soft[D]	53 (365)	60 (415)	...	...
C66410	Copper-zinc-iron alloy	O60	soft[D]	53 (365)	60 (415)	...	...
			Cold-Rolled Tempers:				
C71000	Cupro-nickel 20 %	H01	quarter hard	47 (325)	63 (435)	B 45–72	46–65
		H02	half hard	56 (385)	70 (485)	B 64–78	59–69
			Annealed Tempers:				
		OS035	0.035-mm grain size	52 (355)		B 18–35	28–40
		OS015	0.015-mm grain size	53 (365)		B 35–88	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	...

[A] ksi = 1000 psi.
[B] See Appendix X4.
[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.

TABLE 3 Preferred Cladding Ratios—Copper-Clad Steel

Nominal Total Thickness of Strip		Cladding Ratio, CCS or CAS	Nominal Thickness, in. (mm)			Conductivity, % IACS	
in.	mm		Copper	Steel	Copper	Nominal	Minimum
0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	30	28
0.006	0.15	33.3/33.3/33.3	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	61	60

TABLE 4 Electrical Resistivity and Conductivity

A. Copper Alloy Materials

Alloy No.	Mass Resistivity Ohm·g/m^2	Conductivity %, IACS
C11000	0.15328	100.00
C19400		60
C22000		40
C66400		30
C66410		30
C71000		6

B. Copper-Clad Steel Material

Total Thickness, inch	Cladding Ratio	Mass Resistivity Ohm·g/m^2	Conductivity %, IACS
0.005	16/68/16	...	28
0.006	33.3/33.3/33.3	...	60

9.1.1 There are no grain size requirements for metal in annealed tempers O50, O61, and O81; however, the metal shall be fully recrystallized.

9.1.2 When tested in accordance with Test Methods E 112 copper alloy C71000 in annealed tempers OS035 and OS015 shall conform to the grain size requirements prescribed in Table 2.

9.2 *Hardness*:

9.2.1 *Rockwell Hardness*—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 should be etched off with a suitable reagent prior to testing the steel. This test is not required and shall not be used as a basis of rejection.

9.3 Tensile Strength—The finished product shall conform to the requirements prescribed in Table 2 for the particular material and temper.

10. Dimensions and Permissible Variations

10.1 *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.

10.2 *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.

10.3 *Width*—The width tolerances shall be those required by Specification B 248, Section 5.3, unless otherwise stated in the purchase order.

10.4 *Straightness*—The straightness tolerances shall be those required by Specification B 248, Section 5.5, unless otherwise stated in the purchase order.

10.5 *Cladding Ratio*—Cladding ratios shall be within ± 10 % of nominal; test method shall be metallurgical microsection of at least three samples per lot.

11. Workmanship, Finish, and Appearance

11.1 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.

11.2 Copper-clad material shall be free of defects including unbond or delamination of a nature that interferes with normal commercial operations.

12. General Requirements

12.1 The following sections in the current edition of Specification B 248 are a part of this specification.

12.1.1 Terminology,
12.1.2 Material and Manufacture,
12.1.3 Sampling,
12.1.4 Significance of Numerical Limits,
12.1.5 Inspection,
12.1.6 Rejection and Rehearing,
12.1.7 Certification,
12.1.8 Test Reports,
12.1.9 Packaging and Package Marking, and
12.1.10 Supplementary Requirements.

NOTE 2—The current edition is defined as the edition which is contained in the latest published edition of the ASTM Book of Standards, Vol 02.01.

12.2 Specific requirements in this specification may supersede or compliment any of the above sections.

TABLE 6 Width Tolerances for Slit Metal and Slit Metal with Rolled Edges (applicable to all materials listed in 1.2)

Width, in. (mm)	Width Tolerances,[A] plus and minus For All Thicknesses	
	in.	mm
2 (50.8) and under	0.005	0.13
Over 2 to 12 (50.8 to 305), incl	0.008	0.20
Over 12 to 24 (305 to 610), incl	0.015	0.38

[A] If tolerances are specified as all plus or all minus, double the values given.

13. Sampling

13.1 *Chemical Composition for Copper and Copper Alloys*:

13.1.1 Instead of sampling in accordance with Practice E 255, the manufacturer shall have the option of sampling at the time castings are poured or from the semifinished or finished product.

13.1.1.1 When sampled at the time castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

13.1.1.2 When sampled from a semifinished or finished product, at least one sample representative of the product of each cast bar from a single melt charge continuously processed with heat identity maintained shall be taken.

13.1.1.3 When sampled from semifinished or finished product when heat identity has not been maintained, a single sample representative of each 10 000 lb lot, or fraction thereof, shall be taken. When the product piece is greater than 10 000 lb, one sample to be representative of the product piece shall be taken.

13.2 *Clad Metal*:

13.2.1 When materials of fabrication have been certified to meet the requirements of the specification to which they were ordered, sampling by the fabrication is not required unless specified otherwise in the contract or purchase order.

13.2.2 When sampling of the fabricating materials is specified in the contract or purchase order, sampling shall be as prescribed in the specification to which the material was ordered.

14. Number of Tests and Retests

14.1 *Tests*:

14.1.1 *Chemical Composition*—Determine as the average of at least two replicate determinations for each specified element in Table 1.

14.1.2 *Grain Size and Tensile Strength*—Determine as the average of results from two test specimens.

14.2 *Retests*:

14.2.1 *Chemical Composition*—Should one or more of the determinations fail to conform with the requirements of Table

TABLE 5 Thickness Tolerances

Material	Thickness, in. (mm)	Tolerance, plus and minus in. (mm)	
		12 in. (305 mm) and under in Width	Over 12 in. (305 mm)
Copper and copper alloys	0.004 (0.102) and under	0.0003 (0.0076)	0.0006 (0.015)
	Over 0.004 to 0.005 (0.127), incl	0.0004 (0.010)	0.0008 (0.020)
	Over 0.005 to 0.009 (0.229), incl	0.0005 (0.013)	0.001 (0.025)
	Over 0.009 to 0.013 (0.330), incl	0.0008 (0.020)	0.0015 (0.038)
Copper-clad stainless steel (CCS)	Over 0.004 to 0.005 (0.127), incl	0.0005 (0.013)	
	Over 0.005 to 0.009 (0.229), incl	0.0006 (0.015)	
Copper-clad alloy steel (CAS)	Over 0.004 to 0.005 (0.127), incl	0.0005 (0.013)	
	Over 0.005 to 0.009 (0.229), incl	0.0006 (0.015)	

1, a retest may be made on a new composite made up from the pieces originally selected.

14.2.2 *Grain Size and Tensile Strength*—Should the test results fail to conform with the requirements, a retest shall be permitted on two specimens made up from the pieces originally selected.

15. Specimen Preparation

15.1 *Chemical Composition*—Preparation of the analytical specimens shall be the responsibility of the reporting laboratory.

15.2 *Grain Size*—In case of disagreement, test specimens shall be prepared in accordance with Methods E 3.

15.3 *Tensile Strength*—In case of disagreement, test specimens shall be prepared in accordance with Test Methods E 8.

16. Test Methods

16.1 Test methods for quality control shall be discretionary.

16.2 *Chemical Composition*—In case of disagreement, determination shall be as follows:

Element	ASTM Test Method
Aluminum	ISO 3110 (AA)
Cobalt	E 75
Copper	E 478
Iron	E 478
High Iron	E 54
Lead	E 478 (AA)
Manganese	E 62
Nickel	E 478 (Photometric)
Phosphorus	E 62
Silicon	E 62
Silver	E 478
Zinc	E 478 (Titrimetric)

17. Certification

17.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

18. Keywords

18.1 bimetallic; cladding ratio; copper; copper alloy; copper-clad alloy steel; copper-clad stainless steel; electric cable shielding; electrical conductivity; grain size; Rockwell Hardness; sheet; strip; tensile

APPENDIXES

(Nonmandatory Information)

X1. EXPLANATORY NOTE—CABLE SHIELDING

X1.1 Cable shielding or “cable wrap” is normally used by manufacturers of electrical insulated wire and cable in strips of various widths. The material is wrapped around an insulated wire or group of wires, and may be applied over an intervening layer of wrapping material or over a jacket. The material may be applied in various configurations depending upon the requirements of the finished cable:

X1.1.1 *Helical wrap*—overlapped, butted, or gapped.

X1.1.2 *Longitudinal application*—corrugated or smooth, overlapped, butted, gapped, or welded/soldered.

X1.2 The selection of the particular material and of the thickness of the material to be used is dependent largely upon the specification requirements for the finished wire or cable. Military and Federal Specifications, Rural Electrification Administration (REA) specifications, ICEA (Insulated Cable Engineers Association) specifications among others typically apply.

X1.3 Electrical conductivity of the material is an important characteristic considered in the selection process, and is affected by the material, its thickness, and the method of application. Corrosion resistance is important for various environments. Physical strength requirements may include such features as resistance to tensile stress, resistance to bending stress (including repeated bending), resistance to gopher attack, etc.

X2. PREFERRED THICKNESSES

X2.1 It is recommended that whenever possible, material purchased to this specification be ordered in a thickness as listed in Table X2.1.

TABLE X2.1 Preferred Thickness, Nominal

Material or UNS No.	Thickness, in. (mm)
C11000	0.005 (0.13)
	0.010 (0.25)
C19400	0.006 (0.15)
	0.007 (0.18)
C22000	0.005 (0.13)
	0.007 (0.18)
	0.010 (0.25)
C66400	0.0055 (0.14)
C66410	0.0055 (0.14)
C71000	0.005 (0.13)
Copper-clad stainless steel (CCS)	0.005 (0.13)[A]
	0.006 (0.15)[A]
Copper-clad alloy steel (CAS)	0.005 (0.13)[A]
	0.006 (0.15)[A]

[A] Total thickness of strip. See Table X3.1 for preferred cladding ratio.

X3. METRIC EQUIVALENTS

X3.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.